PARIS ORSAY

JULY 10 - 13

1979

ELEVENTH EGAS CONFERENCE

The following pages are an exact representation of what is in the original document folder.

CONF-790780--(Summ)

EUROPEAN GROUP FOR ATOMIC SPECTROSCOPY

ATOMIC PHYSICS DIVISION
EUROPEAN PHYSICAL SOCIETY

SUMMARIES OF CONTRIBUTIONS

ELEVENTH ANNUAL CONFERENCE

PARIS-ORSAY - JULY 10-13, 1979

LABORATOIRE DE SPECTROSCOPIE HERTZIENNE
DE L'ECOLE NORMALE SUPÉRIEURE - PARIS -

	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
Morning	- Plenary Session : - invited paper : M. KLAPISCH - Communications : 116 and 117 ÷ Session A : 22 to 27 Session B : 50 to 55 Session C : 35 to 40	Session A : 123 to 130 Session B : 56 to 65 Session C : 94 to 101 ÷ Session A : 9 to 13 Session B : 75 to 79 and 102 Session C : 131 to 135	- Plenary Session : - invited paper : J.S. BELL - Communications : 59 and 66 ÷ Poster Session	- Plenary Session : - invited paper : S. LIBERMANN - Communications : 86, 87 and 88 ÷ Session A : 30 to 34 Session B : 89 to 93 and 136 Session C : 103 to 108
Afternoon	- Plenary Session : - invited paper : G.V. MARR - Communications : 1, 2 and 28 ÷ Session A : 3 to 8 Session B : 80 to 85 Session C : 41 to 47	Laboratory visits	- Plenary Session : - invited paper : H. WELLING - General Assembly ÷ Session A : 14 to 21 Session B : 67 to 74 Session C : 109 to 115bis	- Plenary Session : - invited paper : C. COHEN-TANNOUDJI - Communications : 118 and 48 ÷ - Plenary Session : 58 and 119 to 121

PREFACE

This book contains summaries of contributions to the Eleventh Conference of the European Group for Atomic Spectroscopy, EGAS. The summaries are photoprints in reduced size of manuscripts submitted by the authors.

The contributions have been numbered and classified under the following headlines.

Term analysis	2-21	Rydberg levels	85-93
Lifetimes	22-34	Quantum beats	94-101
Collisions, line shape	35-48	Helium and helium like	102-115bis
Hyperfinestructure isotope shifts	49-74	New technics. Metrology	116-130
Saturation spectroscopy	75-79	Molecules	131-135
Hanle effect	80-85	Post dead-line	136-143

However this classification is not strict and is given only as a rough information.

This handbook is not a formal publication. The summaries of talks contained in it have been submitted by the authors for the convenience of participants in the meeting and of other interested persons. The summaries should not be quoted in the literature, nor may they be reproduced in abstracting journals or similar publications, since they do not necessarily relate to work intended for publication.

Data contained in the summaries may be quoted only with the permission of the authors.

MEMBERS OF THE BOARD OF EUROPEAN GROUP FOR ATOMIC SPECTROSCOPY

T. Andersen	Institute of Physics University of Aarhus 8000 C, DENMARK
B. Cagnac	Laboratoire de Spectroscopie Hertzienne de l'E.N.S. Université Pierre et Marie CURIE 4, Place Jussieu- Tour 12- 1ère étage 75230 Paris Cedex 05
R.J. Champeau	Laboratoire Aimé Cotton C.N.R.S. II, Campus d'Orsay Batiment 505 ORSAY
A. Dönszelmann	Zeeman Laboratorium Universiteit van Amsterdam Plantage Muidergracht 4 AMSTERDAM C.
W.R.S. Garton	Imperial College Physics Department Prince Consort Road LONDON SW7 2AZ.
J. Heldt	Institute of Physics University of Gdansk 80-395 Ul Wita Stwosza 57 GDANSK
H. Hühnermann	Fachbereich Physik Univeristät Marburg Renthof 5 D-355 MARBURG
I. Martinson	Institute of Physics University of Lund Sölvegatan 14 223 62 LUND
D.N. Stacey (Chairman)	Clarendon Laboratory Parks Road OX1 3PU OXFORD
R. Winkler	Optisches Institut T.U. Berlin- Sekr P11 Strasse des 17-Juni 135 1 BERLIN 12

Local Organization comittee (E.N.S. PARIS)
Chairmen Prof. A. KASTLER and J. BROSSEL Secretary B. CAGNAC

Electron Correlation Effects in the Photoionization of N_2 and CO

S. Krummacher, V. Schmidt
Fakultät für Physik, Universität Freiburg
and
F. Wuilleumier
LURE and ERA N° 719 du CNRS, Université de Paris-Sud, Orsay

In photoelectron spectra, processes like simple ionization or ionization with simultaneous excitation can easily be recognized as individual peaks. Therefore they are an excellent tool to study effects of electron correlation, and extensive use of this technique has already been made in the case of the rare gas atoms and some metallic vapors. In the diatomic molecules N_2 and CO a particularly interesting situation arises from the fact that the "satellites" of the outer valence orbitals energetically coincide with the "main" line of the inner valence orbital. This can lead to a very strong interaction to the extent that the distinction between the "main" and "satellite" lines might become dificult.

We have studied the photoelectron spectra of N_2, and CO in the photon energy range between 30 and 200 eV using the monochromatized synchrotron radiation from the storage ring ACO. Especially at lower photon energies rich structure can be observed in the energy region of the inner valence band. In particular, one band exhibits a strong energy dependence between 43 and 65 eV. Our results are compared with recent theoretical calculations.

Fe XVII to Fe XXIV, Ni XIX to Ni XXVI and isoelectronic spectra from $\Delta n = 2-3$ transitions.

B. C. Fawcett

Appleton Laboratory, Astrophysics Research Division, Science Research Council, Culham Laboratory, Abingdon, Oxon. U.K.

A B S T R A C T

The spectra of Fe XVII to Fe XXIV and Ni XIX to Ni XXVI occur in the soft X-ray region of solar flare spectra at wavelengths between 8 Å and 17 Å, (Neupert et al 1973) and also in spectrograms of Tokamak fusion plasmas (Schwob et al 1977). Spectroscopic studies based on laser-produced plasma light sources (Bromage et al 1978a, 1978b, Fawcett et al 1979) enable the observation and classification of the relevant spectra. Laser produced spectra, unlike solar flare spectra, include many lines which result from transitions which do not decay to the ground configuration. As a result spectrograms are crowded with lines and the analysis is more difficult. Nevertheless many of the lines of most interest to solar physics can be clearly observed as illustrated in the figure which shows recently acquired spectra of Ni XXV, Ni XXVI, Fe XXIII and Fe XXIV. These were generated through focusing the output of the Rutherford Laboratory multi-gigawatt neodymium laser onto plane solid targets at an irradiance of 10^{16} W cm^2 and recorded with a photographic beryl crystal spectrograph. The status of the classification of these spectra will be discussed. Further data can be acquired by consulting the papers by Bromage et al (1978a, 1978b) and Fawcett et al (1979) and references in these papers.

REFERENCES

Bromage, G. E., Cowan, R. D., Fawcett, B. C., Ridgeley, A. 1978a, Jour. Opt Soc. Am. 68 48-51.

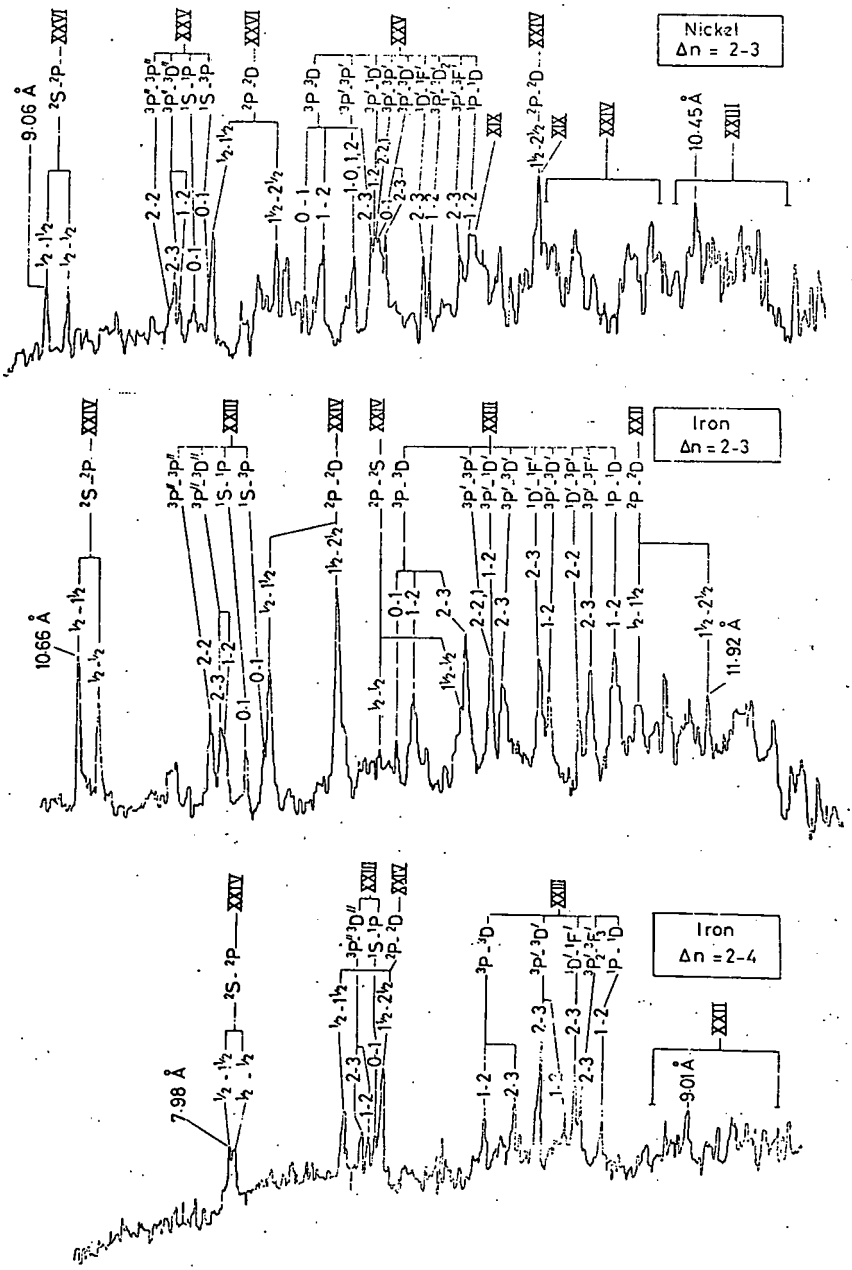
Bromage, G. E., Cowan, R. D., Fawcett, B.C., Gordon, H., Hobby, M. G., Peacock, N.J., Ridgeley, A. 1978b, Culham Laboratory Report CLM-R170 (HMSO).

Fawcett, B. C., Ridgeley, A., Hughes, T. P. 1979. Mon. Not. Roy. astr. Soc. (In the press).

Neupert, W.M., Swartz, M., Kastner, S.O., 1973. Solar Physics 31 171-195.

Schwob, J.L., Klapisch, M., Finkenthal, M., Schweitzer, N. 1977, TFR Group Report No. D. Ph. PFC. SCP. STG1/EUR. CEA. FC 887. (Fontenay aux Roses).

Nickel XXV XXVI, Iron XXII & XXIV Beryllium and lithium-like spectra produced with the Rutherford Laboratory laser.



THEORETICAL EVIDENCE OF SUPER-COSTER-KRONIG TRANSITIONS IN NICKEL SPECTRA: AB INITIO CALCULATIONS.

F.Combet Farnoux and M.Ben Amar

ERA "Spectroscopie Atomique et Ionique", 8âtiment 350, Université Paris-Sud; 91405 Orsay (France)

The absorption spectra of 3d transition elements(with the 3d subshell half-filled at least)obtained with Synchrotron radiation from both solid[1] and vapor[2] samples,point out the existence of a large asymmetrical structure,in the region of 3p edges.Its similar shape for both solid and vapor spectra is in favour of the validity of an atomic model to interpret it. Before our present work,no ab initio calculations of the absorption coefficient of these elements(from Mn to Ni) had been performed in this energy region(about 30-90 eV),although some authors[3,4,5] have already made the assumption of a super-Coster-Kronig $M_{23}M_{45}M_{45}$ transition to explain the large resonance.

In this work,we have used the R matrix theory[6] to calculate the photoionization cross section relative to the 3d subshell of $Ni^+(3p^63d^9$ configuration).Indeed,our preliminary calculations of the same σ_{3d} for neutral $Ni(3p^63d^84s^2)$ and Ni^+ using an independent particle model have shown that the two curves are different close to the 3d threshold but very similar beyond their maximum,i.e. in the region which we are dealing with.Because we have introduced the five 3d thresholds and only the lowest three 3p thresholds in our R matrix calculations,we have coupled 12 channels at most(both open and closed) to find the R matrix basis involved in the description of the initial state $^2D^e(3p^63d^5)$ and the three final states ($^2P^o$,$^2D^o$ and $^2F^o$).

Our results for total σ_{3d} can be seen in figures 1 and 2; both show a wide Fano type profile(whose parameters we have determined)followed by many narrow and intense lines only shown by experimental vapor spectra[2].Our calculations support the hypothesis of a super-Coster-Kronig $M_{23}M_{45}M_{45}$ mechanism to explain the Fano type profile,as far as they introduce the interference of two processus:

1°) creation of an excited state $3p^53d^{10}$ which decays into the continua $3p^63d^8\,\varepsilon f$;

2°) direct ionization: $3p^63d^9 + h\nu \longrightarrow 3p^63d^8 + \varepsilon f$

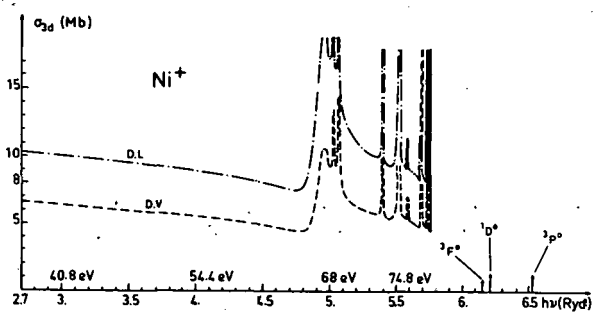


Fig 1: σ_{3d} of Ni^+ in both dipole-length (D.L) and dipole velocity (D.V) formulations.

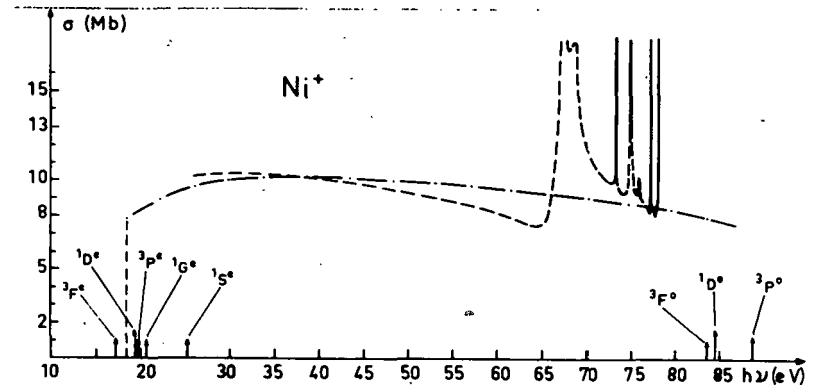


Figure 2: σ_{3d} of Ni^+ ----- our R matrix(D.L) calculations —.—. independent particle model

The other lines(relative to transitions from $3p^6 3d^9$ to $3p^5 3d^9 4s$(5s,4d,5d...etc)are the first lines of series which converge on the various 3p thresholds.It is important to note that while the position of the M_{23} edge is the same for a solid spectrum as that of the autoionizing $3p^5 3d^{10}$ level,the 3p ionization threshold for a vapor spectrum is located much beyond it.

(1) B.Sonntag,R.Haensel and C.Kunz Sol.State Comm.7,597(1969)
(2) R.Bruhn,B.Sonntag and H.W.Wolff DESY Report SR-78/14(1978)
(3) E.J.McGuire J.Phys.Chem.Solids 33,577 (1972)
(4) R.E.Dietz,E.G.McRae,Y.Yafet and C.W.Caldwell Phys.Rev.Lett.33,1372 (1974)
(5) L.C.Davis and L.A.Feldkamp Sol.State Comm.19,413 (1976)
(6) K.A.Berrington,P.G.Burke,M.Le Dourneuf,W.D.Robb,K.T.Taylor and Vo Ky Lan Comp.Phys.Comm. 14,367 (1978)

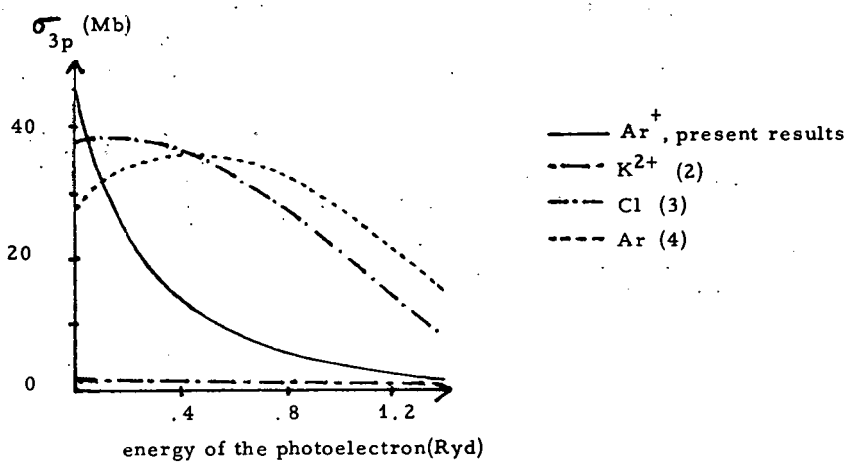
COMPARATIVE THEORETICAL STUDY OF PHOTOIONIZATION CROSS SECTIONS IN THE BEGINNING OF THE $3p^5$ ISOELECTRONIC SERIES.

Lamoureux M. and Combet Farnoux F.
Spectroscopie Atomique et Ionique, ERA 719, Bâtiment 350
Université Paris Sud, 91405 ORSAY -France.

We calculate the 3p photoionization cross section of $Ar^+(3p^5)$ with the R matrix close-coupling model of Berrington et al. (1). We compare the results with previous ones concerning a few neighbouring systems : $K^{2+}(3p^5)$ (2), $Cl(3p^5)$ (3) and $Ar(3p^6)$ (4).

σ_{3p} is indeed very sensitive—for both neutral and slightly ionized atoms— to the choice of the theoretical model and it is necessary to go beyond independent particle models. Moreover, contrary to the case of $3p^6$ closed shell systems, interchannel effects are important in $3p^5$ open shell systems (3). So, we study Ar^+ with the R matrix model (1) as previously (2)(3), i. e. by introducing excitations into a $\overline{3d}$ pseudorbital .

The photoionization curve of Ar^+ beyond the $3p^4\ ^1S^e$ threshold is drawn in the figure below, as well of those of K^{2+} (2) and Cl(3). We thus emphasize the rapid evolution of the resonance maximum with increasing ionization degree. The comparison with the Ar(4) results also plotted in the figure confirms this conclusion.



As an example of the autoionization families located before the $^1S^e$ threshold, we study the $Ar^+ 3p^4 (^1D^e) nd\ ^2P^e$ family converging on the $^1D^e$ threshold. The Fano's parameters (5) and the quantum defects are compared with those of two other members of the isoelectronic series (2)(3).

(1) Berrington K.A., Burke P.G., Le Dourneuf M., Robb W.D., Taylor K.T. and Vo Ky Lan ; Comput. Phys. Commun. 14(1978) 367

(2) Combet Farnoux F., Lamoureux M. and Taylor K.T. ; J. Phys. B, 16(1978)2855

(3) Lamoureux M. and Combet Farnoux F. ; J. Physique (1979), in press

(4) Burke P.G. and Taylor K.T. ; J. Phys. B., 8(1975) 2620

(5) Fano U. ; Phys. Rev., 124(1961) 1866

A REVISED ANALYSIS OF THE SPECTRUM OF XE^+

Jørgen E. Hansen, Zeeman Laboratory, Plantage Muidergracht 4,
1018 TV AMSTERDAM, The Netherlands

Willy Persson, Department of Physics, Lund Institute of Technology,
Box 725, S-220 07 LUND, Sweden

From widely different fields of atomic physics, such as photoelectron spectroscopy, laser and plasma physics, there has recently been a great experimental as well as theoretical interest in the spectrum lines and energy levels of singly ionized xenon. When all new information was put together it became evident that some fundamental discrepancies were present in the analysis of the spectrum of this ion. These factors led us to reconsider the analysis of the Xe II spectrum.

The spectrum of Xe II had been analyzed principally by Humphreys[1] in the 1930s and the results of his and others' extensive work on this complex spectrum are collected in Atomic Energy Levels[2]. We have recently published a first report on a revised and expanded analysis using modern theoretical methods[3]. The energy levels identified at present belong to the $5s^2 5p^5$, $5s5p^6$, $5s^2 5p^4 6s$, 7s, 6p, 7p, 5d, 6d, 4f and 5g configurations. The eigenvectors obtained in least-squares fits of the theoretical energy matrices to the observed levels reveal that the choice of coupling scheme is rather arbitrary for the lowest $5p^4 nl$ configurations, i. e., 6s and 5d, whereas the level distribution in the higher-lying configurations is better described in the jK than in the LS coupling scheme. For many levels the identifications are confirmed by a comparison between calculated and observed g-factors.

Some consequences of the new analysis will be discussed:

I. The revisions and extensions of the analysis of the ns and nd configurations, in particular the new level value for the $(^1D)5d\ ^2S_{1/2}$ level, have facilitated a detailed interpretation of the 5s photoelectron satellite spectrum of atomic Xe.

II. The Auger spectrum of Xe excited to $4d^9(^2D_{3/2,\ 5/2})5s^2 5p^6 6p$ has recently been studied by Eberhardt et al[4]. The $4d^9 5s^2 5p^6 6p$ states of Xe I were assumed to decay to $4d^{10} 5s^2 5p^6 6p$ states of Xe II by emission of an electron. The detailed interpretation of the observed energy spectrum of the emitted electrons is influenced by our revision of the analysis of the 6p configuration of Xe II, particularly by the changed identifications for the levels of the $(^1S)6p\ ^2P$ term.

III. An improved value for the ionization energy of Xe II has been determined in the course of our work. With this new value the discrepancy between the measurements of the kinetic energies of Auger electrons following excitation of a 4d electron in xenon by Ohtani et al.[5] and Werme et al.[6] is removed.

IV. A new identification for the $^1S_0$ level in the ground configuration of Xe III improves on the agreement between measured Auger energies involving this $^1S_0$ level and Auger energies calculated from optical data.

V. Using the eigenvector for the $5s5p^6\ ^2S_{1/2}$ state, determined by parametric fitting to the $5s5p^6 + 5s^25p^4(ns + nd)$ configurations, the lifetime of this state has been calculated. Due to extreme destructive interference in the line strength the lifetime is very sensitive to the eigenvector composition. The value obtained is in good agreement with a recent experimental value[7].

REFERENCES

1. C.J. Humphreys, J. Res. Natl. Bur. Stand. 22, 19 (1939); C.J. Humphreys, W.F. Meggers, and T.L. deBruin, J. Res. Natl. Bur. Stand. 23, 683 (1939).
2. C.E. Moore, Atomic Energy Levels, Natl. Bur. Stand. (U.S.) Circ. No. 467 (U.S. GPO, Washington, D.C., 1958), Vol. III.
3. J.E. Hansen and W. Persson, Phys. Rev. A 18, 1459 (1978).
4. W. Eberhardt, G. Kalkoffen, and C. Kunz, Phys. Rev. Lett. 41, 156 (1978).
5. S. Ohtani, H. Nishimura, H. Swzuki, and K. Wakiya, Phys. Rev. Lett. 36, 863 (1976).
6. L.O. Werme, T. Bergmark, and K. Siegbahn, Phys. Scr. 5, 141 (1972).
7. R.A. Rosenberg, M.G. White, E.D. Poliakoff, G. Thornton and D.A. Shirley, J. Phys. B: Atom. Molec. Phys. 11, L719-22 (1978).

EXPERIMENTAL INVESTIGATION OF ELECTRON CORRELATION IN Cl I BY NUCLEAR ELECTRON CAPTURE

W. Neumann

Institut f. Kernphysik, Universität Münster, D-4400 Münster, Germany

Recent calculations on the sp^6-s^2p^4d configuration interaction (CI) in Cl I gave the unusual result that ~50% of the Hartree-Fock (HF) $3s3p^6$ character is spread out as an excessively broad profile in the $\epsilon d\,^2S$ continuum, whereas the other ~50% are collected in the lowest-lying ^2S state, which approximates the position of the disputed $3s3p^6$ level in the optical spectrum. The present experiment provides first quantitative experimental evidence for mixing-coefficients and transition probabilities resulting from these calculations[1,2].

The electron capture ratios of ^{37}Ar were measured by means of a multiwire proportional counter. While the experimental L/K ratio (0.098±0.001) agrees with the theoretical value based on Bahcall's independent particle ansatz[3] (0.098), the experimental M/L ratio (0.073±0.007) is in strong disagreement with the predictions from this theory (0.129, if the $3s3p^6$ position is taken from HF calculation; 0.019, if $3s3p^6$ is taken from optical spectroscopy[1]). Inclusion of final state correlation in Bahcall's ansatz using the mixing-coefficients from the CI calculation of Cowan et al.[1] and summation over all final states detected in experiment gives the theoretical prediction $P_M/P_L \approx 0.076$-0.079. Initial state correlation is not included in this theoretical estimate, but is expected only to

reduce this value in the order of 10%. Thus, we have agreement between experiment and theory within the experimental (±10%) and computational (~10%) uncertainties. This supports the $3s3p^6$ assignment in the optical spectrum, and confirms the summed $3s3p^6$ character of the two lowest-lying ^2S states ("$3s3p^6$": 43-46%, "$3d^2S$": 2-3%) resulting from the CI calculation[1]. These two states, namely, are discriminated against in experiment.

Low-energy satellites in the 3s photoelectron and L_{23} x ray emission spectra of Cl I are also due to the sp^6-s^2p^4d CI. In contrast to previous assumptions based on analogy to Ar II, however, they do not arise from transitions to the low-lying correlation states 3d, 4d, and $4s^2S$,[4] but are dominated by transitions to the ϵd^2S continuum (double ionization and radiative Auger effect, respectively). Theory predicts approximately equal intensities for satellite and main peak[1,2], in view of large uncertainties inherent in the spectra, only a very rough qualitative agreement can be stated.

1 R. D. Cowan et al., J. Opt. Soc. Am. 64, 1474 (1974),

2 J. E. Hansen, J. Opt. Soc. Am. 67, 754 (1977),

3 W. Bambynek et al., Rev. Mod. Phys. 49, 77 (1977),

4 for a review, see R. L. Martin et al. J. Chem. Phys. 68, 3829 (1978).

CALCULATIONS OF TRANSITION PROBABILITIES IN THE ZN SEQUENCE

Charlotte Froese Fischer
Department of Computer Science, The Pennsylvania State University, University Park, PA 16802, USA

and

Jørgen E. Hansen
Zeeman Laboratory, University of Amsterdam, Plantage Muidergracht 4, 1018 TV, Amsterdam C, The Netherlands.

Multiconfiguration Hartree-Fock calculations have been carried out for a number of ions in the Zn I isoelectronic sequence between Zn I and W XLV. The purpose of the calculations was to obtain reliable oscillator strengths for highly ionized atoms of interest in fusion research. Relativistic effects have to be taken into account for highly ionized systems and it has been found that this is possible, at least for the resonance line, by combining non-relativistic line strengths with relativistic transition energies. If the non-relativistic line strengths include correlation effects the calculated oscillator strengths will take both correlation and relativistic effects into account, at least approximately. In the present calculations the correlation between the valence electrons as well as the correlation (core polarization) between these and the $3d^{10}$ shell have been taken into account.
Calculations have been carried out[1,2] for the $4s^2\ ^1S$ - $4s4p\ ^1P$ and $4s4p\ ^1P$ - $(4s4d + 4p^2)\ ^1D$ transitions where in the latter case the two lowest ^1D terms have been considered. The interaction between $4s4d\ ^1D$ and $4p^2\ ^1D$ is very strong and leads to destructive interference in the oscillator strength for the transition from the lowest ^1D term to $4s4p\ ^1P$. For Ga II the resulting ^1D lifetime turns out to be very long which agrees with the most recent measurements[3,4]. The weakness of the ^1P - ^1D transitions had in fact already been noticed in the thirties for the first elements in this sequence[5].
Except for Zn I large discrepancies have been observed between calculated and measured lifetimes of ^1P. The discrepancies increase with increasing ionization and amounts to a factor of 2 for Kr VII. For the ions, the lifetimes have been determined using the beam-foil technique and similar discrepancies in the Cu I sequence have recently been explained[6] as due to an insufficient cascade analysis in the beam-foil measurements.

REFERENCES

1. C. Froese Fischer and J.E. Hansen, Phys. Rev. A 17, 1956 (1978).
2. C. Froese Fischer and J.E. Hansen, Phys. Rev. A, submitted.
3. T. Andersen, private communication.
4. B. Denne, U. Litzén and L.J. Curtis, Phys. Lett. A, in press.
5. K. R. Rao, Proc. Roy. Soc. (London) A 134, 604 (1931-32).
6. S.M. Younger and W.L. Wiese, Phys. Rev. A 17, 1944 (1978).

Blank

MANY-BODY CALCULATIONS OF THE ELECTROSTATIC TERM STRUCTURE FOR SECOND ROW ELEMENTS

J.MORRISON, S.SALOMONSON

Department of Physics, Chalmers University of Technology, S-412 96 Göteborg, Sweden.

Corrections to the Hartree-Fock theory which arise as a result of electrostatic configuration interaction are calculated for a number of second-row elements. The effect of configuration interaction is represented by effective zero- one- and two-body operators. For a single configuration the two-body operators are responsible for the LS term structure. These operators, which are of the form $\sum_k a_k C_1^{(k)} C_2^{(k)}$, are evaluated using perturbation theory and grafical methods. The operators of even rank correct the Hartree-Fock values of the Slater F^k integrals. The operators of odd rank do not appear within the ordinary Hartree-Fock theory. The Trees parameter α is an operator of this kind. Numerical results are presented for some closed and open shell systems.

NEW LINES OF Hf XLV - Re XLVIII ISOELECTRONIC TO NiI IN LASER PRODUCED PLASMA.

A. Zigler, H. Zmora and N. Spector, Soreq Nuclear Research Center, Yavne, Israel and M. Klapisch and J.L. Schwob, Hebrew University, Jerusalem, Israel.

The X-ray spectra of the Ni-like isoelectronic sequence are characteristic of hot plasmas of high Z elements and are of interest for atomic spectroscopy and plasma diagnostics. This sequence has already been observed for some medium Z elements[1] in plasmas of Tokamaks, vacuum sparks and high power lasers. Recently lines of W, Pt and Au excited by exploding wires[2] were also measured and identified. However, the spectral resolution in this case was quite low, resulting in wavelength accuracy of only 1%.

In this work we report Ni-like spectra of the heavy elements Hf, Ta, W and Re, obtained with a 10J 2ns Nd:glass laser irradiation. The experimental wavelengths are measured with an accuracy of better than 0.005Å and are compared with ab-initio calculations. Excellent agreement is achieved between the calculated and measured values of wavelengths.

The strongest transitions observed in the range of 4-8Å are from the $3d^9 4f$ and $3d^9 4p$ upper J=1 levels of the $3d^{10}$ J=0 ground state. Together with these "resonance" transitions, some "inner-shell" ones, namely, $3p^6 3d^{10} - 3p^5 3d^{10} 4s,4d$ were also observed. A comparison of the observed spectra with those of Sm, Gd and Dy resulted in a revision of some doubtful identifications in these elements.

As an example, we give in Table 1 the observed spectrum of Hf^{44+} in the range of 5.58-7.74Å along with a comparison to the theoretical predictions.

Further aspects of the observational results such as the existence of bands, the variation of intensities and the linear extrapolative behavior of the wavelengths along Z will be presented and discussed.

TABLE 1

Observed and Calculated Hf^{44+} Lines

Ion	Transition	Experiment		Calculated	
		λ(Å)	Intensity	λ(Å)	gf
Hf XLV	$3p^6 3d^{10} - 3p^6 3d^9 (3/2)4p_{1/2}$	7.739	80	7.744	0.136
	$-3p^6 3d^9 (5/2)4p_{3/2}$	7.594	85	7.599	0.255
	$-3p^6 3d^9 (3/2)4p_{3/2}$	7.339	40	7.346	0.027
	$-3p^5 (3/2)3d^{10}4s$	6.596	80	6.596	0.347
	$-3p^6 3d^9 (5/2)4f_{5/2}$	6.419	15[b]	6.411	0.007
	$-3p^6 3d^9 (5/2)4f_{7/2}$	6.317	30	6.322	1.67
	$-3p^6 3d^9 (3/2)4f_{5/2}$	6.125	100	6.122	6.14
	$-3p^5 (1/2)3d^{10}4s$	5.780	30	5.776	0.052
	$-3p^5 (3/2)3d^{10}4d_{3/2}$	5.640	30	5.632	0.052
	$-3p^5 (3/2)3d^{10}4d_{5/2}$	5.586	85	5.579	1.20
	$-3p^5 (1/2)3d^{10}4d_{3/2}$			5.014	0.436

[b] blend

References:

1. P.G. Burkhalter, U. Feldman and R.D. Cowan, J. Opt. Soc. Am. 64, 1058 (1974).

2. P.G. Burkhalter, C.M. Dozier and D.J. Nagel, Phys. Rev. A15, 700(1977).

Blank

Abstract of communication submitted for

11th EGAS Conference in Paris (July 1979)

Title: "Testing for two-step autoionization by multiconfiguration Dirac-Fock calculations"

Authors: J.P. Connerade[+], I.P. Grant[*] and S.J. Rose[*].

+ Blackett Laboratory, Imperial College, London SW7.

* Department of Theoretical Physics, Oxford University, Oxford.

Recently synchrotron radiation has been exploited to obtain photoabsorption spectra of Ca, Sr and Ba in the energy range of the outermost p subshell excitation and the data fix the energies of the intense absorption lines. The analysis of the photoabsorption data and the electron-impact data also determine the energies of the corresponding thresholds; s-d mixing occurs in all these elements and because the d subshell is very soft the mixing coefficients are computed in a fully relativistic model.

Recent MCDF calculations have established that two-step autoionization which may explain the double ionization anomaly in Ba I, is energetically possible and a consistent identification of the intermediate states can be extracted from the observed ejected electron spectrum. Given the energies of the intense absorption lines in Ca and Sr and the energies of the thresholds a similar analysis can be performed to determine whether two-step autoionization is energetically feasible for these elements.

PARAMETERVALUES IN SPECTRA OF ELEMENTS OF THE IRONGROUP

A.J.J. Raassen

Zeeman-Laboratorium, Plantage Muidergracht 4, Amsterdam, Netherlands.

The spectra of elements of the irongroup are characterized by the configurations $3d^n$, $3d^{n-1}4s$ and $3d^{n-1}4p$. These spectra are very complex. In these spectra there is an intermediate coupling. The line intensities are far away from those which can be expected in pure Russell-Saunders coupling. The introduction of large computersystems created the possibility to make calculations by means of the theory developed by Slater [1]. With the aid of the eigenvectors derived from these parametric calculations transition probabilities can be computed. These transition probabilities are of great help analysing the complex spectra. The final Slater parameter values can be obtained by means of a least-squares fit.
To estimate parameter values of an unanalysed spectrum, the final parameters of almost completely analysed spectra can be compared in the iscelectronic and isoionic sequences.
Moreover, Hartree-Fock calculations have been made. From these calculations the value of F^2, F^4 and ζ can be derived.
The behaviour of the ratios of fitted parameter values to Hartree-Fock values will be discussed.

[1] J.C. Slater, Phys.Rev. 34, 1293 (1929).

$4d^8 5s$ - $4d^8 5p$ Transitions in Sb VII and Te VIII

Y. N. Joshi

St. Francis Xavier University, Antigonish, N. S., CANADA

and

Th. A. M. vanKleef

Zeeman Laboratorium, Universteit van Amsterdam, Amsterdam

The Netherlands

The spectra of antimony and tellurium were photographed in the region 1700 Å - 600 Å on a 10.7m normal incidence spectrograph. The source used was a triggered vacuum spark. The pole effect exhibited by the lines helped to sort out different ionization states. All levels belonging to the $4d^8 5s$ configuration and the levels of the $4d^8 5p$ configuration not established in the earlier work[2] of Sb VII and Te VIII have been established. The parametric level fitting calculations support the analyses. A comparison of parameters in Ag III isoelectronic sequence will also be presented.

1. Research supported in part by NATO - Scientific Affairs Division and by the Natural Sciences and Engineering Research Council of Canada.

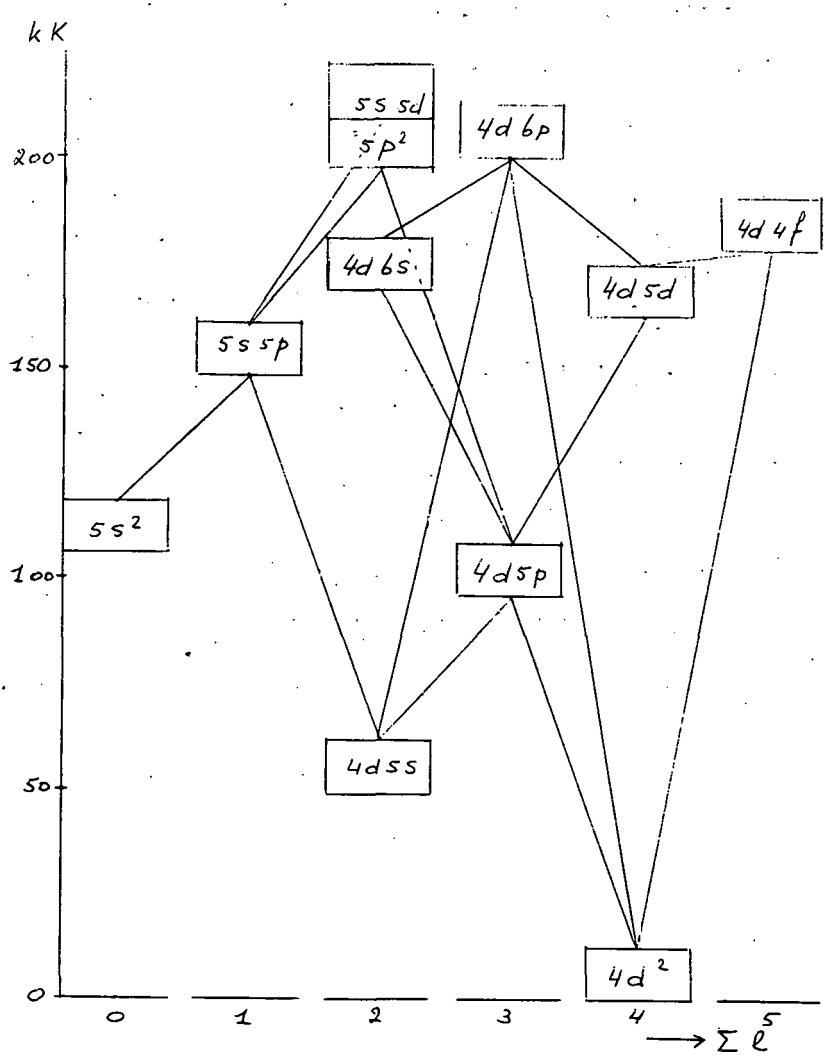
2. Th. A. M. vanKleef and Y. N. Joshi, J. Opt. Soc. Amer. 68, , 1978.

THE ISOELECTRONIC SEQUENCE OF Sr I AND THE ENERGY LEVELS OF Nb IV.

L.N.M. Remijn, F.G. Meijer and E. Meinders
Zeeman-Laboratorium, Plantage Muidergracht 4, Amsterdam, Netherlands.

In connection with the analysis of Ta IV (ground configuration $5d^2$) irregularities were discovered in the level structure of trebly ionised niobium ($4d^2$), still named columbium when Lang *) published his analysis.
Comparison with ions in the same column of the periodic table (V IV - Nb IV - Ta IV) as well as comparison with isoelectronic ions (Sr I - Y II - Zr III - Nb IV - Mo V) showed discrepancies in the singlet system. A new analysis was therefore undertaken. The spectrum was photographed in the region 700 - 3000 Å and a new line list was compiled.
The error in the singlets appeared to be caused primarily by the absence of Nb IV-lines above 2250 Å in Lang's line list. This affected the 4d 5s - 4d 5p transition analysis.
After correction an extension of the analysis could be obtained, the results of which will be presented at the conference.

*) R.J. Lang, Zeeman Verhandelingen p.44 (Martinus Nijhoff, The Hague, 1935).



Configuration system of Nb IV and one-electron transitions.

$4d^9 5d$ AND $4d^9 6s$ CONFIGURATIONS IN THE Cd III - Te VII SEQUENCE.

Th.A.M. van Kleef, Zeeman-Laboratorium, Plantage Muidergracht 4, Amsterdam, Netherlands, and
Y.N. Joshi, St. Francis Xavier University, Antigonish, N.S., Canada.

In the spectra of the Cd III - Te VII sequence all levels of the $4d^9 5d$ configuration - except ^1S_o - and all levels of the $4d^9 6s$ configuration have been determined.
The designation of some levels in the $4d^9 5d$ configuration in Cd III [1] have been changed and some levels in this configuration are incorrect. In In IV [2] a number of levels is erroneous, while in Sn V [3] the given $4d^9 6s$ levels belong to the $4d^9 5d$ configuration.
A comparison between Least-squares fitting (L.S.F.) parameters and Hartree Fock (H.F.) parameters in this sequence will be given.

[1] A.G. Shenstone and J.T. Pittenger, J.Opt.Soc.Amer. 39 (1949) 221.
[2] K.S. Bathia, W.E. Jones and A.M. Crooker, Can.J.Physics 75 (1974) 341.
[3] C.E. Moore, Atomic Energy Levels Vol. III, N.B.S., Washington, D.C. Circular 467 (1958) p.84

A PRELIMINARY ANALYSIS OF W V

F.G. Meijer
Zeeman-Laboratorium, Plantage Muidergracht 4, Amsterdam, Netherlands.

After finishing the analysis of Ta IV [1], isoelectronic with this spectrum, and using the spectrograms and results of W VI [2], the analysis of W V was undertaken.
The most important configurations of this two-electron spectrum are $5d^2$, 5d6s, 5d6p and 6s6p; $6s^2$ is expected to lie rather high and is difficult to find.
Using the above mentioned spectrograms which were taken under conditions not only favourable for the sixth, but also for the fifth spectrum to facilitate discrimination of the lines belonging to different stages of ionization, most of the levels of these configurations could be located.
To find the missing levels, additional exposures were made and the results will be given. The even configurations are the lowest, of which $5d^2$ is the ground configuration and the lowest, of which $5d^2$ is the ground configuration and the lowest level is $5d^2\ ^3F_2$.

[1] F.G. Meijer and B.C. Metsch, Physica 94C (1978) 259-269.
[2] F.G. Meijer, Physica 73 (1974) 415-420.

THE 4d-4f TRANSITIONS IN THE Cr II SPECTRUM

S. Orti-Ortin

O. Garcia Riquelme

Instituto de Optica. MADRID-6

The spectrum Cr II has been analized by C. Kiess in 1951 (1). He determined most of the levels of the fundamental configurations $3d^5$, $3d^44s$, $3d^44p$ and also some levels of the $3d^44d$ and $3d^45s$.

We have done new observations of the Cr spectra in the region 1200-8000 A, by using a hollow cathode and a sliding spark discharge with a ceramic spacer, under different conditions, as light sources.

The sliding spark run at 700 V with a capacitance of 16 uF and a pulsing frecuency of 25 Hz. Two peak current of 700 and 200 A were selected by changing the inductance to the values 0 and 500 uH repectively, the corresponding periods 100 us and 1.2 ms. Under these two limit conditions we have been able to distinguish between the spectra Cr II and Cr III, Cr IV.

Fig. 1 and Fig. 2 show the oscilloscope display of the two signals.

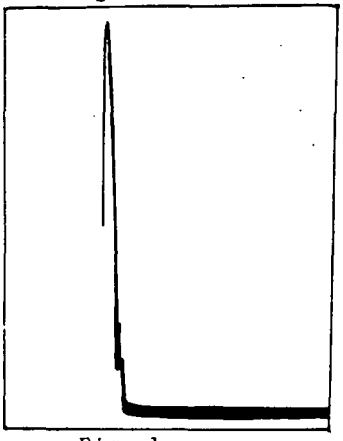


Fig. 1

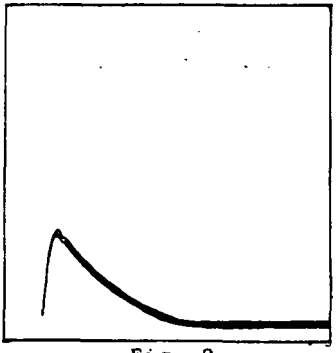


Fig. 2

The hollow cathode discharge was operated at a pressure of 7 mm. Hg, both in a continuous discharge 100 V, 1A and in a condensed discharge 16 uF and 800 V, 800 A, 0 uH and a pulsing frecuency of 25 Hz, that have allwed us to verify the previous lines asignements.

Many new lines have been atributed to the Cr II spectrum and some of them to the 4d-4f transitions. The observed levels of the $3d^4 4f$ configuration are presented.

(1).- C-C. Kiess, J. Res. Nat. Bur. Std. 47,385 (1951).

SPECTROSCOPIC INVESTIGATION OF HIGHLY CHARGED VERY SLOW RECOIL IONS

H.F. Beyer, R. Mann, K.-H. Schartner[+] and F. Folkmann

Gesellschaft für Schwerionenforschung mbH, D-6100 Darmstadt, West Germany
[+]I. Physikalisches Institut der Justus Liebig-Universität, D-6300 Gießen, West Germany

Measured Auger-electron /1/ and x-ray spectra /2/ show that very heavy projectiles of specific energy 1.4 MeV/amu are likely to remove more than six electrons from light ($Z \sim 10$) target atoms in a single collision whenever the target K shell gets ionized. In Fig. 1 the neon x-ray spectrum is displayed for the case of Pb^{36+} impact showing the high degree of ionization. The satellite spectrum is dominated by the helium-like configuration 1s2p, whereas in the high energy part of the spectrum a considerably high intensity from the hydrogen-like series np → 1s is observed.

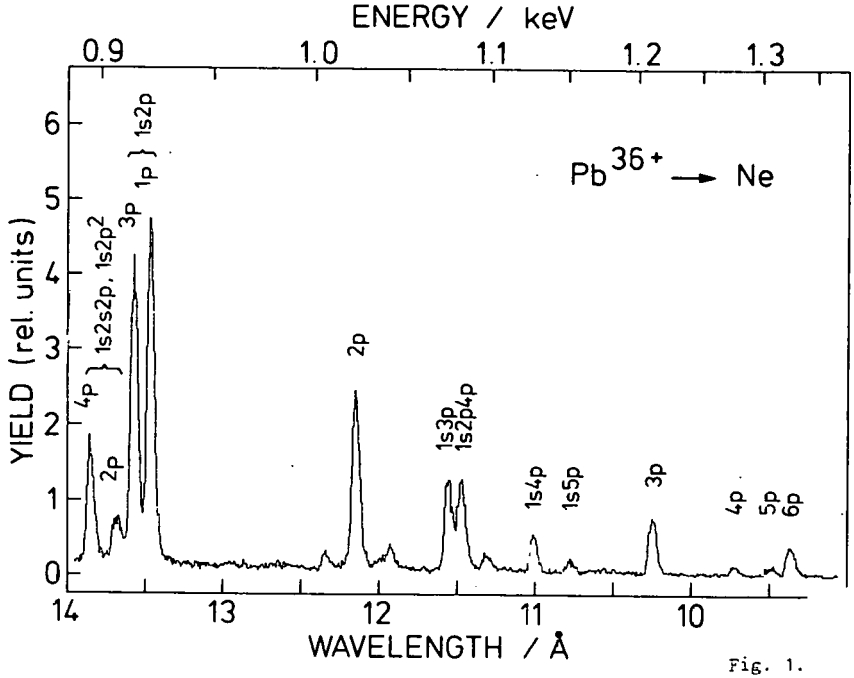


Fig. 1.

The produced few electron recoil ions which are observed in core excited initial configurations $(1s2^p_s)nl$, $(1s)nl$ or nl have only very low recoil energies of $\lesssim$ 10 eV. The slow recoil ions stay for a long time ($\sim$ 300 nsec) after creation in the viewing range of the spectrometers. Thereby information is received not only from promptly decaying states produced in the primary heavy ion collision

but also processes are detected which occur after some time delay and give rise to the emission of x rays or Auger electrons. One such process is selective electron capture from surrounding neutral target atoms into outer shells of metastable highly charged recoil ions what is investigated in both x-ray and Auger decay channel. By application of gas targets containing more than one atomic (molecular) species it is also possible to study electron capture between highly ionized states of one and ground states of another species. It is found that the principal quantum number of the outer shell where the electron is transferred to is systematically raised as the ionization potential of the admixtured gas is lowered.

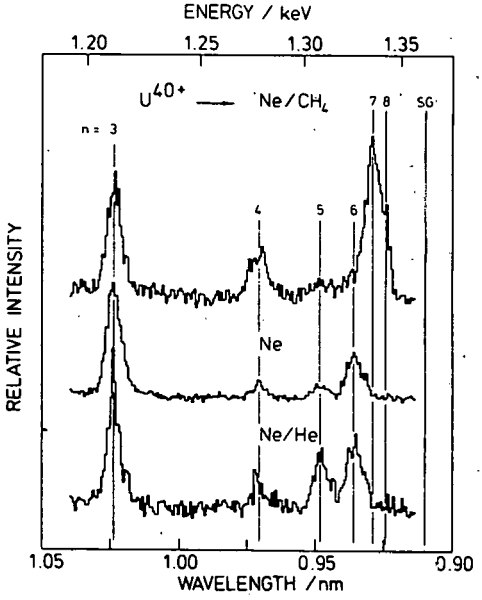


Fig. 2.
X-ray spectra of hydrogen-like neon excited by 1.4 MeV/amu U^{40+}. The vertical lines indicate calculated energies for the transitions np → 1s. Target gases are Ne/He, Ne and Ne/CH_4 respectively.

This leads to an characteristic enhancement of a specific line within line series and is as an example demonstrated for the H-like series in Fig. 2. The electron capture processes followed by cascading transitions as prominent population mechanisms have to be taken into account when analyzing heavy ion induced spectra from few electron systems.

/1/ N. Stolterfoht, D. Schneider, R. Mann and F. Folkmann, J.Phys. B10, L281 (1977)

/2/ H.F. Beyer, K.-H. Schartner, F. Folkmann and P.H. Mokler, J.Phys. B11, L363 (1978)

THE Ni III SPECTRUM IN THE REGION 1300-1600 A.

O. Garcia-Riquelme
Instituto de Optica. MADRID

The Spectra of Nickel using a sliding spark as light source have been measured in the region 1330-1817 A.

The plates were obtained in the 10m. spectrograph of the N.B.St. by V. Kaufman several years ago. The measurements and calculations have been performed at the "Instituto de Optica" in Madrid.

About 1600 lines belonging to the II, III and IV spectra were observed and measured; a clear differentiation between them was possible through the different conditions of excitation. The calculations show an estimated uncertainty of 0.005 A.

The $3d^74s$ and $3d^74p$ configurations have been revised in the view of Shadmi (1) and Roth (2) calculations and all the levels but the higher ^1D of $3d^74p$ found.

Many new lines have been classified as transitions - 4p-4d and 4p-5s. All the terms of $3d^7(^4F)4d$, $3d^7(^4F)5s$ and some levels from higher limits have also been found.

Tables of lines and energy levels are presented.

(1) Y. Shadmi, E. Caspi & J. Oreg, J. Res. N.B.St. 73A, 173 (1969).

(2) C. Roth, J. Res. N.B.St. 72A, 505 (1968).

EXTENSION OF OBSERVATIONS IN THE Pd I AND Ag I ISOELECTRONIC SEQUENCES

Jack SUGAR and Victor KAUFMAN

National Bureau of Standards, Washington, D.C. 20234 - U.S.A.

The Pd I and Ag I isoelectronic sequences are being extended beyond the last known data[1] in Nd XV and Sm XVI. New identifications in lower ionization stages have been made, giving energy levels and ionization energies for these ions. The light source is a vacuum triggered spark with a 14.2 μf capacitor charged at 3 to 15 kV. The exposures were made on the NBS 10.7 m grazing incidence spectrograph.

References

1. J. Sugar, "Resonance lines in the Ag I and Pd I isoelectronic sequences: Ca IX through Sm XVI and Cs X through Nd XV", J. Opt. Soc. Am. 67, 1518-1521 (1977).

HYPERFINE STRUCTURE OF SOME TeII LINES

K.Werel, L.Augustyniak, J.Heldt
Institute of Physics, University of Gdańsk
80-952 Gdańsk, Poland

The spectrum of singly-ionized tellurium has been investigated using PGS 2 spectrograph and Fabry-Perot interferometer. Tellurium enriched to 95.56% in Te^{125} was excited by a microwave oscillator [1]. Several new lines have been found in the range from 4000 Å to 5800 Å. The interferometric hyperfine structure patterns of these lines /although we did not observed complete patterns in many cases/ confirm the assumption that the lines belong to the TeII spectrum. The wavelengths of some new observed lines are consistent with differences of energy levels given by M.B.Handrup and J.E.Mack [2] but this set of levels is not sufficient to classify all of them. This fact suggest that the list of TeII energy levels is not complete. Further study of hfs of the TeII spectrum as well as Zeeman effect data should yield very helpful information to classification of the TeII lines.

The hfs splittings of some TeII levels obtained by us are listed in the table.

Term symbol	Hfs splitting $[cm^{-1}]$	
	Present work	Ross and Murakawa [3]
$83_{1/2}$	+ 0.069 ± 0.007*	+ 0.082
$94_{5/2}$	- 0.107 ± 0.006	
$125_{3/2}$	- 0.118 ± 0.005	
$103^{o}_{3/2}$	- 0.192 ± 0.006	- 0.193
$106^{o}_{1/2}$	- 0.240 ± 0.004	
$116^{o}_{3/2}$	+ 0.106 ± 0.006	

* maximum error

References

[1] L.Augustyniak, Phys.Scr. 15, 63 /1977/.

[2] M.B.Handrup and J.E.Mack,Physica 30, 1245 /1964/.

[3] J.S.Ross and K.Murakawa, Phys.Rev. 85, 559 /1952/.

THE $2p^3 3s$ AND $2p^3 3d$ CONFIGURATIONS OF Mg V AND Aℓ VI

Marie-Christine ARTRU

Observatoire de Paris, 92190-Meudon, France

Victor KAUFMAN

National Bureau of Standards, Washington, D.C. 20234 - U.S.A.

Emission spectra of Mg V and Aℓ VI spectra were produced by triggered-sparks and recorded with the 10.7 m grazing-incidence spectrograph of the NBS, in the range 80-200 Å. Wavelengths are measured to about ± 0.003 Å in several orders of the grating. Most of the lines were previously observed, and the new data generally confirm their identification. Level assignments in the odd configurations $2p^3 3s$ and $2p^3 3d$ were revised on the basis of parametric calculation and isoelectronic comparison. The effects of configuration interaction between $2s2p^5$, $2s^2 2p^3 3s$ and $2s^2 2p^3 3d$ are discussed and compared throughout the O I sequence.

BEAM-FOIL STUDY OF XENON IN THE VACUUM ULTRA-VIOLET.[1]

J. A. Kernahan, J. A. O'Neill, E. H. Pinnington, and J. L. Bahr[2]
Department of Physics, University of Alberta, Edmonton, Canada.

Using a 2 MeV Van de Graaff accelerator, we have studied spectra and mean lives of levels in XeVI and XeVII by the beam-foil technique, for transitions between 500Å and 1000Å. (Results for levels in XeVIII along with KrVIII and ArVIII have been reported elsewhere[3]). Spectral scans were taken at various Xe^+ beam energies between 0.7 and 1.6 MeV, the radiation being detected with a McPherson 1 metre vacuum monochromator equipped with a "Spiraltron" electron multiplier. Decay data for the mean life measurements were obtained with a beam energy of 1.6 MeV. The accelerator was calibrated by observing zero field quantum beats in emission at 3889Å from a helium beam.

A PDP 11/05 minicomputer provided stepping motor control for either the foil or monochromator wavelength drive, floppy disk data and program storage, and direct interface with the main university computer for data transmission and analysis.

Of the total of sixteen lines that we used for mean life studies, only five are classified (as XeVII transitions). Three others are attributed to as yet unclassified transitions in XeVI, while the remaining eight lines are unknown. Thus, we will report mean life results for the $5p\ ^1P^o$, $5p\ ^3P^o$, $5p^2\ ^3P$ and $5d\ ^3D$ levels in XeVII. The $5p\ ^3P^o$ mean life was obtained from the $5s^2\ ^1S - 5p\ ^3P^o$ intercombination line at 996Å, and a preliminary result for the ratio of the $^3P^o$:$^1P^o$ lifetimes gives the value 76 ± 9 in good agreement with the result of 74 obtained from a simple intermediate coupling calculation. Where possible, proposed classifications for the unknown lines will be discussed.

[1]Work supported by the Province of Alberta and the National Research Council of Canada.

[2]On Sabbatical leave from the University of Otago, Dunedin, New Zealand.

[3]E. H. Pinnington et al. (accepted for publication in Physica Scripta).

LIFETIME MEASUREMENT IN COAXIAL ION-LASER BEAM GEOMETRY

D.T.Pegg†,M.Carré,M.Druetta,M.L.Gaillard
Laboratoire de Spectrométrie ionique et moléculaire
Université Lyon I,Villeurbanne,France.

An alternative high precision technique for lifetime measurement in ions has recently been proposed (1).Based on the coaxial ion-laser beam geometry,it benefits from the same advantages as previous crossed beam techniques (2),such as efficient selective excitation with good time reso--lution and detection linearity.The new set up offers furthermore interesting properties concerning ion beam velocity measurement,background correction and normalisation.The possible influence of systema--tic error is thus quite different in the two measur--ement procedure.This provided the motivation for a reevaluation of the lifetime of the $4p^5 5p3/2(1/2)_1$ level in RbII.

Previous measurement of that lifetime by crossed beam technique gave a result of 8.04 ± 0.08ns (3).Surprisingly recent calculations(4) which gave a reasonable overall agreement with the lower pre--cision lifetime obtained for the other $4p^5 5p$ levels (5) still displayed a 40°/$_o$ disagreement on the $5p\ 3/2\ (1/2)_1$ level so that questions were raised about possible hidden systematic errors in precision measurements. Fortunately, our new measurement carried out under entirely new experimental condi-tions is in complete agreement with the previous result at the 1 % level. The theoretical discrepancy is quite real, illustrating tne difficulty of life-time calculation in ions of the rare gas sequence.

1/ H. WINTER, M.L. GAILLARD, Z. Physik A 281 (311) 1977.

2/ H.J. ANDRÄ,A. GAUPP, K. TILLMAN, W. WITTMANN, Nucl. Inst. Method 110 (453) 1973.

3/ M.L. GAILLARD, H.J. ANDRÄ,A. GAUPP, W. WITTMANN, H.J. PLOHN, J.D. STONER, Phys. Rev. A 12 (987) 1975.

4/ P. CEYZERIAT, E.G.A.S. 1978, Cracovie.

5/ M. CZEMPIEL, Diplomarbeit, F. U. Berlin, 1975; C.K. KUMAR, G.E. ASSOUSA, L. BROWN, W.K. FORD Jr, Phys. Rev. A 7 (112) 1973.

+Permanent adress : Department of Physics, University of Tennessee, U.S.A.

BEAM-FOIL STUDY OF Fe V AND Fe VI IN THE VACUUM ULTRAVIOLET.

H.P. GARNIR, Y. BAUDINET-ROBINET, P.D. DUMONT.
Institut de Physique Nucléaire - B 15
Université de Liège
B-4000 Sart-Tilman, Liège, Belgium.

N. GREVESSE, E. BIEMONT.
Institut d'Astrophysique
Université de Liège
B-4200 Cointe-Ougrée, Belgium.

Beam-foil iron spectra were recorded between 1100 and 1900 Å at ion energies ranging from 0.4 to 1.5 MeV. Many lines appearing in our high energy spectra (E > 1 MeV) were identified as transitions in Fe V and Fe VI from the study of the variation of their intensities with the beam energy and from the classifications of EKBERG[1]. For the first time lifetimes have been measured for $3d^3$ 4p and $3d^2$ 4p levels in Fe V and Fe VI respectively. Our lifetime results are given in Table 1 together with the available theoretical values deduced from the transition probabilities calculated by ABBOTT[2].

Possible blends of some listed lines with Fe V and / or Fe VI lines were rejected after a careful analysis of our beam-foil spectra together with the sliding-spark results[1]. The marked discrepancies between theoretical and experimental lifetime results cannot be explained by a bias in the analysis of decay curves due to cascade repopulations which seems to be weak for all the levels studied.

References :

[1]) J.O. EKBERG, Physica Scripta 11, 23 (1975)
Physica Scripta 12, 42 (1975)

[2]) D.C. ABBOTT, J. Phys. B 11, 3479 (1978) and private communication to E. BIEMONT.

TABLE I - LIFETIME RESULTS IN Fe V and Fe VI.

Ion	Wavelength (Å)	Transition [a]	Lifetime of upper level (ns)		Cascade lifetimes (ns)	R(0) [b]
			This work	Theory [c]		
Fe V	1359.01	$(b\ ^2D)\ ^3D_1 - (b\ ^2D)\ ^3F^0_2$	0.51±0.04	-	≈ 5	≈ 0.1
	1373.59	$(^5F)\ ^5F_4 - (^5F)\ ^5F^0_5$	0.52±0.04	-	≈ 10	≈ 0.05
	1373.67	$(^5F)\ ^5F_3 - (^5F)\ ^5F^0_3$				
	1376.34	$(^5F)\ ^5F_4 - (^5F)\ ^5F^0_4$	0.54±0.02	0.28	≈ 20	≈ 0.07
	1376.45	$(^5F)\ ^5F_2 - (^5F)\ ^5F^0_2$		0.17		
	1378.56	$(^5P)\ ^5P_3 - (^5P)\ ^5D^0_4$	1.2 ±0.2	0.66	≈ 0.2	≈ 1
	1387.94	$(^2H)\ ^3H_4 - (^2H)\ ^3I^0_5$	1.0 ±0.1	0.57	≈ 0.1	≈ 3
	1402.39	$(^2H)\ ^3H_5 - (^2H)\ ^3I^0_6$	0.9 ±0.1	0.57	≈ 0.07, ≈ 12	≈ 2
	1415.20	$(^2H)\ ^3H_4 - (^2H)\ ^3I^0_5$	0.9 ±0.1	0.55	≈ 20	≈ 0.03
	1406.82	$(a\ ^2D)\ ^3D_3 - (a\ ^2D)\ ^3F^0_4$	0.40±0.03	0.17	≈ 5	≈ 0.1
	1409.03	$(^5F)\ ^5F_3 - (^5F)\ ^5D^0_2$	0.30±0.02	-	≈ 2	≈ 0.1
	1409.22	$(^5F)\ ^5F_4 - (^5F)\ ^5D^0_3$		0.15		
	1409.45	$(^5F)\ ^5F_5 - (^5F)\ ^5D^0_4$		-		
	1430.57	$(^5F)\ ^5F_5 - (^5F)\ ^5G^0_6$	1.4 ±0.2	0.96	≈ 0.4, ≈ 10	≈ 2
	1440.53	$(^5F)\ ^5F_4 - (^5F)\ ^5G^0_5$	1.5 ±0.3	0.97	≈ 0.4, ≈ 10	≈ 2
	1448.85	$(^5F)\ ^5F_3 - (^5F)\ ^5G^0_4$	1.5 ±0.1	0.99	≈ 0.1	≈ 3
	1456.16	$(^5F)\ ^5F_2 - (^5F)\ ^5G^0_3$	1.7 ±0.2	-	≈ 0.3	≈ 1
Fe VI	1228.60	$(^1G)\ ^2G_{9/2} - (^1G)\ ^2H^0_{11/2}$	0.33±0.05	0.18	≈ 2	≈ 0.1
	1253.68	$(^1G)\ ^2G_{7/2} - (^1G)\ ^2H^0_{9/2}$	0.33±0.03	0.18	≈ 2	≈ 0.1
	1272.07	$(^3F)\ ^4F_{9/2} - (^3F)\ ^4G^0_{11/2}$	0.81±0.05	0.45	≈ 0.1, ≈ 5	≈ 3
	1285.37	$(^3F)\ ^4F_{7/2} - (^3F)\ ^4G^0_{9/2}$	0.62±0.05	0.39	≈ 0.1, ≈ 5	≈ 2
	1296.87	$(^3F)\ ^4F_{5/2} - (^3F)\ ^4G^0_{7/2}$	0.59±0.05	0.41	≈ 0.1, ≈ 5	≈ 2
	1361.82	$(^3F)\ ^2F_{5/2} - (^3F)\ ^2F^0_{5/2}$	0.42±0.04	0.14	≈ 3	≈ 0.05

a. Classification from EKBERG[1]

b. Replenishment ratio at the foil

c. ABBOTT[2]

EXPERIMENTAL TRANSITION PROBABILITIES FOR INTERCOMBINATION LINES IN N IV, O V AND F VI.

L. Engström, B. Denne, S. Huldt, J.O. Ekberg, L.J. Curtis, E. Veje* and I. Martinson

Department of Physics, University of Lund, S-223 62 Lund, Sweden.
* H.C. Ørsted Institute, University of Copenhagen, DK-2100 Copenhagen, Denmark.

In the present work the transition probability for the intercombination line $2s^2\ ^1S_0$ - $2s3p\ ^3P_1$ in N IV, O V and F VI is deduced from precision lifetime measurements of the levels $2s3p\ ^3P_{0,1,2}$. We have also made theoretical calculations of this transition probability using a Hartree-Fock approximation with a limited number of configurations.

We measured the intensity decay curves for each of the transitions $2s3s\ ^3S_1$ - $2s3p\ ^3P_{0,1,2}$ using standard beam-foil techniques. The ions were accelerated with the 3 MV Pelletron tandem accelerator at the University of Lund, and as a monochromator we used a refocused 1 m Czerny-Turner (McPherson 2051) instrument. For O V we measured the decay of each of the three ^3P levels six times at energies 2.5, 3.0 and 3.5 MeV. Four sets of data (for each J-level) were taken for F VI at energies 3.0 and 3.5 MeV. In the case of N IV, measurements as well as our theoretical estimates showed that the effect was too small to permit accurate determination for realizable data accumulation times, and we were thus forced to be content with only one measurement for the J = 2 and J = 1 levels at 2.9 MeV.

From table 1 it is clearly seen that for O V and F VI the lifetimes for $2s3p\ ^3P_0$ and $^3P_2$ are practically identical while $^3P_1$ is significantly shorter (fig. 1). The transition probability for the $1s^2\ ^1S_0$ - $2s3p\ ^3P_1$ intercombination line is calculated from the deviation of the lifetime for $^3P_1$ from those of $^3P_0$ and $^3P_2$.

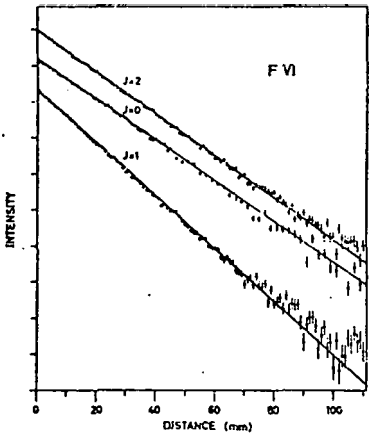


Fig. 1. Intensity decay curves for the $2s3p\ ^3P_{0,1,2}$ levels in F VI. All curves were taken with the same initial statistics; about 10 000 counts/channel at the position closest to the foil, but are shifted for purposes of illustration. The ordinate scale is logarithmic.

Table 1 Results

Spectrum	Upper level	Experimental lifetimes (ns)	Transition probabilities ($10^6 s^{-1}$) $2s^2\ ^1S_0 - 2s3p\ ^3P_1$ Experimental	Theoretical
N IV	$^3P_2$	8.98±0.10	3.3±2.7	5
	$^3P_1$	8.72±0.12		
O V	$^3P_2$	5.36±0.07	22±6	15
	$^3P_1$	4.74±0.07		
	$^3P_0$	5.26±0.07		
F VI	$^3P_2$	3.07±0.04	88±9	120
	$^3P_1$	2.41±0.04		
	$^3P_0$	3.04±0.04		

H.-D. Dohmann, R. Mann, and H. Pfeng, GSI Darmstadt, W-Germany

Beam Foil Spectroscopy of Few-Electron Systems of Heavy Ions

With x-ray and electron spectrometers of high energy resolution prompt and delayed emitted spectra of 56 MeV Ar and 67 MeV Ti ions of the Unilac were measured.

In addition to the four known metastable $(1s2s)^1S_0$, $(1s2s)^3S_1$, $(1s2p)^3P_2$, and $(1s2s2p)^4P_{5/2}$ states of the two and three electron systems promptly decaying levels with lifetimes of about 10^{-14}s could be identified in the delayed x-ray and Auger electron spectra 10^{-9}s after passing the foils. These lines are produced by cascading processes beginning with a high principal quantum number $n \geq 14$ and maximum orbital quantum number $l = n-1$. At the end of the decay the 2p state is populated. Fig. 1 shows the different cascading processes causing deviations of the decay curve from the known exponential law for x-ray and Auger electron measurements.

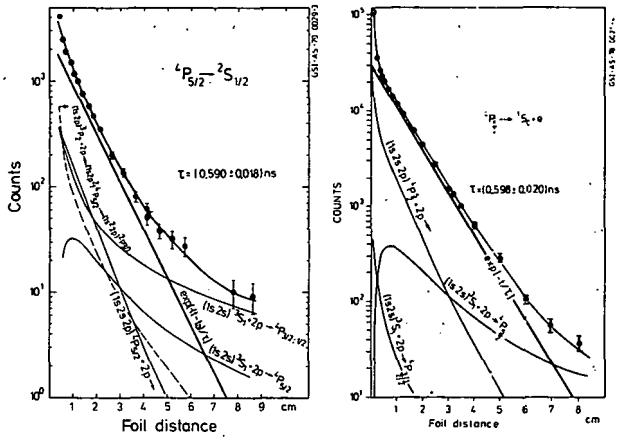


Fig. 1: Decay curves of the $^4P_{5/2}$ state observed in the x-ray (left part) and Auger electron (right part) channel. The intensity of the different contributions follows from the measured intensity of cascades.

The resulting lifetime of the $^4P_{5/2}$ state in Ar^{15+} is τ = (0,594 ± 0,016)ns and is slightly larger than the theoretically predicted value of 0,563 ns. If the $(1s2s)^1S_0$ state, decaying by a 2E1 transition, is populated by a 2p cascading electron the $(1s2s2p)^2P_{3/2}$ state is produced. This state decays by emission of an Auger electron. The time behaviour of the intensity of this line for Ar^{15+} and Ti^{19+} is shown in fig. 2 and allows the determination of the cascading law and the lifetime of the $(1s2s)^1S_0$ state.

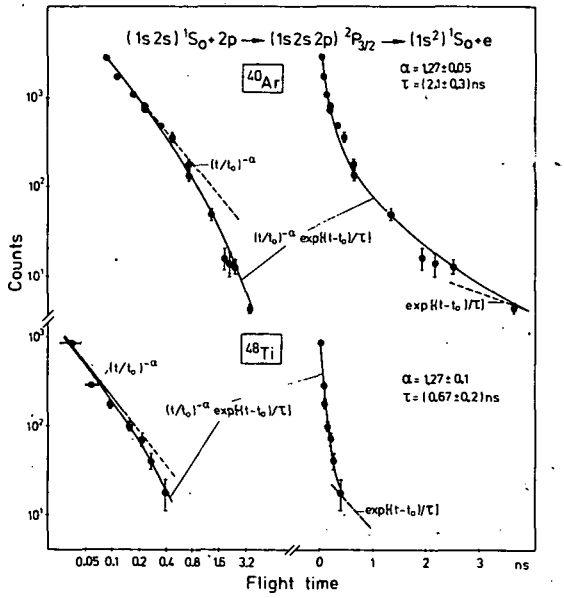


Fig. 2: Intensity of the $(1s2s)^1S_0 + 2p \rightarrow (1s2s2p)^2P_{3/2} \rightarrow (1s^2)^1S_0 + e$ line. The $(1s2s)^1S_0$ state decays by a 2E1 transition. Therefore the intensity obeys an $\exp[-(t-t_0)/\tau] \cdot (t/t_0)^{-\alpha}$ law.

DETERMINATION OF THE OSCILLATOR STRENGTHS OF CERTAIN ION SPECTRAL LINES OF RARE-EARTH ELEMENTS WITH THE AID OF IMPULSE CAPILLARY DISCHARGES

A.Petrakiev, I.Koleva, D.Dobreva

University of Sofia, Faculty of Physics,
Chair of Optics and Spectroscopy,
Sofia-1126, 5 A.Ivanov Blvd.,
BULGARIA

It is well-known that in recent years the interest in the determination of the atomic constants of rare-earth elements has very much increased. This is related to the creation of lasers on their basis, to certain astrophysical problems, and to the elucidation of the structural peculiarities of their spectra. In the works of Andersen et al.(1), Penkin et al.(2), Saifman et al.(3), with the aid of different techniques, the atomic life times and the oscillator strengths of several rare-earth elements have been determined, and comparisons have been drawn with the data from the work of Corliss and Bozman (4). However, with the techniques that these authors utilize, it proves too difficult to study the atomic constants of the spectral lines of these elements with a higher ionization rate.

In the present work an application is shown of the impulse capillary discharge method, proposed by Kiselevskij et al.(5),which is utilized for the determination of the relative strengths of the oscillator of oxygen, fluorine, and lead. Certain preliminary results of the use of this method in rare-earth elements up to the 3rd ionization rate have already been reported by us (6). Further investigations, and a modification and concretization of the above method, are presented in this work for Ce I, Ce II, Ce III, Sm I, Sm II, Sm III, Tm I, Tm II, and Tm III. In order to find the optimum operating conditions, in which the existence of a local thermodynamic equilibrium of the plasma in a given sector of the discharge can be proved, detailed space-and-time investigations were carried out with the aid of time-extended spectroscopy and equidensitometry, and of a study of the radial distribution of the plasma parameters by the Abbel inversion. The spatial course of the temperature is determined on the basis of calculations of the temperature functions of excitation of the respective ion lines, carried out by us. Such calculations were carried out up to a still higher ionization rate, but they were not utilized by us, because it is necessary to prove that in the case of our concrete discharge the excitation of these lines passes through the maximum of the temperature function Similar experiments will form the object of a future work.

The results thus obtained are shown on the following table:

Element	λ, Å	Upper level	E, eV	T.10^{-3}K	f_{rel}
Sm I	4164,79	6	3,2	8,5	15
Sm II	3568,27	15/2	3,96	11,4	0,045
Sm III	3131,54	5	3,89	16,4	0,003
Tm I	3798,54	5/2	3,95	11,4	0,02
Tm II	3131,20	5	3,96	12,5	0,029
	3402,20	5	3,58	12,1	0,005
	3302,02	2	3,72	12,4	0,023
Tm III	2947,16	11/2	8,77	22,1	0,001
Ce I	2709,62	5	4,0	10,7	18,4
Ce II	3186,59	15/2	3,82	11,2	0,07
Ce III	3427,0	5	4,3	10,2	0,004

Comparisons on the basis of recalculation with the aid of the branching ratio, and the results of other authors (1-4) show a relatively good concordance. As reference values those of the works (2) are utilized.

The authors take this opportunity to express their thanks to Professor T.Andersen and Professor N.Penkin for their interest in the present work and the discussion of its results.

REFERENCES

1. T.Andersen, G.Sørensen, Solar Physics, 38, 343, (1974)
T.Andersen, G.Sørensen, Astrophys. Letters 8, 39, (1971)
T.Andersen, O.Poulsen, T.Ramanujam, A.Petrakiev, Sol. Phys., 44, 257, (1975)
2. Н.Пенкин, В.Комаровский, JQSRT, 16, 217, (1976)
К.Благоев, В.Комаровский, ОС, 42, 2, 207, (1977)
К.Благоев, В.Комаровский, Н.Пепкин, ОС, 44, 2, 22, (1978)
3. L.Saffman and W.Whaling, JQSRT, vol.21, 93, (1979)
4. C.Corliss and W.Bozman NBS Monograph 53
5. Е.Трухан, Л.Киселевский, ОС, 23, 5, 691, (1967)
Л.Киселевский, Е.Трухан, ЖПС, 9, 6, 928, (1968)
В.Бондарь, Л.Киселевский, Е.Трухан, Вопр.физ.плазмы 1970
6. A.Petrakiev, I.Koleva, D.Nikolova, VIII Nat.Conff.on Atomic Spectr., Varna, 1978
7. М.А.Ельяшевичь, Спектры редких земель, Гостехиздат., 1953

Blank

LIFETIME MEASUREMENTS OF THE $4s4p\,^1P$ STATE IN THE Zn I ISOELECTRONIC SEQUENCE

T. Andersen, P. Eriksen, O. Poulsen, and P.S. Ramanujam
Institute of Physics, University of Aarhus
DK-8000 Aarhus C, Denmark

ABSTRACT

The realization that highly ionized atoms stripped to configurations with a few electrons outside closed shells contribute significantly to the total energy losses from Tokamak plasmas has resulted in several calculations[1,2] of oscillator strengths for resonance transitions in the Zn I isoelectronic sequence. The agreement with experimental values is good for Zn I, but large discrepancies exist between observed[3] and calculated[1,2] oscillator strengths for Ga II, Ge III, and As IV. A reinvestigation of the lifetimes for the $4s4p\,^1P$ levels in Ga II, Ge III, and As IV, respectively, has been performed by means of the beam-foil technique. The present measurements are performed under significantly better experimental conditions than previously[3], with particular attention drawn to the spatial resolution and limitation of the cascade population. The theoretical predictions[1,2] are supported by the present lifetime measurements.

(1) C.F. Fischer and J.E. Hansen, Phys.Rev. A 17, 1956 (1978)
(2) P. Shorer and A. Dalgarno, Phys.Rev. A 16, 1502 (1977)
(3) G. Sørensen, Phys.Rev. A 7, 85 (1973)

Paper 29 has been cancelled.

PRECISION LIFETIME MEASUREMENT IN Li 2 $^2P_{1/2}$

A.Gaupp, P.Kuske, H.J.Andrä (Institut für Atom- und Festkörperphysik, Freie Universität Berlin)

We report on a lifetime measurement in ^{6,7}Li 2$^2P_{1/2}$ b e beam laser technique (1. cf EGAS 78, paper 59): A fast Li^+ beam (~ 80 keV) is partially neutralized in a differentially pumped gas cell and, after a time of flight of about 0.5 µs the 2 $^2P_{1/2}$ level is selectively excited by irradiation of light emitted by a single mode ring dye laser. Measuring the fluorescence of the in-flight decaying atoms as function of distance and determining the velocity via a calibrated electrostatic energy analyser (1) allowes the investigation of the mean life of the populated level. A preliminary result is τ = 27.29(5) nsec corresponding to an absorption oscillator strength f = $\frac{1}{3}$·.7416(13). A theoretical investigation using a program employing a modified CI expansion (2) reproduces the trend already known in the literature to smaller f values for longer CI expansions.

---

1)H.J.Andrä in "BeamFoil Spectroscopy", ed. I.A.Sellin, D.J.Pegg, Plenum Press 1976, vol.2, p.835

2)D.R.Beck, private communication

3) This work

4)Weiss, Astroph.J. 138, 1262 (1963)

5)Amusia et.al., Phys.Rev. A13, 1466 (1976)

6)Sims et.al., Phys.Rev. A13, 242 (1976)

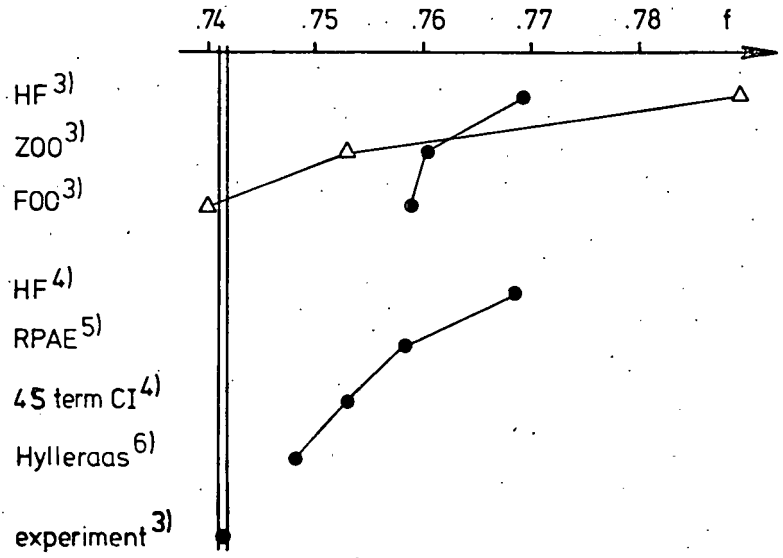


Fig.1: Absorption oscillator strength in Li I $2\,^2S - 2\,^2P$

LIFETIME MEASUREMENTS OF STEPWISE COLLISIONAL AND RADIATIVE EXCITED MN I - LEVELS

U.Becker, M.Kwiatkowski, U.Teppner, P.Zimmermann

Institut für Strahlungs- und Kernphysik
Technische Universität Berlin, Rondellstr. 5, D-1000 Berlin 37

At the last EGAS Conference we have reported on lifetime measurements in the spectrum of neutral Manganese. These measurements have been performed by the delayed coincidence method after pulsed dye laser excitation of collisional excited metastable states. This method allows the determination of lifetimes of high lying levels uneffected by blends and cascades. We have extended these investigations to the theoretically and astrophysically interesting ^6F and ^4D states of the configuration $(3d + 4s)^6 4p$. Together with the branching ratios of Greenlee and Whaling our lifetime measurements yield for 12 relevant transitions a mean Mn solar abundance of $A_{Mn}=5.46$. The next table display our lifetime results together with the experimental and theoretical results of others.

References:
Greenlee, T.R. and Whaling, W.: 1979, JQSRT
Pinnington, E.H. and Lutz, H.O.: 1974, Can.J.Phys.52, 1253
Martinson, I., Curtis, L.J., Brzozowski, J. and Buchta, R.: Phys.Scr.8 , 1973
Kurucz, R.L., Peytremann, 1975, A table of semi-empirical gf values, Smithson.Astr.Obs., Sp.Rep. 362

excited level	wavelengths (Å) observation / excitation	metastable level	lifetimes (ns) this work	other results exp.	other results calc.
$3d^6 4p$	3833.87	$3d^6 4s\ a^6D_{3/2}$	17.7±0.7	18.1±2.7 G.W.	15.4 K.P.
$z^6F_{3/2}$	5042.57	$a^4D_{1/2}$			
$3d^6 4p$	3841.07	$3d^6 4s\ a^6D_{3/2}$	17.9±0.7		15.1
$z^6F_{5/2}$	5029.78	$a^4D_{3/2}$			
$3d^6 4p$	3834.37	$3d^6 4s\ a^6D_{5/2}$	17.7±0.7		14.8
$z^6F_{7/2}$	5004.89	$a^4D_{5/2}$			
$3d^6 4p$	3823.51	$3d^6 4s\ a^6D_{7/2}$	17.5±0.7	17±3 P.	14.4
$z^6F_{9/2}$	4965.86	$a^4D_{7/2}$		18±4 M.	
$3d^5 4s 4p$	3256.13	$3d^6 4s\ a^6D_{3/2}$	8.9±0.4		7.7
$y^6F_{5/2}$	4071.94	$a^4D_{3/2}$			
$3d^5 4s 4p$	3248.51	$3d^6 4s\ a^6D_{5/2}$	9.2±0.4		8.0
$y^6F_{7/2}$	4051.25	$a^4D_{5/2}$			
$3d^5 4s 4p$	3236.78	$3d^6 4s\ a^6D_{7/2}$	10.5±0.4		14.8
$y^6F_{9/2}$	4019.56	$a^4D_{7/2}$			
$3d^6 4p$	4451.58	$3d^6 4s\ a^4D_{7/2}$	12.2±0.5	13.3±2.0 G.W.	9.0
$z^4D_{7/2}$	5388.54	$a^4P_{5/2}$			
$3d^6 4p$	4464.68	$3d^6 4s\ a^4D_{5/2}$	11.9±0.5		13.0
$z^4D_{5/2}$	5348.08	$a^4P_{3/2}$			

G.W.: Greenlee and Whaling; P.: Pinnington et.al.;
M.: Martinson et.al.; K.P.: Kurucz and Peytremann

LIFETIME AND HYPERFINE STRUCTURE MEASUREMENTS OF EXCITED P-STATES IN GALLIUM AND INDIUM.

J.H.M. Neijzen, A. Dönszelmann,

Zeeman-Laboratorium, Plantage Muidergracht 4, Amsterdam, Netherlands.

In the framework of the study of excited P-states in gallium and indium, we determined the lifetime and hyperfine structure constants of some of these states. The levels under investigation were populated by stepwise excitation. A N_2-laser pumped dye laser tuned to one of the blue resonance lines excites the atoms to the first S-state. The second step is made by means of an other N_2-laser pumped dye laser o a CW dye laser. A pulsed amplifier, pumped by the same N_2-laser that pumps the blue dye laser, is used to enhance the power of the CW laser. An amplification factor of about 5000 can be realized. The amplification enlarges the linewidth to more than 200 MHz. The laserbeams intersect an atomic beam of the element under study. The fluorescence from the excited P-states is observed by means of a fast photomultiplier. The photomultiplier signals are processed by a transient digitizer (Tektronix R 7912) coupled to a minicomputer. The digitizer has been modified in such a way that complete decay curves can be averaged at a repetition rate of 50 Hz, the repetition rate of the dye laser. This is of great importance, especially for the longer lifetimes, since the individual decay curves are rather noisy. A typical result is shown in fig. 1.

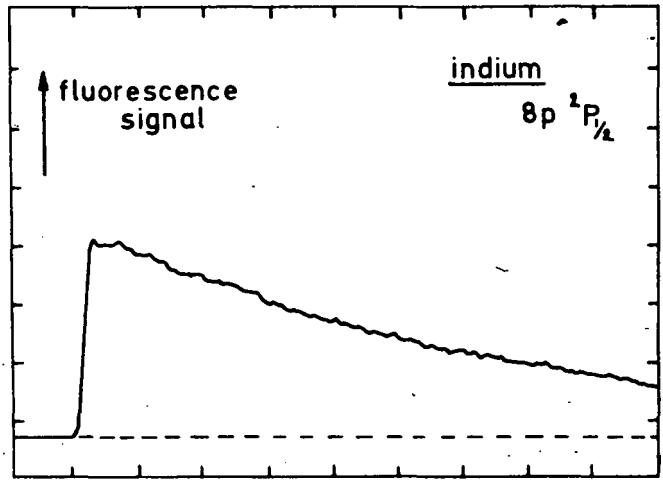


fig. 1

The lifetimes have been determined with an inaccuracy of less than 10%. When the fluorescence is observed through a polarizer quantum beats are detected (fig. 2) under certain excitation conditions. A fourieranalysis of these beats reveals the hyperfine splittings of the excited states.

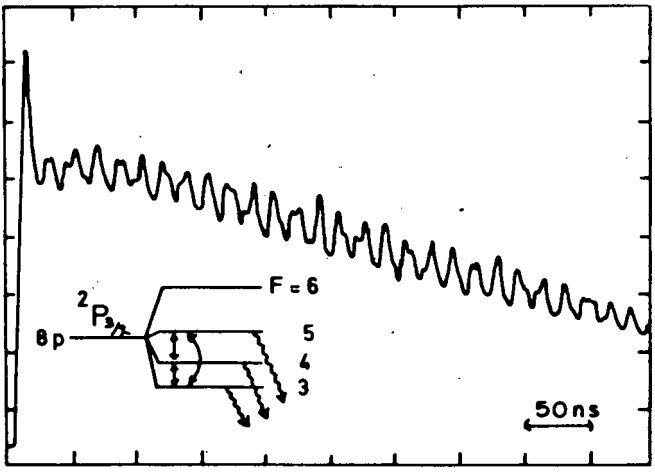


fig. 2

Fig. 3 gives an example. In order to obtain a result as shown it is necessary to compensate the earth's magnetic field to remove the Zeeman splitting of the individual hyperfine levels. A linewidth of 5 MHz is observed in that case. The position of the line centre can be determined with an even higher accuracy. The results of the measurements will be discussed at the conference.

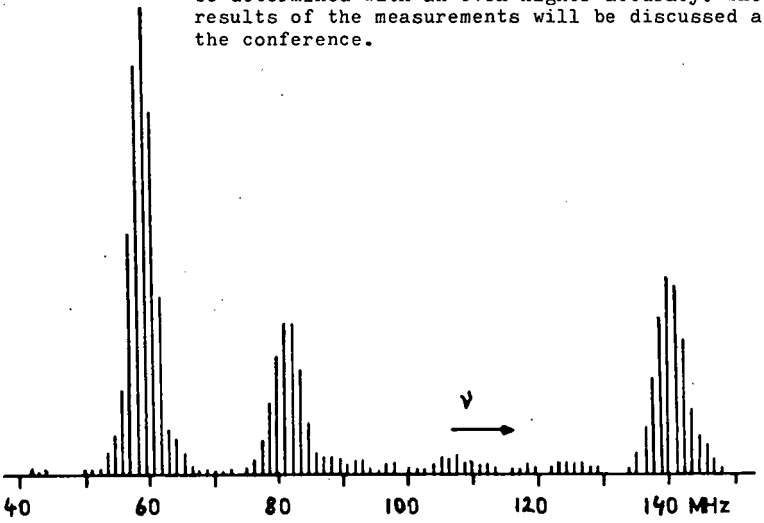


fig. 3

Lifetimes of the singlet states of the Cd (5s nd) $^1D_2$ and (5s ns) $^1S_0$ configurations.

M. CHANTEPIE, J. LANDAIS, B. LANIEPCE
Laboratoire de Spectroscopie Atomique, Université de Caen, 14032 CAEN CEDEX

The lifetimes of the Cd (5s nd) $^1D_2$ and (5s ns) $^1S_0$ levels (n = 6 to 12) have been measured using a pulsed laser excitation. Cadmium atoms contained in the resonance cell are excited by a stepwise excitation technique, first in the intermediate 5^1P_1 state by absorption of the (5^1S_0 - 5^1P_1) 2288 Å line, produced by cadmium arcs, and secondly in the upper level by absorption of the (5^1P_1 - n^1D_2) or (5^1P_1 - n^1S_0) lines produced by a dye laser pumped by a pulsed nitrogen laser.

By observation of the exponential decay we can measure the lifetimes of the excited states. The observation of the fluorescence light is made on the same line as the excitation. In order to take into account the laser light diffused on the walls of the cell the signal slightly detunned of the resonance is substracted from the signal at resonance countaining the fluorescence light. To improve the signal to noïse ratio we use an integration technique.

The experimental results for the n^1S_0 states are given on table 1, results for the n^1D_2 are not quite definitive and will be given at the conference.

Level	Wavelength(Å)	Transition	Z (ns)	(1)	(2)	(3)
6^1S_0	4413	5^3P_1-6^1S_0	42±4			
7^1S_0	5154,6	5^1P_1-7^1S_0	83±7	115±10	20,2±0,5	68,5
8^1S_0	4306,7	5^1P_1-8^1S_0	198±20	230±2	44,0±2,0	136
9^1S_0	3981,9	5^1P_1-9^1S_0	588±40	327±8		
10^1S_0	3818	5^1P_1-10^1S_0	821±80			
11^1S_0	3724,2	5^1P_1-11^1S_0	703±200[X]			
12^1S_0	3663	5^1P_1-12^1S_0	950±150			

[X]Not definitive

(1) A.R. Schaeffer J. Quant. Spectrosc. Radiat. Transfer. Vol. 11p. 197 Pergamen Press (1971).

(2) Y.F. Verolainen A.L. Osherovich Optics Spectrosc. 20 517 (1966).

(3) B. Warner Mon. Not R. Astr. Soc. 140 53 (1968).

LIFETIME MEASUREMENTS OF SOME EXCITED STATES OF THE $4f^{14}6s6d$-CONFIGURATION IN THE YB-I SPECTRUM USING STEPWISE LASER EXCITATION

M. Baumann, M. Geisler, H. Liening, H. Lindel

Physikalisches Institut der Universität Tübingen - Auf der Morgenstelle 14 - D 7400 Tübingen, Germany

The lifetimes of the even levels $^3D_1$, $^3D_2$ and $^1D_2$ of the $4f^{14}6s6d$ configuration have been investigated by detecting the exponential decay of fluorescence following pulsed excitation.

The atoms in a beam of natural Yb were partly excited to the $4f^{14}6s6p\ ^3P_1$ state by irradiation with a CW dye laser which was stabilized to one of the isotopic components of the $6\ ^3P_1$-$6\ ^1S_0$ intercombination transition at λ=555,6 nm. A seccnd N_2 pumped dye laser was tuned to the appropriate spectral lines corresponding to transitions from the $4f^{14}6s6p\ ^3P_1$ state to the various $4f^{14}6s6d$ D-levels (cf. fig. 1). The light pulses had a pulse width of about 5 nsec and a repetition rate of 30 Hz. The laser line width was about 2 GHz.

The decay of the fluorescence radiation from the D-states has been detected with the help of a boxcar-integrator or by a counting technique with a TAC.
The data were stored in a MCA and processed with a PDP 11/45 computer.

Fig. 2 shows one of the measured decay curves. Results for the lifetimes will be given at the conference.

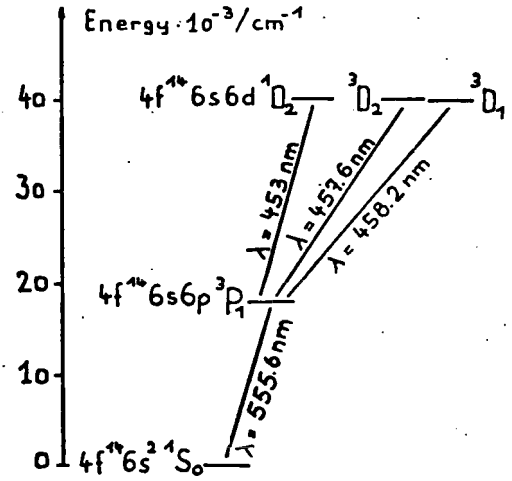


Fig.1 Part of the level scheme of the Yb-I spectrum

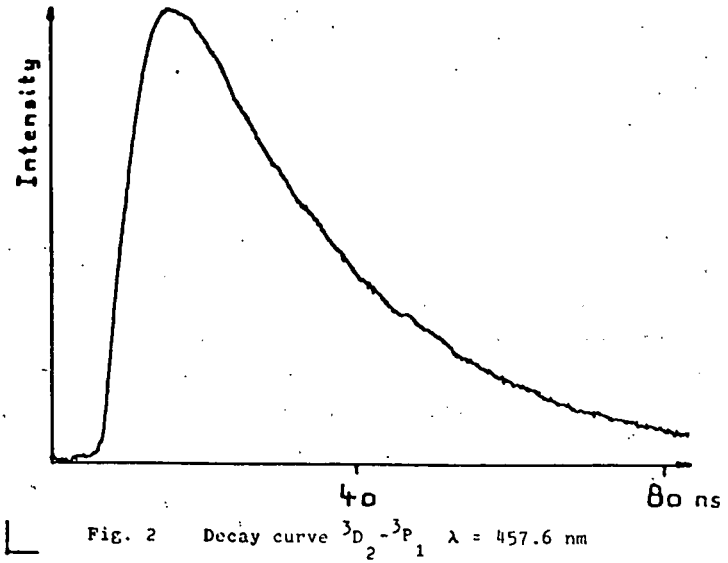


Fig. 2 Decay curve $^3D_2 - ^3P_1$ λ = 457.6 nm

TIME-DEPENDENT SPECTRUM OF LIGHT AFTER TWO-PHOTON EXCITATION

Maciej Kolwas
Institute of Physics of the Polish Acadxmy of Sciences,
Al. Lotników 32/46, 02-668 Warszawa, Poland

In the present work we discuss a time-dependent spectrum [1] after two-photon time-dependent excitation of an atomic system with an off-resonant intermediate state [2]. The atomic system consists of states: ground g, intermediate r, excited e and final for scattering f. We describe this system by von Neuman equations. The density matrix equations, after RWA, can be divided in two groups:
equations for elements between e, r and g states, used to find the time dependent excited state density matrix;
equations for elements between final f and e, r or g states used to obtain the time-dependent spectrum of the emitted light.

The calculations have been accomplished by the perturbation method with respect to the ratio of the amplitude E of the electric field of light to the detuning of the laser frequencies from the e-r or g-r state separation / Δ_{er} and Δ_{gr}, respectively/. We assume also that Δ_{er} and Δ_{gr} are much grater than any other frequency appearing in this work /unless optical one/. To find the time dependent spectrum of light we use the quantum regression theorem and we assume, that spectral measurements are made with the help of a frequency filter with the spectral transmission function $F(t) = \exp(-(i\Omega + \alpha)t)$; Ω is its central frequency, α the spectral bandwidth.

In 4th order of calculation two components of the emitted light can be distinguished - one connected with the excited state population, we will call it the slow component I_s, and a fast component I_f, connected with the optical double-quantum coherence:

$$I_s(t;\Omega,\alpha) \sim 4\alpha^2 \mathrm{Re} \int_{-\infty}^{t} dt' e^{-2\alpha(t-t')} e^{-\Gamma_e t'} \int_{0}^{\infty} d\tau\, e^{-(\alpha+\Gamma_{ef}+\Gamma_e - i(\Omega-\omega_{ef}))\tau} \cdot$$
$$\cdot \mathrm{Re} \int_{-\infty}^{t'-\tau} d\tau'\, e^{(\Gamma_e-\Gamma_{eg}-i\Delta)\tau'} \int_{0}^{\tau} d\tau''\, e^{(\Gamma_{eg}+i\Delta)\tau''} L(\tau') G^{(2)}(\tau', \tau'') ;$$

$$I_f(t;\Omega,\alpha) \sim 2\alpha^2 \mathrm{Re} \int_{-\infty}^{t} dt\, e^{-2\alpha(t-t')}\, e^{-(\Gamma_{eg}+\Gamma_{ef}-\Gamma_{gf})t'} \int_0^{\infty} d\tau\, e^{-(\alpha+\Gamma_{gf}-\Gamma_e)\tau} \cdot e^{-i(\Omega-\omega_{eg})\tau} \int_{t'-\tau}^{t'} d\tau'\, e^{(\Gamma_{ef}-\Gamma_{gf}-i\Delta)\tau'} \int_{-\infty}^{t-\tau'} d\tau''\, e^{(\Gamma_{eg}+i\Delta)\tau''} L(\tau'') G^{(2)}(\tau',\tau');$$

$$G^{(2)}(\tau,\tau') = E^*(\tau)E^*(\tau)E(\tau')\Xi(\tau');$$

$$L(\tau'') = D_{er}D_{rg}\varrho_{gg'}(\tau'')D_{gr}D_{re}/|\Delta_{er}\Delta_{rg}|;$$

Δ is two-photon detuning from resonance.

In the case of adiabatic changes of the light intensity in respect to Δ /large Δ / and for large α, I_f follows the square of the exciting light intensity, I_s is the convolution of the second order correlation function of the light intensity with exponential decay function. It is easy to found now two emission components - the fluorescence I_F on the frequency $\Omega = \omega_{ef}$, $I_F = I_s - |I_f|$; and Raman spontaneously light I_R on the frequency $\Omega = \omega_{ef} - \Delta$, $I_R = I_f$.

The Raman component I_R is the adiabatic one - as I_f follows square of the exciting light intensity, I_F is nonadiabatic component connected with nonadiabatic processes in the atomic ensemble.

By our formulas the experiment e.g. of Liran and al. [3] can be properly described.

1. A.Szöke, E.Courtens Phys. Rev.A15, 1588 /1977/
2. M.Kolwas Phys.Lett.69A, 15, /1978/
3. J.Liran, L.A.Levin, G.Erez, J.Jorttner Phys.Rev.Let. 38, 390, /1977/

TEMPERATURE DEPENDENCE OF COLLISIONAL FINE STRUCTURE TRANSFERS IN MERCURY

S.A. ARBADJI, D. HENNECART, D. VIENNE, M. LUKASZEWSKI and D. LECLER
Laboratoire de Spectroscopie Atomique, Université de Caen, 14 032 CAEN CEDEX

Experiments : *In previous experiments, we have measured cross section for the transfer of population |1| of alignment and orientation |2, 3| between the fine structure levels of the 6s6d configuration of mercury, induced in collisions with noble gas atoms.*

In order to have more experimental informations for comparison with the theory, we have measured the transfer cross-sections of population in a temperature range from 300 K to 900 K.

The experimental procedure is very similar to the one used in our first experiments |1, 2|. Mercury atoms are selectively excited in 6s6d $^1D_2$ or $^3D_2$ levels by stepwise excitation as represented on fig 1. Only the second step (laser excitation) is modulated and allows lock-in detection of the Fluorescence signal F (comming from the laser excited level) and transfer signals T. F and T are successively registered on a XY recorder as a function of the rare gas pressure. Transition probabilities, detection sensitivities, lifetimes used to calculate the cross section σ_{ab} from level a to level b are taken in |1|.

For each transfer we have plotted Log σ_{ab}=f(Log T) and fitted by a least square method a straight line through the experimental points (fig 2). Table 1 gives for He, Ar, Xe the slope of that line (column 2) and the cross section σ_o at $T=T_o=300K$ (deduced from the fitted line).

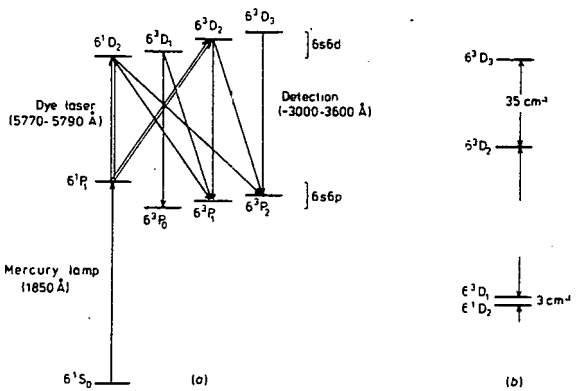
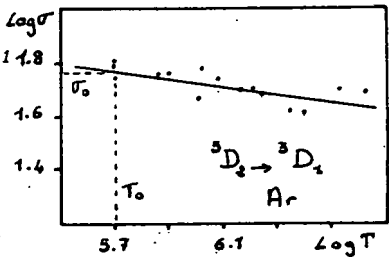


Figure 1. Mercury levels involved in the experiment: (*a*) simplified Grotrian diagram showing excitation and detection lines, (*b*) relative positions of 6s6d levels (to scale).

Comments will be given at the conference.

Theory : *The $^1D_2$ and $^3D_1$ levels are only separated by an energy difference $\Delta E=3cm^{-1}$ so one can expect that the attractive Van der Waals part of the potential is reponsible of the transfer. In the frame of Omont's theory we have performed a numerical integration of the Schroedinger equation to calculate the transfer cross sections in the same temperature range. The results are given at the bottom part of the table with the same conditions and units as the experimental data.*



Transfer	He 1	He 2	Ar 1	Ar 2	Xe 1	Xe 2
$^1D_2 \rightarrow {}^3D_1$	52 (8)	-.16		-.32	145 (20)	.16
$^3D_2$	23 (3)	.71	14 (2)	.17	7 (2)	.37
$^3D_3$	7 (2)	2	2.3(6)	1.7	3.4 (8)	.7
$^3D_2 \rightarrow {}^1D_2$	26 (3)	.61	16 (3)	.4	7.4(1.5)	.25
$^3D_1$	13 (2)	.58	5.8(7)	-.13	2.8 (5)	.07
$^3D_3$	49 (8)	.64	21 (6)	.8	33 (6)	.4
Theory $^1D_2 \rightarrow {}^3D_1$	18	-.22	72.4	-.25	126	-.22

(1) - σ_{ab} at 300 K ($\AA^2$) (2) the uncertainties on the slopes are about 10 to 20 %.

|1| D. LECLER et B. LANIEPCE J. Phys. 37 55 (1976).

|2| M. LUKASZEWSKI and D. LECLER. J. Phys. B atom. molec. phys. 11 2477 (1978).

|3| M. LUKASZEWSKI and D. LECLER Opt. Communications 25 189 (1978).

|4| A. OMONT J. Phys. 26 26 (1965).

J.C. GAY J. Phys. 37 1155 (1976).

LIFETIMES AND COLLISIONAL DEPOPULATION OF ZIRCONIUM LEVELS IN THE PRESENCE OF RARE GASES

P. Hannaford and R.M. Lowe

Division of Chemical Physics, CSIRO, Clayton, Australia.

Relatively few measurements of atomic lifetimes have been reported for the highly refractory elements, such as Zr, Nb, Ta, W and Re, all of which are difficult to vaporize by thermal methods. A convenient method for vaporizing these elements is to use the technique of cathodic sputtering, in which the element is made the cathode of a low-pressure rare-gas discharge. With this method it is possible to produce suitably high number densities of neutral ground-state atoms, and also metastable atoms and singly charged ions, for making atomic fluorescence measurements. However, when using the method, particular care must be taken to allow for any effects of the discharge or the rare gas.

We have used a nitrogen-laser pumped dye laser as a pulsed source of exciting radiation to study the time-resolved fluorescence from a number of levels of zirconium, using vapours produced by cathodic sputtering. Any effects of the sputtering discharge were eliminated by pulsing the discharge and detecting the fluorescence several milliseconds after the discharge pulse was turned off. The duration of the laser pulse (1-2 ns FWHM) and the detection electronics were such that lifetimes as low as 2-3 ns could be measured without instrumental contribution.

Detailed measurements were made on the $4d^2 5s(^4F)5p\ ^3G$ and $4d^3(^4F)5p\ ^5G$ multiplets of Zr I, since these are the only multiplets for which lifetime measurements have previously been reported. Our values for the radiative lifetimes, found by extrapolating to zero pressure of neon (Figure 1), are a factor of three to four smaller than the values found by the ion beam-sputtering excitation technique [1,2] (Table 1). We also find essentially the same lifetime values (but with very much lower precision) using thermal zirconium vapour produced by melting a bead of zirconium on an incandescent filament in the absence of any buffer gas. Checks of the accuracy of our measured values were made by measuring the well-known radiative lifetimes of the calcium $4\,^1P_1$ level (4.5 ns), the sodium $3^2P_{3/2}$ level (16.2 ns), the iron $3d^6 4s(^6D)4p\ ^5F_5$ level (62 ns), and the uranium $5f^3 6d7s7p\ ^7M_7$ level (230 ns). The reason for the large discrepancy between the two sets of zirconium results is not understood.

Our lifetime measurements have been extended to individual levels of 50 multiplets of Zr I belonging to the configurations $4d^2 5s5p$, $4d^3 5p$ and $4d5s^2 5p$, and twelve multiplets of Zr II belonging to the configurations $4d^2 5p$ and $4d5s5p$. These include some levels which are accessible only by transitions from metastable levels. The measured radiative lifetimes of the various levels range from 3 ns to 490 ns.

The observed lifetime of the $4d^2 5s(^4F)5p\ ^3G_3$ level is found to be dependent on the pressure of rare gas in the discharge, particularly for the heavy rare gases (Figure 1). The observed pressure dependences correspond to depopulation cross sections of about 0.5 Å², 3 Å², 17 Å² and 60 Å² for Ne, Ar, Kr and Xe, respectively. Such high cross sections for depopulation by the rare gases are unexpected for low-lowing atomic levels. Similar collisional depopulation is also found for other levels of zirconium which have been investigated. Some of the depopulation can be attributed to the transfer of excitation to other excited levels, but most appears to be due to de-excitation to the ground state.

References

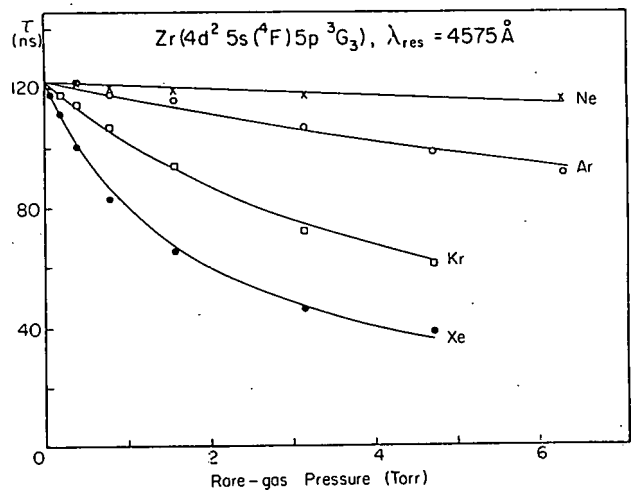
[1] P.S. Ramanujan, Phys. Rev. Lett. 39, 1192 (1977).
[2] T. Andersen, P.S. Ramanujan and K. Bahr, Astrophys. J. 223, 344 (1978).

Table 1

Radiative lifetimes of levels of the $4d^2 5s(^4F)5p\ ^3G$ and $4d^3(^4F)5p\ ^3G$ multiplets of Zr I.

Level	λ_{exc} (Å)	This work (ns)	Previous work (ns)
$4d^2 5s(^4F)5p\ ^3G_3$	4575.5	121± 4	440± 25 [1]
$4d^2 5s(^4F)5p\ ^3G_4$	4634.0	109± 4	380± 15 [1]
$4d^2 5s(^4F)5p\ ^3G_5$	4688.5	108± 4	450± 25 [1]
$4d^3(^4F)5p\ ^5G_4$	3879.1	12.7± 0.5	41± 2 [2]
$4d^3(^4F)5p\ ^5G_5$	3916.6	13.0± 0.5	40± 2 [2]

Figure 1



SOLVABLE MODELS FOR OPTICAL AND RADIATIVE COLLISIONS*

E. J. Robinson, Physics Department, New York University, New York, NY 10003 USA

Over the past several years, substantial attention has been paid to the problems of "optical" and "radiative" collisions.[1-8] In the first category, transitions in the "wings" are enhanced by foreign gas collisions. The second group encompasses those processes in which excitation is transferred between unlike atomic species via the simultaneous effect of a collision and the interaction with the radiation field. While similar methods may be used to treat both classes theoretically, we will emphasize radiative collisions here.

In the conventional treatment of the radiative collision problem,[3,4,6] the radiation field and nuclear motion are considered to be classical, and the electrons quantal. The further simplification of straight line paths for the nuclear motion is assumed. Thus the role of the nuclear motion is to generate a time-dependent potential for the electrons. The process proceeds via virtual intermediate states. By summing over these, it is possible to reduce the problem to an approximate two-level system, driven by the Hamiltonian

$$H = \sum_{j=1}^{\infty}(C_j/R^6 + Q_jE^2)\ |j\rangle\langle j| + (KE/R^3)\ (\ |1\rangle\langle 2|\ \exp(i\Delta t) + |2\rangle\langle 1|\ \exp(-i\Delta t)\ ),$$

where E is the amplitude of the radiation field, R the internuclear separation, and Δ the detuning. Q_j, C_j are the Stark and van der Waal coefficients of state $|j\rangle$, and K an atomic parameter obtained by summing over intermediate states and averaging over angles. The states $|1\rangle$ and $|2\rangle$ are composite states of the two atom system, i.e., state $|1\rangle$ has atoms A and B in states A_o, B_o, respectively, while state $|2\rangle$ has the atoms in states A_f, B_f.

For the actual R^{-m} potentials that exist in nature in the large R region, this problem cannot be solved in closed form. However, we have found that it is possible to closely approximate $1/R^3$ and $1/R^6$ by suitably parametrized hyperbolic functions, and to solve this modified problem exactly. Specifically, we replace $1/R^3$ by a hyperbolic secant, $1/R^6$ by (hyperbolic secant)^2, and find that the transition amplitude is proportional to a confluent hypergeometric function for finite detuning, and to a Bessel function at exact resonance. Analogous formulae apply for the optical collision case.

Numerical results will be presented and compared with other calculations and experiment.

*Work supported by the U.S. Office of Naval Research

References

1. S. Yeh and P Berman, Phys. Rev. A (In the press), and references therein.

2. S. E. Harris and D. L. Lidow, Phys. Rev. Lett. 33, 674 (1974); Phys. Rev. Lett. 34, 172 (1975).

3. S. E. Harris and J. C. White, I. E. E. E. J. Quant. Elect. QE13, 972 (1977).

4. V. S. Lisitsa and S. E. Yakovlenko, Soviet Physics J.E.T.P. 39, 759 (1974).

5. E. J. Robinson, J. Phys. B: Atom. and Mol. Phys. (In the press.)

6. S. Geltman, J. Phys. B: Atom. and Mol. Phys 9, L569 (1976).

7. P. L. Knight, J. Phys. B: Atom. and Mol. Phys. 10, L195 (1977).

8. M. G. Payne and M. N. Nayfeh, Phys. Rev. A 13, 596 (1976).

Blank

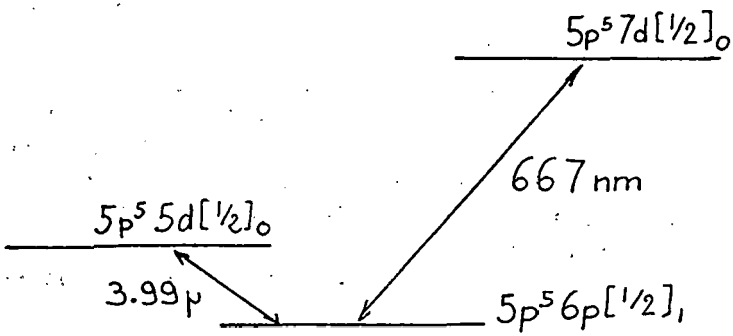
DEPOLARIZING VELOCITY-CHANGING COLLISIONS IN NON-LINEAR LASER SPECTROSCOPY

Jean-Louis LE GOUET and Raymond VETTER
Laboratoire Aimé Cotton, C.N.R.S. II, Orsay - France

Non linear laser spectroscopy techniques enable one to select both atomic velocity and m-component of angular momentum. One may take advantage of this property to study velocity changes associated with collisional transfers between magnetic sublevels.

A simple experimental situation, available in Xe I, occurs in a three level system with angular momenta J = 0, 1, 0 (see fig.). The levels are connected by two optical transitions. A polarized laser beam, resonant with one transition, prepares a definite combination of sublevels in the common level. A second polarized laser beam explores the other transition and detects the modifications in the population of the common level. In the J = 0, 1, 0 case, the cross-polarization signal is only due to the atoms which have undergone a transfer. It needs not be extracted from a non-collisional background as it is the case for other J values.

First results obtained in this experiment will be reported.



PHOTON CORRELATION AND ANTICORRELATION EFFECTS IN MULTI-PHOTON RAMAN SCATTERING PROCESSES

P.Szlachetka, S.Kielich, V.Peřinová and J.Peřina

Institute of Physics, A.Mickiewicz Univ., 60-780 Poznań, Poland
Laboratory of Optics, Palacky Univ., 771-46 Olomouc, Czechoslovakia.

We report theoretical results for spontaneous and stimulated scattering due to the interaction of two or more photons with phonons. The short-time solutions of the Heisenberg equations of motion permit the calculation of intermodal correlation functions of the type

$$(*)\quad \langle \Delta W_i(t)\Delta W_j(t)\rangle = \langle a_i^+(t)a_j^+(t)a_i(t)a_j(t)\rangle - \langle a_i^+(t)a_i(t)\rangle\langle a_j^+(t)a_j(t)\rangle ;\ i,j = L,S,P ,$$

where a_i , a_i^+ are annihilation and creation operators relative to the i-th mode.

For example, let us consider the covariance function for the laser and Stokes photons $\langle \Delta W_L(t)\Delta W_S(t)\rangle$ and the variance of intensity for the laser photons $\langle (\Delta W_L(t))^2\rangle$ in three-photon scattering.

If, at the time $t=0$, molecular vibrations are described by chaotic phonons whereas the laser and Stoke modes are coherent, we obtain:

$$(**)\quad \langle \Delta W_L(t)\Delta W_S(t)\rangle = -2|\partial\mathcal{S}_S|^2 t^2 n_L n_S [n_L(2n_P+1)+2n_P] < 0 ,$$

where n_L, n_S and n_P are the averige number of photons at the time $t=0$ in the laser, Stokes and phonon modes, respectively and $\partial\mathcal{S}_S$ is the coupling constant for the Stokes process. We see that the anticorrelation $(**)$ takes place in stimulated three-photon Raman $(n_S \neq 0)$ only. In the spontaneous case $(n_S = 0)$ this effect vanishes but in the laser mode antibunching of photons occurs i.e.

$$(***)\quad \left\langle \left(\Delta \bar{W}_L(t)\right)^2 \right\rangle = -2\,|\mathcal{E}_S|^2 t^2 n_L^2 (n_p+1).$$

No antibunching of laser photons occurs in spontaneous two-photon Raman scattering ($\omega_S = \omega_L - \omega_p$) .
Aport from anticorrelation effects in degenerate multi-photon Raman scattering ($\omega_S = n\omega_L - \omega_p$) , **we consider the possibility of anticorrelation in multi-photon non-degenerate Raman scattering** ($\omega_S = \omega_1 + \omega_2 + \ldots \omega_n - \omega_p$).

THE 130 nm OI LINE PROFILES OF LOW PRESSURE HELIUM-OXYGEN DISCHARGE LAMPS USED IN THE MEASUREMENT OF ATOMIC OXYGEN IN THE UPPER ATMOSPHERE

D.B. JENKINS, University College of Wales, Aberystwyth, U.K.
G.H.C. FREEMAN, National Physical Laboratory, Teddington, U.K.
D.J. MACKINNON, Appleton Laboratory, Slough, U.K.

The line profiles of the 130 nm OI resonance triplet emitted by sealed, r.f. excited, low pressure, helium-oxygen discharge lamps, of the type used to provide in situ measurements of atomic oxygen in the upper atmosphere, (Dickinson *et al* [1974], [1976], Anderson [1975], Howlett *et al* [1976], Megill *et al* [1976]) have been examined using a 1.5m Photoelectric Echelle Spectrometer. Measurements were made over a wide range of helium and oxygen partial pressures.

In the absence of significant self absorption, i.e. at very low oxygen partial pressures, it was found that the line profiles could be represented to a high degree of accuracy by the sum of two Gaussian (thermal) distributions of widely different widths, with the relative amplitude of the wider Gaussian decreasing as the helium pressure was increased. This led to a decrease of the overall width of the line at increased helium pressures. As pressure, Stark, and natural broadening are all at least two orders of magnitude less than that needed to explain the observed line widths (Clyne and Piper [1978]), it is inferred that the $O(^3S_1)$ is present as two separate populations with temperatures of about 5000° K and 350°K. At a helium pressure of 0.9 torr the "hot" $O(^3S_1)$ population comprises about 93% of the total, dropping to 34% at 14 torr.

Rawlins and Kaufman [1977] have shown that the two major OI excitation processes in lamps of this type are electron impact excitation of O and dissociation excitation of O_2 by helium metastables. The first process would hardly change the translational energy of the atom, but the second would create excited oxygen atoms with very high translational energies, i.e. "hot" atoms which, because of their very short upper state lifetime, would radiate before making a first thermalising collision. Our results therefore suggest that the narrowing of the lines at high helium pressures is due to a decrease in the relative efficiency of the helium metastable excitation process.

The geometry of the discharge and the oxygen partial pressures normally used are such that a full resonance trapping modelling of the line profiles is not required, while a simple two-layer model was found to be inadequate. A multilayer model giving line profiles of the form

$$G(A,B,C,D,E,F,\lambda) = \sum_{n=1}^{n=N} \left\{ \frac{1}{N} \left(A \exp\left[-\tfrac{1}{2}\left(\frac{\lambda-\lambda_o}{B}\right)^2\right] + C \exp\left[-\tfrac{1}{2}\left(\frac{\lambda-\lambda_o}{D}\right)^2\right]\right) \right.$$

$$\left. \cdot \exp\left[\frac{nE}{N} \exp\left[-\tfrac{1}{2}\left(\frac{\lambda-\lambda_o}{F}\right)^2\right]\right] \right\}$$

gave excellent fits to the observed line profiles, however. A and C are the amplitudes of the two Gaussian emission lines, B and D their standard deviations. E is a function of the concentration and temperature of the atomic oxygen in the lamp, while F is the standard deviation of the self absorption line. N is the number of emission and self absorption lamp layers used, about 300 being more than adequate. A and C varied strongly with helium partial pressure, E with atomic oxygen partial pressure. The best fits were found with B at about 0.7 pm and D and F at about 0.2 pm, representing emission temperatures of about 5000°K and 350°K, and a self absorption temperature of 350°K.

This work was stimulated by the Appleton Laboratory/U.C.W. Aberystwyth collaborative rocket programme in which 14 lamps of this type have been flown, yielding 12 mesospheric atomic oxygen concentration profiles to date.

REFERENCES

Anderson, J.G. 1975 Geophys.Res.Lett. 2, 231-234.

Clyne, M.A.A. and Piper, L.G. 1976 J.Chem.Soc.Farad. Trans.II, 72, 2178-2190.

Dickinson, P.H.G., Bolden, R.C. and Young, R.A. 1974 Nature 252, 289-291.

Dickinson, P.H.G., Twiddy, N.D. and Young, R.A. 1976 Space Research XVI, Akademie Verlag, Berlin, 301-305.

Howlett, L.C., Baker, K.D., Ulwick, J.C. and Young, R.A. 1976 EOS Trans. AGU 57, 301.

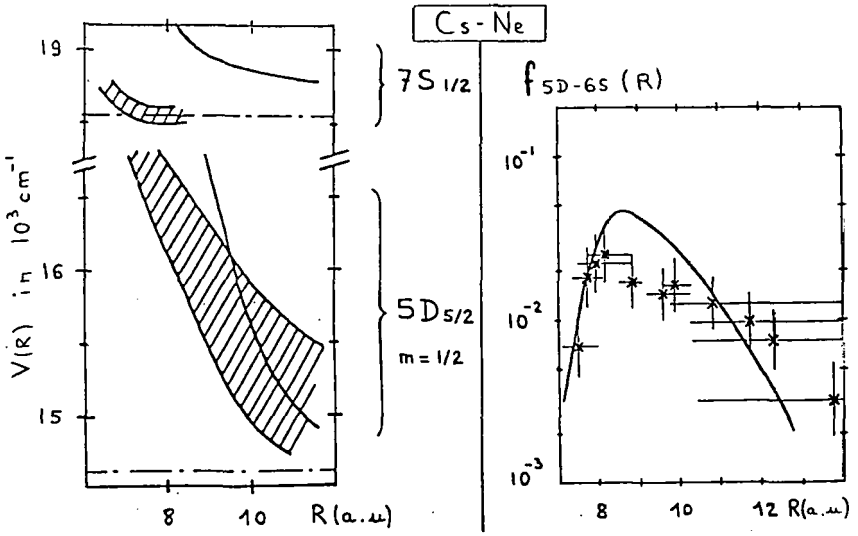
Megill, L.R., Howlett, L.C., Pendleton, W.R. and Baker, K.D. 1976 EOS Trans. AGU 57, 301.

Rawlins, W.T. and Kaufman F. 1977 J.Quant.Spectrosc.Radiat.Transfer 18, 561-572.

the coupling of these potential curves with those of Cs (7S)-RG is found to be much weaker than predicted.

The measured oscillator strengths are also compared with those calculated from the induced dipole moment[4] : a relatively good agreement is found. Values as large as a few 10^{-2} are obtained; this shows that the transition is almost completely allowed in the range of 8 - 12 a.u.

Examples of these comparisons are given below in the case of Ne.



REFERENCES :

1 - R. Scheps, Ch. Ottinger, G. York and A. Gallagher, J. Chem. Phys., 63, 2581, (1975) and references therein.

2 - B. Sayer, M. Ferray and J. Lozingot, J. Phys. B Atom. Molec. Phys., 12 227, (1979) and X° EGAS Conference.

3 - J. Pascale and J. Vandeplanque, J. Chem. Phys., 60, 2278, (1974).

4 - J. Pascale, J. Chem. Phys., 67, 204, (1977).

Cs ($6S \longrightarrow 5D_{5/2}, m = 1/2$) TRANSITION IN THE PRESENCE OF A RARE GAS : INTERACTION POTENTIAL AND INDUCED OSCILLATOR STRENGTH

B. SAYER, M. FERRAY, J.P. VISTICOT and J. LOZINGOT

Centre d'Etudes Nucléaires de Saclay, Service de Physique Atomique
B.P. N°2, 91190 -GIF-sur-YVETTE (France)

The far wing profile of a line corresponding to the $A \longrightarrow A^*$ transition perturbed by collisions with atoms B is closely related to the interatomic A-B and A^*-B potentials. According to the quasi static theory, the absorption profile is $K(\lambda) \sim n_A n_B \lambda^2 R^2 f(R) \frac{d\lambda}{dR} \exp\left[-V_{AB}(R)/kT\right]$ where $n_{A,B}$ is the absorber, perturber density, λ the wavelength, R the interatomic distance, f(R) the oscillator strength, $V_{AB}(R)$ the potential energy of the atomic pair separated by a distance R, and T the temperature. The experimental study of the temperature dependence of $K(\lambda)$ permits to deduce the correspondance between λ and V_{AB} and, therefore between V_{AB} and the potential energy of A^*-B pair, $V_{A^*B} = V_{AB} + hc/\lambda$.

This method has been extensively used by Gallagher and coworkers[1] for investigating the resonance lines of alkali atoms perturbed by rare gases, and more recently extended to the cesium 6S-7S forbidden transition with the same perturbers[2]. For the particular case of forbidden transitions the induced dipole moment is a fast varying function of R. Using the available $V_{AB}(R)$ determined elsewhere (by scattering experiments for example) the variation of f with R can be drawn from this method.

The present experimental work is devoted to another forbidden transition, $Cs(6S) \longrightarrow Cs(5D_{5/2}, m = 1/2)$, also perturbed by rare gas atoms. This study is complementary to the previous one related to the 6S-7S transition, because the adiabatic potential curves calculated by a pseudo potential method indicate a strong coupling between the $7S_{1/2}$ and the $5D_{5/2}, m = 1/2$ states[3].

The absorption coefficient is determined by a sensitive laser fluorescence technique[2]. The experimental conditions are taken for avoiding the contribution onto the spectrum of both cesium dimers and cesium atoms interacting with two perturbers : $N_{Cs} \leqslant 10^{14}$ cm^{-3}, $N_{RG} \leqslant 2 \times 10^{19}$ cm^{-3}. The explored temperature range is 180 - 410° C.

The results obtained show a progressive increase of the repulsivity of the Cs ($5D_{5/2}, m = 1/2$) - RG potential from Xe to Ne. Except for Ar,

INTERATOMIC POTENTIALS IN CESIUM-GAS SYSTEMS. SHIFT AND BROADENING OF HYPERFINE COMPONENTS

E. BERNABEU and J.M. ALVAREZ

Departamento de Física Fundamental, Cátedra de Optica.
Universidad de Zaragoza, España.

In previous works[1] we have determined the shift and broadening of D_1(8943 Å) and D_2(8521 Å) fine structure lines of Cs-noble gas and Cs-light molecular gas (H_2,N_2) systems, under pressures not greater than 150 torr and temperatures about 295 K, from our measurements of the shift and broadening of ground state hfs components of these lines.

We present here the calculation of the interatomic potential constants for Cs-gas systems with a Lenard-Jones [12-6] potential using our experimental results. A classical theory[2] has been used in the case of noble gases (Ne, Ar, Kr, Xe) and N_2, and a quantum theory[3] for He and H_2, due to the fact that the experimental results obtained for these latter fall out of the applicability domain of classical theory[4]. Among all the values obtained, those which fit best our experimental results are shown in Table I.

The interatomic potential constants obtained by us have been used for the theoretical determination of shift and broadening of D_1-line ground state hyperfine components. For this calculation we have employed the hyperfine theory of collision broadening developed by Omont[5] and Rebane[6], and the classical path approximation together with a Van der Waals potential interaction[4] have been assumed. Table II shows the theoretical values obtained from our experimental results. These values fall into the experimental error range, except for the shift of Cs-He, Cs-H_2 and Cs-N_2. This is in agreement with the fact that the aproximations assumed in the theory are not valid for these systems.

Table I.- Summary of results for ΔC_6 and ΔC_{12} for D_1 D_2 lines of Cs in He, Ne, Ar, Kr Xe and H_2, N_2. (ΔC_6 and ΔC_{12} are in units of 10^{-58} erg cm^6 and 10^{-102} erg.cm^{12}).

System	D_1(8943 Å)		D_2(8521 Å)	
	ΔC_6	ΔC_{12}	ΔC_6	ΔC_{12}
Cs-He	0.87±0.26	-0.24±0.31	0.67±0.28	-3.38±0.61
Cs-Ne	1.57±0.28	34.0±5.6	0.64±0.13	0.76±0.36
Cs-Ar	5.4±0.38	84.2±15.1	4.73±0.65	55.2±8.6
Cs-Kr	13.2±0.53	1.6×10^4	7.29±0.42	461.8±20.5
Cs-Xe	9.2±0.31	308.2	249.27	9.9×10^4
Cs-H_2	2.16±0.71	29.5±8.2	3.35±0.64	56.9±10.1
Cs-N_2	26.9±0.43	2.5×10^4	15.1±0.51	1.7×10^4

Table II.- Theoretical and experimental values of shift and broadening of hfs components of D_1-line of Cs in Cs-gas systems (in units of mk/torr).

System	Broadening		Shift	
	theoretical	experimental	theoretical	experimental
Cs-He	0.58±0.06	0.64±0.04	-0.21±0.02	0.13±0.03
Cs-Ne	0.42±0.01	0.34±0.03	-0.164±0.004	-0.21±0.03
Cs-Ar	0.65±0.03	0.66±0.04	-0.24±0.01	-0.29±0.03
Cs-Kr	0.80±0.08	0.66±0.08	-0.29±0.03	-0.29±0.01
Cs-Xe	0.78±0.08	0.72±0.09	-0.28±0.03	-0.27±0.04
Cs-H_2	1.03±0.04	1.34±0.2	-0.37±0.02	0.08±0.01
Cs-N_2	1.35±0.01	1.01±0.23	-0.49±0.01	-0.242±0.03

REFERENCES

(1) E. Bernabeu, F. García-Peralta and J.M. Alvarez, J. Opt. Soc. Am, 67, 24 (1977).
(2) W. Behmenburg, J. Quant. Spectrosc., 4, 177 (1964).
W.R. Hindmarsh, A.D. Petford and G.Smith, Proc. Royal. Soc., 247, 296 (1967).
(3) M. Baranger, Phys. Rev., 111, 481 (1958).
(4) J.M. Alvarez, Ph.D. Thesis. Zaragoza University (1977).
(5) A. Omont, J. Phys. (France), 34, 179 (1973).
(6) V.N. Rabane, Opt. Spectros., 41, 214 (1976);
Opt. Spectros., 41, 526 (1976).

Information on interatomic potentials from computation of atomic line profiles. Application to Hg 6^3P_1 level perturbed by krypton or xenon and to Hg 6^1P_1 - Hg 6^1S_0 level.

E. LEBOUCHER, NGUYEN HOE

Département de Recherches Physiques
Université Pierre et Marie Curie
4, place Jussieu
75230 PARIS CEDEX 05 - FRANCE

When the interaction mechanisms are completely mastered, potential models can be tested from computation of theoretical profiles and comparison with experimental results ; the range of interatomic distance where these models are valid can be estimated from the exploration of spectral zones which are specially sensitive to this domain.

—The non resonnant interactions Hg 6^3P_1 - noble gases have been investigated from Hg 2537 Å profile. The dispersion term, $(-C_{6dd}R^{-6})$, quite satisfactory for large interatomic distances is replaced by $-C_6R^{-6}+C_qR^{-q}$ models ($C_6 \neq C_{6dd}$) for short and intermediate distances inferred from experimental measures in the wings [1]. These interactions are characterized by an intensive anisotropy. We use an analytical recent method [2] to solve the Schrödinger equation relative to the radiative atom evolution. The computed optical efficace cross-sections Re σ and Im σ are compared to the measures in the impact domain [3]. The characteristics of the potentials are tested from the analysis of the results :

* Anisotropic effects (more important for Re σ than for Im σ : 8 to 10%) emphasize the requirement of taking account correctly of the evolution connected with the anisotropic part of the interaction, even in the impact region.

* Im σ constitutes a real test of the asymptotic

branch (large R) of the interactions, while the dependence of Pe σ is critical on the short and intermediate range part of the potentials.

— An another kind of potential test based on the determination of the position of a satellite has been investigated for Hg 6^1P_1 - Hg 6^1S_0 level. The long-range development of the potential with its two first terms (resonnant interaction and correction with the Van der Waals interaction) is significant for $R \gtrsim 7$ au, as it gives, with a good approximation, the blue satellite of Hg 1850 Å line [4].

References

(1) Z. Ben Lakhdar, D. Perrin, R. Lennuier, J. Phys. 37, 831, (1976)
Z. Ben Lakhdar, Thesis Paris (1978)

(2) E. Leboucher, Nguyen Hoe, R. Lennuier, J. Phys. 38, 1361, (1977)
E. Leboucher, Thesis Paris (1979)

(3) J. Butaux, F. Schuller, R. Lennuier, J. Phys. 33, 635, (1972)
J. Butaux, Thesis Paris (1972)

(4) N. Bras, Thesis Paris (1979)
C. Bousquet, N. Bras to be published.

SPECTRAL PROFILES OF THE MERCURY RESONANCE LINE $\lambda = 1849$ Å BROADENED BY Hg-Hg OR Hg-Xe COLLISIONS. DETERMINATION OF INTERACTION POTENTIALS.

C. BOUSQUET, N. BRAS

Département de Recherches Physiques, Université P. et M. Curie 4, place Jussieu 75230 Paris France.

The spectral profiles are studied in absorption in order to have well defined thermodynamical conditions; they have been determined in the 1800 - 2300 Å range. The temperature dependence of the far wings profiles (beyond the red satellite for Hg-Xe) is studied in details; it gives information on the interaction potentials for the Hg-P pairs (P: Hg or Xe) :

$$V_{|m|}(R) \begin{cases} V_i(R) & \text{for the } Hg(6^1S_0)\text{-}P(^1S_0) \text{ pair} \\ V_1(R) & \text{for the } Hg(6^1P_1\ m=\pm1)\text{-}P(^1S_0) \text{ pair} \\ V_0(R) & \text{for the } Hg(6^1P_1\ m=0)\text{-}P(^1S_0) \text{ pair} \end{cases}$$

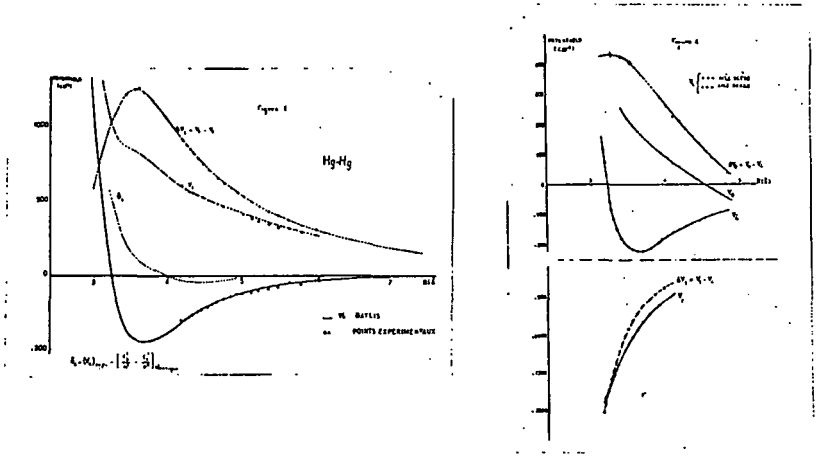
Indeed, according to the quasistatic theory, if we assume a constant transition probability, the absorption coefficient, $k(\nu)$, is proportional to $R^2 \left|\frac{dR}{d\nu}\right| \exp\left[-V_i(R)/kT\right]$ in these far wings. R, interatomic distance, is such as $h\nu = \Delta V(R)$ where ΔV is $V_1 - V_i$ or $V_0 - V_i$ according to the observed wing. The observed temperature dependence determines the relation between V_i and ν, while the $T=\infty$ extrapolated profile gives the correspondence between R and ν. Nevertheless, this last correspondence generally depends on an adjustable parameter. When this parameter can be fixed $V_i(R)$ and $V_{|m|}(R)=V_i(R)+h\nu$ are entirely determined.
This method, first proposed by Gallagher and al. (1), is often used to determine interaction potentials.

The results obtained for Hg-Hg and Hg-Xe potentials are sc in figures 1 and 2 respectively.

Hg-Hg interaction : V_1 and V_i have been determined in the range $4\text{Å} < R < 6\text{Å}$. V_i is in very good agreement with Baylis's calculation (2). In the present case, we have to emphasize that the function $\nu(R)$ does not depend on any parameter since the resonant part of $V_{|m|}(R)$ is prevailing in the range 4 - 6 Å.

Hg-Xe interaction : V_1, V_0 and V_i are shown in figure 2. The R scale has been specified by assuming $V_i(R)$ minimal for R=3,65 Å (value given by Heller (3)).

In order to make more complete these results we have studied the temperature dependence of the steep wing of the marked satellite observed in the blue wing of the profiles (for the Hg-Xe profile this satellite is preceded by a bandlike structure). If we ascribe this satellite to a maximum of ΔV, at R_M, its position gives approximately the value $\Delta V(R_M)$ and according to Szudy and Baylis's results (4), the observed temperature dependence gives values of $V_i(R_M)$ and of the second derivative $\Delta V''(R_M)$. By reference to the potential V_i calculated by Baylis for Hg-Hg and to the one experimentally determined for Hg-Xe, the knowledge of $V_i(R_M)$ determines R_M in both cases. Consequently the quadratic expansion for ΔV about R_M is determined. This parabolic representation of ΔV is shown in figures 1 and 2 for Hg-Hg and Hg-Xe. The dashed lines have been interpolated.



(1) R.E.M. HEDGES, D.L. DRUMMOND, A. GALLAGHER, Phys. Rev. A6, 1519 (1972)

(2) W.E. BAYLIS, J. Phys.B 10, L583 (1977)

(3) R. HELLER, J. Chem. Phys. 9, 154 (1941)

(4) J. SZUDY, W.E. BAYLIS, J.Q.S.R.T. 15, 641 (1975)

THE EXTRAPOLATION ANOMALY IN PRESSURE BROADENING

J.L. Nicol, D.N. Stacey and R.C. Thompson

Clarendon Laboratory, Parks Road, OXFORD OX1 3PU, ENGLAND

The extrapolation anomaly is an effect concerned with the width of a pressure-broadened spectral line extrapolated to zero perturber density. In scanning Fabry-Perot experiments, Kuhn and Vaughan (1) found this width to be significantly greater than the radiation width for resonance broadened helium lines, due allowance having been made for the Doppler effect and instrumental contributions.

The effect has been further studied in helium (2,3) and in particular a recent experiment on the 2.06 μm line showed a large anomaly (4). Kuhn and Lewis (5) found a similar effect in neon; other experimental evidence has also been reported (e.g.,6).

No satisfactory theoretical explanation for the anomaly appears to exist; for example, velocity correlation effects can account for only a small excess width (7). Some experimental work suggests that the effect is at least in part associated with line profile distortion due to the excitation mechanisms active in a discharge (8,9).

One of the difficulties in conventional emission experiments is the proper determination of the instrumental function. One way of overcoming this is to use a dye laser as a tunable monochromatic source for an absorption experiment; there is then effectively no instrumental contribution to the linewidth. Our measurements using this technique on the line 585.2 nm in neon showed no indication of an extrapolation anomaly (10).

One can also eliminate the instrumental contribution in a conventional emission experiment of the type we have carried out in neon (11) by using a narrow band laser fixed in frequency to record the instrumental profile directly. This profile is then used in the fitting procedure. This method has been applied to the line 585.2 nm; the table shows our results compared with previous work.

Natural width (see 10)	3.6 ± 0.1 mK
Emission (5)	5.4 ± 1.2 mK
Absorption (10)	3.6 ± 0.6 mK
Emission (this work)	3.9 ± 0.5 mK

Our recent measurements are thus consistent with the natural width, in contrast to the earlier emission data.

At the Conference our recent results will be presented together with a critical summary of the present evidence for the existence of the anomaly and possible theoretical explanations.

References

1. Kuhn H.G. and Vaughan J.M., 1964 Proc. Roy. Soc. A277, 297-311

2. Vaughan J.M., 1966 Proc. Roy. Soc. A295, 164-81

3. Malvern A.R., Pinder A.C., Stacey D.N. and Thompson R.C., 1979 to be submitted to Proc. Roy. Soc.

4. Damaschini R., Malvern A.R. and Verges J., 1978 Phys. Lett. 69A, 4-5

5. Kuhn H.G. and Lewis E.L., 1967 Proc. Roy. Soc. A299, 423-33

6. Vetter R. and Reymann D., 1974 J. Phys. B 7, 323-34

7. Cooper J. and Stacey D.N., 1974 J. Phys. B 7, 2143-8

8. Malvern A.R., Nicol J.L. and Stacey D.N., 1974 J. Phys. B 7. L518-21

9. Vetter R. and Marié E., 1978 J. Phys. B 11, 2845-53

10. Baird P.E.G., Burnett K., Damaschini R., Stacey D.N. and Thompson R.C., 1979 J. Phys. B 12, L143-6

11. Stacey D.N. and Thompson R.C., 1978 Acta Physica Pol. A54, 833-9

Blank

The pressure broadening of the He I line at 2.06 μm.

R. DAMASCHINI, A. MALVERN* and J. VERGÈS

Laboratoire Aimé Cotton, C.N.R.S. II, Orsay, France.

The pressure broadening of the He I line ($2\,^1P - 2\,^1S$) at 2 μm has been studied in the 0.3 - 20 torr pressure range and liquid nitrogen temperature (77 K) using Fourier Transform spectroscopy.

In earlier works some visible lines were studied with the Fabry-Perot spectrometer. The principal advantages of studying the infrared line compared to the visible lines are :

- the Doppler width is about 4 times smaller ;
- the apparatus function is well determined ;
- because of strong trapping of the resonance line $1\,^1S - 2\,^1P$ at $\lambda = 58.4$ nm one can expect that the $2\,^1P$ population is well thermalized.

The experiment shows that the homogeneous width is a linear function of the pressure with a slope of 250 MHz/torr. This slope is a little lower (20%) than the theoretical resonance broadening one. A extrapolation anomaly is found like in earlier works.

---

* University College, London.

INVESTIGATION OF THE DIFFUSION PROCESS OF LASER ORIENTED ATOMS IN BUFFER GASES THROUGH THE DETECTION OF THEIR OPTICAL ACTIVITY

P.BICCHI*, L.MOI, P.SAVINO, B.ZAMBON

LABORATORIO DI FISICA ATOMICA E MOLECOLARE DEL C.N.R.
VIA DEL GIARDINO, 3 - PISA - ITALY
*ISTITUTO DI FISICA DELL'UNIVERSITA' DI SIENA
VIA BANCHI DI SOTTO, 57 - SIENA - ITALY

The detection of the polarization evolution at different points of the radius r of a cilindrical cell along whose axis an orientation is created by a resonant laser beam, permits us to study the diffusion of the oriented atoms in the buffer gas. This detection is carried out by observing the optical activity[1] at different points along r. The experimental apparatus is sketched in figure 1. The chopper allows a resonant light pulse to illuminate the cell at its centre and the detection system records the rotation of the polarization plane of a linearly polarized analysis beam as the latter moves itself parallel to the pumping beam inside the cell. Tipical signals, for different distances between the two beams, are shown in figure 2 together with the laser pulse. For a fixed distance the rotation intensity is first zero and it goes on increasing till it reaches its maximum when the oriented atoms arrive at the zone under analysis by diffusion; later it decreases both because the atoms go on diffusing and because of the relaxation. In such a way we determined the diffusion coefficients for some buffer gases after having solved exactly the diffusion equation; other aspects of the diffusion process are now under investigation.

(1) P.BICCHI,L.MOI,B.ZAMBON: Nuovo Cimento 49B, 9 (1979)

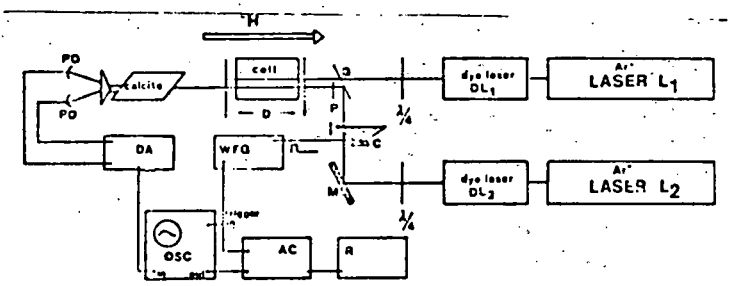


Fig. 1 - Experimental apparatus

C chopper
D diaphragms
G semi-transparent glass
M mirror
P polaroid
PD photodiodes
DA differential amplifier
WFG wave functions generator
AC averaging computer
R recorder

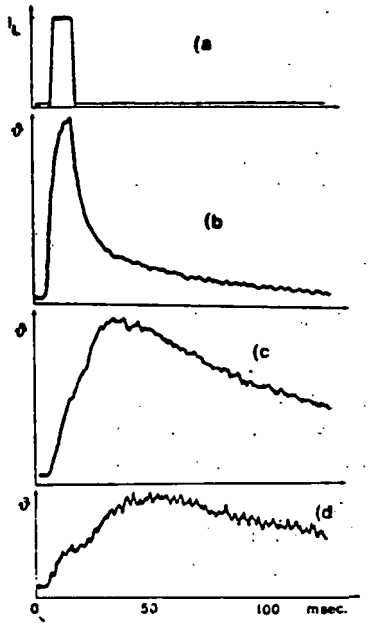


Fig. 2 - a) Pumping laser pulse

Rotation signals for different distances d between the pumping and the analysis beams:
b) d = 2 mm; c) d = 5.5mm
d) d = 7 mm.
The rotation intensities are not comparable eachother.

SPECTROSCOPY OF FINE STRUCTURES OF 3d AND 4d LEVELS OF NEON

N. BILLY, C. LHUILLIER and J.P. FAROUX
Laboratoire de Spectroscopie Hertzienne de l'E.N.S.
24, rue Lhomond, 75231 PARIS CEDEX 05 - France

We have studied the $2p^5nd_4d'_4$ and $2p^5nd'_1d''_1$ levels of Neon (n = 3 and 4) with a level-crossing technique. These levels were excited by transverse bombardment with a neutral beam (H or He). Nearly all the level-crossing resonances $\Delta M = 2$ of those structures have been measured. These measurements provide us with very precise but complex informations about fine structure, wave functions and Zeeman effects of those levels.

The best description of the intermediate configurations of Neon, especially of the d configurations which are studied here, has been obtained by LIBERMAN. This model using the central field approximation, takes into account, in a parametric way, of the electrostatic interaction, both direct and exchange, the spin-orbit interaction of the p electrons and the interaction between $2p^5$ (n+1)s and $2p^5$ nd configurations. With such a theoretical description, LIBERMAN obtained a calculated energy spectrum which is in good agreement with the experimental one (Mean square deviation of 0.5 cm^{-1}, for a configuration extended on about 3000 cm^{-1}).

For these configurations, the angular momentum coupling is very near Racah's coupling, i.e. $[\{ (\ell_1, s_1)\ j_1, \ell_2 \}\ k; s_2]J$. The doublets we have studied, which are labeled $d_4d'_4$ and $d'_1d''_1$ in Paschen's notation, are respectively in Racah's coupling :

$d_4d'_4$ $\quad j_1 = 3/2$; $\quad k = 7/2$; $\quad J = 4$ and 3

$d'_1d''_1$ $\quad j_1 = 3/2$; $\quad k = 5/2$; $\quad J = 3$ and 2

From previous results, we could think that each of these doublets, in the n = 3 or 4 levels, seems to be very near a two-level system. Its fine structure has two origins : exchange electrostatic interaction (taken in account by LIBERMAN) and spin-orbit interaction of the d electron (which now cannot be neglected at our level of precision).

1°) n = 3 structure

The sets of results we obtained for this configuration are in a really good agreement with the previous description. But such experimental results carry informations not only on the energy spectrum, but also on the wave functions and on the Zeeman effect. We have obtained a really better description of the 3d levels when we take into account the interaction with distant configurations by an "effective" hamiltonian (which alters both energy spectrum and Landé factors). This model accounts for the experimental energy spectrum and level-crossings positions with a precision better than 2.10^{-4}. Introduction of some other relativistic interactions (for example spin-spin or spin-other orbit interactions) or diamagnetic hamiltonian seems not to be significant at this level of precision.

2°) n = 4 structure

Our results about n = 4 structure are not so easy to explain with such a description. Particularly they are not consistent with a two-levels system description, showing that the coupling in the n = 4 structure is far from the Racah's coupling.

The parametric description of the whole configuration which has been previously described is not either able to explain our experimental data. To try to solve this problem, we completed our model with diamagnetic hamiltonians, spin-spin and spin-other orbit interactions; we included perturbations induced by interactions with the nearest d configurations, and an "effective" hamiltonian to take into account interactions with distant configurations (for example doubly excited ones). All these attempts have been unsuccessful. Now a finer analysis of the interactions of configurations can provide us with the most credible progress.

H.F.S. of ^{83}Kr, ^{129}Xe and ^{131}Xe

X. HUSSON, J.P. GRANDIN
Laboratoire de Spectroscopie Atomique, Université de Caen, 14032 CAEN CEDEX
H. KUCAL
Institut Fisyki U.J. Ul Reymonta 4, 30 059 Cracow - Poland.

We have measured hyperfine structure constants for 3 levels o $4p^5 5p$ configuration of ^{83}Kr and 5 levels of $5p^5(6p+7p)$ configuration of ^{129}Xe and ^{131}Xe by the level crossing method. The studied levels were selectivly excited in a discharge with a cw dye laser spanning the red and infrared part of the spectrum from 6900 Å to 8500 Å.

Magnetic dipolar A and electric quadrupolar B H.F.S. constants were determined from the crossing positions taking into account hyperfine and Zeeman interactions between fine structure levels.

The obtained values for A and B are given in tables I and II, where they are compared with other recent experimental results of F.P. interferometry (Jackson and coll 1973 and 1977). One generaly notices a good agreement between these values and an improvement of their accuracy by the method we used.

In order to improve the knowledge of ^{83}Kr H.F.S. constants which was very poor until now we used the experimental values of table I together with other precise experimental values obtained for the levels of $4p^5 5s$ configuration to compute radial monoelectronic parameters by the semi empirical method of Liberman (1969 and 1971). From these parameters we could determine A and B values for some of the lowest configurations ^{83}Kr these theoretical values are listed in table I for $4p^5$ 5p configuration.

We are now performing at the laboratory similar experiments but using a cw dye laser in the blue part of the spectrum. We hope to be able at the time of the conference to give new results concerning other levels of $4p^4(5p+6p)$ configuration of ^{83}Kr and $5p^5$ $(6p+7p)$ configuration of

^{129}Xe and ^{131}Xe.

References.

JACKSON D.A. and COULOMBE M.C. 1973 Proc. R. Soc. Lond. A 335 127.

JACKSON D.A. 1977 J.O.S.A. 67 1638.

LIBERMAN S. 1969 Journ. de Physique 30 53.

LIBERMAN S. 1971 Thèse Orsay.

^{83}Kr

level (Racah notation)	Experimental value A^x	A^{xx}	B^{xx}	Theoretical value A^x	B^x
5p (1/2) 1				- 4.59	- 0.68
5p (5/2) 1				- 3.44	-14.4
5p (5/2) 2				- 5.27	-13.6
5p (3/2) 1	- 5,905±0,008			- 5.99	- 2.27
5p (3/2) 2				- 3.62	- 2.7
5p'(3/2) 1	- 19,243±0,02	- 19,240±0,005	0,76±0,1	-19,05	0,81
5p'(3/2) 2				- 9,63	1,9
5p'(1/2) 1	7,567±0,006	7,56 ±0,02	0,70±0,1	7,62	0,69

Table I (values in mK)

Level	^{129}Xe A^x	^{129}Xe A^{xxx}	^{131}Xe A^x	^{131}Xe B^x	^{131}Xe A^{xxx}	^{131}Xe B^{xxxx}
6p' (1/2) 1	66.09±0,05	66,2±0.3	-19.59±0.02		-19.44±0.2	
6p' (3/2) 1	-147.67±0.05	147.6±0.1	43.762±0.015		43.97±0.2	
7p (3/2) 1	- 91.43±0.03	-90.9±0.2	27.094±0.008		27.09±0.2	
6p' (3/2) 2	- 96.24±0.12	-96.45±0.2	28.52±3,04	-0.57±0.01		
6p (3/2) 2	- 29.57±0.03	-29.76±0.2	8.76±0.01	1.01±0.02		1.0

Table II (values in mK)

x this work

xx Jackson D.A. (1977)

xxx Jackson D.A. et Coulombe M.C. (1973)

xxxx Liberman S. (1971)

Blank

LASER-RF DOUBLE-RESONANCE STUDIES OF ATOMIC STRUCTURES AND NUCLEAR MOMENTS IN URANIUM

W.J. Childs. O. Poulsen[§], and L.S. Goodman
Argonne National Laboratory
Argonne, Ill. 60439, USA

ABSTRACT

The hyperfine structure (hfs) of ^{235}U is of interest in the development of optical methods for isotope separation of natural uranium. The laser-rf double-resonance technique was used to obtain high-precision hfs results for both the $5f^36d7s^2\ ^5L_6$ ground state and the $5f^36d7s^2\ ^5K_5$ state at 620 cm^{-1} as well as several higher-lying levels in ^{235}U[1,2]. Also precise isotope shifts $\Delta(^{234}U-^{235}U)$ and $\Delta(^{235}U-^{238}U)$ were measured. Eigenvectors were obtained by diagonalizing the complete energy matrix for the $5f^36d7s^2$ configuration and least-squares adjusting the parameters to 61 known energy levels. Using relativistic radial integrals, the theoretically obtained hfs parameters thus could be compared to the experimental data, the only unknown parameters being the magnetic dipole and the electric quadrupole moments. Good internal consistency was obtained, thus making possible a secure evaluation of these nuclear moments. Based on the above results, a method of separating the uranium isotopes is suggested[3]. Finally, the capability of the laser-rf double-resonance technique will be discussed.

(1) W.J. Childs, O. Poulsen, and L.S. Goodman, Optics Letters 4, 35 (1979)
(2) W.J. Childs, O. Poulsen, and L.S. Goodman, Optics Letters 4, 63 (1979)
(3) L.S. Goodman, O. Poulsen, and W.J. Childs, Optics Comm. 28, 309 (1979)

[§]Permanent address: Institute of Physics, University of Aarhus, DK-8000 Aarhus C, Denmark

MEASUREMENT OF THE NUCLEAR ELECTRIC QUADRUPOLE MOMENT OF ^{50}V BY A LASER-RF DOUBLE-RESONANCE EXPERIMENT

W.Ertmer, U.Johann, G.Meisel

Institut für Angewandte Physik der Universität Bonn
Wegelerstr.8, D-5300 Bonn 1, West Germany

In order to study the hyperfine structure (hfs) of ^{50}V, which occurs with only 0.25 % in the natural abundance, we took full advantage of the high sensitivity of the detection scheme of the ABMR-LIRF method (atomic beam magnetic resonance detected by laser induced resonance fluorescence)[1]. The detection scheme of this method consists of two interaction regions of an atomic beam with two single mode cw dye laser beams of the same wavelength crossing the atomic beam rectangularly. The first laser beam depopulates selectively one of the hfs states under study by optical pumping. The second laser beam measures the residual population of the optically pumped level by observing the laser induced resonance fluorescence signal at the second interaction region. If rf-transitions are induced from a neighbouring hfs level to the optically pumped level in an rf-loop between the two interaction regions, an increase in the occupation of the optically pumped level is produced and can be detected very efficiently.

With this method we measured the hfs-splitting of the ground state $(3d^3\ 4s^2)\ a^4F_{3/2}$ of ^{50}V. We found the ground state very suitable for the determination of the ratio $Q(^{50}V)/Q(^{51}V)$. For this measurement the laser wavelength was tuned to the very weak line $a^4F_{3/2} - z^6D^o_{1/2}$ (5527,64 Å). From these measurements the following magnetic dipole and electric quadrupole interaction constants A and B have been obtained:

$$^{50}V : A(^4F_{3/2}) = 212,297(2)\ \text{MHz}$$
$$B(^4F_{3/2}) = -15,911(2)\ \text{MHz}$$

Using the known electric quadrupole moment Q of ^{51}V (measured in the same fine structure multiplet)[2)3)] we obtained (preliminary results, without Sternheimer corrections):

$$Q(^{50}V) \;/\; Q(^{51}V) = -3,74(2)$$

and

$$Q(^{50}V) = 0,196(14)\,\text{barn}$$

---

1) Ertmer,W., Hofer,B.: Z.Physik A 276, 9 (1976)
2) Childs,W.J., Goodman,L.S.: Phys.Rev. 156, 64 (1967)
3) Childs,W.J.: Phys.Rev. 156, 71 (1967)

INVESTIGATION AND ANALYSIS OF HFS AND CORE-POLARIZATION IN THE CONFIGURATION 5p6s OF $^{121}_{51}$Sb-II

M. Voss, W. Weiss, R. Winkler

Optisches Institut der Technischen Universität Berlin

Strasse des 17. Juni 135, D-1000 Berlin 12, Germany

After our hfs-analysis of the $5p^3$ and $5p^2 6s$ configuration in Sb-I /1,2/, the analysis of the highly-excited configuration 5p6s of the first ionized Sb should confirm the obtained information, especially as to the quadrupole-moments and core-polarization by 6p-electrons.

In the configuration 5p6s up to now only older measurements with very inconsistent results in the levels $^3P_1$ and $^3P_2$ were known /3 - 8/. For the remaining 5p6s $^1P_1$ level no hfs-data were obtained at all.

It was, therefore, desirable to carry out a complete new hfs-analysis of the 5p6s configuration of Sb-II with the more modern experimental optical equipment and the numerical analysis by our computer programm system.
In the table below the hfs-data for the three levels ($^3P_1$, $^3P_2$, $^1P_1$) with the present accuracy are shown:

Conf.	level	^{121}A/mK	^{121}B/mK
5p6s	$^3P_1$	195,0(6)	4(1)
5p6s	$^3P_2$	74,0(6)	-25,3(1,4)
5p6s	$^1P_1$	-11,3(5)	-12,5(1,2)

With this more complete set of hfs-data of this configuration theoretical hfs-analysis (in intermediate coupling) was performed in which the effective operator technique of Sandars and Beck /9/ was applied. The hfs-parameters $a^{ks\ kl}_{nl}$ and $b^{ks\ kl}_{nl}$ are treated as adjustable parameters to the measured magnetic A-factors and the electric B-factors in a least-squares fit.

From the electric hfs-parameters we calculated the quadrupole-moment of this configuration 5p6s to be $^{121}Q = -0,4(1)^{+)}$ barn. This figure supports our previous Q-determinations in $5p^3$ and $5p^2 6s$ of Sb-I /1,2/ and eliminates the uncertainty which existed regarding the value of Q in Sb so far. From the lines investigated, we also achieved data for the isotope shift (IS) which are compiled in the next table:

+) A preliminary value of Q was already reported at DPG-Conference in Berlin 1979.

λ(nm)	Transitions	IS(mK)
192,3	$5p^2\ {}^1S_o \rightarrow 5p6s\ {}^1P_1$	+8,5(3,5)
517,6	$5p6p\ {}^1S_o \rightarrow 5p6s\ {}^1P_1$	+5,0(1,8)
538,1	$5p6p\ {}^1D_2 \rightarrow 5p6s\ {}^3P_2$	+2,4(1,4)
563,9	$5p6p\ {}^3S_1 \rightarrow 5p6s\ {}^3P_2$	+5,6(1,2)
589,5	$5p6p\ {}^3P_o \rightarrow 5p6p\ {}^3P_1$	+5,1(1,6)

The line λ 192,3 nm was investigated with the help of the 5m vacuum-spectrograph at the Physikalisch Technische Bundesanstalt, Institut Berlin, the other lineswith a normal optical experimental set-up in our laboratory.
The calculated core-polarization field constant a_{cp} is equal to -3,4(4) mK (equivalent to a magnetic field of -146(17) kG per p-electron spin). This shows that the core-polarization (C.P.) fields in various Sb-configurations have small differences. So a_{cp} for 5p6s (in Sb-II) is somewhat smaller than the figure of the field from the Sb-I configuration $5p^3$ (a_{cp} = -6,6(4) mK) but a little larger than the figure (a_{cp} = -1,0(3) mK) of the Sb-I $5p^2 6s$ field.

This is contrary to Bi where for some analogous configurations practically equal C.P.-fields were found.

Literature:

/1/ Buchholz, B. , Kronfeldt, H.-D. , Müller, G. , Voss, M. Winkler, R. : Z. Physik A288, 247 (1978)

/2/ Buchholz, B. , Voss, M. , Winkler, R. : X. Conference for Atomic Spectroscopy (EGAS), No. 19, Garching/München (1978)

/3/ Badami, J.S. : Z. Physik 79, 224 (1932)

/4/ Tomboulian, D.H. , Bacher, R.F. : Phys. Rev. 58, 52 (1940)

/5/ Sprague, G. , Tomboulian, D.H. : Phys. Rev. 92, 105 (1953)

/6/ Murakawa, K. , Suwa, S.: Phys. Rev. 76, 433 (1949)

/7/ Murakawa, K. : Phys. Rev. 93, 1232 (1954)

/8/ Murakawa, K. : Phys. Rev. 100, 1369 (1955)

/9/ Sandars, P. , Beck, J. : Proc. Roy. Soc. A289, 97 (1965)

HYPERFINE STRUCTURE MEASUREMENTS IN ^{185,187}Re AND CORE POLARIZATION IN $5d^N6s^2$ ATOMS

S. Büttgenbach, R. Dicke, G. Gölz, and F. Träber
Institut für Angewandte Physik der Universität Bonn,
Wegelerstr. 8, D-5300 Bonn, West Germany

The atomic-beam magnetic-resonance (ABMR) method has been used to study the hyperfine structure (hfs) of the atomic ground state $5d^56s^2\ ^6S_{5/2}$ and the metastable states $5d^56s^2\ ^4P_{5/2}$ (11584 cm^{-1}), $5d^56s^2\ ^4G_{5/2}$ (14621 cm^{-1}), and $5d^66s\ ^6D_{9/2}$ (11754 cm^{-1}) of the stable Re isotopes ^{185,187}Re. The atomic beam of this refractory element was produced by locally heating a small area of a cylindrical rhenium target with the focussed beam of an 100 kV electron gun /1/. The ABMR apparatus used for the experiments is a conventional flop-in type machine equipped with an electron bombardment ion source and a 60° mass spectrometer.

Using intermediate coupling wave functions, derived for the configurations $(5d+6s)^7$ /2/, the experimental data have been analysed with respect to the effective operator formalism. From this analysis we find the following values for the electric quadrupole moments: $Q(^{185}Re) = 2.6(3)$ b and $Q(^{187}Re) = 2.5(3)$ b. These values are consistent with results from optical spectroscopy /3/. For the ratio of the quadrupole moments we obtain from the ratios of the experimental B factors

$Q(^{185}Re)/Q(^{187}Re) = 1.056710\ (4)$ (from $^6S_{5/2}$),
$Q(^{185}Re)/Q(^{187}Re) = 1.056707(24)$ (from $^4P_{5/2}$).

Combining the results of the present investigation with results for the radioactive isotopes ^{186,188}Re /4/ we find for the hyperfine anomaly between neighbouring isotopes the values $^{185}\Delta^{186} = -1.43(23)$ % and $^{187}\Delta^{188} = -1.29(28)$% indicating a strong influence of the additional valence neutron on the distribution of the nuclear magnetic moments.

The analysis of the data with respect to the effective operator formalism also yields an estimate of the influence of core polarization effects. We obtain for the associated radial

expectation value: $\langle r^{-3}\rangle_d^{10}$ ($5d^5 6s^2$) = -1.4 a.u. This value is in good agreement with the results for the other 5d-shell atoms. Fig. 1 shows the $\langle r^{-3}\rangle_{10}$ values for the $5d^N 6s^2$ series as obtained from a recent analysis /5/ of the hyperfine structure of the 5d transition elements. Although it is hard to estimate the uncertainties arising from deficiencies of the eigenvectors being used as well as from simplifying assumptions made for the effective radial parameters, there is clear evidence from Fig. 1 that the contact part of the hfs interaction of the 5d-electrons cannot be explained by relativistic effects alone, but shows considerable contributions from core polarization.

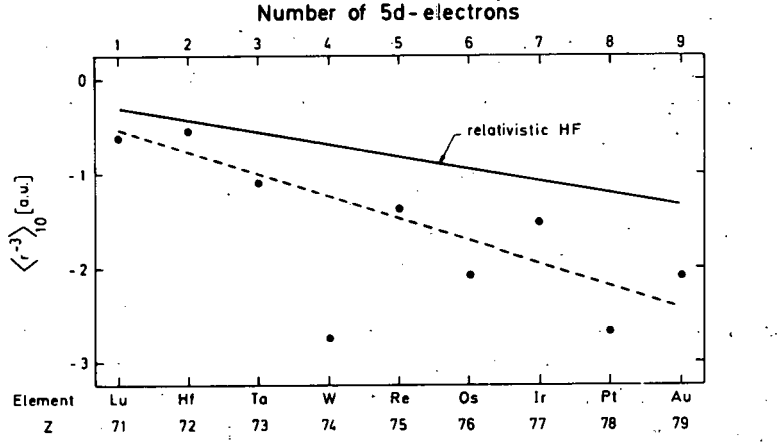


Fig. 1. $\langle r^{-3}\rangle_d^{10}$ values in the $5d^N 6s^2$ series.

/1/ S. Büttgenbach, G. Meisel, S. Penselin, K.H. Schneider, Z. Phys. 230 (1970) 329

/2/ J. F. Wyart, Phys. Scr. 18 (1978) 87 and private communication

/3/ J. Kuhl, A. Steudel, H. Walther, Z. Phys. 196 (1966) 365

/4/ L. Armstrong, R. Marrus, Phys. Rev. 138 (1965) B310

/5/ S. Büttgenbach, R. Dicke, H. Gebauer, R. Kuhnen, F. Träber, Z. Phys. A283 (1977) 303; S. Büttgenbach, R. Dicke, F. Träber, to be published

A PRECISION METHOD FOR HYPERFINE-STRUCTURE STUDIES IN LOW-ABUNDANT ISOTOPES: THE QUADRUPOLE MOMENT OF ^{43}Ca

P. Grundevik, M. Gustavsson, I. Lindgren, G. Olsson, L. Robertsson, A. Rosén and S. Svanberg
Department of Physics, Chalmers University of Technology, S-412 96 Göteborg Sweden.

Precision hyperfine-structure measurements in the 4s4p $^3P_2$ metastable state of ^{43}Ca were performed using the atomic-beam magnetic-resonance method combined with a single-mode dye-laser for the detection. For the first time the electric quadrupole moment of the particularly interesting ^{43}Ca nucleus was accurately determined: $Q(^{43}Ca) = -0.065(20)$ b /1/. In addition, isotope shifts and hyperfine structure in the transition 4s4p $^3P_2 \leftrightarrow$ 4s5s $^3S_1$ were obtained using high-resolution laser spectroscopy.

In our experiments on the ^{43}Ca isotope, which has a very low natural abundance (0.145%), two separate atomic-beam set-ups were used in connection with a narrow-band single-mode dye laser spectrometer. The experimental arrangement is shown in Fig. 1. In the lower part of the figure the ABMR apparatus is shown. This equipment was used in the radio-frequency experiments. In the right-hand part of the figure the collimated-atomic-beam apparatus for high-resolution optical spectroscopy studies is shown. A recording obtained in a laser scan of the 6162 Å line is shown in Fig. 2.

/1/ P. Grundevik, M. Gustavsson, I. Lindgren, G. Olsson, L. Robertsson, A. Rosén and S. Svanberg, to be published.

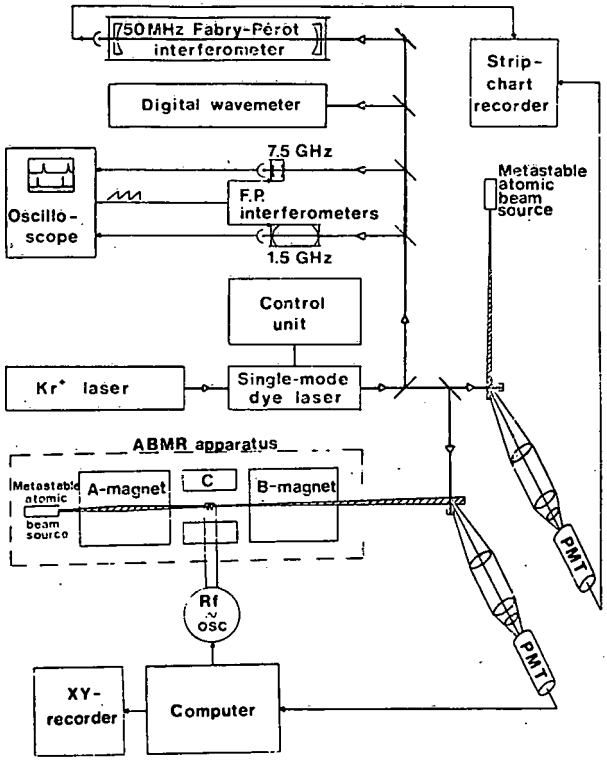


Fig. 1. Experimental set-up for fluorescence spectroscopy and atomic-beam magnetic resonance measurements.

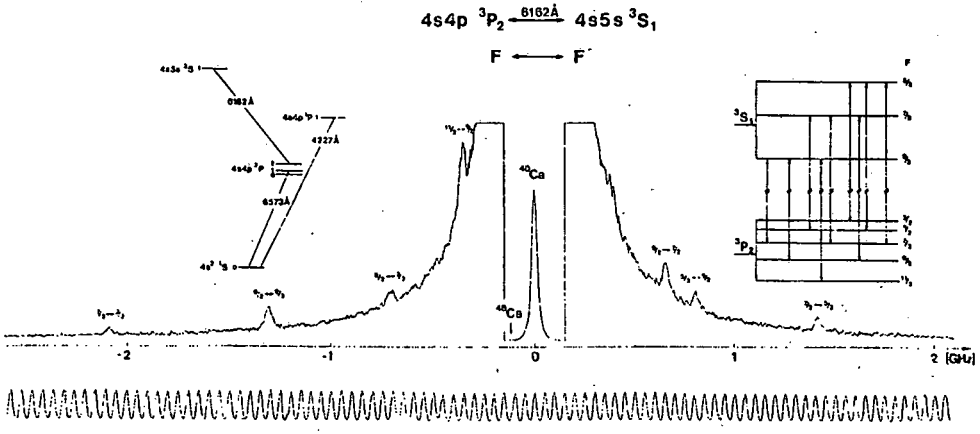


Fig. 2. High-resolution laser scan of the 6162 Å Ca line, displaying the hyperfine structure for ^{43}Ca.

HYPERFINE STRUCTURE OF SEVEN RESONANCE LINES OF BiI IN THE 200 NM SPECTRAL REGION.

Y. GUERN, A. BIDEAU-MEHU, R. ABJEAN and A. JOHANNIN-GILLES
Faculté des Sciences et Techniques, 6, Avenue Le Gorgeu, 29200 Brest, France.

In the course of an atomic absorption study of the resonance lines of bismuth I, we needed to know the hyperfine structure of these resonance lines. We found in the literature (1) (2) (3) (4) some data about the concerned levels and this problem has already been set at the fourth EGAS Conference by Dr Winkler and coworkers (5) who presented results concerning three levels. Nevertheless we estimated necessary to investigate the hyperfine structure of the considered lines and to test its agreement with the preceding data. So we obtained new measurements of the A constants for the upper levels.

The literature contains very accurate values for the splitting constants of the $6p^3\ ^4S^o_{3/2}$ ground level and we adopted for this level the values A = -446.942 MHz, B = -304.654 MHz given by Hull and Brink (6).

This work was performed with a pressure scanned Fabry-Perot interferometer. The light sources were hollow cathode lamps. The signal was digitalized and recorded on a punched tape. The A and B splitting constants were adjusted by fitting the computed signal to the experimental one. The computing program is analogous to that used by Hühnerman (7) with this difference that the simulation of the Fabry-Perot response is calculated by a direct convolution (with F.F.T.) of the involved functions (Voigt, Airy, defect finesse, diaphragm...) instead of an analytical expression.

Fig. 1 shows an example of a computed signal (a) and below the difference between this computed signal and the experimental one (b). The presented fringe pattern is obtained for the 227.6 nm line ($6p^26d\ ^2D_{3/2}$ - $6p^3\ ^4S^o_{3/2}$) with 755.5 mK free spectral range.

Fig. 2 shows the computed structure of the 222.8 nm line ($6p^27s\ ^4P_{3/2}$ - $6p^3\ ^4S^o_{3/2}$) and also the position of its 10 components.

The results are summarized in table I. For the A constants, the accuracy may be estimated to better than 0.1 mK and the agreement with literature data is satisfying with the exception of the level $6p^27d\ ^2D_{5/2}$ for which we find 0.51 mK instead of 6.8 mK given in Landolt Borstein tables, from Mrozowski data (1). In fact, the value calculated from Mrozowski data seems to be 0.68 mK. We did not find, within our limits of accuracy for B ($\pm$ 3 mK), any evidence of B values different of zero, with the exception of the $6p^27s\ ^4P_{5/2}$ level.

References :
(1) S. MROZOWSKI, Phys. Rev. 62, 526 (1942).
(2) O. POULSEN and J.L. HALL, Phys. Rev. A, 18, 1089 (1978).
(3) J. DEMBCZYNSKI and M. FRACKOWIAK, Acta Phys.Pol.A, 48, 139 (1975).
(4) L. HOLMGREN and S. SVANBERG, Phys. Scripta, 9, 211 (1974).
(5) M. FRANK, D. SKROK and R. WINKLER, 4 EGAS Conference, Amsterdam (1972).

(6) R.J. HULL and G.O. BRINK, Phys. Rev. 1, 685 (1970).
(7) H. HÜHNERMANN, J. Phys.Paris, 28,C2, 260 (1967).
M.S.W.BRIMICOMBE, D.N. STACEY, V. STACEY, H. HÜHNERMANN and N.MENZEL, Proc.R.Soc.Lond.A, 352, 141 (1976).

level	A mK	B mK
$6p^2 6d\ ^2D_{3/2}$ (227.6 nm)	4.25	0.
$6p^2 6d\ ^2D_{5/2}$ (223.1 nm)	0.49	0.
$6p^2 7s\ ^4P_{3/2}$ (222.8 nm)	-2.26	0.
$6p^2 8s\ ^4P_{1/2}$ (211.0 nm)	34.68	-
$6p^2 7s\ ^4P_{5/2}$ (206.1 nm)	124.16	-2.6
$6p^2 7d\ ^2D_{3/2}$ (195.9 nm)	11.11	0.
$6p^2 7d\ ^2D_{5/2}$ (195.3 nm)	0.51	0.

Table 1

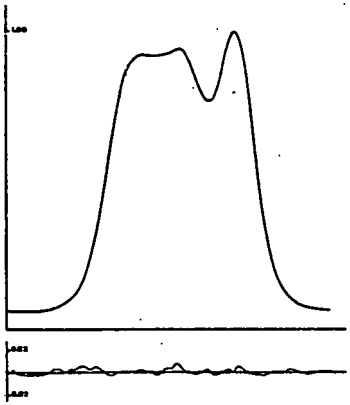


Fig. 1

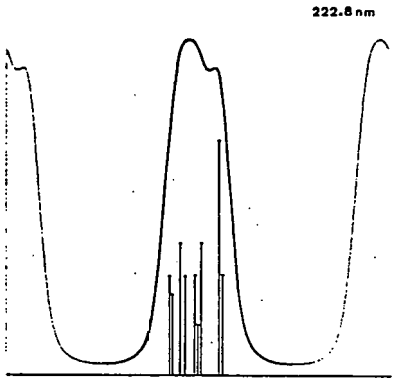
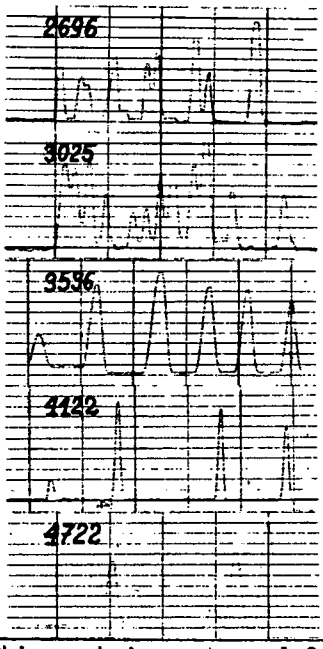


Fig. 2

OBSERVATION OF $6p \rightarrow n'p$ EXCITATION EFFECTS ON THE FINE AND HYPERFINE STRUCTURE OF THE BISMUTH ATOM.*

J. Dembczyński, E. Arcimowicz, H. Szuba and E. Kobielska
Institute of Physics, Technical University of Poznań.

The existence of the excitation $np^N \rightarrow np^{N-1}n'p$ in any element should be proved, if the relation $X^{01}/a^{01} = X^{12}/a^{12} = x_2 = Q^{(2)}/\zeta$ is fulfilled, where x_2 is a configuration interaction parameter defined by Bauche-Arnoult [1], a^{01} and a^{12} are hyperfine structure /hfs/ parameters following from Sandars and Beck's [2] effective operators theory, X^{01} and X^{12} are parameters representing effects of the $np \rightarrow n'p$ excitation on the hfs, $Q^{(2)}$ is a parameter of electrostatically correlated spin-orbit interactions [3,4], and ζ is the spin-orbit constant. According to the configuration interaction theory developed by Judd [5] and Bauche-Arnoult [4] the magnetic-dipole hfs constants A in intermediate-coupling for any p^3 configuration can be expressed by four independent parameters a^{01}_{mc}, a^{12}_{mc}, a^{10} and X^{12} (2) where a^{01}_{mc} and a^{12}_{mc} include first- and second order effects, which can be separated by the relations $a^{01}_{mc} = a^{01} + X^{01}/6$, $a^{12}_{mc} = a^{12} + 11 \cdot X^{12}/30$ (3) In order to prove the relation (1) we performed: (i) Measurements of the constants A for the levels $^2D_{3/2}$, $^2D_{5/2}$ and $^2P_{1/2}$ from hfs splittings of the lines 2696 Å, 3025 Å, 3596 Å, 4122 Å and 4722 Å, using a grating spectrograph PGS-2 in higher orders, e.g. microphotometer traces of the lines are shown in Fig.1. (ii) A fine structure (fs) fit, in which five levels of the $6p^3$ configuration of Bi were fitted



*This work is sponsored from the MRI.5 problem coordinated by the Institute of Experimental Physics of the Warsaw University

exactly by five fs parameters for which the following values were obtained / in cm^{-1}/ F_0= 7541.4, F_2= 1041.1, α = -161.8, ζ = 9999.4, $Q^{(2)}$= 1117.3 . (iii) A hfs fit, in which five magnetic-dipole constants A were fitted by four parameters(2). The results of this fit are / in MHz/:

Level	$^4S_{3/2}$	$^2D_{3/2}$	$^2D_{5/2}$	$^2P_{1/2}$	$^2P_{3/2}$
$A_{exp.}$	-446.937(1) Ref. 6	-1213	2508	11260	491.028(1) Ref. 7
$A_{calc.}$	-446.940	-1216	2521	11257	491.023
$A_{exp.} - A_{calc.}$	0.003	3	-13	3	0.005

a^{01}_{nl} = 2586 a^{12}_{nl} = 5351 a^{10} = -2020 X^{12} = 529

Using the above values and eqs (3) the values of the hfs parameters corrected to second order for the $6p^3$ configuration of Bi I are: a^{01}= 2541 MHz , a^{12}= 5157 MHz

Recapitulating, we have:

1/ directly from hfs investigations $x_2 = X^{12}/a^{12} = 0.102$

2/ from fs fit $x_2 = Q^{(2)}/\zeta = 0.112$

Therefore, the relation (1) is fulfilled excellently.

The effect of $6p \rightarrow n'p$ excitation On the quadrupole hfs interaction is under study.

[1] C.Bauche-Arnoult,Proc.Roy.Soc. A 322, 361 /1971/.

[2] P.G.H.Sandars, J.Beck,Proc.Roy.Soc. A 289, 97 /1965/.

[3] K.Rajnak, B.G.Wybourne,Phys.Rev. 134 A, 596 /1964/.

[4] A.Pasternak, Z.B.Goldschmidt,Phys.Rev. A6 , 55 /1972/.

[5] B.R.Judd,in La Structure Hyperfine des Atoms et des Molecules p.311/eds R.Lefebre,C.Moser/,Paris 1967.

[6] R.J.Hull, G.O.Brink,Phys.Rev. A1 , 685 /1970/.

[7] D.A.Landman, A.Lurio,Phys.Rev. A1, 1330 /1970/.

LEVEL CROSSING POLARIZATION SPECTROSCOPY

J. Mlynek and W. Lange
Institut für Angewandte Physik, Universität Hannover,
Welfengarten 1, D-3 Hannover, Germany

H. Brand
Institut A für Experimentalphysik, Universität Hannover,
Appelstrasse 2, D-3 Hannover, Germany

A new method is described for level crossing spectroscopy in transmission by use of a polarization technique. It relies on magnetic field dependent anisotropic contributions to the complex susceptibility originating from coherences between atomic or molecular substates[1]. The scheme of the experimental set-up is shown in Fig. 1. A strong resonant light beam of suitable polarization ("pump beam") induces coherences between nearly degenerate sublevels. These coherences are sensitively detected by placing the sample between crossed polarizers and transmitting a weak probe beam, while scanning the magnetic field. The probe beam and pump beam are of the same frequency and direction.

The width of the signals is determined by the lifetime of the crossing levels and is not affected by Doppler broadening. It should be emphasized that an experiment of this type does not

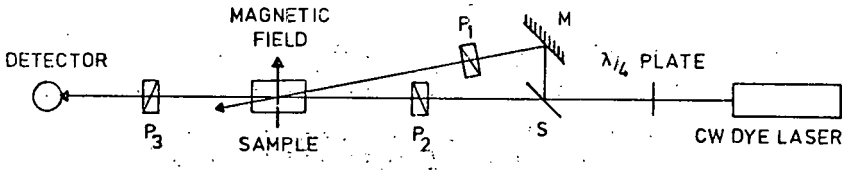


Fig. 1 Experimental scheme

P_1 polarizer, P_2,P_3 pair of crossed polarizers

necessarily require a light source of narrow bandwidth. Moreover the method can be applied to level crossings in the lower as well as in the upper state of the transition.

As a demonstration the method was applied to zero field level crossings in the Sm I spectrum. The results are discussed and the method is compared to other related techniques in level crossing spectroscopy in transmission[2-4].

1) W. Lange, J. Mlynek, Phys. Rev. Lett. 40, 1373 (1978)

2) A. Corney, B.P. Kibble and G.W. Series, Proc. Roy. Soc. A293, 70 (1966)

3) M.S. Feld, A. Sanchez, A. Javan and B.J. Feldman, Proceedings of Aussois Symposium, May 1973 (Publ. N217, CNRS, Paris 1974), pp. 87-104

4) I. Colomb, M. Gorlicki and M. Dumont, Opt. Commun. 21, 289 (1977)

FARADAY SPECTROSCOPY OF TRANSITIONS BETWEEN LEVELS OF THE GROUND CONFIGURATION OF ATOMIC BISMUTH

P.E.G. Baird, M.W.S.M. Brimicombe, G.J. Roberts,
P.G.H. Sandars, D.R. Selby and D.N. Stacey

Clarendon Laboratory, Parks Road, OXFORD OX1 3PU, ENGLAND

We have studied the Faraday rotation in the vicinity of two transitions of mixed electric quadrupole and magnetic dipole character within the $6p^3$ ground configuration of atomic bismuth, $J = 3/2 \rightarrow J = 5/2$ (648 nm) and $J = 3/2 \rightarrow J = 3/2$ (876 nm). Our object in each case was to measure χ, the ratio of the E2 and M1 reduced matrix elements. The work is connected with our search for parity non-conserving effects in bismuth (1), but measurements of χ are also useful as a test of atomic calculations.

The apparatus was similar for both lines (figure 1). Light from a tunable dye laser passed through an oven containing bismuth vapour at 1350 K (648 nm) or 1100 K (876 nm). The oven was included in a crossed polariser/Faraday modulator system for measuring small optical rotations (1). The longitudinal magnetic field due to the alternating heating current produced a Faraday rotation $\phi_B \cos \omega_B t$ in the bismuth. An additional rotation $\phi_m \cos \omega_m t$ was produced in the water Faraday cell. The transmitted intensity for small angles can be written

$$I = I_o (\phi_B \cos \omega_B t + \phi_m \cos \omega_m t)^2$$

The crossterm, linear in the required signal ϕ_B, was measured by phase sensitive detection.

The signal was recorded as the laser frequency was scanned over the hyperfine components of the line. A theoretical lineshape was calculated, and fitted to the data (figure 2) with χ as one of the parameters to be determined. We obtained $\chi = -0.60 \pm 0.02$ (λ648 nm) and $+0.13 \pm 0.07$ (λ876 nm). No previous measurements of χ for these transitions have been reported; the theoretical values are -0.65 and +0.11 respectively (2).

Faraday spectroscopy is a sensitive method for determining such ratios, because the rotation depends on interference between the M1 and E2 contributions to the transition and yet does not need the very large magnetic fields previously used to observe M1, E2 interferences for these transitions (3).

We note also that in the case of λ648 nm there is a strong molecular background present in a conventional absorption experiment; however the molecular contribution to the Faraday rotation is negligible.

Faraday spectroscopy can of course also be applied to measure the hyperfine intervals themselves, though in our present work we used published data (4) in our computer fitting.

References

1. Baird et al, Phys. Rev. Lett. 39, 13, 798, 1977
2. Garstang, J. Res. Nat. Bureau of Standards, 68A, 1, 61, 1964
3. Heldt and Mrozowski, J. Opt. Soc. Am., 60, 4, 467, 1970

Hull and Brink, Phys. Rev. A, 1, 3, 685, 1970;

Winkler, reported by Heldt J. Opt. Soc. Am., 58, 11, 1576, 1968;

Mrozowski, Phys. Rev. 62, 526, 1942
and 69, 169, 1946

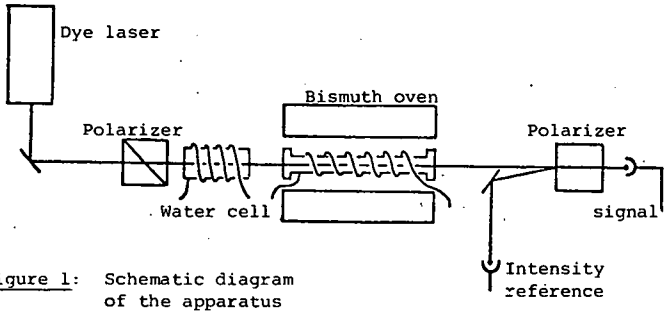


Figure 1: Schematic diagram of the apparatus

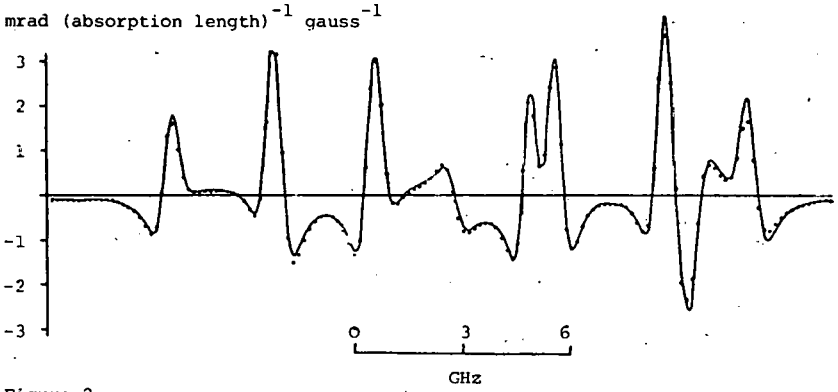


Figure 2:

Experimental (·) and fitted (-) Faraday rotation for the 876 nm transition

HYPERFINE STRUCTURE INVESTIGATIONS IN RYDBERG LEVELS OF THE CONFIGURATIONS $4f^{14}6s\ nd$ OF Yb I

Luc BARBIER and René-Jean CHAMPEAU

Laboratoire Aimé Cotton, Orsay, France

1. High Rydberg levels of many-electrons atoms have two interesting characteristics that distinguish them from those of alkali atoms :

(i) - Their properties are influenced by the presence of the non-excited optical electrons.

(ii) - In the energy range where high Rydberg levels are located there can also exist levels belonging to doubly excited electronic configurations that interact with the usual Rydberg series. The investigations of such "perturbed" series is an important and interesting subject of investigation.

2. Very high resolution studies of Rydberg levels of Yb I have been performed on an atomic beam of metastable Yb atoms. This beam consists of the usual thermal atomic beam apparatus but, in addition, a discharge is produced at the exit aperture of the oven. One thus obtains a beam containing a few percent of the atoms in each of the metastable levels [1].

High Rydberg levels of the series $4f^{14}6s\ nd$ were excited from the metastable $4f^{14}6s\ 6p\ ^3P_0$ level using the U.V. beam of a frequency-doubled single mode dye laser [2] which provides U.V. pulses of about 50 ns duration, 50 Watts peak power at a repetition rate of 50 Hz. The laser beam and the atomic beam intersect at right angles. The width of the recorded resonance is approximately 2 mK (60 MHz) due to the spectral width of the laser light and to the residual Doppler shift corresponding to the divergence of the atomic beam.

The Rydberg levels are detected by using the phenomenon of ionization by a static electric field. The positive ions so produced are accelerated by the electric field and detected by an electron multiplier. A temporal gate with a delay and duration properly adjusted counts only the ions of interest.

3. The hyperfine structures of about 20 transitions of the type $4f^{14}6s\ 6p\ ^3P_0 \rightarrow 4f^{14}6s\ nd\ E_e$ (n ranging from 23 to 53 and E_e being the energy of the excited level) have been investigated for the two odd isotopes ^{171}Yb and ^{173}Yb. The structures of these transitions are due to the upper level since the J value of the lower level is zero.

The main interactions responsible for the level structure of the $4f^{14}6s\ nd$ configuration are :

(i) - The electrostatic interaction between the 6s and the nd electron : G.

(ii) - The spin-orbit interaction of the nd electron : $\mathcal{A}$.

(iii) - The magnetic hyperfine interaction of the 6s electron : H_m.

The matrix elements of the first two operators decrease rapidly with increasing n (approximately as $(n^*)^{-3}$), whereas those of the last term H_m are independent of n. As a consequence the structures of the highest observed levels ($n \sim 50$) are strongly dominated by the hyperfine structure of the 6s electron. In a first approximation, the influence of G and $\mathcal{A}$ can be neglected. The structure of the Rydberg level is then the same as for the ground level $4f^{14}\ 6s\ ^2S_{1/2}$ of Yb II.

4. For lower n values, the contributions of the three operators G, $\mathcal{A}$ and H_m are of the same order of magnitude, thus no simple coupling scheme can be used.

In order to give a theoretical interpretation we had therefore to apply the parametric method, to the $4f^{14}$ 6s nd configuration as a whole. The matrix of the operator $G + \mathcal{A} + Hm$ was built in the $|SLJFM_F\rangle$ basis and diagonalized. The radial integrals G_2 (Slater integral for the electrostatic interaction G) and ζ_d (fine structure splitting factor of the nd electron) where considered as adjustable parameters and fitted by the usual least-squares method. The hyperfine radial parameter a_s was fixed to the value deduced from the hyperfine structure of the ground level of Yb II [3].

A rather good agreement between theory and experiment was thus obtained, but the final values of the ζ_d and G_2 parameters are found to be almost equal. This fact is rather surprising since Hartree-Fock predictions give a value of about 8 for the ratio G_2/ζ_d. A possible explanation for this anomaly is that the G_2 and ζ_d are "effective parameters" which take into account interactions that have not been considered in the preceding theoretical treatment. The usual parametric method is probably not adequate for dealing with the hyperfine structure of Rydberg levels; it would be worthwhile to try to apply the MQDT method to this problem.

[1] - U. BRINKMANN J. GOSCHLER, A. STEUDEL, H. WALTHER, Z. Physik, 228, 427 (1969)

[2] - J. PINARD, S. LIBERMAN, Opt. Comm., 20, 344 (1977)

[3] - CHAIKO, Yu, Opt. i Spektr., 20, 760 (1966).

INVESTIGATION OF HYPERFINE STRUCTURE AND ISOTOPE SHIFT OF THE 573.7 nm LINE OF LUTETIUM BY LASER SPECTROSCOPY

G.Aepfelbach, A.Kuhnert, D.Zimmermann, P.Zimmermann

Institut für Strahlungs- und Kernphysik
Technische Universität Berlin, Rondellstr.5, D-1000 Berlin 37

Using a tunable single mode dye laser the hyperfine structure of the transition $5d(6s)^2\ ^2D_{3/2}$-$5d6s6p\ ^4F_{3/2}$ (λ=573.7 nm) has been investigated. The experimental setup was the same as in our previous work (1). Using Lutetium in natural mixture of isotopes (97.4% Lu^{175}, 2.6% Lu^{176})we were able to detect 9 hyperfine components for each isotope (see the figure below). The one missing hyperfine component of Lu^{175} is expected to have zero intensity assuming natural excitation, the corresponding one of Lu^{176} is accidentally hidden by a much stronger line of Lu^{175}. From the experimental spectra the following values of the hyperfine constants could be deduced

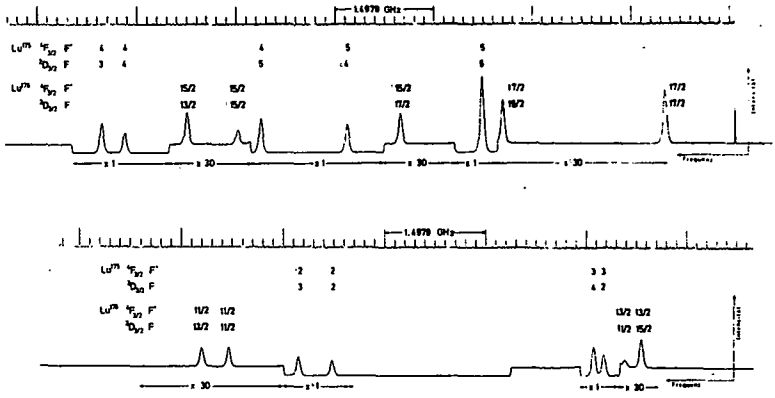


fig: Experimental curve of the hfs of the 573.7 nm line of lutetium. The frequency is increasing from right to left. The right end of the lower part continues at the left end of the upper part. For detection of the hfs components of Lu^{176} the sensitivity of the detection circuit has been increased by a factor of 30.

Lu^{176} $5d6s6p\ {}^4F_{3/2}$: A = - 651.4(0.3)MHz; B = 2494(4)MHz

$5d(6s)^2\ {}^2D_{3/2}$: A = 138.0(0.3)MHz; B = 2131(3)MHz

Lu^{175} $5d6s6p\ {}^4F_{3/2}$: A = - 924.7(0.5)MHz; B = 1767(4)MHz

The values of Lu^{175} and of the $^2D_{3/2}$-state of Lu^{176} are in good agreement with earlier measurements (2, 3) but are more accurate. Comparing the ratios of the hfs constants of both isotopes (see table below) we find good agreement between the ratios of the B-factors of different electronic states. The deviations between the ratios of the A-factors are outside limits of error and are most probably due to the hfs anomaly between both isotopes.

The isotope shift of the 573.7 nm-line has been determined to be $IS(Lu^{176}-Lu^{175})$ = - 394(5)MHz yielding a value of -403(5)MHz for the combined effect of the specific mass shift and of the field shift.

	A^{176}/A^{175}	B^{176}/B^{175}
$5d(6s)^2\ {}^2D_{3/2}$	0.7101(16)	1.410(2)
$^2D_{5/2}$	0.7092(21)	1.414(3)
$5d6s6p\ {}^4F_{3/2}$	0.7044(7)	1.411(6)
$^4F_{5/2}$	0.7075(7)	1.400(17)
$(6s)^2 7s\ {}^2S_{1/2}$	0.7029(29)	---
$5d6s\ {}^3D_1$ LuII	0.7042(22)	1.414(14)

Ratios of hfs splitting constants for different electronic states

(1) A.Nunnemann, D.and P.Zimmermann: Z.Physik A290(1979),123
(2) I.J.Spalding,K.F.Smith: Proc.Phys.Soc. 79 (1962), 787
(3) J.Verges, J.F.Wyart: Physica Scripta 18 (1978), 87

High resolution laser-atomic-beam spectroscopy on Dy I.

E.R. Eliel, W. Hogervorst, G.J. Zaal and K.A.H. van Leeuwen,
Natuurkundig Laboratorium, Vrije Universiteit,
Amsterdam, The Netherlands.

With tunable CW dye lasers we have performed high resolution experiments on samples of natural dysprosium in the wavelength regions 437 - 470 nm and 564 - 665 nm[1]. In this frequency region some 30 transitions were studied originating from the atomic ground state as well as from the metastable states at 4134 and 7050 cm^{-1}.

The laser beam is intersecting a well collimated atomic beam at right angles, thus eliminating the Doppler-broadening to a great extent. Fluorescent emission is detected with a photomultiplier when the laser frequency is scanned over an atomic absorption line. Laser scans have been calibrated with a temperature stabilized 50 cm confocal etalon (free spectral range 150 MHz). The metastable states have been populated thermally at oven temperatures of about 2000 K, resulting in populations of about 5% and 1% for the states at 4134 and 7050 cm^{-1} respectively.

As examples the transitions at 458.9 nm and 569.9 nm are shown in fig. 1 and 2. Hyperfine structure constants of the isotopes ^{161}Dy and ^{163}Dy and isotope shifts can be obtained from this type of spectra. An interpretation of the results in terms of the effective operator formalism[2] and nuclear moments and deformations will be given.

[1] W. Hogervorst, G.J. Zaal, J. Bouma and J. Blok, Phys. Lett. 65A (1978) 22

[2] L. Armstrong, Theory of Hyperfinestructure, Wiley and Sons, New York 1971.

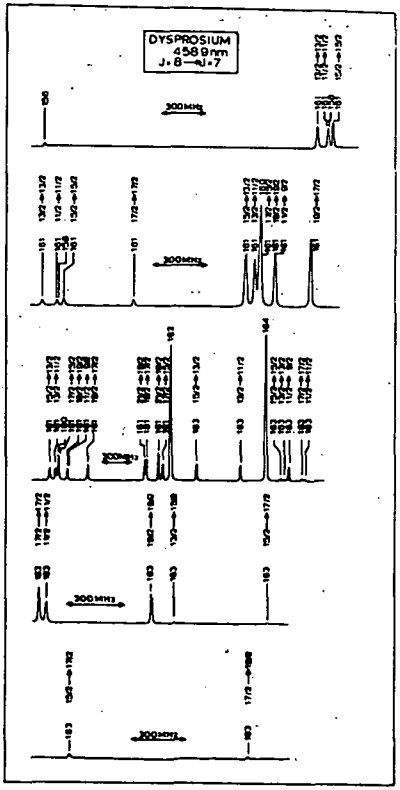


Fig. 1. The transition 458.9 nm of Dy I starting from the atomic ground state (J = 8)

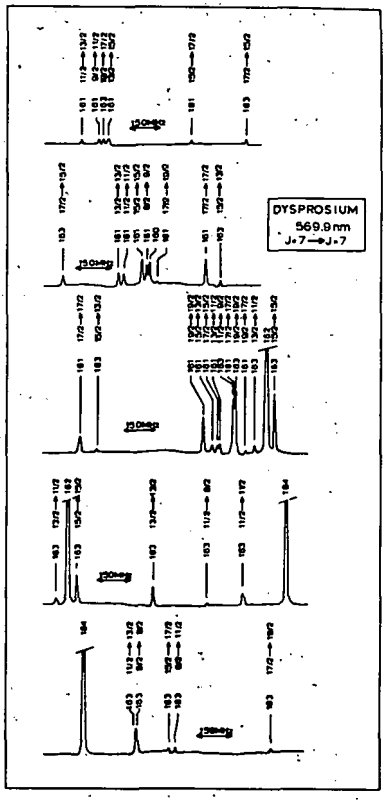


Fig. 2. The transition 569.9 nm of Dy I starting from the metastable state at 4134 cm^{-1} (J = 7)

LASER-SPECTROSCOPY INVESTIGATIONS OF ALKALI- AND ALKALINE-EARTH ATOMS

K. Fredriksson, P. Grundevik, H. Lundberg, L. Nilsson and S. Svanberg
Department of Physics, Chalmers University of Technology, S-412 96 Göteborg, Sweden.

Using high-resolution laser fluorescence spectroscopy on a collimated atomic beam we have recently performed several investigations on alkali and alkaline-earth atoms. The fine-structure intervals of the 5 and 6 ^{2}D states of K were measured using step-wise laser excitations with the first P-state as an intermediate level. In addition to collimated-beam measurements, level-crossing spectroscopy was used to achieve a very high resolution /1/. The fs splittings of the 10-17 ^{2}F states of Cs were determined in experiments using the excitation scheme shown in Fig. 1. Laser scans like the one shown in Fig. 2 yield, apart from the fs splittings, also the D state hyperfine structure /2/. Stark effect measurements for a large number of S and D states of K, Rb and Cs have also been performed /3/.

A program of high-resolution experiments for alkaline-earth atoms has recently been initiated in our laboratory. Experiments for Ca are reported separately at this conference. For Ba we have performed a detailed hyperfine-structure study of 8 states belonging to the 5d6p configuration. Isotope shifts in a large number of lines connecting the 6s5d and 5d6p configurations were also measured. Theoretical calculations of the hyperfine interactions are in progress /4/.

/1/ L. Nilsson and S. Svanberg, Z. Physik A, in press.
/2/ K. Fredriksson, H. Lundberg and S. Svanberg, Phys. Rev. A, in press.
/3/ K. Fredriksson, L. Nilsson and S. Svanberg, to be published.
/4/ P. Grundevik, H. Lundberg, L. Nilsson and G. Olsson, to be published.

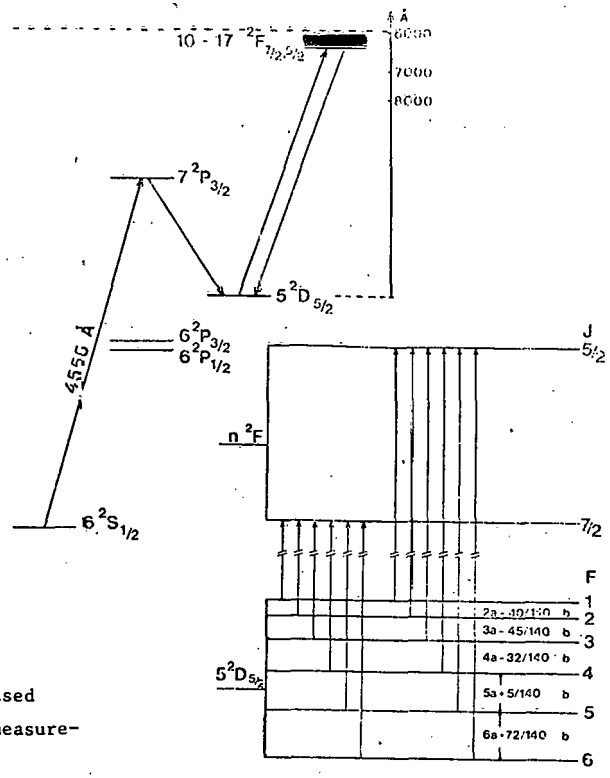


Fig. 1. Transition diagram used in high-resolution measurements on Cs atoms.

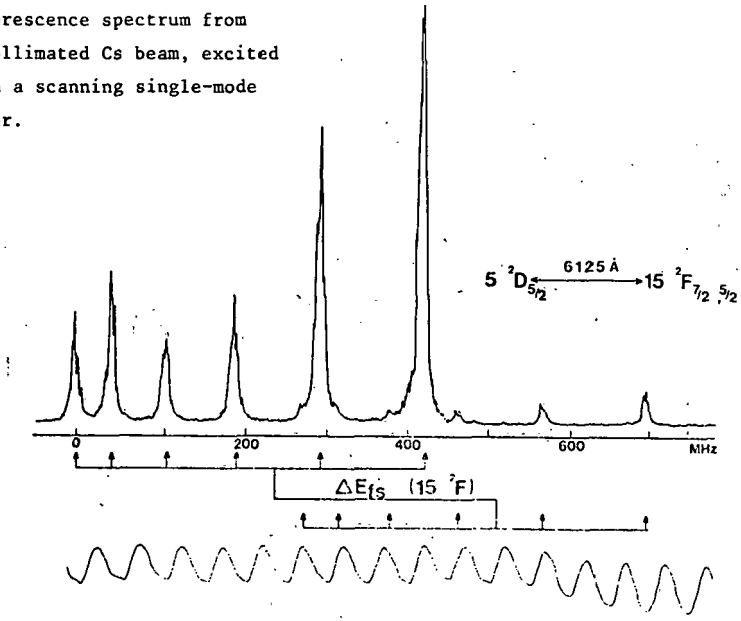


Fig. 2. Fluorescence spectrum from a collimated Cs beam, excited with a scanning single-mode laser.

HIGH RESOLUTION LASER SPECTROSCOPY OF XENON ISOTOPES IN THE BLUE SPECTRAL RANGE

H. Gerhardt, E. Matthias, H. Rinneberg,
F. Schneider, A. Timmermann, P.J. West

Institut für Atom- und Festkörperphysik
Freie Universität Berlin

High resolution saturation spectroscopy was used to investigate the optical transition $6s(3/2)_2 \longrightarrow 7p(5/2)_3$ occurring in xenon at 467.1 nm. Isotope shifts as well as hyperfine constants were determined for all stable xenon isotopes between A=124 and A=136. In addition, preliminary results for the radioactive isotope ^{133}Xe ($T_{1/2}$ = 5.3 d) are presented.

The frequency of the cw dye laser spectrometer, operating in the blue spectral range, was digitally scanned with the aid of a HP 21 MX computer. In this way, time averaging could be used to improve the signal to noise ratio /1/.

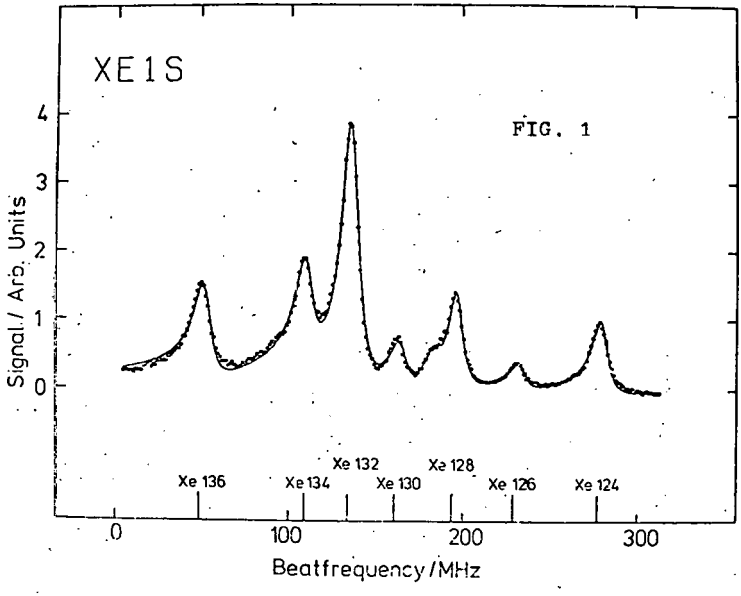


Fig. 1 shows a typical spectrum of all even stable xenon isotopes obtained after two frequency scans. The solid line represents a least-squares fit to the experimental data represented by the dots in Fig. 1.

For frequency calibration the offset locking technique was employed yielding an overall accuracy of better than 1 MHz /2/. In a King diagram the isotope shifts listed in Table 1 are compared with earlier data /3,4,5/.

T A B L E 1 ($IS' = IS_{exp} - NME$)

pair(136-134)	(134-132)	(132-130)	(130-128)	(128-126)	(126-124)
-IS'117.3(1.0) (MHz)	74.7(1.0)	79.5(1.0)	85.8(1.0)	94.7(1.0)	108.3(1.0)

To a good approximation the isotope shifts linearly decrease with increasing neutron number, except for the ^{136}Xe - ^{134}Xe pair involving the isotope with a closed neutron shell. Consistent with previous conclusions, the mean square nuclear charge radii of the even xenon isotopes increase with increasing mass number /3,4/.

Using recently published deformation parameters ß for the xenon isotopes /6/ the effect of the nuclear deformation was estimated and compared to the experimental isotope shift data.

/1/ Gerhardt, H.,Matthias, E.,Schneider, F.,Timmermann, A.: Z.Physik A 288, 327 (1978)

/2/ Gerhardt, H.,Timmermann, A.: Opt. Comm. 21, 343 (1977)

/3/ Fischer, W.,Hühnermann, H.,Krömer, G.,Schäfer, H.J.: Z.Physik 270, 113 (1974)

/4/ Jackson, D.A.,Coulombe, M.-C.: Proc. R. Soc. Lond. A . 338, 277 (1974)

/5/ Vetter, R.: Phys. Let. 42 A, 231 (1972)

/6/ Gordon, D.M.,Eytel, L.S.,de Waard, H.,Murnick, D.E.: Phys. Rev. C 12, 628 (1975)

COLLINEAR LASER SPECTROSCOPY ON FAST BARIUM AND LANTHANUM IONS

C.Höhle, K.Dörschel, H.Hühnermann, Th.Meier, L.Schmidt and H.Wagner

Fachbereich Physik, Renthof 5, D-3550 Marburg, Germany

With the help of a cw dye laser beam superposed on a fast ion beam hyperfine structures (hfs) and isotope shifts (IS) can be investigated. There are principally two different ways to measure hfs. Either one scans the laser frequency and keeps the ion velocity fixed, or one keeps the laser frequency constant while tuning the ion velocity with an auxiliary electric field (Doppler tuning). The method of Doppler tuning provides two advantages:

1. The laser frequency can be locked to the resonance signal of a particular hfs component to eliminate laser frequency drifts as well as drifts of the acceleration voltage.
2. IS can be measured by splitting the laser beam into two beams which are superposed on two mass separated ion beams of a mass separator.

The experimental developments we have tested on barium ion beams. Furthermore we have determined the hfs splitting constants A and B of ^{139}La II metastable even $5d^2$- and 5d6s-levels and of odd $5d^4f$- and 5d6p-levels by measuring the hfs of absorption lines. The table gives the preliminary results of the A- and B-values of the investigated lines.

570.3 nm	A(a $^3P_1$) = -7.490 (25) mK B(a $^3P_1$) = .85 (9) mK	A(z $^3P^o_2$) = 1.143 (14) mK B(z $^3P^o_2$) = .37 (17) mK
612.6 nm	A(b $^1D_2$) = 1.604 (2) mK B(b $^1D_2$) = 1.32 (3) mK	A(x $^3P^o_2$) = 8.351 (3) mK B(x $^3P^o_2$) = 1.73 (3) mK
576.9 nm	A(b $^1D_2$) = 1.610 (5) mK B(b $^1D_2$) = 1.36 (5) mK	
580.8 nm	A($^3F_2$) = 13.253 (3) mK B($^3F_2$) = .66 (3) mK	A($^3F_2$) = 12.204 (3) mK B($^3F_2$) = -.13 (3) mK
593.6 nm	A(a $^1D_2$) = 31.649 (27) mK B(a $^1D_2$) = 1.66 (21) mK	A(y $^3F^o_3$) = 4.973 (9) mK B(y $^3F^o_3$) = .24 (15) mK
580.6 nm	A(a $^3P_3$) = 3.380 (4) mK B(a $^3P_3$) = .84 (6) mK	A(y $^3F^o_3$) = 4.956 (4) mK B(y $^3F^o_3$) = .13 (7) mK
586.4 nm	A(a $^1G_4$) = 5.002 (3) mK B(a $^1G_4$) = 5.06 (9) mK	A(y $^1F^o_3$) = 5.476 (4) mK B(y $^1F^o_3$) = .68 (8) mK

Table: Preliminary A- and B-values of ^{139}La II absorption lines.

HIGH RESOLUTION SPECTROSCOPY OF RADIOACTIVE ALKALI ISOTOPES

S. Liberman, J. Pinard, H. T. Duong, P. Juncar, J.-L. Vialle and P. Jacquinot
Laboratoire Aimé Cotton, C.N.R.S. II, Bâtiment 505, 91405 - Orsay, France.

and

G. Huber, F. Touchard, S. Büttgenbach, C. Thibault and R. Klapisch
Laboratoire René Bernas du Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, 91406 - Orsay, France.

and

A. Pesnelle
The ISOLDE Collaboration, C.E.R.N., Geneva, Switzerland.

In order to study the evolution of the nuclear structure of atoms versus the number of neutrons, mainly looking for deformations, we have done systematic, spectroscopic experiments on long chains of isotopes of a some element. These generally short lived isotopes, make it necessary to work on line behind the accelerator which produces them. These experiments have therefore been done at CERN like the previous Na experiments [1] but, in the frame of the ISOLDE facility. The Isotope Separator on Line "ISOLDE" produces, in particular, series of Alkali isotopes (for which our detection method is well adapted) in a beam of singly ionized species ; the ions are neutralized in order to get a thermalized atomic beam which is treated the same way as in the Na experiments, using optical pumping and mag selection, each spectrum being positioned in frequency by simultaneously recording the corresponding line of the stable element produced in a reference atomic beam. We have thus studied 36 isotopes and isomers of cesium, 29 of rubidium, and we have found and studied the D_2 line of francium for 6 of its isotopes.

The first experiments have been done on cesium on the second D_1 resonance line ($6\ ^1S_{1/2} - 7\ ^2P_{1/2}$) at $\lambda = 459.4$ nm because of the available dye, at that time, oscillating in a single mode operation (stilben or coumarin). The results on eleven isotopes of masses 123 to 132, the 137 and 130^m show clearly an important odd even staggering. Then, using HITC dye we have succeeded in getting a good tunable single mode laser system oscillating around 8.500 Å, and we have systematically recorded the hyperfine structure of the D_2 line ($6\ ^2S_{1/2} - 6\ ^2P_{3/2}$) for 36 consecutive isotopes of Cs, the longest chain ever observed. The results permit to measure the magnetic moment, the isotope shift, from which we can deduce the volume effect as well as the nuclear quadrupole moment. However, theoretical interpretation of this numerous results is not yet achieved.

Similar results have been obtained on the isotopes of rubidium on the D_2 line ($5\ ^2S_{1/2} - 5\ ^1P_{3/2}$) at $\lambda = 780$ nm using DEOTC dye.

The case of the francium studies is quite different because no resonance line had been observed before so we have looked for this line using a special broadband laser system in order to avoid too long recording time.

The D_2 line has been found at $\lambda = 717.97 \pm 0.01$ nm then, using our high resolution method we have recorded the hyperfine structure of this line for 6 isotopes of masses 208 to 213, showing an important hyperfine structure of the ground state : $\simeq 45$ GHz .

[1] Spins-magnetic moments and isotope shifts of $^{21-31}Na$ by high resolution laser spectroscopy of the atomic D_1 line
G. Huber, F. Touchard, S. Büttgenbach, C. Thibault and R. Klapisch ;
H. T. Duong, S. Liberman, J. Pinard, J.-L. Vialle, P. Juncar and P. Jacquinot, Phys. Rev. C 18, 5, 2342, 1978.

HYPERFINE STRUCTURE OF SOME GOLD ISOTOPES DETERMINED BY ON-LINE ABMR TECHNIQUES

C. Ekström* and L. Robertsson

Department of Physics, Chalmers University of Technology and University of Gothenburg, Gothenburg, Sweden

S. Ingelman and G. Wannberg

Institute of Physics, University of Uppsala, Uppsala, Sweden

and

The ISOLDE Collaboration, CERN, Geneva, Switzerland

The atomic-beam magnetic resonance (ABMR) apparatus /1/, connected on-line at the ISOLDE facility /2/, CERN, has been used to study the hyperfine structure in a number of elements, giving nuclear spins and moments of short-lived radioactive nuclides. The most extensive series of measurements have been made in the alkali elements rubidium, cesium and francium /3/. As a continuation of our previous spin measurements in the gold isotopes $^{186-189}$Au /4/, we here report on the determination of the nuclear spin of ^{185}Au and the nuclear magnetic moments in ^{187}Au and ^{188}Au.

The radioactive gold isotopes were obtained as daughter products of mercury produced in spallation reactions when irradiating a molten lead target of the isotope separator with 600 MeV protons from the CERN synchro-cyclotron. The ion-beam from the isotope separator was focused on the on-line oven of the atomic-beam apparatus. The activity transmitted through the apparatus was measured in well shielded NaI(Tl) detectors, sensitive to the K X-rays following the EC decay.

In a weak-field experiment, the nuclear spin of ^{185}Au was determined to be I = 5/2. Strong-field measurements in the isotopes ^{187}Au and ^{188}Au yielded the hyperfine structure separations with errors at the 1% level. The small g_I-factor in ^{188}Au precluded a determination of the sign of the magnetic moment. In ^{187}Au, on the other hand, the large magnetic moment could be measured directly, both with regard to sign and magnitude. The error in the latter, however, amounts to 10%.

The magnetic moments may be calculated from the measured dipole constants through a direct comparison with known values /5/ in the stable gold isotope ^{197}Au. The results, shown in the table, column 4, have further been corrected for diamagnetic shielding /6/.

Isotope	Nuclear spin /4/	Dipole constant (MHz)	Magnetic moment (n.m.) a)	b)
^{187}Au	1/2	44350(600)	0.706(10)	0.72(7)
^{188}Au	1	±1995(19)	±0.0636(6)	±0.07(3)

a) $^{197}\Delta^{187} = 0$ b) cf. text

* Present address: E.P. Division, CERN, CH-1211 Geneva 23, Switzerland

A comparison between the calculated and directly measured magnetic moments in ^{187}Au gives a measure of the differential hyperfine anomaly, $^{197}\Delta^{187} = 1.5 \pm 9.9\%$. This value is rather small, indicating similar nuclear structure of the two isotopes, although there is a difference in the ground state spins. In fact, nuclear structure calculations show that the main component in both isotopes is due to a $d_{3/2}$ proton. If the ground state of ^{187}Au were described by a $s_{1/2}$ proton, the differential hyperfine anomaly $^{197}\Delta^{187}$ may be shown to be about 10%. The large error in the experimental value also includes this interpretation.

An analysis of possible configurations for the ground state of ^{188}Au suggests the main component to be $1^-(\pi d_{3/2}\ \nu p_{3/2})$. Since a large hyperfine anomaly is expected for this configuration, we give as a final value for the magnetic moment $\mu = \pm 0.07(3)$ n.m.

The nuclear spin of ^{185}Au gives evidence for a strongly deformed nuclear shape of the ground state, with a Nilsson model assignment $5/2^-[541\ 1/2]$. In fact, the band structure arising from the "$h_{9/2}$"-proton system, recently observed in ^{185}Au /7/, may be interpreted only by assuming a prolate deformation of about $\varepsilon = 0.25$. The gold isotopes thus exhibit a change to strongly deformed ground state shapes at mass number A = 185, similar to the change observed in the mercury isotopes /8/.

This work has been supported financially by the Swedish Natural Science Research Council.

References:

/1/ C. Ekström et al., Nucl. Instr. and Meth. 148(1978)17.
/2/ H. Ravn et al., Nucl. Instr and Meth. 139(1976)267.
/3/ C. Ekström et al., Nucl. Phys. A292(1977)144, Phys. Lett. 76B (1978)565, Physica Scripta 18(1978)51, Nucl. Phys. A311(1978)269 and Physica Scripta (in press).
/4/ C. Ekström et al., Phys. Lett. 60B(1976)146.
/5/ H. Dahmen et al., Z. Physik 200(1967)456.
/6/ F.D. Feiock et al., Phys. Rev. 187(1969)39.
/7/ M.G. Desthuilliers et al., Nucl. Phys. A313(1979)221.
/8/ J. Bonn et al., Z. Physik A276(1976)203.

HYPERFINE STRUCTURE AND ISOTOPE SHIFT OF THE ISOMERS ^{191m,189m,187m,185m}HG DETERMINED BY LASERSPECTROSCOPY

P. Dabkiewicz, H.-J. Kluge, H. Kremmling and H.A. Schuessler

Institut für Physik, Universität Mainz, Germany and the ISOLDE Collaboration, CERN, Geneva, Switzerland

At EGAS 1978 we reported on an odd-even staggering effect (Ref. 1,2) and an isomer shift in ^{185}Hg (Ref. 3) which are about one magnitude larger than normally observed (Fig. 1) and are caused by a coexistence of an oblate and a strongly deformed prolate shape. In this contribution we present the whole set of nuclear properties as deduced from the HFS and IS for the 8 isomers ^{199m}Hg - ^{185m}Hg which are now known. Due to their deformation of $\beta \approx -0.15$ these isomers can neither be specified as spherical nor as well deformed and represent therefore typical transitional nuclei.
As reported earlier (Ref. 2) the unstable isotopes under investigation produced by the on-line mass separator ISOLDE at CERN were excited by a 3 nsec frequency-doubled laser puls (600 W, 40 Hz). Tuning the laser wavelength over the resonance line $^1S_0 - {}^3P_1$; $\lambda = 2537$ Å, the HFS and IS in the intercombination line was measured.

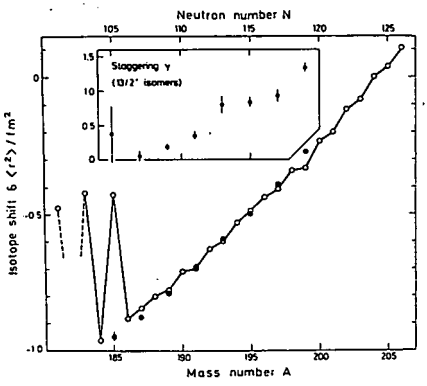


Fig.1: Mean-squared charge radii of $^{206-181}$Hg and staggering parameter of the isomeric states $^{199m-185m}$Hg.

The calibration of the laser frequency was done by recording simultaneously the fluorescence stemming from the Zeeman-shifted $^3P_1$ substates of the stable even-

even Hg isotopes. The nuclear spins of the isomers $^{191m-185m}$Hg were determined via the g_F-factor to be I=13/2 by observing Hanle quantum beats.

In the mass region in question ($185 \leq A \leq 199$) most probably the $i_{13/2}$ subshell is suczessively filled. The persistence of the nuclear spin I=13/2 for all isomeric states is in contradiction to the Nillson model in which the observable projection number Ω of the $i_{13/2}$ orbits increases from Ω = 1/2 for the heavy mass isomer up to Ω =13/2 for the light one. The differential behaviour of the nuclear charge radii calculated from the IS can be described by the staggering parameter

$$\gamma_A = (\delta\langle r^2\rangle_{A+1} - \delta\langle r^2\rangle_A)/(0{,}5(\delta\langle r^2\rangle_{A+2} - \delta\langle r^2\rangle_A)).$$

For the isomers this parameter shows a trend from $\gamma \approx 0$ in ^{185}Hg to $\gamma \approx 1$ in ^{199m}Hg (Fig. 1). In Fig. 2 μ_I and Q_s are plotted as deduced from the HFS constants A and B.

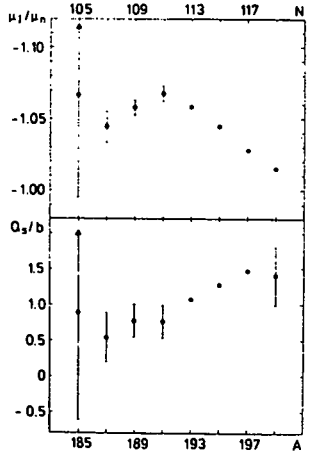


Fig.2: Magnetic moments and spectroscopic quadrupole moments of the Hg isomers.

The large absolute values of Q_s point to a collective effect but in contrast to the reorientation measurements of the neighbouring even-even isotopes and the theory one deduces a nuclear deformation of positive sign by applying the usual Bohr-Mottelson formula. The sign of the deformation as well as the trend of the staggering parameter γ and the persistence of nuclear spin I=13/2 can be explained by means of the "rotation aligned coupling scheme" due to coriolis effects in particle-core coupling. (Ref. 4)

Supported by the BMFT and DFG.

1) J. Bonn et al., Z.Phys. A276, 2o3 (1976)
2) T. Kühl et al., Phys.Rev.Lett. 39, 18o (1977)
3) P. Dabkiewicz et al., in print by Phys.Lett. B
4) F.S. Stephens, Rev.Mod.Phys. 47, 43 (1975)

Blank

HIGH RESOLUTION LASER SPECTROSCOPY OF NEUTRON-RICH RB AND CS ISOTOPES IN A FAST ATOMIC BEAM

K.P.C. Spath, J. Bonn, W. Klempt, R. Neugart, B. Schinzler
Institut für Physik, Universität Mainz, Germany

Laser spectroscopy is performed in the $6^2S_{1/2} - 7^2P_{3/2}$ λ = 455,5 nm resonance line of Cs and the $5^2S_{1/2} - 6^2P_{3/2}$ λ = 42o,3 nm resonance line of Rb. The velocity bunching in a fast atomic beam is used to reduce the Doppler width.[1] Magnetic moments, spectroscopic quadrupole moments and changes in the mean squared charge radii are obtained for the nuclei $^{137-142}Cs$ [2-3] and $^{89-93}Rb$.[4]

At the TRIGA reactor in Mainz neutron-rich isotopes of Rb and Cs are produced by thermal fission of ^{235}U. An on-line mass separator delivers isotopically pure beams of Rb and Cs at a beam energy of 5-1o keV and an intensity of up to $1o^8$ ions per second. This beam is neutralized by charge transfer to a vapor containing the stable isotope of the element under investigation. The residual line width is 1o MHz allowing the determination of a and b factors of the excited state with reasonable accuracy. For the determination of isotope shift a beam of stable Rb or Cs is run alternativelly through the apparatus both beams being Doppler tuned to the fixed laser frequency.

References:

1) K.-R. Anton, S.L. Kaufman, W. Klempt, G. Moruzzi, R. Neugart, E.-W. Otten, and B. Schinzler
Phys. Rev. Letters 4o, 642 (1978)

2) B. Schinzler, W. Klempt, S.L. Kaufman, H. Lochmann, G. Moruzzi, R. Neugart, E.-W. Otten, J. Bonn, L. von Reisky, K.P.C. Spath, J. Steinacher, D. Weskott,
Phys. Letters B 79 B, 2o9 (1978)

3) J. Bonn, W. Klempt, R. Neugart, E.-W. Otten, and B. Schinzler
Z. Physik A289, 227 (1979)

4) W. Klempt, J. Bonn, R. Neugart
Phys. Lett. B, 82 B, 47 (1979)

ISOTOPE SHIFTS OF ^{102}Cd, ^{104}Cd AND ^{118}Cd DETERMINED BY ON-LINE LASER SPECTROSCOPY

F.Buchinger, Ph.Dabkiewicz, H.-J.Kluge, A.C.Mueller and E.W.Otten
Institut für Physik, Universität Mainz, Fed. Republic of Germany
and
The ISOLDE-Collaboration, CERN, Geneva, Switzerland

During the last years measurements of the hyperfinestructure and isotope shift (IS) had been performed successfully on the ^{181}Hg-^{206}Hg chain [1]. Very recently the same technique was applied to a series of Cd isotopes in the range $102 \leq A \leq 120$. Thereby the knowledge of hfs and IS, known so far only for stable and some very longlived isotopes could be enhanced considerably. A sufficient amount of radioactive material, needed for optical spectroscopy, is produced at the ISOLDE-2 facility by spallation of tin with 600 MeV protons. In the peak of the production yield the on-line mass separated Cd isotopes are available with intensities up to 10^9 ions/sec.

Here we report measurements of the IS of even-even ^{102}Cd, ^{104}Cd and ^{118}Cd. The atomic transition $5\ s^2\ ^1S_0$ - $5s\ 5p\ ^3P_1$ λ = 3261 Å was excited by a pulsed tunable dye laser (Molectron DL 400), pumped by a nitrogen laser (Molectron UV 400). Tuning of the laser is accomplished by a grating and an internal etalon controlled by a minicomputer (NOVA 1220). The λ = 3261 Å line in the ultraviolet region can be reached by frequency doubling the λ = 6522 Å laser action of the CVP - R6G dye in an angle phase matched KDP crystal with an efficiency of 5% (bandwidth ≈ 1 GHz).

That beam passes a quartz cell, in which the ions are collected on a Mo-foil during one half-life and heated out as atoms in a 200 Torr Helium atmosphere. The fluorescence light is detected by a 56 DUVP-photomultiplier. In order to normalize the signal to constant laser intensity, the latter is monitored by a photo-diode. The laser frequency is calibrated by recording simultaneously the resonance of stable ^{114}Cd in a reference cell. This cell is placed in the gap of a magnet in order to split the Zeeman components giving the frequency scale by the known g_J-factor. Since the lifetime of the $^3P_1$-state of Cd (τ = 2.2 µsec) is long compared to the length of the laser pulse (τ = 3 nsec), background from scattered laser light can be suppressed by delayed observation. The currents of the photomultipliers and of the photo-diode are analyzed by a 10-bit ADC and stored in the memory of a minicomputer. In cases of very low vapour density in

the resonance cell we used the photon counting technique instead.

Fig. 1 shows the reconance signal of ^{118}Cd (upper part) and the calibration signal of the three Zeeman components of ^{114}Cd in a magnetic field of 1932 Gauss (lower part). The channel numbers correspond to a frequency scale of 52.6 MHz per channel. Each data point represents the result of 58 laser pulses. The solid lines are least-square fits with a Gaussian profile. Obviously the IS is the distance between the centers of the ^{118}Cd signal and the π-component of the ^{114}Cd reference signal with $\delta\nu^{114,118}$ = = -520 MHz. Sources of errors have still to be studied. The final error is expected to be less than 50 MHz.

The results of further measurements on ^{102}Cd and ^{104}Cd are :

$\delta\nu^{114,102}$ = 3400 MHZ

$\delta\nu^{114,104}$ = 2450 MHz

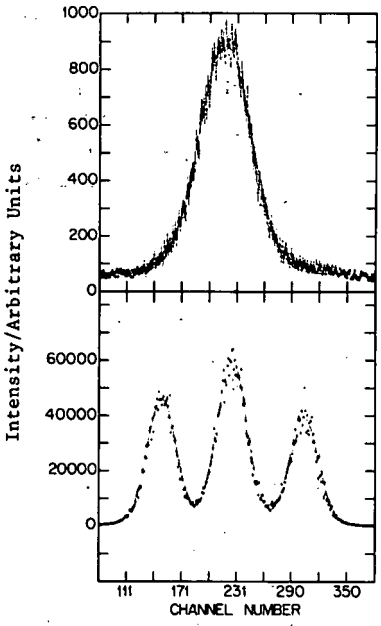


Fig. 1 : Intensity of the fluorescence light of ^{118}Cd (upper part) and the ^{114}Cd reference (lower part) versus the frequency of the exciting laser light.

REFERENCES :

[1] See, e.g., contributions to this and former EGAS conferences.

This work was supported by the Bundesministerium für Forschung und Technologie and the Deutsche Forschungsgemeinschaft.

CHANGES IN NUCLEAR MEAN SQUARE CHARGE RADII OF Kr ISOTOPES BELOW N = 50

H. Gerhardt, E. Matthias, H. Rinneberg, F. Schneider
A. Timmermann, R. Wenz und P.J. West
Institut für Atom- und Festkörperphysik
Freie Universität Berlin

The isotope shifts of seven Kr isotopes (A=78,80,82,83,84,85, and 86) below the magic neutron number N = 50 were measured by saturation spectroscopy. From the isotope shifts the changes in the nuclear mean square charge radii were inferred. The specific mass shifts were estimated by comparing the optical isotope shift data with nuclear binding energies as well as with preliminary data for the muonic isotope shift of the pair ^{86}Kr-^{84}Kr |1|. The isotope shifts $\delta\nu'^{A',A}$ (A'>A) observed in the optical transition $5s|3/2|_2 \rightarrow 5p'|1/2|_1$ at 557 nm, corrected for the normal mass shifts, are given in Table 1. Within the experimental accuracy of the preliminary muonic isotope shift, the specific mass shift in the 557 nm transition can be set equal to zero. The $\delta\langle r^2\rangle^{A',A}$ values listed in Table 1 were deduced for $\delta\nu_{SME}$=0. Starting from ^{78}Kr a monotonic decrease of $\langle r^2\rangle^A$ with increasing mass number is found for the even Kr isotopes, filling the $g_{9/2}$ neutron shell (see Fig. 1). For the isotope ^{83}Kr a strong inverse odd-even staggering was observed. The effect of nuclear deformation on $\delta\langle r^2\rangle^{A',A}$ between even isotopes as well as possible contributions

Table 1:

A'>A	80-78	82-80	84-82	86-84	84-83	85-84
$\delta\nu'^{A',A}$ (MHz)	+ 8.3(8)	+5.2(8)	-0.5(6)	+ 6.3(6)	- 9.0(2)	+1.2(9)
$\delta\langle r^2\rangle^{A',A}$ ($10^{-3}fm^2$)	-15.4	-9.6	+0.9	-11.7	+16.7	-2.2

Isotope shifts $\delta\nu'^{A'A}$ (557 nm) of Kr isotopes corrected for the normal mass shift.

due to changes in the skin thickness of the nuclear charge distribution will be discussed.

|1| G. Fricke, G. Mallot, L. Schellenberg, K. Käser, L.A. Schaller, H. Schneuwly, to be published.

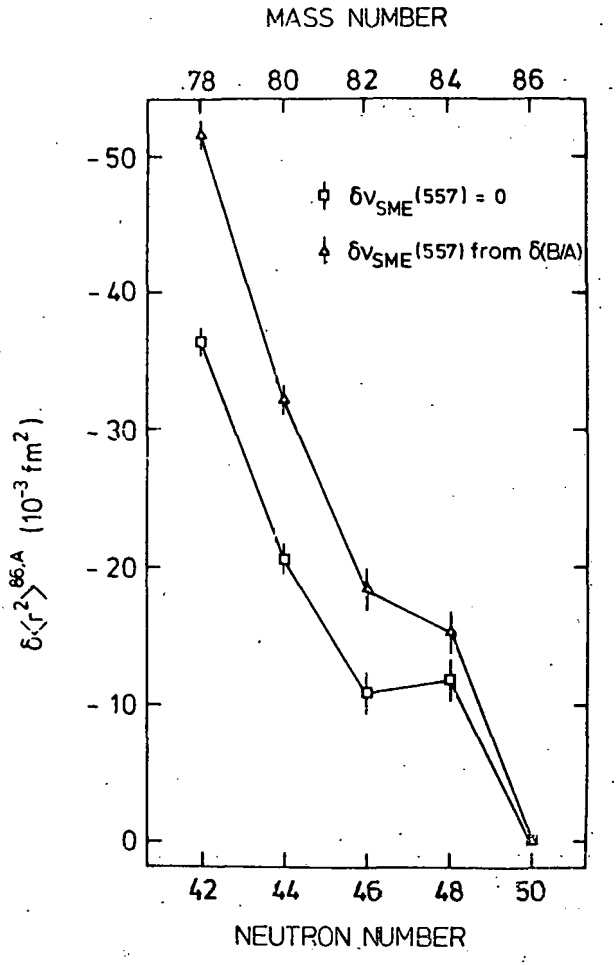


Fig. 1: Changes in the nuclear mean square charge radii $\delta\langle r^2\rangle^{86,A}$ for even krypton isotopes throughout the $g_{9/2}$ shell. The two curves correspond to a specific mass shift $\delta\nu_{SME}^{86,84}$ (557 nm) = 0 (muonic isotope shift data) and -2 MHz (obtained from $\delta(B/A)$).

ISOTOPE SHIFT IN THE GROUNDCONFIGURATIONS $5d^8 6s$ AND $5d^7 6s$ IN THE IRIDIUM-I-SPECTRUM

J. Bauche
Laboratoire Aimé Cotton, C.N.R.S., Orsay,

H. Grethen, G. Sawatzky, R. Winkler
Optisches Institut, Technische Universität Berlin

We have continued the systematic IS investigations on 5d-elements (Pt, Os, W: see (1)) by performing new measurements in the low even configurations $5d^8 6s$ and $5d^7 6s^2$ of the IrI-spectrum and their interpretation by the parametric method as outlined in (2). Ir, between Os (Z = 76) and Pt (Z = 78), has two stable isotopes, ^{191}Ir and ^{193}Ir, both of which show hyperfine structure ($I_{191} = I_{193} = 3/2$). The relative small hfs-splitting constants and the high J-values of the finestructure levels mostly cause a dense structure with 10 components for each isotope, so that small IS differences of the levels cannot be observed directly. So to the IS measurements by v. Siemens (1953) (3) and Nöldeke (1962) (4) - carried out mainly for level classification - we had to add further measurements, evaluated by modern computer analysis, to connect as many levels as possible (some of them more than two times) to a reference level with sufficient accuracy. We have chosen the level $5d^7 6s^2\ {}^4F_{9/2}$ as reference, setting its shift value to $124 \cdot 10^{-3}$ cm^{-1} arbitrarily. The level IS values obtained are shown in Tab. 1. After having calculated the coefficients of the IS parameters by the standard parametric method for the fine structure analysis, regarding intermediate coupling and configuration interaction, we can write for each level IS and for each IS difference (Tab. 1) one equation with the linear combination of the parameters on one side and the experimental IS value on the other. We obtain 11 equations for the 5 unknown parameters:

- a - general additive constant,
- s - IS of configuration $5d^8 6s$ minus IS of configuration $5d^7 6s^2$,
- g_2, h_2 crossed-second-order electrostatic interactions,
- z - crossed-second-order magnetic interactions.

Least squares fit calculations of these 11 equations yield the parameter values in Tab. 2. A re-calculation of the level IS with these parameter values shows, that the consistency of our experimental results is fairly good. The comparison of the ratios of the Ir-parameter values with those of other 5d-elements (Os,Pt) (5) shows a remarkable analogy between the IS behaviour in the Os-, Ir- and Pt-spectrum and gives another strong indication for the physical significance of the isotope shift parameters (Tab. 3).

Tab. 1: Values of the experimental isotope shift for ^{191}Ir - ^{193}Ir in 10^{-3} cm^{-1} (deduced from our measurements and data in (3) and (4)).

LEVEL SHIFTS:		
$5d^8 6s$	$^2P_{3/2}$	56(5)
"	$^4F_{5/2}$	71(5)
"	$^4F_{7/2}$	52(3)
"	$^4F_{9/2}$	42(2)
$5d^7 6s^2$	$^4F_{3/2}$	111(5)
"	$^4F_{5/2}$	71(5)
"	$^4P_{5/2}$	116(3)
"	$^4F_{7/2}$	108(3)
"	$^4F_{9/2}$	124(1)
"	$^2G_{9/2}$	119(3)
"	$^2H_{11/2}$	128(4)

Tab. 2: Values of the isotope shift parameters in 10^{-3} cm^{-1}.

a	s	g_2	h	z
121(3)	-101(13)	-10(7)	-1,7(0,6)	1,2(1,4)

Tab. 3: Comparison of the parameter ratios for Os, Ir and Pt.

s(Pt) : s(Ir) : s(Os) = 1,2 : 1 : 0,9

g(Pt) : g(Ir) : g(Os) = 1,5 : 1 : 1,4

h(Pt) : h(Ir) : h(Os) = 0,8 : 1 : 1,9

(1) J. Bauche, H. Grethen, R. Winkler, EGAS-Abstract Cracow (1977) 38.
(2) J. Bauche, R.-J. Champeau, Advances in Atomic and Molecular Physics 12 (1976) 39.
(3) W.v. Siemens, Ann. Phys. 6.13 (1953) 136.
(4) G. Nöldeke, Habilitationsschrift, Mainz 1962.
(5) J. Bauche, H. Grethen, R. Winkler, to appear in Physica, Netherlands.

THE ISOTOPE SHIFT OF THE $4f^7 5d6s$ CONFIGURATION IN THE EUROPIUM-I-SPECTRUM

H.-D. Kronfeldt, J. Kropp and R. Winkler
Optisches Institut der Technischen Universität Berlin
Straße des 17. Juni 135, 1000 Berlin 12, Germany

Although much hfs and IS work was performed in the spectrum of Eu I, II and III in the past, rather little is known about the interesting configuration Eu-I $4f^7 5d6s$ of which at least the a ^{10}D term of this configuration should be rather pure (SW 65). Only two lines i. e. λ563,3 nm and 583,1 nm were investigated so far (B 52) - (see dashed lines in fig. 1). They gave a hint of the IS of the levels of $4f^7 5d6s$ but its IS was not connected to the IS of all the other configurations and especially not to the IS of the ground state $4f^7 6s^2$ which is set equal to 0(see table 1),(but about - 260 mK in reference to the series limit).

terms	level-IS (mK)
$4f^7 6s^2\ ^8S_{7/2}$	≡ 0!
$4f^7 5d6s$ a $^{10}D_{5/2}$	-145,3(7)
$^{10}D_{7/2}$	-144,8(9)
$^{10}D_{9/2}$	-144,1(1,5)
$^{10}D_{11/2}$	-143,1(1,5)
$4f^7 5d6p$ z $^{10}D_{7/2}$	-115,9(5)
y $^{10}P_{9/2}$	-200(1)

table 1: Resulting level-IS's of Eu-I

The configuration $4f^7 5d6s$ is of the same even parity as the ground configuration and their IS can therefore only be connected with transitions via an odd parity configuration. Therefore, we measured the IS of several transitions $4f^7 5d6p$ - $4f^7 5d6s$ (fig. 1). The IS of the levels a $^{10}D_{5/2,\ 7/2,\ 9/2,\ 11/2}$ of the configuration $4f^7 5d6s$ which we obtain using the connection of the line λ 321,0 nm to the ground state, is presented in table 1. It shows, that the IS of those $4f^7 5d6s$ levels is very much equal and lies within about ±1 mK at -144 mK.

The screening ratio $(f^7 6s^2 - f^7 5d6p)/(f^7 5d6s - f^7 5d6p)$ for europium can now be determined. It will be compared with those of (BS 68) and theoretical ratios given by non-relativistic Hartree-Fock-calculations of (W 72) and relativistic Hartree-Fock-calculations of (C 73). The screening of the s-electron density at the nucleus by a 5d-electron (and other electrons) will be discussed.

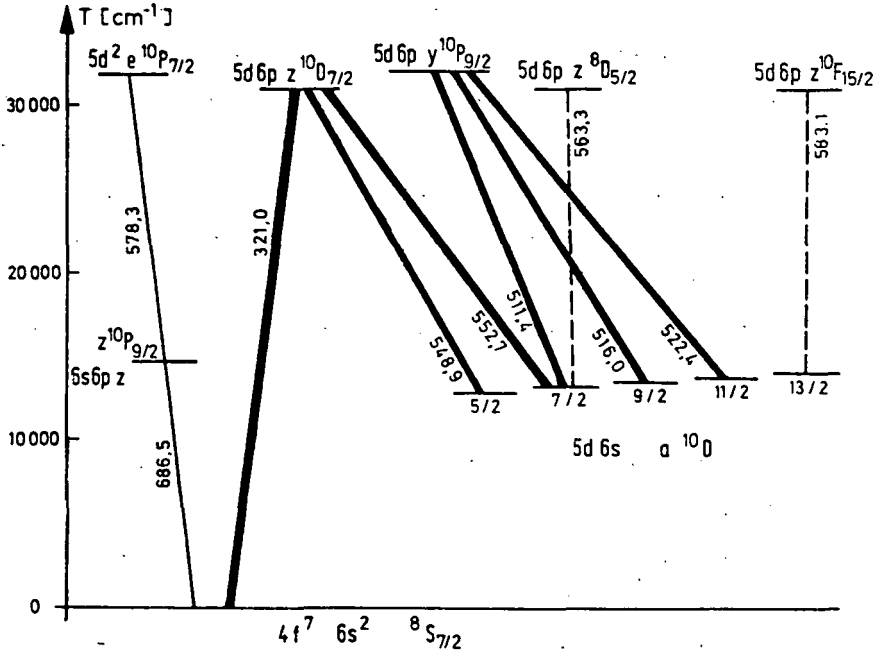


fig. 1: Level-scheme of Eu-I (section)

BIBLIOGRAPHY

(B 52) Brix, P.
Z. f. Phys., 132, 579 (1952)

(BS 68) Blaise, J. , Steudel, A.
Z. f. Phys., 209, 311 (1968)

(C 73) Coulthard, M.A.
J. Phys. B , 6, 23 (1973)

(SW 65) Smith, G. , Wybourne, B.G.
J.O.S.A., 55, 121 (1965)

(W 72) Wilson, M.
J. Phys. B, 5, 218 (1972)

HYPERFINE STRUCTURE OF THE ^{57}Fe ATOM / I = 1/2/

J. Dembczyński*

Institute of Physics, Technical University of Poznań, Poland

Measurements by ABRM-LIRF of the hyperfine structure splittings of levels belonging to two different metastable multiplets ^{5}F and ^{3}F of the $3d^7 4s$ configuration have been reported earlier /1/. The main topic of this paper is a theoretical analysis of the experimental hfs results for the $3d^7 4s$ configuration. In the calculations of intermediate-coupling eigenvectors, besides Slater and spin-orbit parameters, also parameters taking into account two-and three-electron electrostatic interactions with distant configurations were included /2/. The two-electron magnetic interactions within each configuration were included by way of Marvin integrals as parameters.

It was found impossible to express, within experimental error, the hfs magnetic-dipole constants A measured for levels belonging to two different multiplets ^{5}F and ^{3}F only by means of hfs parameters predicted by the effective operator theory of Sandars and Beck /3/. This proves the presence of SL-dependent configuration interaction /SL-CI/ /4/ on the hfs of the ^{57}Fe atom For this reason, an exact analysis of the configuration interaction /CI/ on the hfs of the iron atom was performed. In th I analysis, also the $3d^6 4s^2$ configuration was included, where the

---

* This work was performed mainly during stay as Alexander von Humboldt fellow in the Institut für Angewandte Physik, Universität Bonn.

hfs splittings for the levels $^5D_{1,2,3,4}$ had been measured by Childs and Goodman /5/.

The values obtained for the parameters discribing SL-CI according to the Bauche-Arnoult /4/ definitions are:

$x_2 = x_3 = 0.08, \quad x_4 = -0.062, \quad x_7 = 0.068,$

$x_{11} = -0.113, \quad x_1 = x_5 = x_6 = x_8 = x_9 = x_{12} \approx 0.$

The radial integrals evaluated from the experimental data corrected to second-order effects are the following /in a.u./:

for the $3d^7 4s$ configuration:

$\langle r^{-3} \rangle^{01} = 3.913, \quad \langle r^{-3} \rangle^{12} = 3.982, \quad \langle r^{-3} \rangle^{10}_{3d} = -2.087$

and $\left[d P_{4s}(r)/ dr \right]^2_0 = 37.0,$

and for the $3d^6 4s^2$ configuration:

$\langle r^{-3} \rangle^{01} = 4.518, \quad \langle r^{-3} \rangle^{12} = 4.594, \quad \langle r^{-3} \rangle^{10} = -0.722.$

To render the SL-CI apparent, a parameter β independent of relativistic effects and of the SL-independent CI is introduced and defined as:

$$\beta^{k_s k_l}_{SL,S'L'} = a^{k_s k_l}_{SL} / a^{k_s k_l}_{S'L'}$$

The values obtained from ^5F and ^3F multiplets of the $3d^7 4s$ configuration are the following:

$$\beta^{01}_{5F,3F} = 1.034, \qquad \beta^{12}_{5F,3F} = 1.02$$

$$\beta^{10}_{3F,5F} / 4s\text{-electron}/ = 0.994$$

References:

1. J. Dembczyński, W. Ertmer, U. Johann, S. Penselin, P. Stinner: Abstract of Contributed Paper of the Sixth International Conference on Atomic Physics, Riga 1978.
2. J. Dembczyński /submitted to Physica/.
3. P.G.H. Sandars, J. Beck: Proc. Roy. Soc. /London/ A289, 97 /1965/.
4. C. Bauche-Arnoult: Proc. Roy. Soc. /London/ A322, 361 /1971/; and also Journal de Physique 34, 301 /1973/.
5. L.S. Goodman, W.J. Childs: Phys. Rev. 148, 74 /1966/.

RYDBERG CONSTANT FROM POLARIZATION SPECTROSCOPY OF H_α

J.E.M.Goldsmith, T.W.Hänsch, and E.W.Weber[+]
Department of Physics, Stanford University, Stanford, Calif. 94305

A new value of the Rydberg constant, $R_\infty = 10\,9737.314\,76(32)\ cm^{-1}$ [3 289 841 941.8(7.9)MHz], has been determined from an absolute wavelength [frequency] measurement of the $D_1(2S_{1/2}-3P_{1/2})$ component of the hydrogen Balmer-α line [1]. Polarization spectroscopy of a mild He-H_2(15%) dc discharge with a cw dye laser provides a more than threefold higher accuracy compared to previous measurements [2].

The polarization spectrometer used to resolve single fine and hyperfine structure components of the H_α line is shown in Fig.1a. A 5.5 cm-diam., hot cathode dc discharge tube filled with He plus 15% H_2 is used to generate the H* atoms. It has several important advantages compared to the previously used Wood's tube with coated walls and filled with pure H_2: About an order of magnitude smaller axial electric field in the positive column, almost no interdependence between pressure and current, and three times smaller current densities for the same polarization signals. The derivative of a dispersion-shaped resonance is recorded by using frequency modulation (amplitude ± 8MHz) of the dye laser and lock-in detection (Fig.1b) thus reducing the observed linewidth (35-40 MHz) by a factor of 2.

The absolute wavelength measurement of the H_α $D_1(2S_{1/2}-3P_{1/2})$ line is carried out in three steps (Table 1): (1) The absolute wavelength [frequency] of a near coincident $^{127}I_2$ reference line is determined with an interferometer calibration technique [3] by comparing it with a previously measured iodine line at 632.8 nm [4]. (2) The separation between H_α D_1 and the $^{127}I_2$ line is measured at optimum discharge conditions. (3) Systematic shifts of the H_α D_1 line are carefully corrected for by evaluating 500 individual spectra [5].

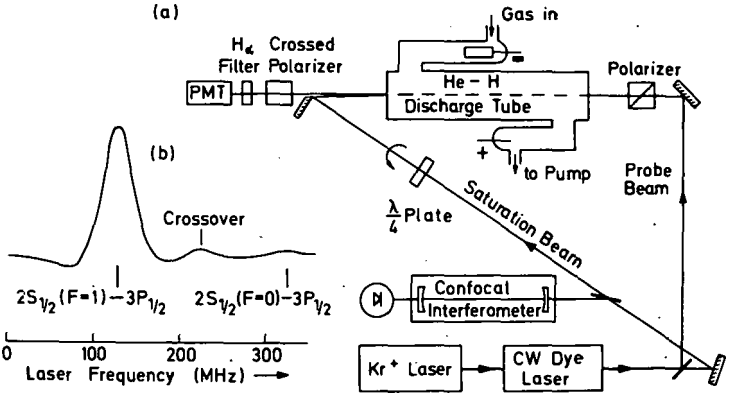


Fig.1(a) Experimental setup for polarization spectroscopy of H_α in a He-H dc gas discharge. (b) Polarization spectrum of the H_α $D_1(2S_{1/2}-3P_{1/2})$ fine structure component.

Table I. Wave numbers [frequencies] and corrections measured in determing the Rydberg constant.

656.3-nm iodine reference line ($^{127}I_2$ B-X R(73) 5-5,i)	15 233.367 39o(42)cm^{-1} [456 684 866.6(1.o)MHz]
Measured H_α D_1-iodine separation	-3368.o4(3o)MHz
Systematic corrections:	
Discharge current (18o ± 2omA)	+2.92(33)MHz
Pressure (He-H_2(15%),o.13o Torr)	+1.26(2o)MHz
Electric field (2.51 V/cm)	+o.65(1o)MHz
$2S_{1/2}$ hyperfine splitting	+44.41(oo)MHz
Total	+49.23(4o)MHz
Corrected H_α D_1-iodine separation	-3318.81(5o)MHz
H_α D_1-center of gravity wavelength [frequency]	15 233.256 686(45)cm^{-1} [456 681 547.8(1.1)MHz]
Calculated Rydberg constant	1o9 737.314 76(32)cm^{-1} [3 289 841 941.8(7.9)MHz]

By fitting the measured wave number for H_α D_1 with a recent calculation [6] which uses an assumed Rydberg value, the new value of the Rydberg constant given in Table 1 is obtained. It is consistent with and three times more accurate then a previous Doppler-free Rydberg measurement[2]. The quoted error in R_∞ is due almost entirely to uncertainties in the λ or ν measurement of the $^{127}I_2$ reference line and not introduced by corrections for the discharge conditions. With a more precise determination of the reference line frequency and the given separation H_α D_1-iodine the accuracy in R_∞ can be improved by another factor of 2 to 1.1 parts in 10^9, making R_∞ the most precisely known fundamental constant.

A considerable improvement in the accuracy of R_∞ would require either a redefinition of the wavelength standard or building up a frequency chain from the Cs standard to the visible. Higher resolution can be achieved by double-quantum saturation transitions $H\alpha$ (2S-3S) [7]which can be narrower by a factor of 3o than the resonant (2S-3P) signals when using a beam of metastable 2S hydrogen atoms. Ultimately the1S-2S two-photon transition with the 1/7 sec natural lifetime of the 2S state should provide the highest resolution.

One of us (E.W.W.) would like to thank the Max Kade Foundation for a fellowship. This work was supported by the National Science Foundation under Grant No. NSF-9687.

+Present adress:Phys.Institut,Univ.Heidelberg,D-69 Heidelberg.

References:

1 J.E.M.Goldsmith,et al. Phys.Rev.Lett.41,1525(1978).
2 T.W.Hänsch,et al., Phys.Rev.Lett.32,1336(1974).
3 J.E.M.Goldsmith,et al.,submitted to Appl.Opt.
4 W.G.Schweitzer,et al.,Appl.Opt.12,2927(1973),H.P.Layer, et al. Appl.Opt.15,734(1976).The frequency of the 632.8 nm iodine line has been measured relative to the Cs standard.
5 E.W.Weber andJ.E.M.Goldsmith,Phys.Lett., 7oA,95(1979), E.W.Weber,submitted to Phys.Rev..
6 G.W.Erickson,J.Phys.Chem.Ref.Data 6, 831(1977).
7 E.W.Weber and J.E.M.Goldsmith,Phys.Rev.41,94o(1978).

Blank

A NEW TYPE OF RESONANCES IN SATURATED ABSORPTION SPECTROSCOPY OF 3-LEVEL SYSTEMS

M. HIMBERT, S. REYNAUD, J. DUPONT-ROC
and C. COHEN-TANNOUDJI
Ecole Normale Supérieure and Collège de France
24 rue Lhomond - 75231 PARIS CEDEX 05 - FRANCE
présenté par S. REYNAUD

ABSTRACT

In saturated absorption spectroscopy, narrow sub-Doppler resonances are observed on the absorption (or dispersion) of a detection beam when atoms are simultaneously interacting with a counterpropagating pump beam. An interesting situation occurs when optical transitions joining a level b to two sublevels a and a' of a different level are considered. The structure a - a' can be measured by comparing the two sub-Doppler saturation resonances $a\ b$ and $a'\ b$. It is well-known that halfway between these two resonances, one observes a so-called "cross-over" resonance corresponding for example to the modification of the absorption on $a\ b$ due to the saturation of $a'\ b$.

We show in this work that it is possible to observe two extra resonances which are twice farther from the cross-over than the two resonances $a\ b$ and $a'\ b$ and which, to our knowledge, have not yet been predicted or reported. We interpret them as related to a modification of the stimulated Raman processes between a and a' (involving one photon from both counterpropagating beams) due to a simultaneous resonant saturation of $a\ b$ or $a'\ b$ (by the pump beam). Therefore, these "Raman type resonances" involve at least two pump photons, and require higher intensities of the pump beam than the $a\ b$, $a'\ b$ and cross-over resonances. If we restrict ourselves to processes involving only one detection photon (weak detection beam), there is no other resonances than the $a\ b$, $a'\ b$, cross-over and Raman type ones.

We discuss the conditions of observation of these new resonances and present experimental spectra demonstrating their existence. They exhibate important light shifts in good agreement with theoretical predictions.

OPTICAL PUMPING EFFECTS IN POLARIZATION SPECTROSCOPY

W. Gawlik* and G.W. Series

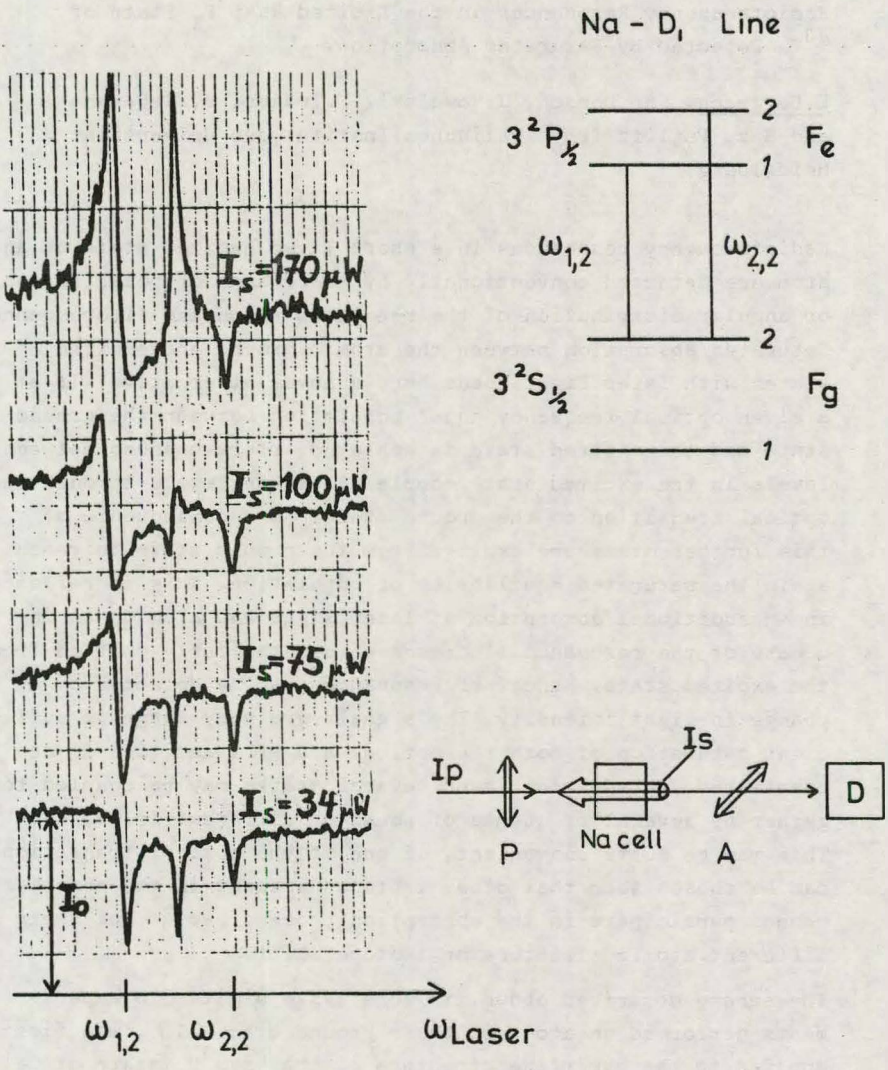
J.J. Thomson Physical Laboratory,
The University of Reading,
Whiteknights,
Reading RG6 2AF,
U.K.

We wish to report some effects observed in Doppler-free polarization spectroscopy when the polarizing beam is of such a low intensity that saturation effects can be excluded. We scan the Na D_1 line in zero magnetic field. We observe narrow hyperfine resonances which we attribute to optical pumping (not saturating) effects in the atomic ground states.

A remarkable feature of the resonance signals is that they change in form, and even in sign, with the intensity of the pumping beam (see figure). It is hoped to present an analysis of these effects at the meeting.

---

* On leave from Jagiellonian University, Cracow, Poland.



Signals recorded with a polarization spectroscopy technique for various intensities I_s of a circularly polarized pumping beam of diameter 4 mm. Polarizer P and analyser A were exactly crossed. I_o represents a background level which is the same for all signals.

Radiofrequency Resonances in the Excited $4s4p\,^3P_1$ State of ^{43}Ca Detected by Saturated Absorption.

E.Bergmann, Chr.Dorsch, J.Kowalski, F.Träger, B.Wiegemann and G.zu Putlitz (Physikalisches Institut der Universität Heidelberg)

Radiofrequency resonances in a short lived excited state of an atom are detected conventionally by the change of polarization or angular distribution of the reemitted resonance fluorescence. Saturated absorption between the atomic ground and excited states with laser light opens here a novel alternative: If at a given optical frequency equal population between the ground state and the excited state is achieved, rf resonances between levels in the excited state couple all these levels through the optical transition to the ground state. As a consequence of this further atoms are excited from the ground state to reach again the saturated equilibrium of population. This is reflected in an additional absorption of laser light and also in an increase of the resonance fluorescence spontaneously emitted from the excited state. Hence, rf resonances can be detected by a change in light intensity. The signals are very large if sufficient saturation of both the optical and rf transition is accomplished. In addition, even several states may be coupled together by several rf quanta of equal or different frequency. This may be quite convenient, if one of the optical transitions can be chosen such that other isotopes present in the absorber cannot participate in the absorption process because of their different atomic structure or isotope shift.

The scheme described above, in some sense similar to experiments performed on atoms in their ground state [1], was first applied to the hyperfine structure of the $4s4p\,^3P_1$ state of Ca. Fig. 1 shows the experimental set-up. A collimated atomic beam of calcium in its natural abundance is intersected at right angles with the beam of an intense dye laser exciting a hyperfine level of the $4s4p\,^3P_1$ term with a wavelength of 657.3 nm.

A triple prism reverses the laser beam in such a way that it intersects the atomic beam again some 4 cm above the first intersection point. Thereafter a plane mirror reflects the laser beam into itself. With a small rf coil placed between the two intersection regions of the laser light beam and the atomic beam the magnetic dipole transitions between two hyperfine levels are induced. Tuning of the rf frequency results in fluorescence light signals from which an example is shown in fig. 2 recorded for the F=5/2-F=7/2 transition of ^{43}Ca, present with 0.14% in the natural isotope composition.

The technique described above will be used to measure the hyperfine structure of both odd Ca isotopes with A=41 and 43.

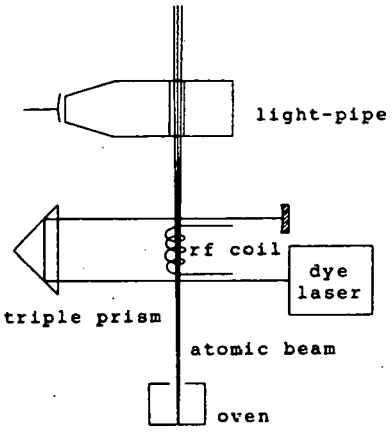


Fig.1: Experimental set-up

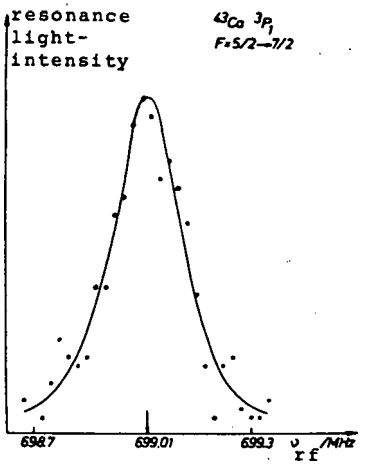


Fig.2: Radiofrequency transition F=5/2→7/2 in the $4s4p\,^3P_1$ state in ^{43}Ca.

References:

[1] : S.D. Rosner, R.A. Holt and T.D. Gaily: Phys. Rev. Lett. 35, 785 (1975)

W. Ertmer and B. Hofer: Z. Physik A 276, 9 (1976)

ALIGNED ATOMS IN STRONG OSCILLATING RF - FIELDS

E. Jacobson Phys. Institut der Universität D-7400 Tübingen

Oriented atoms in a steady magnetic field B_o and a transverse oscillating RF field B_1 have been investigated in a lot of works[1-4] generally concerned with the shift of the RF resonances (Bloch-Siegert shift). Aligned atoms however will show a more complicated behavior (cf. fig 2), which will be discussed in this contribution, presenting some experimental studies which have been confirmed by numerical computations.

The experiment has been carried out on the even Mercury isotopes in the metastable 6^3P_2 state, excited by electron impact resulting in a longitudinal alignment[5]. Due to the long relaxation times (≈10 µsec) it is possible to use low RF ($\omega/2\pi$ = 156 kHz) so that the oscillating field ($2B_1\cos\omega t$) easily can exceed the resonance field $B_o = \omega / \gamma$ = 7.5 µTesla = 75 mGauss. Fig. 1 shows a set of experimental resonance curves observed in the absorption of π-light (mercury line 5461 Å, 6^3P_2 - 7^3S_1). The oscillating field was parallel to the direction of observation. Starting with low RF amplitudes, the well known Bitter-Brossel resonances appear both at $B=B_o$ and $B=-B_o$. As B_1 is increased the resonance curves overlap, they become asymmetric and are shifted towards lower B values (as in the case of the Bloch-Siegert shift). Then the central minima flatten out and disappear. On the other hand new resonances appear at higher B values, due to (odd) multiquanta transitions, which show the typical shapes of the Bitter-Brossel

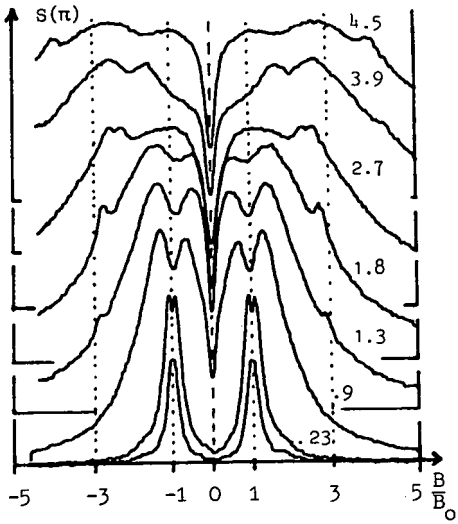


Fig.1: Experimental resonance curves at different amplitudes of the oscillating field ($2B_1/B_o$)

resonances, too, and a strong RF shift.

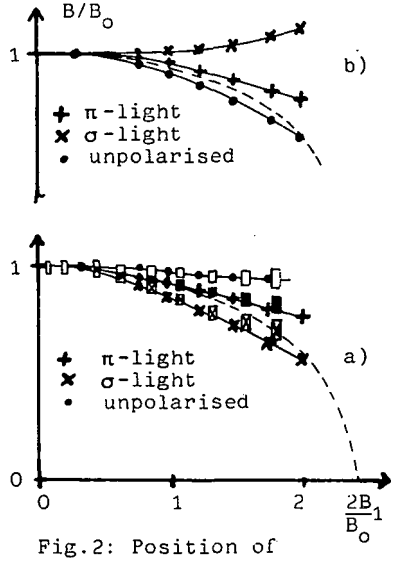


Fig.2: Position of RF resonances versus RF-amplitude (+ × • computed, ▯ measured, outlines indicating limits of error). a) Observation parallel to B_1. b) Observation perpendicular to B_1. The broken lines are calculated from [4] for the Bloch-Siegert shift of oriented atoms).

These resonance curves have been reproduced by numerical computations with good agreement. Observation of σ-light or unpolarised light or observation perpendicular to B_1 yields resonance curves which differ significantly both in shape and RF shift. In fig.2 the positions of the resonances are shown for the different modes of observation. The resonances of the multiquanta transitions show a more rapid shift.

In another experiment the absorption of linearly polarised light was observed using a time resolving technique[5]. Modulations have been found containing only integral multiples of the RF (up to the 13^{th} harmonic). According to the incoherent excitation only even harmonics are seen in π- and σ-light. Odd harmonics are seen in addition at all other angles. The amplitudes of the harmonics have been computed as a function of the static field B_o with good agreement with the experimental values. Although their structures are rather complicated, simple correlations have been found between the n^{th} odd harmonics and the n^{th} multi-quanta transitions.

References:
1. Bloch, Siegert (1940), Phys.Rev. 57, 552
2. C.Cohen-Tannoudji and S.Haroche (1969), J.Phys.(Paris) 30, 153
3. S.Stenholm (1972), J.Phys. B5, 890
4. G.W.Series (1978), Phys.Rep. 43, 1 (giving a lot of references)
5. E.Jacobson (1977), J.Phys. B10, 3409

EXPERIMENTAL EVIDENCE for the "OPTICAL HANLE EFFECT"

C. DELSART, J.-C. KELLER
Laboratoire Aimé Cotton (*), C.N.R.S. II, Orsay, France.

and

V. P. KAFTANDJIAN
Université de Provence, Centre St Jérôme, Marseille, France.

Two different types of zero-field level-crossing (Hanle effect) have been demonstrated in the past using either a static magnetic field or a static electric field [1]. These two phenomena are related respectively to the Zeeman and Stark effects and the physical basis of both is found in the lifting of the m-state degeneracy by an externally applied static field. Optical analogs of these classical effects have been proposed recently where it is the dynamic Stark effect produced by high power laser radiation which shifts the levels [2, 3]. Circular polarization is the analog of a magnetic field and linear polarization can play the role of an electric field. The theory of these effects have been done for a three-level system : a weak beam is used to create a coherent superposition of Zeeman sublevels in the upper state b of the a $\leftrightarrow$ b transition and a powerful one to produce a dynamic Stark shift in the coupled transition b $\leftrightarrow$ c .

In order to investigate the "optical Hanle effect" under favourable experimental conditions, we had to turn to a two-level experiment. The level scheme and the light polarization directions are indicated on Figure 1. The barium atomic beam is crossed at right angle by two counter propagating beams from CW single-mode dye lasers. The frequency of the linearly polarized weak beam is locked to the ^{138}Ba resonance line ($\lambda = 5535$ Å) . The frequency of the powerful circularly polarized beam is detuned of $\Delta\omega_2$ from exact resonance thus producing a shift Δ of the level $|+1\rangle$; Δ is equal to $-\beta^2/\Delta\omega_2$, 2β is the Rabi nutation frequency. The fluorescence emitted perpendicularly both to the atomic beam and to the laser beams is detected by a photomultiplier. The polarization direction of the weak beam is rotated at a frequency ν ; the in-phase and in-quadrature fluorescence signals modulated at a frequency 2ν are respectively proportional to real part and to the imaginary part of the Zeeman coherence ρ_{+1-1} [4] The corresponding signals are recorded as a function of the non-resonant beam power for different values of the detuning $\Delta\omega_2$.

Typical experimental curves are shown on Figure 2 ; the extremum on the dispersive curve is obtained for $\Delta \simeq 5$ MHz as expected (the natural width is about 20 MHz). Similar curves have been obtained for $\Delta\omega_2$ going up to 6000 MHz . Much broader curves have also been recorded using broad-band excitation instead of narrow-band excitation.

(*) Laboratoire associé à l'Université Paris-Sud.

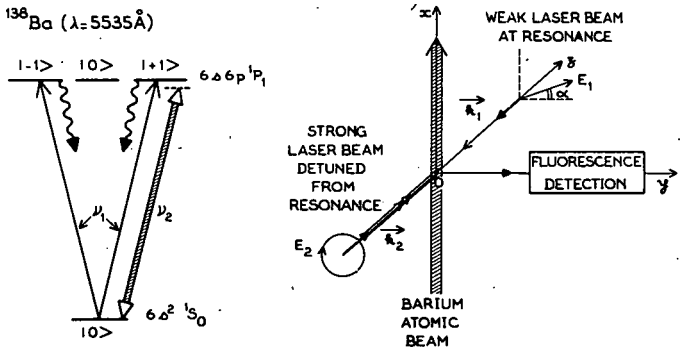


Figure 1

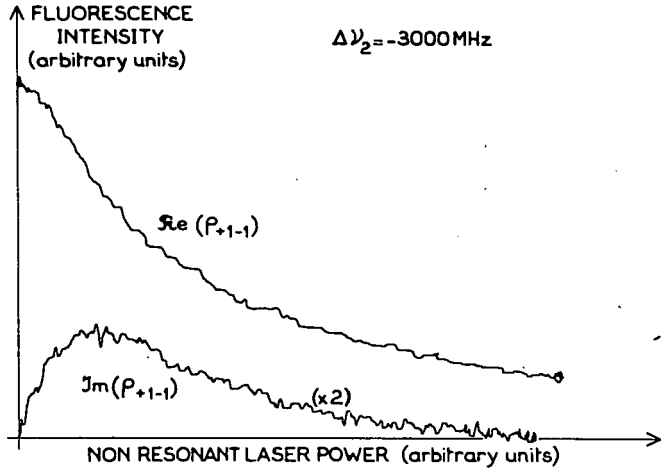


Figure 2

[1] W. HANLE Z. Phys. 30 (1924) 93 ; Z. Phys. 35 (1926) 346.
[2] V. P. KAFTANDJIAN, L. KLEIN Phys. Letters 62A (1977) 317.
[3] V. P. KAFTANDJIAN, L. KLEIN, W. HANLE Phys. Letters 65A (1978) 188.
[4] D. LECLER, R. OSTERMANN, W. LANGE, J. LUTHER J.de Phys. 36 (1975) 647.

EFFECTS of ZEEMAN DEGENERACY on OPTICAL DYNAMIC STARK SPLITTING

C. DELSART and J.-C. KELLER

Laboratoire Aimé Cotton (*), C.N.R.S. II, Orsay, France

Due to the Zeeman degeneracy, the coupling between a two-level system and a monochromatic optical field is generally characterized by several values of the Rabi nutation frequency (Figure 1). In a double resonance experiment with a strong pump beam and a weak probe beam (optical analogue of the Autler-Townes experiment [1]) , this permits the observation of multiplet structures due to the A.C. Stark effect [2-4]. We report the observation of such a Autler-Townes multiplet.

The linearly polarized beams from a CW dye laser (pump beam) and a I_2 stabilized He-Ne laser (probe beam) are counter-propagating in the neon discharge cell and the saturating laser frequency is tuned across the resonances (Figure 2). At moderate dye laser power, one gets a single narrow (Doppler free) resonance (Absorption line narrowing effect [5]). When the pump power is increased, the resonance is found to split into two peaks (in the case $\varphi = 0°$, i.e. for parallel polarizations of the two beams) ; the doublet separation is proportional to the Rabi frequency corresponding to the π_1 transition of Figure 1 [3, 5]. For $\varphi \neq 0°$, one also gets a contribution of the second doublet (π_2 transition of Figure 1) which is twice as separated as the first one. The quadruplet structure (Figure 3) has been observed both for zero and for non-zero detuning δ_2 of the probe beam, and for various values of the angle φ between the polarization vectors.

The corresponding calculations for the three-level system with degenerate levels have been performed using the density matrix formalism. The theory includes the coupling of the various Zeeman sublevels by spontaneous emission and by the interaction with the two beams, and takes into account the finite value of the Doppler width. The theoretical and experimental behaviour of the quadruplet structure when the angle φ or the detuning δ_2 is varied, are compared and are found to be in good agreement.

[1] AUTLER S. H., TOWNES C. H. Phys. Rev. 100 (1955) 703.
[2] SKRIBANOWITZ N., KELLY M. J., FELD M. S. Phys. Rev. A 6 (1972) 2302.
[3] DELSART C., KELLER J.-C. J. Phys. B 9 (1976) 2769.
[4] COHEN-TANNOUDJI C., REYNAUD S. J. de Physique Lettres 38 (1977) L173.
[5] DELSART C., KELLER J.-C. Optics Communications 15 (1975) 91.
[6] DELSART C., KELLER J.-C. J. de Physique 39 (1978) 350.

(*) Laboratoire associé à l'Université Paris-Sud.

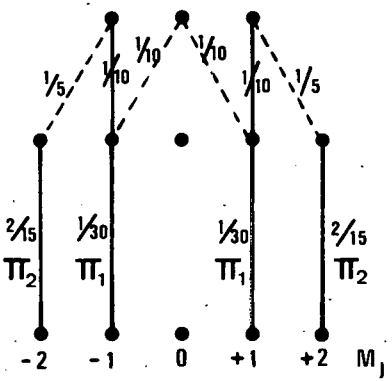


Figure 1 : Relative transition probabilities between Zeeman sublevels in our particular three-level system. The Rabi nutation frequency is proportional to the square root of these probabilities and is thus twice as large for the π_2 transitions as for the π_1 transitions.

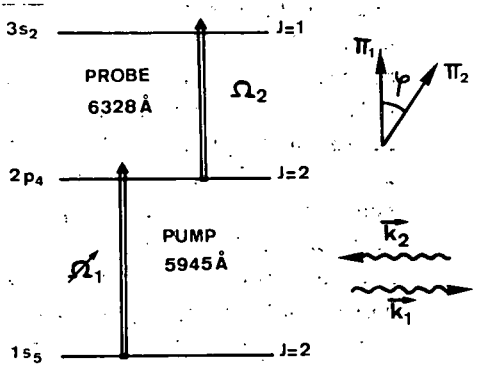


Figure 2 : Characteristics of the three-level system and of the laser beams involved in the experiment.

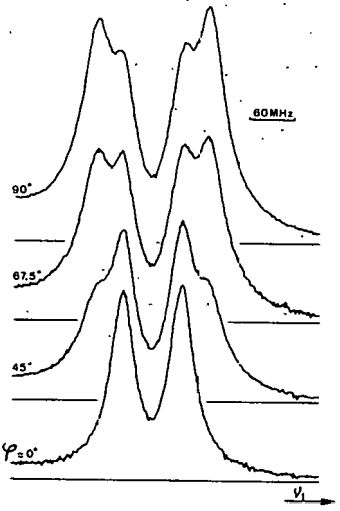


Figure 3 : Experimental curves (probe beam absorption versus pump beam frequency) for various values of φ in the case $\delta_2/2\pi \simeq 10$ MHz .

INVESTIGATION OF OPTICAL POLARIZATION EFFECTS IN RADIATION FROM ION-N_2 COLLISIONS WITH RESPECT TO LIFETIME DETERMINATIONS OF N II LEVELS

U.Becker, A.Dietrich, G.v.Oppen, M.Schmidt, W.Wefel

Institut für Strahlungs- und Kernphysik
Technische Universität Berlin, Rondellstr. 5, D-1000 Berlin 37

Lifetime determinations of many levels in the spectrum of ionized Nitrogen have been performed by the beam foil method (for example Brink et.al.1978). Only some levels belonging to strong transitions have not been determined in this way until yet. For these levels, especially the upper 2p3d ^3F state of the strong transition at 5004 Å we have tried to investigate their lifetime by a level crossing experiment. For this purpose it was necessary to investigate the line intensities and optical polarisation effects in radiation from ion (He^+, N^+, Ne^+,Ar^+) N_2 collisions for N II transitions. For the most transitions no polarisation effect could be observed. Only the 2p3d ^3F-2p3p ^3D transition shows an optical polarisation effect in the order of 10^{-3}. This polarisation degree varies only sligthly in the investigated ion energy range of 5 keV to 20keV. The measured half width of the magnetic depolarisation signal is not in agreement with the calculated lifetime values (for example Nysten and Weckström 1972). This may be explained by strong influence of cascades from higher lying levels, especially from the 2p4p ^3D state.

References:

Brink, J.A., Coetzer, F.J., Olivier, J.H.I., Westhuizen P., Pretorius, R. and Mc Murray, W.R., 1978, Z.Physik A288, 1
Nysten, K.-E., Weckström, K.: 1972, Comment.Phys.-Math. 42, 59

THE LIFETIME MEASUREMENTS FOR EXCITED LEVELS OF Cd I AND In I WITH ELECTRONIC EXCITATION

L. Frasiński, T. Lubowiecka, T. Dohnalik

Institute of Physics, Jagellonian University
ul. Reymonta 4, 30-059 Kraków, Poland

Hanle effect for cadmium, contained in sealed-off quarz cell, and for indium in atomic beam has been examined using electronic excitation / at energies 8 - 50 eV /.
The electronic beam is perpendicular to the magnetic field in order to obtain Zeeman coherence. The light is observed parallel or perpendiculary to that field trough a rotating linear polarizer. The spectral lines are separated by prism monochromator. The photomultiplier signal is amplified by lock-in detector combined with averaging system and is recorded as a function of magnetic field.

The results of the measurements for CdI and preliminary ones for InI will be presented at the conference.

CIRCULARLY POLARIZED RESONANCE FLUORESCENCE AND THE HYPERFINE STRUCTURE IN THE $^2P_{3/2}$ STATES

M.Kraińska-Miszczak

Instytut Fizyki Doświadczalnej, Uniwersytet Warszawski, ul. Hoża 69, 00-681 Warszawa, Poland.

The magnetic field dependence of the circularly polarized resonance fluorescence of alkali atoms excited with π polarized D_2 light has been analysed. Atoms with nuclear spin I=3/2 have been studied. Fig.1 shows the calculated difference of the intensities $I_{\sigma^-}-I_{\sigma^+}$ versus the $x=g_J\mu_0 H/A$ parameter (where g_J is the electronic Landé factor, μ_0 - the Bohr magneton, A - magnetic dipole interaction constant and H the magnetic field strength). Broad line excitation is assumed. Curve 1 is obtained when the levels in the excited state are well resolved and the interference terms in the Breit formula for resonance fluorescence can be neglected. Curve 2 presents the case when the level widths are taken into account (with $\Gamma/2\pi = A$). Here the maximum is lowered and shifted in the direction of higher magnetic field strengths, the relative shift being smaller than 3%. When $\Gamma/2\pi > A$, the level crossing technique becomes less efficient and the measurement of position of the $(I_{\sigma^-}-I_{\sigma^+})$ signal maximum can allow direct determination of the magnetic dipole interaction constant in the $^2P_{3/2}$ states.

When the effect of the electric quadrupole interaction constant B is taken into account the change of the ratio B/A

from 0 to 0.99 gives a shift of the maximum by about 10%. The value of B influences the shape of the curves especially at small magnetic field strength. With increasing B/A ratio the position of the minimum shifts towards zero and at the same time the absolute value of the minimum decreases. A similar effect is obtained when the natural radiation width of the levels increases (cf. curve 2). The position of the minimum or the magnetic field strength at which $I_{\sigma^-} = I_{\sigma^+}$ determines the value of B, however the range B values that can be determined by this method is limited by the value of Γ.

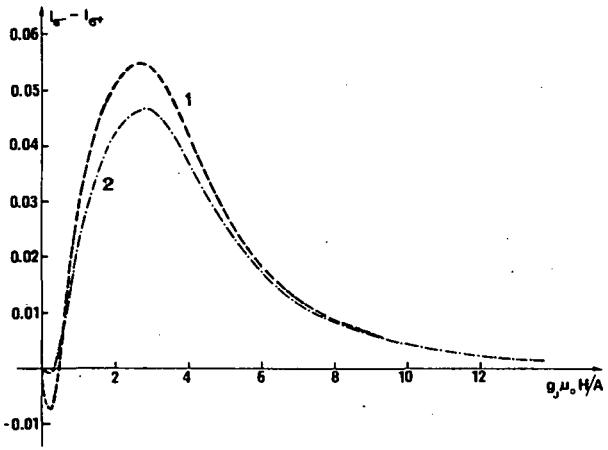


Fig. 1. Intensity difference of the circularly polarized components of the resonance fluorescence excited with π polarized D_2 line, with $I_\pi + I_{\sigma^-} + I_{\sigma^+} = 1$, $B \approx 0$:
1 - $\Gamma \approx 0$, 2 - $\Gamma/2\pi = A$.

LIFETIME AND HYPERFINEINTERACTION IN $^1P_1$ STATES WITH NUCLEAR SPIN I=1/2

M. Baumann, H. Liening
Physikalisches Institut der Universität, Auf der Morgenstelle 14
D 7400 Tübingen, Germany

Hyperfine (hfs)-measurements in $^1P_1$ states with I=1/2 are usually very easily performed with the level-crossing (lc) technique because there is only one lc-signal in the field range unequal zero apart from the zero field crossing signals (Hanle-effect).

If the natural radiation width $\Gamma=\hbar/\tau$ in the excited state is small compared to the hfs-splitting the non zero lc-signal is well resolved. On the other hand if Γ is larger than the hfs the crossing signal may be completely overlapped by the Hanle signal, which makes an evaluation of a hfs-splitting from a measured curve rather delicate or even impossible.

Fig. 1 shows a number of lc-signals for a $^1P_1$ state with I=1/2 calculated due to the Breit formula. Starting from a negligible hfs splitting with A=0 first of all the line width (fwhm) of the curves becomes larger with increasing hfs coupling constant A. If the hfs splitting is larger than Γ the signal is eventually a superposition of a well resolved single LC-signal and a Hanle curve, but at the same time the line width of the Hanle-effect decreases and converges to a value quite different from the fwhm value of the signal curve with A=0.
This is due to the fact that the line width of the Hanle signal is determined by the g_F-values of the excited state if the hfs splitting is large compared to Γ whereas in the case of a negligible hfs splitting the g_J-value determines the line width of the signal curve.

Therefore it is possible only with the aid of the lifetime of the excited state to distinguish between a very small hfs-

splitting and a hfs which is much larger than Γ provided that the lifetime of the excited state under investigation has been measured independently e.g. from the Hanle effect of the even isotopes.

The method described here will be discussed in the case of the very small hfs of the $4f^{14}6s\ 7p\ ^1P_1$ state of ^{171}Yb ($I=1/2$). A detailed analysis of the measured signal curves using the lifetime $\tau(6s\ 7p\ ^1P_1)=8.9(5)$ nsec yields the following value for the hfs splitting constant:

$$|A\ (6s\ 7p^1P_1)| = 3.5(1.0)\ \text{MHz}\ .$$

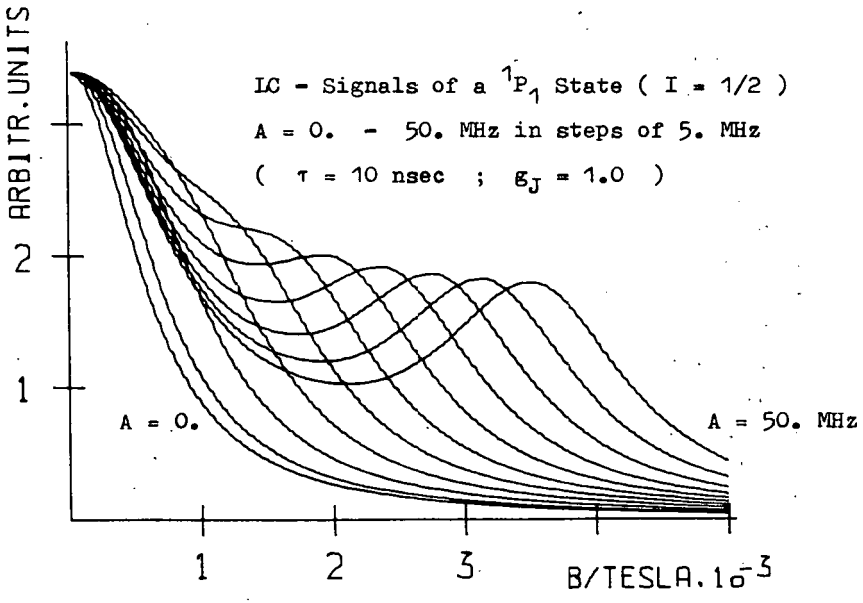


Fig. 1: Calculated lc-signals due to the Breit formula.

RYDBERG STATE MICROSCOPIC MASERS AND MICROWAVE SUPERRADIANT SYSTEMS

M. GROSS, C. FABRE, P. GOY, J.M. RAIMOND and S. HAROCHE

Laboratoire de Physique de l'E.N.S., 24 rue Lhomond,
75231 PARIS CEDEX 05 - France

Due to their unusually large electric dipoles, Rydberg atoms interact very strongly with microwave radiation resonnant on transitions connecting nearby levels. This feature can be exploited to observe millimetric superradiance (SR) with a very little number N of excited atoms at threshold. It is also possible to build up a Rydberg state maser with extremely low radiated energy per pulse ($\sim$ 10 eV).

Fig. 1 shows the scheme of our Rydberg SR (1-a) and maser (1-b) system. In both cases a collimated atomic beam of alkali is intersected by two pulsed colinear N_2-laser-pumped dye laser beams (wavelengths λ_1 and λ_2). The lasers excite the atoms from their nS ground state to the first resonant nP state (λ_1 = 8523 and 5890 Å for the SR Cs and Maser Na experiment respectively), then on a Rydberg nS level ($n \sim 25$, λ_2 = 5150, 4100 Å respectively). At t = 0, a pencil shaped volume (length 5 mm, diameter a $\sim$ 1 mm) of Rydberg state is thus prepared within about 2 ns. In the maser case (fig. 1-b), the active medium is pumped in a semi-cofocal millimeter Fabry Perot cavity (finesse $\mathcal{F} \sim 200$). Such a system can then emit at each frequency corresponding to a transition from the upper level nS to a lower n'P state (see insert fig. 1). In fact, the maximum gain transition appears alone, which corresponds to n' = n-1 for SR; at threshold N is typically 10^5. In the maser case, the wavelength is tuned by cavity and at resonance with an atomic transition nS-(n-1)P, N is 10^3 only at threshold.

Of course such a small number of microwave photons is difficult to detect. Nevertheless, by using time resolved field ionization technique, it is possible to measure the populations of the nS and n'P levels The ionization signal at different times t_n and $t_{n'}$ is then proportional to the initial and final state populations (Figs. 2 and 3). Absolute calibration of these populations is achieved by reducing with calibrated filters the pumping light intensity until individual atom counts are registered.

Fig. 2 shows the ionization signal as a function of time in the SR Cs case for n = 24. t_n is 2 μs and N is respectively 2×10^5 (a), 4×10^5 (b), 6×10^5 (c), $1.2\ 10^6$ (d). The ionization peak corresponding to the 23P level appears above the threshold $N \gtrsim 5 \times 10^5$, which is in fair agreement with theory. The SR pulse delay is of the order of a microsecond. Fig. 3 shows the ionization signal in the maser Na experiment for n = 27, $N = 10^4$, and $t_n \gtrsim 30$ μs (flight time between cavity and condensor), averaged over 20 laser pulses. The upper trace corresponds to an exactly 27S-26P tuned cavity, and the lower one to a 40 MHz detuning. Exact tuning is achieved by control microwave double resonance experiment. By sweeping the cavity, 2 close resonances are observed and fine structure splitting of n'P state can be deduced. Note that in both cases, the system is tilted by blackbody radiation. This experiment opens the way to blackbody-triggered, small sample (of the order of the wavelength) and small atom number SR experiment. With better cavity microwave spectroscopy using blackbody radiation as source is also possible.

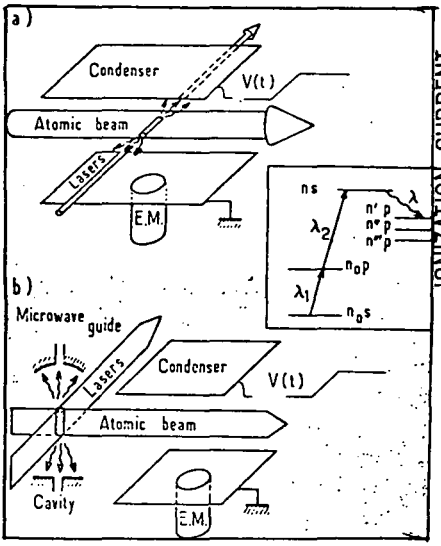


FIG. 1

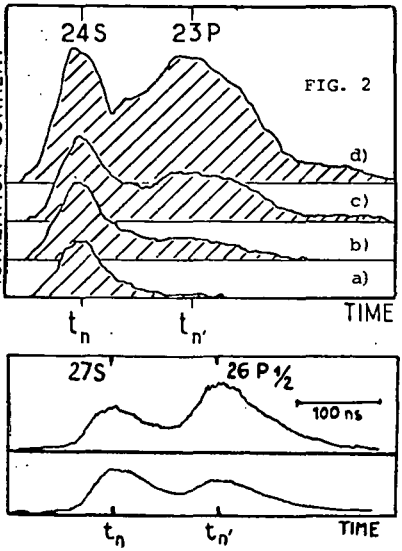


FIG. 3

VERY HIGH RESOLUTION MILLIMETER TWO-PHOTON SPECTROSCOPY ON SODIUM RYDBERG STATES

C. FABRE, P. GOY, S. HAROCHE

Laboratoire de Physique de l'E.N.S.
24, rue Lhomond, 75231 PARIS CEDEX 05 - France

Due to their very long lifetimes, and hence to their very narrow natural widths, very excited states of atoms are particularly well suited to ultra high resolution spectroscopy. The ultimate linewidth ($\simeq$ 1 kHz for principal quantum number n around 40) may be obtained either on a transition linking the ground state to the Rydberg state (UV range) or a transition between two Rydberg states (mm range). In the optical or UV domain, one measures the line wavelength by comparing to length etalon; in the mm domain, one measures the line frequency by comparing to frequency etalon, which yields a much more accurate ultimate determination, and opens the possibility of improving by a large amount the determination of the Rydberg constant. We report here the observation of very narrow lines of the latter kind.

The experiment is performed on an atomic beam of sodium. A nS level is excited by a stepwise process via the 3P level, by two pulsed dye lasers at point A of the atomic beam. Excited atoms travel through a microwave semi-cofocal cavity (Q $\simeq$ 10000) which is coupled to an external mm wave source. After the cavity, the atoms enter into a condensor and are submitted to a ramp of electric field. If the mm wave is off-resonance, atoms remain in in the initial nS state and the ionization in the electrostatic field occurs at a given time t_o. If the mm wave is resonant for a transition linking the nS state to any other level n'ℓ , ionization then occurs at the time t_o for atoms remaining in nS state, but also at a slightly different time t_1 for atoms transferred in n'ℓ state, corresponding to a different value

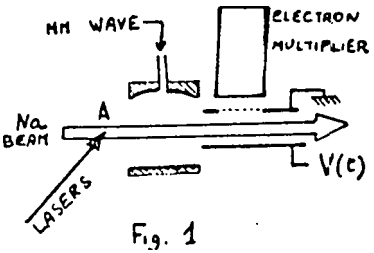


Fig. 1

of the ionizing electrostatic field. The line is then recorded by monitoring the ionization signal at time t_1 as a function of the mm source frequency. In order to get rid of Doppler broadening, we have studied double quantum nS-(n+1)S transitions in the standing wave existing inside the mm cavity, using in the mm domain the Doppler-free two photons transition technique well known in the optical domain. The main limitation of the linewidth is due to the interaction time between the atoms and the microwave. In the preliminary experiments reported here, t_o is of the order of 70 µs, corresponding to a linewidth of 50 kHz.

As a microwave source, we used a 75-77 GHz Backwave oscillator (Thomson CSF carcinotron) which was stabilized on the 7th harmonic of a 9-12 GHz klystron, itself stabilized on a harmonic of a high stability quartz oscillator. The obtained bandwidth is less than 1 kHz. For some measurements we could use directly on the atoms the harmonic generated on a diode by the X band klystron.

Fig. 2 shows recordings performed on the 36S-37S transition. The first curve, obtained without cavity and with the mm wave nearly colinear to the atomic beam, displays the Doppler broadened and shifted line. The 2 other curves correspond to Doppler-free transitions inside the cavity with 2 different interactions times. The finest line corresponds to a resolution better than 10^{-6} and the signal to noise ratio allows us to measure the line center with a precision of the order of 10^{-7}. The obtained value of the transition frequency : $\Delta\nu_{37S-36S}$ = 151,538,236 ± 10 kHz yields a very precise value of the S-levels quantum defect for n around 36

ε_S = 1.34805000 ∓ 0.0000006

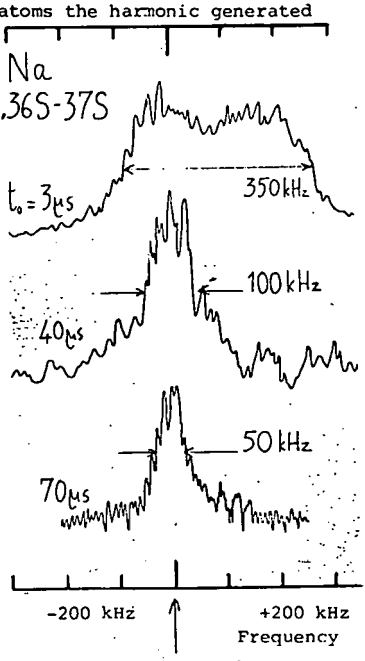


FIG. 2

STRONG MAGNETIC FIELD PERTURBATION OF CAESIUM RYDBERG STATES

J.C. GAY, L.R. PENDRILL[+]

Laboratoire de Spectroscopie Hertzienne de l'ENS - Université Pierre et Marie Curie - Tour 12 - E01 - 4, place Jussieu - Paris 5e - France

We have made measurements on the Rydberg energy levels n^2F (n up to 150) of atomic caesium and have studied the effects of external magnetic fields of up to 80 kG.

A C.W. single mode tunable dye laser is used to excite the atomic vapour producing, firstly, excited 5^2D Cs atoms by photodissociation of Cs_2 molecules and, secondly, selective excitation via fundamental series transitions to the atomic Rydberg states. The Rydberg atoms are detected with a thermoionic diode installed in the vapour cell which, itself, is placed in the core of a superconducting selenoid.

In addition to extending the range of measured term values [1] of the n^2F levels of Cs to n=150 (fig. 1), we have also observed diamagnetic shifts of the n^2F levels ($n \sim 60$) of several cm^{-1} in magnetic fields of a few kG. These shifts are in accord with values calculated using a simple hydrogenic model (cf fig. 2).

The goal of this experiment is to observe quasi-Landau resonances close to the ionisation limit which are expected to appear [2] in magnetic fields greater than about 20 kG. The Cs n^2F levels present an interesting case because of (i) the large atomic mass and (ii) the small quantum defect (~ 0.03) of the F levels. Studies of crossed $\vec{E}$, $\vec{B}$ fields effects on the atomic spectra [3] [4] [5] are also planned.

[+] J.J. Thomson Physical Laboratory - University of Reading (U.K.)

(1) C.B. COLLINS, B.W. JOHNSON, M.Y. MIEZA, D. POPESCU, I. POPESCU - Phys. Rev. A 10, 3 (1974) 813
(2) R.J. FONCK, D.H. TRACY and D.C. WRIGHT and F.S. TOMKINS - Phys. Rev. Lett. 40, 21 (1978) 1366
(3) A.R.P. RAU - J. Phys. B, Atom. Molec. Phys. 12, 6 (1979) L193
(4) H. CROSSWHITE, U. FANO, K.T. LU and A.R.P. RAU - Phys. Rev. Lett. 42, 15 (1979) 963
(5) J.C. GAY, L.R. PENDRILL and B. CAGNAC - Submitted to Physics Letters

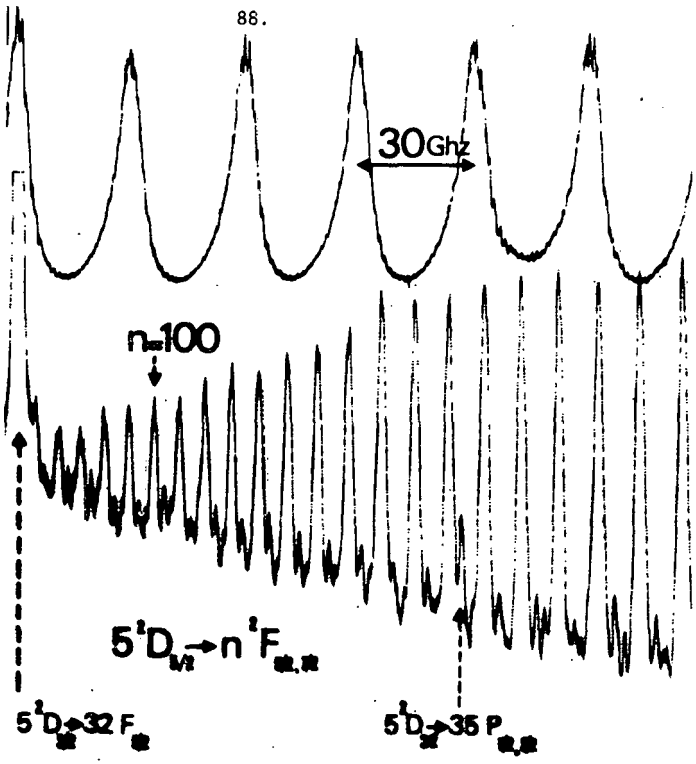

30Ghz
n=100
$5^2D_{3/2} \rightarrow n\,^2F_{5/2,7/2}$
$5^2D_{3/2} \rightarrow 32\,F_{5/2}$
$5^2D_{3/2} \rightarrow 35\,P_{3/2}$

FIG. 1

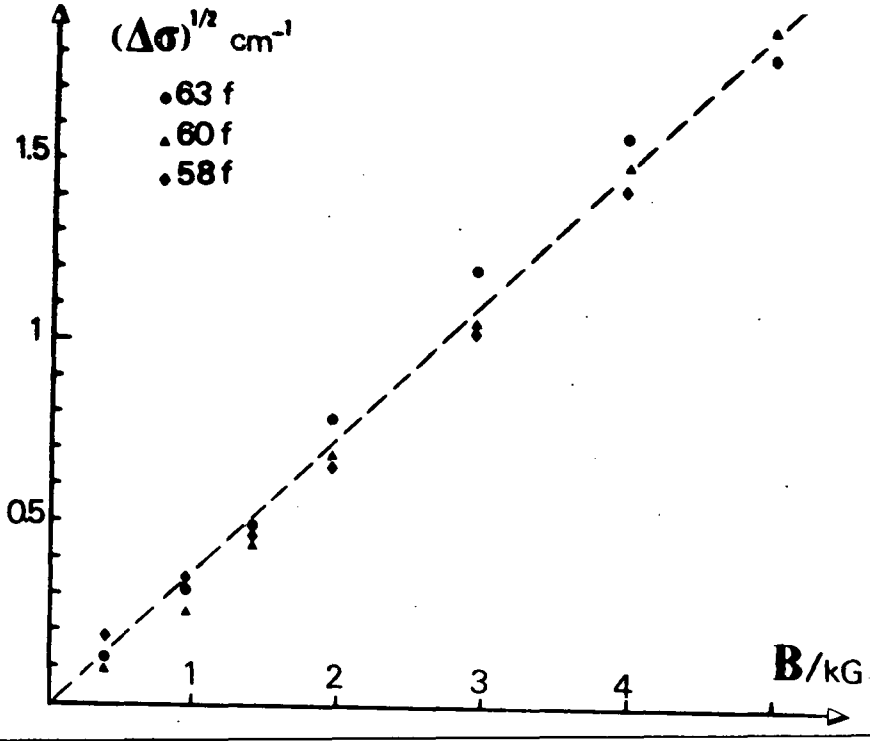

$(\Delta\sigma)^{1/2}$ cm^{-1}
•63 f
▲60 f
•58 f
1.5
1
0.5
1
2
3
4
B/kG

FIG. 2

RADIATIVE LIFETIMES OF RUBIDIUM HIGH RYDBERG STATES

F.GOUNAND, P.R.FOURNIER and M.HUGON

Centre d'Etudes Nucléaires de Saclay, Service de Physique Atomique - B.P. N° 2 - 91190 GIF-SUR-YVETTE (France)

We report here a wide set of measured radiative lifetimes of highly excited rubidium in the S, P, D and F series ($9 \leqslant n \leqslant 22$). The results concerning the P and F states have already been published [1,2]. The effective lifetime of a state for a given rubidium pressure in a cell[3] is measured by a technique of time-resolved-fluorescence. The extrapolation of the effective lifetimes to zero rubidium pressure yields the radiative lifetime τ_{exp}. The lifetimes have been corrected for thermal escape effects[4]. Our experimental results are presented in figure 1 and are compared with the theoretical values τ_{th} calculated by using the Bates-Damgaard method[5]. The dependence of these calculated lifetimes on the effective quantum number n^* ($n^* = n-\delta$, δ being the quantum defect) is given by $\tau = \tau_0 (n^*)^{\alpha}$ with τ_0 and α reported in Table 1 for each of the S, P, D and F series.

	S	P	D	F
α	2.94	3.02	2.85	2.95
τ_0	1.43	2.76	2.09	0.76

Table 1 : α and τ_0 (in 10^{-9}s) parameters of the equation $\tau = \tau_0 (n^*)^{\alpha}$ for rubidium given in ref. 5.

The α-values are close to the value $\alpha = 3$ predicted by the quantum-defect theory. Figure 1 shows that theory and experiment are in good agreement in the case of the F states[2]. For the S, P and D levels, the experimental results τ_{exp} are somewhat smaller than the theoretical values τ_{th}. This discrepancy can be partially removed by taking into account the interaction of the blackbody radiation with highly excited atoms[6]. In figure 1, the τ_{cal}

values corrected for this effect exhibit a closer agreement with our experimental data (note that the correction is small for the F states). This clearly indicates that the Bates-Damgaard method[5] provides good estimates for the radiative lifetimes of highly excited states of heavy alkali having a large quantum defect.

REFERENCES

1 - F. Gounand, P.R. Fournier, J. Cuvellier and J. Berlande, Phys. Lett. 59A, 23 (1976).

2 - M. Hugon, F. Gounand and P.R. Fournier, J. Phys. B 11, L 605 (1978).

3 - M. Hugon, F. Gounand, P.R. Fournier and J. Berlande, J. Phys. B, to appear (1979).

4 - L.J. Curtis andP. Erman, J. Opt. Soc. Am. 67, 1218 (1977).

5 - F. Gounand, J. Physique 40, 457 (1979).

6 - T.F. Gallagher and W.E. Cooke, Phys. Rev. Lett. 42, 835 (1979).

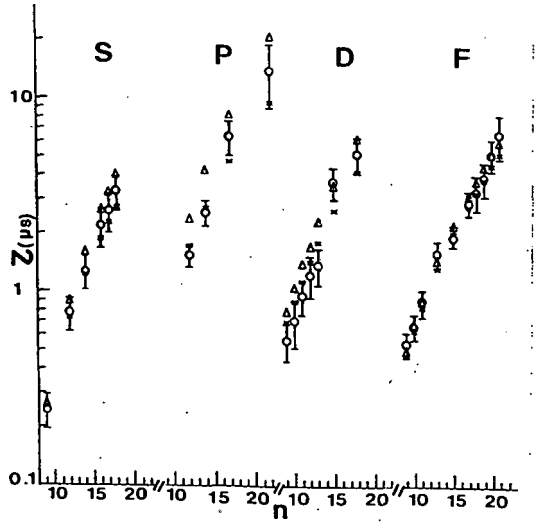


Figure 1 : radiative lifetimes of the rubidium S-D-F (T=520K) and P (T = 460K) levels: τ_{exp}, ⊖ ; τ_{th}, Δ ; τ_{cal}, × (see text).

Blank

POLARIZATION AND PENETRATION EFFECTS IN THE HYDROGEN-LIKE TERMS OF THE nf AND ng CONFIGURATIONS OF CS I.

Craig Sansonetti and K. L. Andrew, Dept. of Physics, Purdue University, W. Lafayette, IN 47907 U.S.A. Jean Verges, Laboratoire Aimé Cotton, C.N.R.S. II, Campus d'Orsay, 91405 Orsay, FRANCE.

The term values for levels of hydrogen-like nonpenetrating series can be represented as a function of the dipole and quadrupole polarizabilities of the atom or ion core by a polarization formula. Because the polarizabilities are fundamental characteristics of the core, a polarization formula determined from one nonpenetrating series should also predict the terms of any other nonpenetrating series of the same atom or ion.

We have observed the Cs I Rydberg series members $4f\,^2F\text{-}ng\,^2G$ for n=5 to 11. This is the first time members of this series have been observed for $n > 6$. We have used this data and available data for the terms nf (n=4 to 14) to determine the core polarizabilities and the series limit. The separate results for the two series do not agree within the experimental uncertainties. Such discrepancies have often been dismissed as due to residual penetration of the core. We have attempted to make ab initio calculations of the penetration energy for each term of these two series to see if this can account for the deviations. Our calculations indicate that the ng electrons actually have negligible penetration. We thus used the fitted polarization formula for the ng series to infer the penetration energies for the nf electrons. The n dependence of the penetration energy obtained in this way shows close qualitative agreement with our ab initio calculations and reasonable agreement in magnitude. It appears plausible that penetration effects could explain the observed discrepancies. More refined ab initio calculations are needed to permit quantitative conclusions.

LASER MEASUREMENT OF INTENSITY RATIO ANOMALIES IN PRINCIPAL SERIES DOUBLETS IN CAESIUM RYDBERG STATES

J.M. RAIMOND, M. GROSS, C. FABRE, S. HAROCHE
Laboratoire de Spectroscopie Hertzienne de l'E.N.S.
24, rue Lhomond, 75231 PARIS CEDEX 05 - France

H.H. STROKE
Department of Physics, New York University, 4 Washington Place, NEW YORK, NY 10003 - U.S.A.

The problem of anomalous ratios of the oscillator strength in the alkali principal series doublets, though fifty years old, is still not completely solved, especially for high n values. In particular, in caesium, the ratio $\rho(n) = f_{3/2} / f_{1/2}$ ($f_{3/2,1/2}$: oscillator strengths of transitions $n P_{3/2,1/2} \rightarrow 6S_{1/2}$ respectively) which should be equal to 2 according to the statistical weights of the lines, appears to be very different from 2, and to grow very rapidly with principal quantum number n.

There were some experimental and theoretical arguments predicting the divergence of ρ for n of the order of 20. Measurement of $\rho(n)$ by classical absorption methods have been performed only up to n = 21 and become increasingly difficult when n becomes larger and larger. We report in this paper a measurement of ρ for $18 < n < 30$ by completely different techniques which rules out the possibility of such a pole for ρ (i.e. the disappearance of the D_1 line).

The pulsed light of a nitrogen pumped dye laser, frequency doubled in an ADP crystal, excites an atomic beam of Cs atoms in a given $nP_{1/2}$ or $nP_{3/2}$ state. The resulting population of this state proportional to f and to the laser intensity is then monitored by field ionization technique: The atoms in the very excited nP level are ionized by a pulse of static electric field and the electrons are detected by an electron multiplier. The signal is then averaged and normalized with respect to the laser intensity by a dual channel boxcar integrator. In order to compare the line intensities of D_1 and D_2 lines without changing the gain of the detection system we have placed a calibrated filter of atte-

nuation 370 in front of the laser beam for the recording of the D_2 line. Fig. 1 gives recordings for n = 19 and n = 25 of the boxcar output as a function of the laser frequency. The 1-2 and 3-4 line splittings correspond to the hyperfine splitting of the caesium ground state. ρ is then given by the ratio between intensities of lines 3-1 (or 4-2). Fig. 2 gives the experimental results for n ranging from 19 to 30. We have displayed not directly ρ in fonction of n because of the too rapid variation of ρ with n, but rather the Fano parameter $x = \frac{2(\rho/2)^{1/2}+1}{(\rho/2)^{1/2}-1}$ as a function of the photon energy E, because x varies smoothly with E when crossing the ionization limit E_i. The dotted line, corresponding to the theoretical values of Norcross, fits very well our experimental data. Our results show that the x(E) curve cannot be extrapolated to a $x(E_i)$ value smaller than 2 (the value 2 of x corresponds to the divergence of ρ). This gives an experimental evidence that there is no pole for ρ in the discrete spectrum i.e. that the D_1 line decreases continuously without vanishing when $n \to \infty$. Further details and references on this experiment are given in reference [1].

([1]) J.M. RAIMOND, M. GROSS, C. FABRE, S. HAROCHE, H.H. STROKE, J. Phys. B 11 (1978), L765

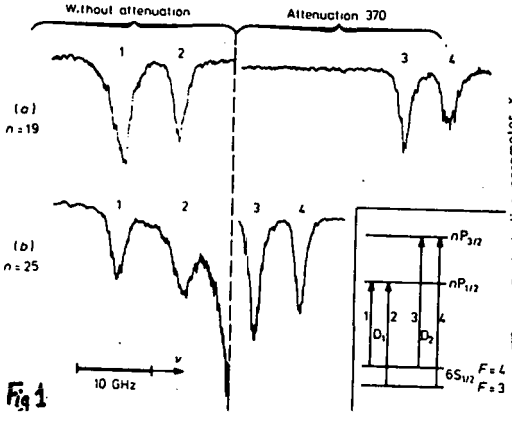


Fig 1

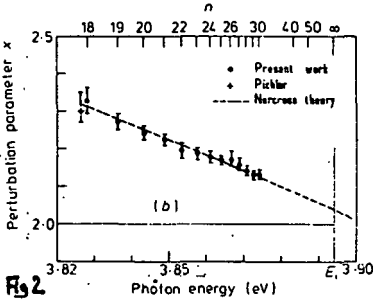


Fig 2

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

OBSERVATION OF FANO PROFILES IN PHOTOIONIZATION OF RUBIDIUM IN THE PRESENCE OF A d.c. FIELD.

A. Taleb, S. Feneuille, S. Liberman, J. Pinard
Laboratoire Aimé Cotton, C.N.R.S. II, Bâtiment 505, 91405-Orsay France.

The pgotoionization spectrum of Rb atoms in the presence of a d.c. eletric field exhibits properties which are able to reveal the nature of the processes involved in such effects. At first, above the saddle-point limit, sharp resonances have been observed in that spectrum using σ-polarized laser excitation of the atoms from their ground state. Almost nothing (very small amplitude) was observed in the same conditions except that the exciting laser light was π-polarized. However, as the π- polarized transitions correspond to the less hydrogenic levels, they permit to check the assumptions which could explain the photoionizatcn processes in the presence of a static electric field, for all atoms but hydrogen. In fact, above the saddle-point limit, quasi stable Stark levels exist and they are embedded in ionization continua. In the case of hydrogen, because of the particular symmetry of the Coulomb interaction, there is no interaction between these levels and continua. In the case of atoms other than hydrogen, such an interaction takes place and then ionization occurs through mechanisms similar to autoionization for atoms of predissociation for molecules. That interaction mixes in some way discrete Stark levels with continuum and makes interference effects to appear on sharp resonances, as characteristically asymmetric Fano profiles [1].

Other possible resonances of different origin may also occur. Their quite different properties from the previous ones will be discussed.

[1] S. Feneuille, S. Liberman, J. Pinard, A. Taleb,
to be published in Phys. Rev. Letters.

Electric-field-induced oscillations in the photoionization cross-section of a one-electron atom above the ionization potential.

E. LUC-KOENIG, A. BACHELIER

Laboratoire Aimé Cotton, C.N.R.S. II, Orsay, France.

In recent experiments on rubidium in an external electric field $\mathcal{F}$, strong oscillations have been observed in the photoionization spectrum for a π-polarization of the exciting light ; the structure exists not only for energies just above the classical field ionization threshold $E_c^p = E_0 - 2\sqrt{\mathcal{F}}$ [1], but also more surprisingly above the ionization limit of the unperturbed atom E_0 [2]. Following several authors this striking dependence upon the polarization of the light may be explained from simple semi-classical arguments as arising from the existence of quantized states $m=0$, even at energies $E > E_0$; these states can be excited from the ground state only with the π-polarization of the light [2, 3]. We present here a quantum mechanical treatment which does not agree completely with the classical results.

Exact calculations can be performed for a hydrogen-like atom in a constant electric field $V = -Z/r + \mathcal{F}z$, since the corresponding hamiltonian is separable in parabolic coordinates [4]. The energy E, the magnetic quantum number m, and the separation constant Z_1 (or the number of nodes n_1 in the bound-state type wavefunction) correspond to a complete set of operators [5]. The resolution method which allows us to obtain normalized wavefunctions for any real value of Z ($\gtrless 0$ or $\leqslant 0$) was presented [6]. For the continuum spectrum a partial density of states $\mathcal{C}_{n_1}^{|m|}(E)$ can be defined : this quantity is equal to the weight of the state E, m, n_1 in the time-development of the wavefunction associated with an electron located at the nucleus at the initial time. We have shown that no significant difference exists in the energy-dependence of the partial density of states for different $|m|$-value : they exhibit oscillations too shallow to be observed. So the presence of a resonant structure in the density of states is not sufficient to explain the experimental spectra obtained for atomic Rydberg states. Nevertheless the existence of broad widely-spa oscillations in the density of states at $E > E_0$ is not surprising : i has been observed for a long time in solid-state-physics, where the effective electric field corresponds to the ultra strong limit (Franz-Keldysh effect [7, 8].

In atomic physics the density of states cannot be studied experimentally ; only the total density of oscillator strengths df/dE in the absorption spectrum from a state Ψ_i (for example the ground state) can be recorded ; df/dE is the sum over all partial contributions $df/dE\ (n_1, |m|, E)$ which correspond to upper states n_1, m, E and which are proportional to the

nondiagonal matrix element of the transition operator. For $Z = 0$ the hydrogen wavefunction is associated with a charge distribution asymmetric with respect to the plane $z=0$; its largest part lies on the positive side of z for $Z_1 > Z_2 = Z - Z_1$ and on the negative side for $Z_1 < Z_2$ [4]. For $Z_1 = Z_2$ the wave function is symmetric. For a π-polarization of the exciting light, transitions between symmetric states disappear ; similar results cannot be observed for a σ-polarization of the light since in this case the transition operator does not present any symmetry properties with respect to the $z=0$ plane. We have shown that in the presence of an electric field, the symmetry properties of the wavefunctions remain approximately valid not too far from the nucleus : for a π-polarization of the exciting light transitions from the ground state toward upper states disappear in the energy range such that $Z_1 \sim Z_2$ leading to a relatively constrasted minimum in the photoionization cross-section. The energy spacing predicted from the hydrogenic model reproduces very well the experimental observations in rubidium, but the depth of the modulation varies from an atom to an other.

In conclusion, in presence of an external electric field, the striking dependence of the photoionization spectra of Rb upon the polarization of the exciting light does not depend on specific properties of states $m=0$ - such as their important non-hydrogenic character - but is related to the respective symmetry properties of the electric field and of the exciting light. So similar structures could be observed even in hydrogen, and for transitions between states $|m| \neq 0$ for a π-polarization of the exciting light - for example from a state ℓ,m with even value of $\ell + |m|$ in a one-electron spectrum. Moreover since no scaling law with Z exists, the structures in neutral or ionized spectra are expected to be very different. Such experiments will present a great interest in the study of field-ionization properties of atomic Rydberg states.

[1] S. Feneuille, S. Liberman, J. Pinard and P. Jacquinot, C. R. Acad. Sci., Ser. B 284 291 (1977).

[2] R. R. Freeman, N. P. Economou, G. C. Bjorklund and K. T. Lu, Phys. Rev. Lett. 41 1463 (1978).

[3] A. R. P. Rau, J. Phys. B 12 L193 (1979).

[4] H. A. Bethe and E. E. Salpeter, Quantum Mechanics of One- and Two-Electron Atoms - Springer Verlag Berlin (1957).

[5] G. J. Hatton, Phys. Rev. A 16 1347 (1977).

[6] E. Luc-Koenig and A. Bachelier, to be published.

[7] W. Franz, Z. Naturforsch. 13 484 (1958).

[8] L. V. Keldysh, Soviet Phys. J E T P 7 788 (1958).

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

Quantum beats in superradiance in Rb vapour.

J.Marek, Institut für Experimentalphysik, Universität Kiel, Germany

Using laser excitation of the 6^2P levels (4 nsec pulse length) in the natural isotopic mixture of Rb atoms, modulation of the superradiance intensity (SR) of some transitions to lower levels was observed. The linewidth of the laser was varied from 4 to 300 mÅ by use an extracavity Fabry-Perot etalon. The Rb atoms were placed in an absorption cell. The SR emission was detected both in the foreward and in the backward direction of the laser beam with the aid of photodiodes. The signals which were equal in both directions were displayed on the screen of a 500 MHz oscilloscope and photographed using a 400 MHz storage oscilloscope.

Exciting the $6^2P_{1/2}$ level by laser light of extended linewidth (300 mÅ) only one modulation frequency f= 124 MHz of the SR signal could be registered. In this case all hyperfine structure levels of the $6^2P_{1/2}$ state were excited from all HF levels of the ground state in both isotopes. Using a narrow laser linewidth (4 mÅ) and scanning the laser over the $5^2S_{1/2}$- $6^2P_{1/2}$ transition, three basic groups of the signals were observed attributable to the fact, that the excitation of the $6^2P_{1/2}$ HFS levels was performed from different ground state HFS levels. Two registered modulation frequencies, 117 and 263 MHz, were interpreted as quantum beat signals between the HFS transitions in Rb^{85} and Rb^{87}. These values agree with data known from other measurements. The third group of frequencies was attributed to the quantum beat effect between the transitions of both isotopes.

When a transverse magnetic field was applied to the sample a single SR pulse was registered on the 6^2P - 4^2D transitions. It was found that the behaviour of the SR signal shows the properties similar to those described theoretically for two-level system.

STARK EFFECT INDUCED Ly_α -QUANTUM BEATS FROM A SLOW BEAM OF METASTABLE HYDROGEN ATOMS IN A MAGNETIC FIELD

W. Hartmann and A. Oed, Physikalisches Institut der Universität Tübingen, Morgenstelle, D-7400 Tübingen, Germany

Ly_α -quantum beats have been observed many times since 1968 using fast beams of hydrogen atoms /1/. In these fast beam experiments the time dependence of the signals is measured usually indirectly via x=v·t by changing the position x of the detector (v= velocity of the beam).

In our experiment we use a slow beam of metastable hydrogen atoms ($v \approx 8 \times 10^3 ms^{-1}$), single photon counting, and a "real-time" measurement by means of a time-to-amplitude-converter: The metastable 2S-atoms are produced in an electron gun by electron bombardement of molecular hydrogen. Approximately 25 cm behind the gun they are quenched in a 50 Ohm transmission line capacitor by short electric pulses (rise time $t_r <$ 0.5 ns, pulse length $\approx$ 20 ns) and the emitted Ly_α-photons are detected perpendicular to the beam by a two stages micro channel plate multiplier. Due to the channel plate multiplier the time resolution of the complete detection system is about 0.8 ns. Thus quantum beat frequencies up to 1 GHz can be detected. By means of a magnetic field, which is parallel to the beam axis, the term differences between the hfs-Zeeman-levels of the states $2^2S_{1/2}$ and $2^2P_{1/2}$ and consequently the beat frequency can be varied. Furthermore a hfs-state selection can be performed by quenching the metastable hydrogen atoms in the states $2^2S_{1/2}(F=1, m_F=0, \pm 1)$ with an electric RF-field in the region between the electron gun and the quenching capacitor. A comparison of a measured quantum beat signal with hfs state selection of the level $2^2S_{1/2}$ (F=0) and a theoretical curve is shown in fig.1. The theoretical signal is computed using the two level approximation (levels $2S_{1/2}$ $m_J=-1/2$, $m_I=+1/2$; $2P_{1/2}$ $m_J=+1/2$, $m_I=-1/2$) which is exact to about 2×10^{-2} at the magnetic field B $\approx$350 G.

The influence of the rise time of the pulsed electric field on the quantum beat signal is investigated experimentally and theoretically and will be discussed in detail.

/1/ For reviews of quantum beat experiments see e.g.
Beyer, H.-J.: Lamb shift and fine structure...
in: Progress in atomic spectroscopy, Eds.
W. Hanle a. H.Kleinpoppen, Plenum Press 1978
Andrä, H.J.: Phys. Scr. 9, 257, 1974

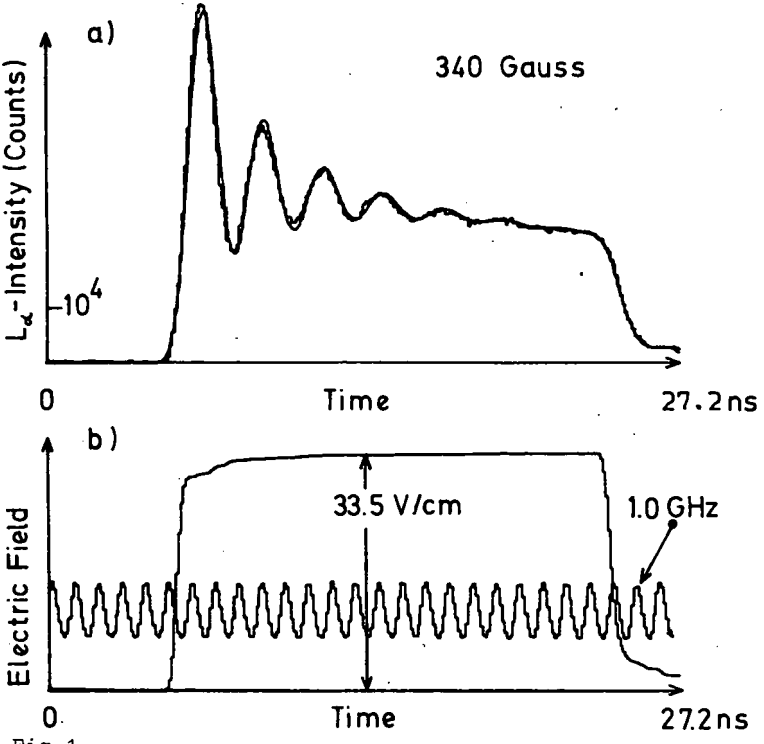


Fig.1

a) Quantum beats due to the quenching of the level $2^2S_{1/2}$, $m_J=-1/2$, $m_I=+1/2$ by the electric pulse of fig.1 b)

b) Time dependence of the pulsed electric field. This shape is digitized and is used for the computation of the theoretical quantum beat signal. The sine curve is a 1 GHz frequency (measured by means of the TAC) which provides a calibration of the time scale accurate to $5\ 10^{-5}$.

DELAYED QUANTUM BEATS AS A METHOD OF SUBNATURAL LINEWIDTH SPECTROSCOPY.

A.Denis and J.Désesquelles.

Laboratoire de Spectrometrie Ionique et Moléculaire,Université de Lyon 1,Campus de la Doua,69621 Villeurbanne.

Quantum beats experiments in fast ion beams excited by a thin solid target provide information on excited atomic states and have proved a powerful time-resolved fluorescence spectroscopic technique.

The resolution of a Q.B. experiment is essentially limited by the atomic linewidth Γ.From the time modulation of intensity $I(t) \propto \sum_n A_n \cos \omega_n t \, e^{-\Gamma t}$,the frequency spectrum is obtained by Fourier transform.The Fourier peaks have a Lorentzian shape,are centered on the frequencies ω_n and are resolved only if their separation $\Delta\omega_n$ is more than Γ.

In our experiments a 0.25 MeV/amu H^+(or He^+) beam was excited by passage through a thin carbon foil($7\,\mu g/cm^2$).The foil was moved in steps of 200 μm (100 μm) along the beam axis.The light emitted perpendicularly to the ion beam was detected by a spectrometer-photomultiplier combination.A 200 μm (100 μm) spatial resolution was obtained using suitable lenses and slits.

The spectral resolution has been improved by observing the light only from those atoms which have survived in excited states after some time delay.

We report both the observation of narrowed Fourier spectrum lines from a time-delayed quantum beats experiment (in H_α),Fig.1,and alsothe resolution in a time-delayed Stark beats experiment (in HeII,n=4),Fig.2,of two previously overlapping lines.The theoretical analysis and computer simulation of the line profiles are in agreement with the observed linewidth and wing oscillations.

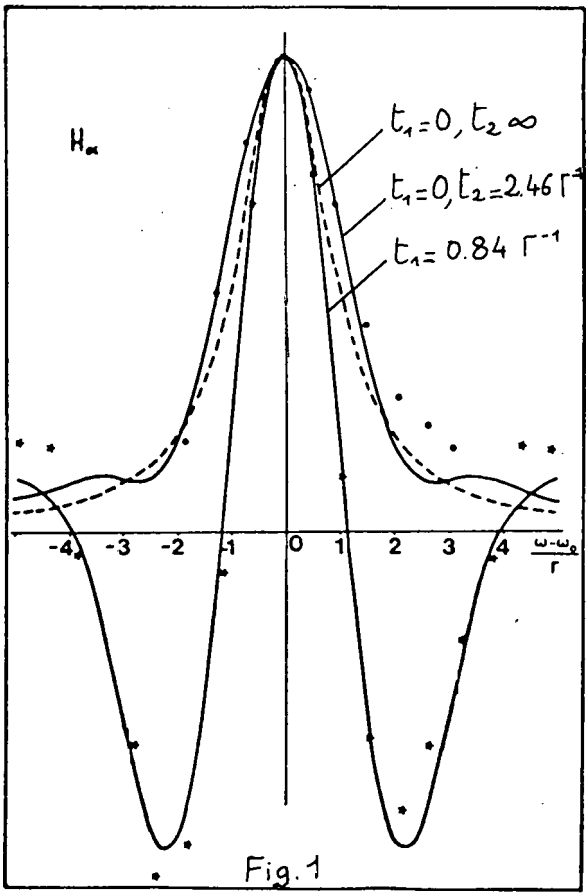

H_α
$t_1=0, t_2\infty$
$t_1=0, t_2=2.46\,\Gamma^{-1}$
$t_1=0.84\,\Gamma^{-1}$
-4 -3 -2 -1 0 1 2 3 4
$\frac{\omega-\omega_0}{\Gamma}$

Fig. 1

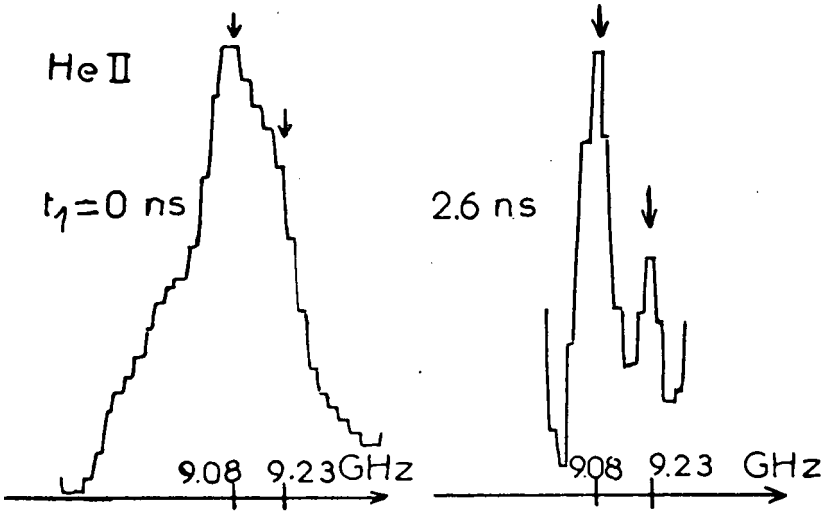

He II
$t_1=0$ ns
9.08 9.23GHz
2.6 ns
9.08 9.23 GHz

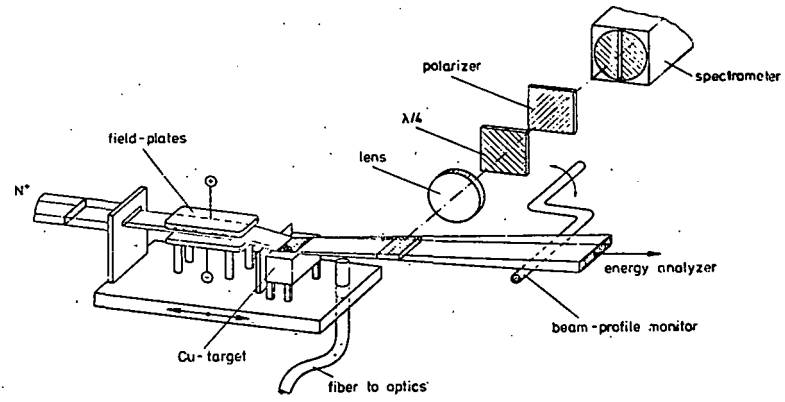
Fig. 2

Hyperfine Structure of ^{14}NII 2p3p $^1P_1$ by Zero Field Quantum Beats After Ion Surface Interaction at Grazing Incidence

H. Winter and H.J. Andrä
Fachbereich Physik der Freien Universität Berlin
Boltzmannstrasse 20, 1000 Berlin 33, W.-Germany

The interaction of fast ions with a surface at grazing incidence (IBSIGI) produces atomic angular momentum states of large orientation (1). In recent publications it was shown that this anisotropy together with the coherent excitation by the ion-solid collision allows the application of IBSIGI for high resolution studies in atomic spectroscopy (2).

In extending the former work we report on zero field quantum beats by observing the emission of circularly polarized light in the ^{14}NII 2p3s $^1P^o$ - 2p3p $^1P_1$ λ = 648,2 nm transition after the excitation by the surface interaction. The experimental setup is shown in fig. 1.



By recording as a function of distance from the target the

right and left hand circularly polarized light (I^-, I^+) we get the quantum beat structure in fig. 2 in the normalized Stokes parameter $S/I = (I^- - I^+)/(I^- + I^+)$.

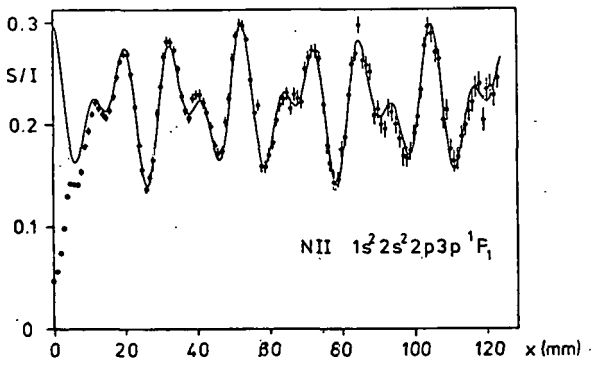


Fig. 2

The structure in fig.2 and a determination of the velocity of ions after the surface interaction results in the hyperfine constants A = 103 MHz and B = 4,6 MHz.

From these constants we deduce a quadrupole moment $Q(^{14}N)$ = 19.3 mb with an error of about 5% which clearly improves the knowledge of $Q(^{14}N)$ extracted from data in molecular physics.

(1) H.J. Andrä, Phys. Letters 54A (1975) 315
H.J. Andrä, R. Fröhling, H.J. Plöhn, and J.O. Silver Phys. Rev. Letters 37 (1976) 1212
H.G. Berry, G. Gabrielse, A.E. Livingston, R.M. Schectman, and J. Desesquelles, Phys. Rev. Letters 38 (1977) 1473
(2) H.J. Andrä, H.J. Plöhn, A. Gaupp, and R. Fröhling, Z. Physik A281 (1977) 15
H.J. Andrä and H. Winter, Hyperfine Interactions 5 (1978) 403

Blank

'Observation of Optical Nutations and Free Induction Decay Measurements of Stark Shifts in Atoms'

M.C. Standage & W.R. MacGillivray

School of Science, Griffith University, Nathan, Queensland, Australia 4111

In this paper we report the use of a pulsed electric field technique to carry out coherent optical transient studies of Rabi nutational effects, and absolute and differential Stark shift measurements in the D_1 and D_2 transitions of atomic sodium vapour. Transient Rabi nutational signals have also been observed in the resonance fluorescence emitted from these transitions.

The sodium vapour contained in a cell fitted with internally mounted electrodes is irradiated by a single-mode c.w. dye laser tuned to resonance with either the D_1 or D_2 transition. The application of an electric field pulse from a high voltage pulsing unit suddenly Stark shifts the set of atoms excited by the laser out of resonance and brings a new set of atoms into resonance. The first set of atoms decay emitting radiation at their new Stark shifted frequency, while the second set of atoms interact resonantly with the laser radiation. Radiation emitted in the forward scattering direction from both sets of atoms heterodynes with the laser field; the atoms shifted off resonance produce an FID signal with a beat frequency equal to the Stark shift caused by the electric field, while the atoms brought into resonance give rise to an optical nutational signal. Selection of suitable experimental conditions allows either signal to be studied in isolation. The signals were recorded using a photo-diode and a high speed oscilloscope. Single-photon counting techniques were used to study transient signals produced in the resonance fluorescence emitted at right angles to the laser beam.

The general form of the coherent optical transient signals can be explained in terms of a quasi-two-level approximation. The optical nutational measurements show the expected dependence of the Rabi frequency on the square root of the laser intensity and the actual value obtained agrees with that calculated from approximate measurements of the laser intensity. The FID measurements of the Na D_1 and D_2 scalar and tensor polarizabilities are in reasonable agreement with previously obtained values and demonstrate the feasibility and high resolution of this technique in Stark effect studies.

The form of the resonance fluorescence transient signals show a marked disagreement with that theoretically predicted for pure two-level atoms. The discrepancy is tentatively attributed to the influence of multi-level effects in the experiment.

QUANTUM BEATS IN FORWARD SCATTERING

J. Mlynek, K.H. Drake, and W. Lange
Institut für Angewandte Physik, Universität Hannover
D-3000 Hannover, Welfengarten 1

It has recently been shown that quantum beats can be observed in forward scattering/1,2,3/. In this technique the time evolution of a coherent superposition of atomic substates excited by a short resonant laser pulse is monitored via changes in polarization of a delayed probe pulse. In a phenomenological description the method makes use of time dependent anisotropic contributions to the complex (linear) susceptibility originating from the coherence and displaying its time development.

In this communication we will primarily report on the observation of single-atom ground state quantum beats in forward scattering/4/. It is shown that coherence between nondegenerate sublevels of an atomic ground state is efficiently induced by means of a short resonant laser pulse. It gives rise to quantum beats in forward scattering of a probe beam, which can sensitively be detected by the technique described in Ref. /1/. As a demonstration a Zeeman quantum beat experiment was performed on the $4f^6 6s^2\ ^7F_1 - 4f^6 6s6p\ ^7F_0$ transition of samarium. By use of a cw probe beam Zeeman quantum beats in the Na ground state were recorded in a single-shot experiment.

The range of applications of the method is discussed as well as the close relationship to coherent Raman beats/5/ and to the 'susceptibility echoes' observed in picosecond spectroscopy/6/.

/1/ W. Lange and J. Mlynek, Phys. Rev. Lett. 40, 1373 (1978).
/2/ W. Lange and J. Mlynek, J.Opt.Soc.Am. 68, 1637 (1978).
/3/ J. Mlynek, F. Mitschke, K.H. Drake, and W. Lange, to be published.
/4/ J. Mlynek and W. Lange, submitted to publication.
/5/ R.L. Shoemaker and R. Brewer, Phys.Rev.Lett. 28, 1430 (1972).
/6/ J.P. Heritage, T.K. Gustafson, and C.H. lin, Phys.Rev.Lett. 34, 1299 (1975).

THE ZEEMAN COHERENCE INDUCED BY THE OPTICAL PUMPING WITH THE MODULATED LIGHT

Krystyna Kolwas
Institute of Physics, Polish Academy of Sciences,
02-668 Warszawa, Al.Lotników 32/46.

It is possible to create atomic Zeeman ground-state coherence in a purely optical way applying an intensity modulated light beam at a frequency Ω close to the Zeeman frequency of atoms ω_0, the beam being circularly polarized and transverse to the static magnetic field $\vec{H}_0$ /$\delta H_0 = \omega_0$/ [1]. In previous papers [2,3] we presented a quantum model of an atom dressed in photons of modulated light. Using this model we have shown, that during the passage with ω_0 through the resonance $\omega_0 \approx \Omega$, the transitions with absorption of Ω frequency take place. The interaction of atoms with the light produces the degeneracy of dressed-atom levels but not of level-crossing type [4]. One can see [3], that the degeneracy takes place for the region of H_0, where the condition:

$$\Omega - 2\omega_1 \leq \omega_0 \leq \Omega + 2\omega_1 \qquad /1/$$

/ω_1 is proportional to the light intensity and the modulation ratio/ is fulfilled.

The fact of the degeneracy of the dressed-atom energy levels is connected with the possibility of the creation of the Zeeman coherence in the atomic system. In the case of two Zeeman sublevels in the ground state we obtain / thermal relaxation with the rate T_2^{-1} taken into account / the mean atomic magnetisation in the plane perpendicular to $\vec{H}_0$:

$$\langle M_\perp \rangle = \langle M_x \rangle + i\langle M_y \rangle , \qquad /2/$$

where:

$$\langle M_x \rangle = u \sin\Omega t - v \cos\Omega t,$$
$$\langle M_y \rangle = -v \sin\Omega t - u \cos\Omega t, \qquad /3/$$

and v i u are lorentzian and dispertion curves:

$$v = \frac{2\omega_1 T_2^{-1}}{(\omega_0 - \Omega)^2 + (T_2^{-1} + T_p^{-1})^2 - 4\omega_1^2} , \qquad /4/$$

$$u = \frac{2\omega_1 T_2^{-1}}{T_2^{-1} + T_p^{-1}} \frac{\omega_o - \Omega}{(\omega_o - \Omega)^2 + (T_2^{-1} + T_p^{-1})^2 - 4\omega_1^2}, \qquad /5/$$

T_p^{-1} is the pumping rate proportional to the light intensity.

As we see the resonance is narrowed by the presence of the erm $4\omega_1^2$. So the optical pumping with the modulated light hortens tha atomic liftime in the ground state in function of the modulation ratio.

References:

1. W.E.Bell, A.L.Bloom; Phys.Rev.Lett.6/1961/280,
2. K.Kolwas, M.Kolwas; Opt.Comm.17/1976/149,
3. K.Kolwas; Opt.Comm.25/1978/387,
4. S.Haroche; Ann.Phys.6/1971/189.

MANY-ATOMS INTERACTIONS EFFECT ON THE SECOND-ORDER CORRELATION FUNCTION OF RAYLEIGH LIGHT SCATTERING BY SIMPLE FLUIDS

K.Knast, W.Chmielowski and S.Kielich
Nonlinear Optics Division, Institute of Physics, A.Mickiewicz University, Grunwaldzka 6, 60-780 Poznań, Poland

The influence of time-dependent interatomic interactions of the second order correlation function $C^{(2)}(t)$ of the electric field of scattered light is analyzed. For comparison the first order correlation /heterodyne/ function $C^{(1)}(t)$ conveys information on the spectral composition of the scattered light intensity, the coherent part of which is related with binary atomic interactions. Assuming atomic motion to conform to the translational diffusion model, we write [1]:

$$C^{(1)}(t) = \langle N\rangle e^{-(\Delta k)^2 Dt} + \langle \varrho\rangle^2 \iint G_2^d(\vec{r},\vec{r}',t)\, e^{-i\Delta\vec{k}\cdot(\vec{r}-\vec{r}')}\, d\vec{r}d\vec{r}', \qquad (1)$$

with $\langle N\rangle$ the mean number of atoms /$\langle\varrho\rangle = \frac{\langle N\rangle}{V}$ /, $\Delta\vec{k}$ the scattering wave vector, and D the translational diffusion coefficient. Eq.(1) results from the irreducible decomposition of the van Hove [2] two-body correlation function $G_2 = G_2^s + G_2^d$, where G_2^s describes autocorrelation of one atom, and G_2^d — mutual correlation of two unlike atoms at positions $\vec{r},\vec{r}'$ in the time interval t.

To calculate the /homodyne/ function $C^{(2)}(t)$, we had recourse to the van Hove four-body correlation function $G_4(\vec{r},\vec{r}';\vec{r}'',\vec{r}''',t)$ consisting of four irreducible parts: $G_4 = G_4^s + G_4^p + G_4^t + G_4^d$, related respectively with time-dependent correlations of one, two, three and four atoms. Our final result is:

$$C^{(2)}(t) = \langle N\rangle^2 \left[1 + e^{-2(\Delta k)^2 Dt}\right] + \langle \Delta N(0)\Delta N(t)\rangle +$$
$$+ \langle\varrho\rangle^4 \iiiint \Big[G_4^p(\vec{r},\vec{r}',\vec{r}'',\vec{r}''',t) + G_4^t(\vec{r},\vec{r}',\vec{r}'',\vec{r}''',t) +$$
$$+ G_4^d(\vec{r},\vec{r}',\vec{r}'',\vec{r}''',t) - F(\vec{r},\vec{r}',\vec{r}'',\vec{r}''',t)\Big] \times \qquad (2)$$
$$\times e^{-i\Delta\vec{k}\cdot(\vec{r}-\vec{r}'+\vec{r}''-\vec{r}''')}\, d\vec{r}d\vec{r}'d\vec{r}''d\vec{r}''',$$

with fluctuation correlation function of the number of atoms given as :

$$\langle \Delta N(0)\Delta N(t)\rangle = \langle N\rangle + \langle\varrho\rangle^2 \iint \left[G_2^d(\vec{r},\vec{r}',t) - 1\right] d\vec{r}d\vec{r}', \qquad (3)$$

and $F(\vec{r},\vec{r}',\vec{r}'',\vec{r}''',t)$ having the meaning of a normalisation factor. Eq.(2) is of more generality than that of Schaefer and Berne [3,4], who took into account only the first two terms assuming a lack of mutual correlations between the molecules. Hence, non-Gaussian corrections arise not only from fluctuations in number of the atoms but also from their mutual radial interactions. In as much as $C^{(1)}(t)$ depends only on two-atom interactions, $C^{(2)}(t)$ is affected moreover by ternary and quaternary interactions and fluctuations in the number of atoms described by Eq.(3). When time-space redistribution processes related with many-atoms interactions [5] are taken into account in considerations of the functions (1) and (2), there appear additional anisotropic compoments, defining the depolarized spectrum of light scattered from simple fluids.

References

[1] Komarov,L.I., Fisher,I.Z., ZhETF,43,1927/1962/.
[2] van Hove,L., Phys.Rev.,95,249/1954/.
[3] Schaefer,D.W., Berne,B.J., Phys.Rev.Lett.,28,475/1972/.
[4] Crosignani,B., Di Porto,P., Bertolotti,M., Statistical Properties of Scattered Light,Academic Press, NY 1975.
[5] Kielich,S.,J. Physique,29,619/1968/; Optics Comm., 4,135/1971/.

Dye Laser Saturation Spectroscopy of the 2^3S_1-2^3P Transition in $^{6,7}Li^+$-Ions

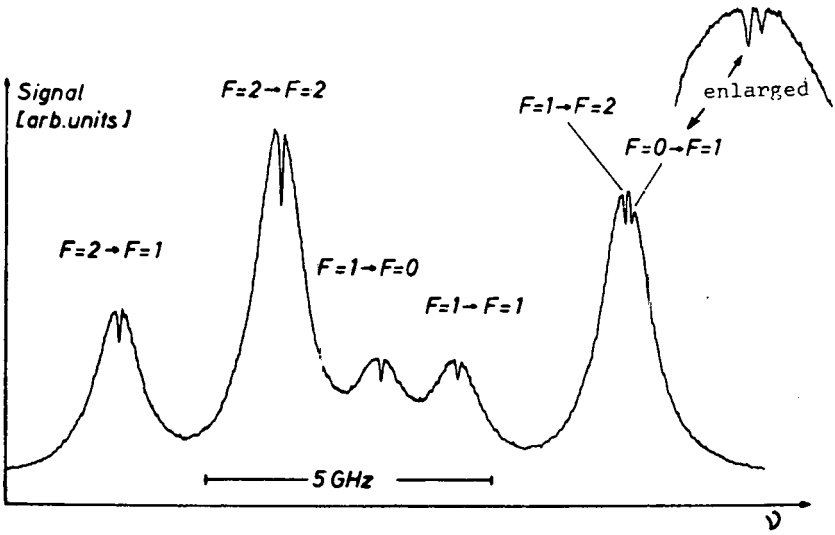
R.Bayer, J.Kowalski, R.Neumann, S.Noehte, H.Suhr, K.Winkler and G.zu Putlitz (Physikalisches Institut der Universität Heidelberg)

The two-electron atom He and the members of its isoelectronic sequence Li^+, Be^{++} etc. represent atomic systems which are regarded fundamental in the sense, that their spectroscopic properties, in particular fine structure (fs) and hyperfine structure (hfs), can be calculated with similar accuracy as those for hydrogen. Except for helium, however, none of these systems has been investigated with greater precision.

This paper reports on a first attempt to investigate the $1s2s^3S_1$ and the $1s2p^3P$ hfs and fs splittings of $^{6,7}Li^+$ with high precision by dye laser saturation spectroscopy. The experimental set up consists of an atomic beam of Li atoms, which are excited by electron impact into the ionic metastable $^3S_1$-level which lies 64 eV above the atomic ground state. The beam of metastable ions with an energy of 200 eV is crossed at right angles by a cw dye laser light beam, which is reflected onto itself in order to produce saturation dips in the 2^3S_1-2^3P transitions at 548.5 nm. Saturation of the transitions is observed via the fluorescent light of the 2^3P-2^3S_1 decay with τ=45 nsec.

About 10^9 sec^{-1} metastable Li^+-ions were detected. An example of a registration of the $^3S_1$-$^3P_1$ hfs transitions is shown in the figure. All hfs transitions for both $^{6,7}Li^+$ isotopes have been observed. Tuning ranges of the dye laser of 60 GHz had to be achieved in order to measure the large fs splittings. The frequency of the dye laser is measured by 1 m confocal interferometer calibrated to one part in 10^5. The Lamb dip widths of about 100 MHz are determined by the time of flight of the ions through the laser beam. For the fs and hfs separations in

both $^{6}Li^{+}$ and $^{7}Li^{+}$ and the isotope shift of the used line measured values with an accuracy of $\sim 10^{-4}$ are obtained so far. These data can be improved by at least two orders of magnitude if radio-frequency techniques are applied in addition.



Resonance fluorescence and Lamb dip signals of the $2^{3}S_{1}$-$2^{3}P_{1}$ transition in $^{6}Li^{+}$.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

BEAM-FOIL SPECTROSCCPY ON DOUBLY EXCITED BERYLLIUM.

T. Andersen, S.M. Bentzen and O. Poulsen
Institute of Physics
University of Aarhus
DK8000 Aarhus C, Denmark.

ABSTRACT

The doubly excited spectra in neutral helium and in higher charged helium-like ions have both been subject to theoretical calculations[1] as well as several experimental investigations using, among others Beam-Foil excitation[2] and laser produced plasmas.[3]

Doubly excited states in Be III have so far only been studied by means of electron spectroscopy[4] identifying many autoionizing levels.

In this work results on doubly excited Be III will be presented using the B-F excitation. Besides populating the BeIII doubly excited levels effectively the B-F technique allows an easy identification of observed transitions on different charge states by measuring relative excitation cross sections as function of incident ion energy. In this experiment the incoming ion energy was varied from 200 to 1000 keV. A number of spectral lines, appearing between 70A and 5000 A have been assigned, thus making possible an identification of the $2p^2\ ^3P$, $2p3p\ ^3P, ^3D$ and the $2pnd\ ^3P, ^3D$ levels.

1) H. Doyle, M.Oppenheimer and S.W.F.Drake, Phys.RevA5, 26(1972)
2) H.G.Berry, Physica Scripta, 12, 5(1975)
3) N.J.Peacock, M.G.Hobby and M.Galanti, J Phys B6, L298(1973)
4) M.Rødbro, R.Bruch and P. Bisgård, to appear in J Phys B

Measurement of the $1s2p^3P_{1,3/2}$-$^3P_{2,5/2}$ splitting in helium-like fluorine by a laser resonance technique

I.A.Armour, N.A.Jelley, E.G.Myers, J.D.Silver and E.Träbert

University of Oxford,
Clarendon and Nuclear Physics Laboratories,
Oxford, England.

H.J.Andrä and P.Kuske
Institut fur Atom und Festkörperphysik,
Freie Universität,
Berlin, West Germany.

A measurement of the $1s2p^3P_{1,3/2}$-$^3P_{2,5/2}$ finestructure splitting in the helium-like ion F^{7+} is in progress. Ions from the Oxford EN Tandem Van de Graaff accelerator are stripped and excited by passage through a thin carbon foil. 10 cm after the foil (i.e. a few nanoseconds later) M1 transitions are induced from the long lived $^3P_{2,5/2}$ state (10.8ns lifetime) to the short lived $^3P_{1,3/2}$ state (0.53ns lifetime) using 300W of 10.6μm radiation from a CO_2 laser. The resonance is scanned by changing the ion beam velocity thus using the Doppler shift to tune the effective frequency of the laser, as described by Andrä et al 1976. Transitions are detected by monitoring the 731 eV X ray decay from $1s2p^3P_1$ to the ground state using proportional counters. We will report on the progress of this experiment, and hope to present a new value for the splitting which will be compared with theoretical predictions

(Schiff et al 1973, Ermolaev and Jones 1973, Aashamar and Hambro 1977).

References

.Aashamar and L.Hambro J Phys B10, 553 (1977)

H.J.Andrä, J.Macek, J.D.Silver, N.A.Jelley and L.C.McIntyre 'Beam-foil Spectroscopy 2' Editors I.A.Sellin and D.J.Pegg, Plenum Press 1976 p877

A.M.Ermolaev and M.Jones supplement to J Phys B7, 199 (1974)

B.Schiff, Y.Accad and C.L.Pekeris, Phys Rev A8, 2272 (1973)

Measurement of the lifetime of the $1s2p\,^3P_1$ state of helium-like magnesium and aluminium

I.A.Armour, E.Träbert, E.G.Myers and J.D.Silver

University of Oxford,
Clarendon and Nuclear Physics Laboratories,
Oxford, England

The results of measurements of the $1s2p\,^3P_1$ lifetimes of helium-like magnesium and aluminium will be presented. The Beam-foil decay curve method was used, to study the intercombination E1 decay to the ground state, with an X-ray spectrometer (see Armour et al (1979)). To reduce possible systematic errors, the measurements for each ion were made for 2 beam energies and 2 observation windows. Values obtained will be compared to the theoretical predictions of Lin et al (1977), Laughlin (1978), and Vainshtein and Safronova (1978).

References

I.A.Armour, S.Bashkin, N.A.Jelley, R.O'Brien, J.D.Silver and E.Träbert, J de Phys 40, C1-211, (1979)

C.Laughlin, J Phys B11, L391 (1978)

C.D.Lin, W.R.Johnson and A.Dalgarno, Phys Rev A15, 154 (1977)

L.A.Vainshtein and U.I.Safronova, Atomic Data and Nuclear Data Tables 21, 49 (1978)

RADIATIVE LIFETIMES OF THE 1s2p $^3P_{2,0}$-LEVELS IN Al XII

B. Denne, S. Huldt, D.J. Pegg[+]. K. Ishii[*]
Department of Physics, University of Lund, S-223 62 Lund, Sweden

R. Hallin, J. Pihl, R. Sjödin
Department of Physics, University of Uppsala, S-751 21 Uppsala, Sweden

[+] University of Tennessee, Knoxville, Tenn., U.S.A.
[*] Department of Engineering Science, Kyoto University, Kyoto 606, Japan.

The electric dipole transitions 1s2s $^3S_1$ - 1s2p $^3P_2$ and 1s2s $^3S_1$ - 1s2p $^3P_0$ in He-like Al (Z = 13) have been observed in a foil-excited beam using the EN Tandem accelerator in Uppsala.

The radiative lifetimes of the 1s2p $^3P_2$ and 1s2p $^3P_0$-levels were measured by taking spectral scans over the lines at different positions downstream the foil. The obtained data points were computer-fitted to a distorted gaussian profile plus a variable background. The intensity was then determined assuming the same line-shape at all distances downstream. The obtained lifetimes will be compared with theoretical calculations.

We also determined the $^3P_2$ - $^3P_0$ fine-structure splitting.

1s2s ^{3}S-1s2p ^{3}P Transitions in Helium-like Silicon

E.Träbert, E.G.Myers, I.Armour and J.D.Silver

University of Oxford,

Clarendon Laboratory, Parks Road,

Oxford, England

and

Nuclear Physics Laboratory, Keble Road,

Oxford, England

Highly ionized silicon atoms have been produced by the beam-foil technique. A 1m normal-incidence spectrometer was used to observe the 1s2s ^{3}S-1s2p $^3P_{0,2}$ transitions which lie in the VUV. Refocussing of the spectrometer (Leavitt, Robson and Stoner 1973) resulted in a reduction of the Doppler width of the spectral lines from 0.6 nm observed in a previous experiment (O'Brien et al 1979) to 0.07 nm. Spectra were recorded for silicon ion energies of 44-50 MeV.

For calibration, wavelengths of Rydberg transitions in Li-like ions were obtained by applying the polarization corrections of Edlén (1979) to the hydrogenic values of Erickson (1977).

The precision of the wavelength determination of the Si XIII 2^3S_1-$2^3P_{0,2}$ transitions is at present limited by the spectrometer scanning mechanism to about ±0.01 nm. This precision corresponds to about 3% of the Lamb shift contribution to the transition energies. The

present experiment and similar experiments are able to test calculations of the 2^3S-2^3P intervals (including the Q.E.D. corrections) for two-electron systems made by Ermolaev, Mohr and others. Present theoretical uncertainties are greater than the experimental ones.

An extension of the measurements to sulphur is in preparation.

Berry H G, DeSerio R, Livingston A E, Phys.Rev.Lett. 41, 1652 (1978).

Edlén B, Physica Scripta 19, 255 (1979).

Erickson G W, J.Phys.Chem.Ref.Data 6, 831 (1977).

Fawcett B C, Atom.Data Nucl.Data Tables 16, 135 (1975).

Leavitt J A, Robson J W, Stoner J O, Nucl.Instr.Meth. 110, 423 (1973).

O'Brien R, Silver J D, Jelley N A, Bashkin S, Träbert E, Heckmann P H, J.Phys.B 12, L41 (1979).

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

On the Possibility of Precise Measurement of the $1s2p\ ^3P_1$-$1s2s\ ^1S_0$ Transition Energy in Helium-like Ions

E.G.Myers and J.D.Silver

University of Oxford,

Clarendon Laboratory, Parks Road,

Oxford, England

and

Nuclear Physics Laboratory, Keble Road,

Oxford, England

Laser resonance measurement of the $1s2p\ ^3P_1$-$1s2s\ ^1S_0$ energy interval of helium-like ions will be discussed. These transitions generally lie in the I.R. and for Z>5 are very sensitive to Q.E.D. corrections. Because the 2^3P_1 level in helium-like ions is longer lived than the $2^2P_{1/2}$ level in hydrogenic ions, this transition has a smaller natural linewidth than the $2^2P_{1/2}$-$2^2S_{1/2}$ Lamb shift transition in the hydrogenic ion of the same Z. Consequently a much higher fractional precision may be obtained for the 2^3P_1-2^1S_0 interval than may be obtained for the $2^2P_{1/2}$-$2^2S_{1/2}$ hydrogenic transition. Such measurements represent a high precision test of calculations of energy levels in two-electron atoms, and in some cases may be capable of testing Q.E.D. energy corrections to a higher precision than is achievable in Lamb shift measurements in hydrogenic ions.

A fast-beam laser resonance experiment to measure the 2^3P_1-2^1S_0 transition energy in N VI and other experiments are proposed.

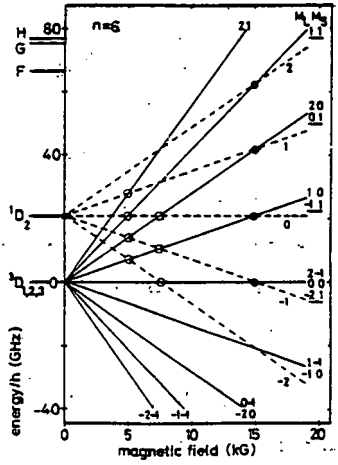
ELECTRIC-FIELD-INDUCED SINGLET-TRIPLET ANTICROSSINGS IN He

H-J. Beyer

Institute of Atomic Physics
University of Stirling, Stirling, Scotland

Some years ago singlet-triplet intervals in He were measured for the first time in a direct way using singlet-triplet anticrossing signals. Results were obtained for the n^1D-n^3D intervals (n=3 to n=20)[1-5] which were much superior to previous optical values[6] and could be used to make a sensible comparison with theoretical values[7]. No external perturbation was required, the coupling at the crossing of suitable Zeeman substates (marked by full circles in Fig.1) being provided by the off-diagonal spin-orbit operator H_3^1[1]. In reality the 4 singlet-triplet anticrossings are not exactly degenerate as a result of differing contributions from the relativistic fine structure of the ^3D state, from the quadratic Zeeman effect and from shifts caused by motional and stray electric fields. Furthermore, the internal coupling is strong and drives the signals well into saturation. Therefore, only a single, very broad structure was observed (FWHM 400G, 560MHz for n=6[5]) and attempts to extract the 4 anticrossing components failed.

This shortcoming of the singlet-triplet anticrossings can be overcome by application of a static electric field (perpendicular to the magnetic field) which, acting together with the spin-orbit coupling, converts the crossings marked by open circles in Fig.1 into electric-field-induced singlet-triplet anticrossings. The coupling is at least of third order, and in all cases but one a coupling path $^1D \xrightarrow[\text{el.}]{} {}^1F \xrightarrow[\text{s-t}]{} {}^3F \xrightarrow[\text{el.}]{} {}^3D$ is allowed by the selection rules. The amount of coupling can be controlled by the electric field, and it is possible to stay well below saturation with a corresponding reduction of the signal width. The separation of the anticrossing components is further helped by their greatly differing Stark shifts. In the experiment the excited states are produced by electron impact and the signals



are detected as intensity changes of either the $n^1D \rightarrow 2^1P$ or $n^3D \rightarrow 2^3P$ transition lines.

First results[8] indicated that these signals would not only provide proved values for the singlet-triplet intervals, but also allow the measurement of the constants A and b of the relativistic fine structure of the ^3D states and of the magnetic susceptibility χ_A. In addition, the extrapolation of the crossing positions to zero electric field is equivalent to a measurement of the Stark effect of the 2 crossing states.

A detailed study of the electric-field-induced singlet-triplet anti-crossings $6^1D - 6^3D$ has been carried out using a new system with an improved Stark plate arrangement, which resulted in a reduction of the signal width by approximately a factor of 2 over the old system[8]. The signal width is found to depend on the electric field strength and the Stark constants. It is typically of the order of 10 G (~ 40 MHz), still about one order of magnitude larger than the natural width. The excessive width is probably caused by motional electric fields and for this reason the signal shapes are no longer Lorentzian. The amplitudes of the signals differ widely and depend on the excitation conditions. The measured Stark shifts agree to at least a few percent with the values calculated on the basis of hydrogenic eigenfunctions. Together, the crossing positions, extrapolated to zero electric field, provide an overdetermined system of equations for the ^1D-^3D interval and the constants A, b and χ_A. Results will be reported.

References

1. T.A. Miller, R.S. Freund, F. Tsai, T.J. Cook and B.R. Zegarski, Phys. Rev. A9, 2474-84 (1974).
2. T.A. Miller, R.S. Freund and B.R. Zegarski, Phys. Rev. A11, 753-7 (1975).

H-J. Beyer and K-J. Kollath, J. Phys. B8, L326-30 (1975).

H-J. Beyer and K-J. Kollath, J. Phys. B9, L185-88 (1976).

5. J. Derouard, R. Jost, M. Lombardi, T.A. Miller and R.S. Freund, Phys. Rev. A14, 1025-1035 (1976).
6. W.C. Martin, J. Phys. Chem. Ref. Data 2, 257-66 (1973)
7. T.N. Chang and R.T. Poe, Phys. Rev. A10, 1981-85 (1974) and Phys. Rev. A14, 11-17 (1976).
8. H-J. Beyer and K-J. Kollath, J. Phys. B 10, L5-L9 (1977)

FORBIDDEN SINGLET-TRIPLET ANTICROSSINGS IN ^3He : PRECISE DETERMINATION OF n^1D-n^3D (n = 3 - 6) INTERVALS.

Jacques DEROUARD, Maurice LOMBARDI, Rémy JOST

Laboratoire de Spectrométrie Physique, Université Scientifique et Médicale de Grenoble, B.P. 53 X - 38041 GRENOBLE CEDEX - France -

---

Anticrossings in ^4He have been used for the experimental measurement of n^1D-n^3D as well as nD - nF, G, H ... intervals. Concerning the n^1D-n^3D separations, direct spin-orbit singlet triplet couplings were first used ; then electric field singlet triplet induced couplings provided more precise determinations, as the resulting signals were narrower.

We have observed in ^3He same forbidden, narrow anticrossings signals due to the conjonction of fine and hyperfine interaction, which have no equivalent in ^4He. That give precise values for the electrostatic n^1D-n^3D separation in ^3He.

An unexpected large ($\sim 10^{-3}$), negative isotope shift is found compared to the ^4He equivalent values.

The experimental procedure is identival as previous ones, although the homogeneity of the magnetic Bitter coil was considerably improved, allowing the field to be driven by a NMR probe with a precision of 10^{-5}.

The deconvolution of the signals involves two steps :

- first least square analysis of the experimental curves considered as the superposition of four Lorentzian shapes
- secondly entire diagonalization of the ^3He Hamiltonian inside the D subspace, as a function of the magnetic field.

^{3}He this work	^{4}He anticrossing measurement	R.F. measurement ^{4}He
n 3 102125 ± 10	102100 ± 200[a]	
4 58985 ± 10	59036 ± 80[a]	
5 34021 ± 15	34066.3 ± 7.2[b]	
6 20893 ± 25	20918.0 ± 9.2[b]	
7	13632.8 ± 5.3[b]	13633.8 ± 0.3[c]

n^1D-n^3D electrostatic interval (MHZ)

[a] Derouard et al, Phys. Rev. A 14, 1025 (1976)

[b] Beyer and Kollath, J. Phys. B 10, L 5 (1977)

[c] Mac Adam and Wing, Phys. Rev. A 12, 1464 (1974).

CASCADE-LEVEL-CROSSING INVESTIGATIONS ON HE I-LEVELS

S.Aynacioglu, G.v.Oppen, W.Schilling, D.Szostak, A.Wolf

Institut für Strahlungs- und Kernphysik
Technische Universität Berlin, Rondellstr.5, D-1000 Berlin 37

Noble-gas ion-impact excitation of 1snd→1s2p transitions in He I has been used in order to perform level-crossing measurements on the 1snf-states (n=4,5). Beside direct excitation of the 1snd-levels, cascade-excitation through 1sng- and 1snf-levels contributes significantly to the observed transitions as has been discussed earlier (EGAS 1978). With regard to cascade-level-crossing investigations, a strong polarization and coherence transfer from cascade levels to the observed fluorescence line is essential. For Ne^+-impact excitation the polarization of the n'D → 2'P fluorescence-lines is largely produced by cascade processes as indicated in fig. 1 for 3'D. In particular at an ion energy of 16.7keV, the polarization of the fluorescence line is produced completely by cascade processes. Two such energies (at 15.7keV and 19.6keV) have been found for the 4'D-2'P transition.

Ne^+-excitation at these energies has been used in order to investigate the electric field splitting of the 4 and 5 ^1F levels using level crossing techniques. To this end we investigated the magnetic depolarization of the 3 and 4 'D-2'P-transitions at different electric field strengths($\vec{\mathcal{E}} \parallel \vec{\mathcal{H}} \perp$ ion beam $\perp$ direction of observation). A signal at $\mathcal{E}$=182V/cm is shown in fig. 2. The electric field strength is chosen such that the level crossings of the F-levels usually occurir at zero-magnetic field are shifted to non-zero field strengths, but (in regard to a sufficient coherent transfer) not too far beyond the half width of the 3'D magnetic depolarization signal. Due to the much smaller tensor polarizability, the 3'D-level remains approximately unaffected by the electric field. Some measured tensor polarizabilities are shown in table 1.

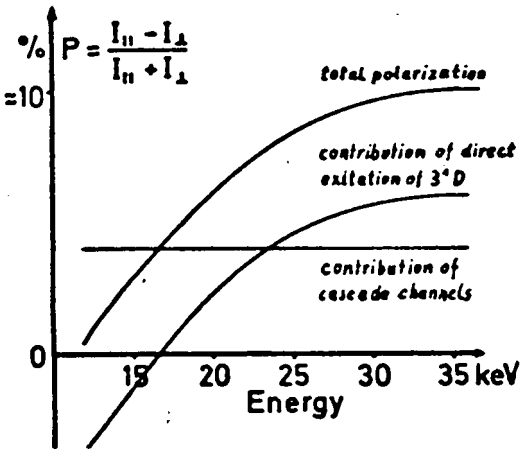


Fig.1: Coarse plot for the dependence of the polarization of the $3^1D - 2^1P$-fluorescence line on the Ne^+-ion energy as inferred from magnetic and electric depolarization signals.

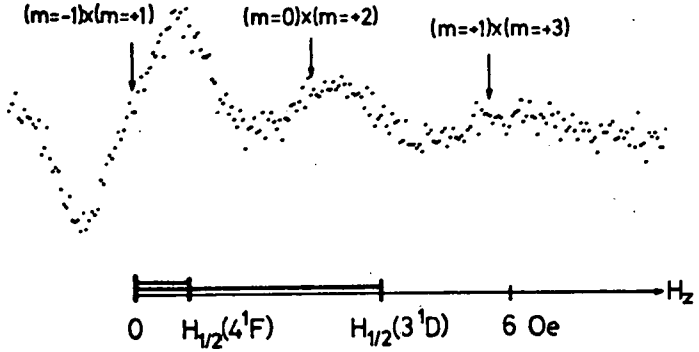


Fig.2: Cascade-level-crossing signals of 4^1F at ε_Z=182V/cm

Level	$\lvert\alpha_{ten}(n\,^1L)\rvert$	$\lvert\alpha_{ten}(n\,^1F)/\alpha_{ten}(n\,^1D)\rvert$
3^1D	12,3	
4^1D	421	
5^1D	2580 ±3%	
4^1F	557	1.32(1)
5^1F	4080	1.60(5)

Table 1: Tensor polarizabilities of He I in $Hz/(V/cm)^2$ (evaluated under the assumption $g_J = 1$)

HIGH RESOLUTION SPECTROSCOPY IN HELIUM

E. GIACOBINO, E. DECLERCQ, F. BIRABEN, G. GRYNBERG[+] and B. CAGNAC

Laboratoire de Spectroscopie Hertzienne de l'ENS - 4, place Jussieu - 75230 Paris cedex 05

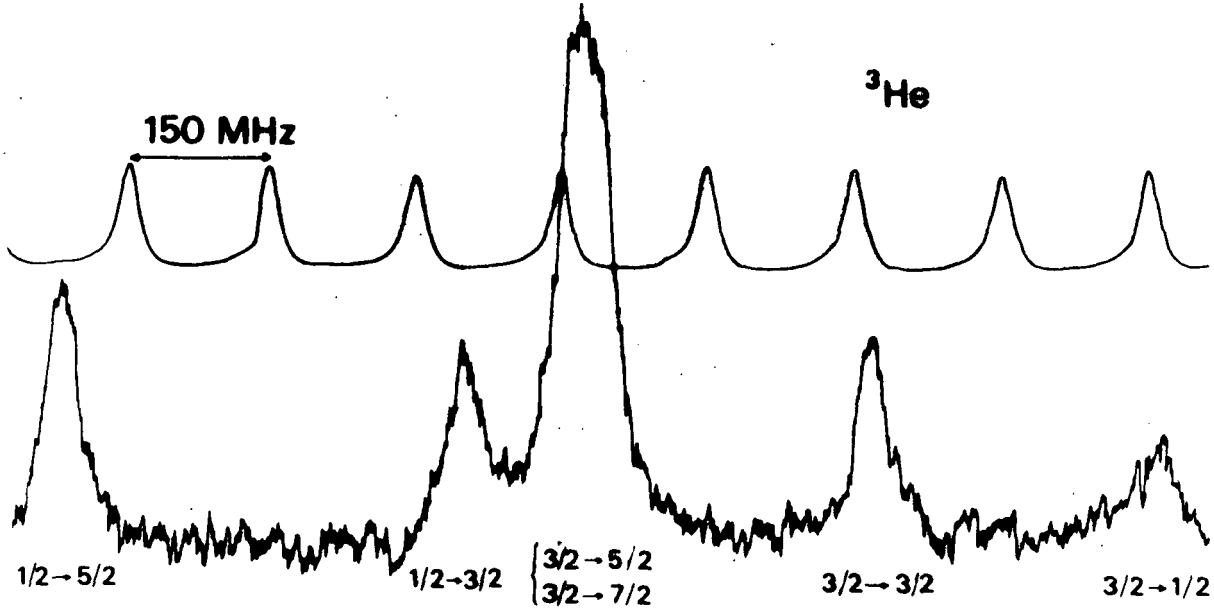
[+] Laboratoire d'Optique Quantique - Ecole Polytechnique - 91128 Palaiseau cedex France.

Although helium is of fundamental theoretical interest, only a limited number of experiments have been performed up to now on the even states, especially on the S states. In particular, the isotope shifts and hyperfine structure constants are rather poorly known (except in the metastable 2^3S state).

Using Doppler-free two-photon absorption starting from the metastable 2^3S state, we are able to excite these levels and obtain directly the values of the hyperfine structures and isotopic shift with an accuracy of a few MHz.

The helium atoms are excited in the 2^3S state using a chopped discharge. Then they are excited to other S or D states by absorbing two photons from a cw monomode laser. Indeed the cell containing the atoms is placed in the standing wave produced inside a Fabry-Perot cavity. This cavity is piezo-electrically tuned to the laser wavelength. The fluorescence light emitted from the level under investigation is detected sidewards during the afterglow and recorded as the laser wavelength is scanned.

The adjacent figure shows a recording of the two-photon spectrum of ^3He for the transition $2^3S - 4^3D$. All the hyperfine components allowed by the selection rules of two-photon excitation are present. As we know the hyperfine structure of the 2^3S state such a recording permits to deduce accurate values of the hyperfine intervals in this level.



Recording of the $2^3S \rightarrow 4^3D$ Doppler-free two-photon spectrum in ^3He. The initial (F_i) and final (F_e) hyperfine states are indicated under each component. The intensities of the components are proportional to $(2F_e + 1)$. The frequency scale (abcissa) is given by the transmission peaks of a Fabry-Perot (top recording).

Blank

Non resonant multiphoton ionization of metastable states of helium.

Mireille AYMAR and Michèle CRANCE

Laboratoire Aimé Cotton, C.N.R.S. II, Orsay, France.

One generally considers that non resonant multiphoton ionization can be described only with a cross section calculated by perturbation theory in the first non vanishing order. However for strong field this description has to be questioned.

We have investigated multiphoton ionization (2-photon or 3-photon processes) for helium atoms in the $2\,^1S$ and $2\,^3S$ metastable states. In each studied case, the ionization probability is calculated in the framework of dressed atom, by diagonalizing the hamiltonian of the system atom + field on a restricted basis. The dressed atom is built with a few s, p, d and f discrete atomic levels ; the contribution of highly excited and continuum s, p, d, f levels is taken into account by introducing effective operators between the discrete levels of the restricted basis.

The atomic parameters are computed within the framework of a single-particle model (non relativistic) using a central potential. We have utilized an analytic potential depending on 3 parameters. Two different potentials have been determined for singlet and triplet systems by comparing the experimental energies of excited levels to the zero-order calculated ones.

As expected for weak fields, (weaker than 1 G W/cm^2) we find again the results of perturbation treatment in the first non vanishing order [1]. For strong field (160 G W/cm^2) our results are in good agreement with recent experimental data obtained in the Saclay group by Mathieu et al. [2].

[1] T. Olsen, P. Lambropoulos, S. E. Wheatley and S. P. Rountree J. Phys. B (Atom. Molec. Phys.) 11 (1978) 4167.

[2] B. Mathieu, Thèse, Paris

STUDY OF HIGHER ORDER ANTICROSSING SIGNALS IN He^+, n=4

G.G. Tepehan*, H-J. Beyer and H. Kleinpoppen

Institute of Atomic Physics
University of Stirling, Stirling, Scotland

Multistep dipole transitions have been employed on several occasions for direct investigations of fine structure intervals with $\Delta L > 1$ in hydrogenic systems. Both, multiphoton (microwave) transitions and higher order electric field induced anticrossing signals have been used. (See review in Ref.1 and Ref.2,3). Even though these signals require a larger electric field strength than first order transitions and are, therefore, subject to Stark shifts, they nevertheless should ultimately provide very accurate fine structure results, partly since short lived P states can be avoided by observing intervals like S-D, S-F and partly since the intervals themselves are larger and a certain level of absolute accuracy corresponds to a higher level of relative accuracy.

From the higher order anticrossing signals of He^+ states, the 4S-4D and 4S-4F signals provide the best signal to noise ratio and therefore appear most suited for a precision study. These anticrossing signals are observed as intensity or polarisation change in the transition line complex from n=4 to n=3 at 4686 Å, when the magnetic field is varied through appropriate crossings with a static electric field applied perpendicular to the magnetic field. The excited states of n=4 are produced by electron impact excitation, and a monochromator or an interference filter is used to isolate the spectral line.

The system has been redesigned to give a better defined and more homogeneous electric field over the interaction region and to allow the variation of the He pressure. A large number of data has been collected as a function of the electric field, the gas pressure (1 - 15 mTorr), the excitation energy (250 - 350V), the excitation current (150 - 500μA). The signals have been fitted using a six parameter Lorentz function with combined absorption and dispersion components. The signals observed were $\alpha J(4^2S_{1/2},\ m_j=1/2 - 4^2D_{3/2},\ m_j=-3/2)$, $\alpha G'(4^2S_{1/2},\ m_j=1/2 - 4^2F_{7/2},\ m_j=-5/2)$ $\beta H'(4^2S_{1/2},\ m_j=-1/2 - 4^2F_{7/2},\ m_j=-7/2)$, $\alpha N'(4^2S_{1/2},\ m_j=1/2 - 4^2F_{5/2},\ m_j=-5/2)$

*On leave of absence from Department of Atomic and Nuclear Physics, Faculty of Science, University of Istanbul, Istanbul, Turkey.

$\alpha E(4^2S_{1/2}, m_j=1/2 - 4^2D_{5/2}, m_j=-3/2)$. All experimental parameters apart from the electric field were found to have relatively minor effects on the signals. As in earlier measurements[4] the signal positions were extrapolated to zero electric field and this constitutes a measurement of the non-linear low field Stark effect. Owing to the improved accuracy of the electric field, closer error limits can be given for the Stark constants which are in general nearer to the theoretical values than the previous results.

It was found that no general conclusion valid for all signals can be drawn regarding the pressure effects. The Stark constant of αJ shows a noticeable change with pressure, but the other Stark constants are little affected. The signal amplitudes (for fixed electric field) tend to show a broad maximum at around 8 mTorr for $\alpha G'$, $\beta H'$ and little change in the other signals. The signal width usually alters in the opposite way to the amplitude.

The extrapolated crossing positions and thus the fine structure intervals are little affected by the pressure even if the Stark constant changes as in the case of αJ. Single measurements of the crossing positions show statistical uncertainties of the order of 0.3 G and are consistent with previous results[4]. Yet within their respective error limits they do not agree with the theoretical values[5] by ~1G. The research for possible further systematic effects is being continued.

References

1. H-J. Beyer, in Progress in Atomic Spectroscopy, Ed. W. Hanle and H. Kleinpoppen (Plenum Press, New York, 1978) pp 562-565, 583-584.

2. M. Glass-Maujean, L. Julien and T. Dohnalik, J. Phys. B11, 421-430 (1978).

3. B.O. Clark, D.A. van Baak, S.R. Lundeen and F.M. Pipkin, Phys. Lett. 64A, 172-174 (1977).

4. H-J. Beyer and H. Kleinpoppen, J. Phys. B4, L129-32 (1971) and J. Phys. B5, L12-15 (1972), H-J. Beyer, H. Kleinpoppen and J.M. Woolsey, J. Phys. B6 1849-55 (1973).

5. G.W. Erickson, J.Phys. Chem Ref. Data 6, 831-869 (1977).

THEORETICAL STUDY OF HANLE EFFECT FOR TWO HELIUM LINES: APPLICATION TO MEASUREMENTS OF MAGNETIC FIELDS IN SOLAR PROMINENCES.

V. BOMMIER and S. SAHAL-BRECHOT,

Département d'Astrophysique Fondamentale,
Observatoire de Paris-Meudon,
92190 MEUDON, FRANCE.

The general aim of this work is the determination of magnetic fields in astrophysical plasmas. This can be done by interpreting polarization line measurements. Usually, in astrophysics, one uses the Zeeman effect: the circular polarization degree of the observed line is related to the component of the magnetic field along the direction of observation. In this work, we use the Hanle effect, which relies the linear polarization parameters to the magnetic field, for the first time in astrophysics. In the present work, linear polarization measurements of the helium D_3 line 5876 Å ($3d\,^3D \rightarrow 2p\,^3P$) of solar prominences, performed by J.L. Leroy at the Pic-du-Midi Observatory, are interpreted.

Without magnetic field, a prominence line must be partially linearly polarized, with its direction of polarization parallel to the solar limb, owing to the scattering of anisotropic incident light coming from the photosphere. In fact, the observed direction of polarization is rotated with respect to the solar limb, and the polarization degree is smaller than expected by simple scattering theory; this indicates the presence of a magnetic field.

Aiming to rely quantitatively the measurements to the magnetic field, we have calculated the linear polarization parameters of the triplet helium lines of solar prominences as functions of the magnetic field. We will present the results of this calculation, after having recalled the mechanisms of formation of these lines in solar prominences. The method of calculation, which uses the formalism of density matrix to describe atom and photons, will be briefly described. We will show the effect of level-crossing and anti-level-crossing of Zeeman sublevels on the Hanle effect of the D_3 line.

.../...

The interpretation of polarization measurements of D_3 line with our calculations has now begun; but two components of the magnetic field are obtained because two polarization parameters are measured; in a first approach, the magnetic field is assumed to be horizontal, which is rather probable for various reasons. Therefore, we will show how "perspective" effects of solar rotation added to simultaneous measurements of two lines, for instance He 5876 Å and He 10830 Å ($2p\,^3P \rightarrow 2s\,^3S$) which we have calculated, or of the two components of He 5876 Å, could give the three components of the field, which is the interest of this method, which is developed for the moment by astronomers.

References:

J.L. Leroy, G. Ratier, V. Bommier, Astron. and Astroph., 54, 811, (1977).

V. Bommier, S. Sahal-Bréchot, Astron. and Astroph., 69, 57, (1978).

S. Sahal-Bréchot, V. Bommier, J.L. Leroy, Astron. and Astroph., 59, 223, (1977).

V. Bommier, S.Sahal-Bréchot, Proceeding of the IAU Colloquium n°44 "Physics of solar prominences", Oslo 14-18 August 1978, P. 87

V. Bommier, id., P. 93

MEASUREMENT OF THE LIFETIME AND H.F.S. CONSTANT OF SOME ^{3}He EXCITED LEVELS BY USING THE ELECTRONIC ORIENTATION TRANSFERED FROM NUCLEAR ORIENTATION IN ^{3}He GROUND STATE

J.P. BARRAT - UNIVERSITE DE CAEN - U.E.R. de SCIENCES - CAEN, France.

J. HAMEL, H. LEMERY - UNIVERSITE DE CAEN, Laboratoire de Spectroscopie Atomique, associé au CNRS n° 19 - CAEN, France.

This paper describes a method, proposed by F. Laloë, for measuring the lifetime and hyperfine structure of some excited levels of ^{3}He.

Metastable (2^3S_1) He are produced by a R.F. discharge in a spherical cell containing ^{3}He at a pressure of about 0.2 torr. The metastable He atoms are oriented by optical pumping. The hyperfine structure coupling transforms the electronic orientation into a nuclear orientation. Metastability transfer collisions between He atoms in the 2^3S_1 state and in the ground state transfers this nuclear orientation into the ground state of ^{3}He. The R.F. discharge populates the various excited levels of helium without destroying the orientation of the nuclei. As long as the Zeeman splitting is smaller than the hyperfine splitting, the hyperfine interaction in the excited levels couples the electronic angular momentum with the nuclear spins, so that electronic orientation is again created in these levels [1]. If ground state helium atoms are submitted to magnetic resonance, at the frequency N_0 = 3.24 KHz/gauss, the nuclear spins precess coherently at the frequency N_0 around the static magnetic field $\vec{H}_0$. The transverse electronic orientation, induced into an excited level, is thus modulated at N_0. If the magnetic field is low, the free Larmor precession angle in the excited level is negligible during its lifetime, so that the stationary transverse electronic orientation of the level also precesses at the frequency N_0. On the other hand, if the magnetic field is high enough, so that the Zeeman splitting is larger than the natural width of the level, the Larmor precession angle during the lifetime is large and the stationary transverse electronic orientation vanishes. This electronic orientation is monitored by the modulation of the circularly polarized light emitted in a direction perpendicular to $\vec{H}_0$. The variation of the modulation amplitude with the frequency allows then a measurement of the lifetime of the excited level.

A modulation of the light can be again observed in the vicinity of a level crossing ($\Delta M_F = \pm 1$). The determination of the level crossing position gives a measurement of the excited level hyperfine structure constant.

The lifetime and H.F.S. constant of the 3^1D_2 and 4^1D_2 He levels have been already measured [1], [2], [3], [4]. We have computed the expected variation, with the magnetic field $\vec{H}_0$, of the modulation amplitude of the light emitted from these levels at 6678 Å $[2^1P_1-3^1D_2]$ and 4923 Å $[2^1P_1-4^1D_2]$, using these previously determined values.

The preliminary experiments on the 3^1D_2 and 4^1D_2 levels of He are in good agreement with the theoretical previsions.

We hope, with this method, to improve the accuracy with which the lifetimes and H.F.S. constants of these levels are known. We also hope to extend this experiments to other helium singulet levels and, perhaps, to some triplet levels.

The authors are indebted to Dr F. Laloë for the suggestion of this experiment and for many helpful discussions. They also thank Dr. F. Laloë for the loan of a large part of the experimental apparatus.

[1] M. Pavlovic ; F. Laloë. Jour. Phys. 31 (1970) 173.

[2] J.P. Descoubes. Thèse Paris (1967)
C.R. Acad. Sci. (1964) 259, 327 ; (1964) 259, 3733 ; (1965) 261, 916.

[3] M. Maujean, J.P. Descoubes C.R. Acad. Sci. (1967) 264, 1653.

[4] D. Dily ; J.P. Descoubes C.R. Acad. Sci. (1971) 19, 272

Still Higher Precision Measurement of Muonium hfs and the Muon Magnetic Moment

W.Beer, P.R.Bolton, P.O.Egan, K.Gardner, V.W.Hughes, D.C.Lu, F.Mariam, U.Moser, P.A.Souder and J.Vetter (Yale University, New Haven, CT 06520, USA)

H.Orth and G.zu Putlitz (Universität Heidelberg, D-6900 Heidelberg)

Measurement of the muonium (μ^+e^-) hyperfine interval, $\Delta\nu$, is an important benchmark for the theory of the electromagnetic interaction (QED). Since both interacting particles are leptons, the value of $\Delta\nu$ can, in principle, be determined precisely by QED without strong interaction corrections. In addition, the electron-muon interaction provides an important test of lepton universality.

The theoretical expression for $\Delta\nu$ can be written

$$\Delta\nu_{TH} = \frac{16}{3}\alpha^2 R_\infty c(\mu_\mu/\mu_p)(1+QED) \qquad (1)$$

To compare this value with experiment requires a knowledge of the fundamental constants α, R_∞ and c, the muon magnetic moment, and the QED corrections. Recent theoretical work [1] has brought the uncertainty in the QED corrections to the level of ~1 ppm, and work is in progress to further reduce this uncertainty.

We have recently completed an experiment at LAMPF which will yield extremely precise values for <u>both</u> $\Delta\nu$ <u>and</u> μ_μ/μ_p. Our preliminary analysis indicates that the measured uncertainty will be ~0.03 ppm for $\Delta\nu$ and 0.4 ppm for μ_μ/μ_p, a fourfold improvement over our previous results. [2]

The major basis for the improvement in accuracy was the development of a high-flux, 28 MeV/c "surface" μ^+ beam [3], which provides an unprecedented muonium formation rate in a thin (50 mg/cm^2) krypton target. The measurement technique is iden-

tical to that used in our previous work. Polarized muonium, formed in a 0.5 atm Kr target in a strong (1.36 T) magnetic field, is depolarized by microwave-induced Zeeman transitions. The change in polarization is observable through the electron decay asymmetry. The two resonance transitions corresponding to the two muon spin-flip transitions $(M_J, M_\mu) = (\frac{1}{2}, \frac{1}{2}) \leftrightarrow (\frac{1}{2}, -\frac{1}{2})$ and $(-\frac{1}{2}, \frac{1}{2}) \leftrightarrow (-\frac{1}{2}, -\frac{1}{2})$ are measured concurrently. The sum of the two resonance line centers yields $\Delta\nu$ directly, while the difference yields the muon moment.

Figure 1 shows a typical resonance line shape obtained with our apparatus in about 3 hours. Our experiment consists of ~ 100 such resonance lines.

Our measurement of $\Delta\nu$ and μ_μ/μ_p will provide a clear test for further theoretical progress in Eqn. 1. Also, once the theoretical corrections are well-understood, our results could be used to determine α, the fine structure constant, to a precision comparable to that obtained by measurement of the a.c. Josephson effect and the electron g-2 value.

[1] G.P.Lepage, Phys.Rev. A16, 863 (1977); G.T.Bodwin, D.R. Yennie, and M.A.Gregorio, Phys.Rev.Lett. 41, 1088 (1978); W.E.Caswell and G.P.Lepage, Phys.Rev.Lett. 41, 1092 (1978).

[2] D.E.Casperson, et al., Phys.Rev.Lett. 38, 956 (1977).

[3] H.-W.Reist, et al., Nucl.Instr. and Meth. 153, 61 (1978).

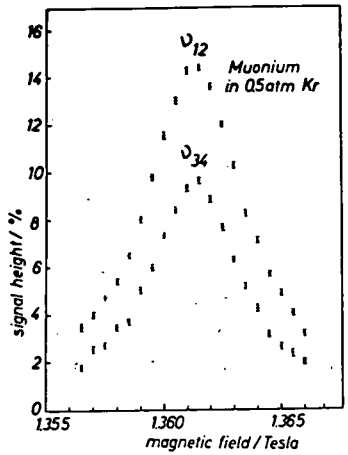


Figure 1
Typical muonium resonance lines for the muon spin-flip transitions ν_{12} and ν_{34}. The signal is defined as the change in the decay electron rate as the microwave transition frequency is switched on and off.

Measurement of the Ground State Hyperfine Structure in Muonic Helium $\alpha\mu^-e^-$

K.P.Arnold, P.O.Egan, M.Gladisch, W.Jacobs, H.Orth, G. zu Putlitz, W.Wahl, M.Wigand; Universität Heidelberg, 69 Heidelberg
V.W.Hughes, J.Vetter; Yale University, New Haven, CT 06520

The neutral muonic helium atom $\alpha\mu^-e^-$ is an interesting system because it provides the unique possibility to study the interaction of the negative muon with an atomic electron. The quantity most accessible to experiment is the hfs in the ground state. It arises from an unusual type of contact interaction between the electron and the "pseudonucleus" formed by the muon orbiting the α particle. Though the radius of this muonic nucleus (130 fm) is large compared to nuclear dimensions it is quite small by atomic standards. Hence the electronic structure of $\alpha\mu^-e^-$ is hydrogenic and the hfs splitting $\Delta\nu$ is roughly similar to muonium.

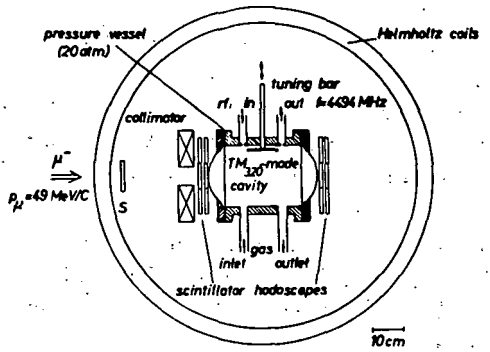
A variational calculation has been performed /1/ to determine the wave function for this three-body system. Including corrections to the energy levels due to QED it yields $\Delta\nu$= 4494.1 MHz. This is in very good agreement with the simple assumption of two hydrogenic wavefunctions for the muon and the electron, moving in the field of a nucleus with Z=2, $M=m_\alpha$ for the muon and Z=1, $M=m_\alpha+m_\mu$ for the electron, respectively.

An experiment to measure $\Delta\nu$ was carried out at the Schweizerisches Institut für Nuklearforschung (SIN). The apparatus used is shown in the figure. Muonic helium with a residual polarization of 1.7% is formed in a magnetic field < 20mGauss by stopping polarized negative muons in a gas target of 20 atm He+1.5% Xe /2/. Applying an rf-field at the hfs frequency destroys the polarization which can be detected by a change in the counting rate of the μ-decay electrons. In our

apparatus the resonant hfs transition is indicated by an enhancement of the decay electron rate with microwaves "ON" in the upstream scintillation counter and by a decrease in the downstream scintillation counter. We have observed a 6 standard deviation effect in the counting rate for each telescope at $\Delta\nu$(2o atm)=4465.2(o.5) MHz. The error quoted here is in the order of one line width of the resonance. An at least five times better precision is expected when the data are completely analysed.

The value for $\Delta\nu$ of $\alpha\mu^-e^-$ contains a pressure shift contribution due to the buffer gas. From observation of the muonium hfs resonance in the same target gas and with the assumption of the pressure shift to be the same for $\Delta\nu$ in $\alpha\mu^-e^-$ than in μ^+e^- we get $\Delta\nu(\alpha\mu^-e^-)$=4464.9(o.5) MHz. This result differs by 3o MHz from initial theoretical calculations. The discrepancy must be attributed to an incomplete description of the unusual type of atomic structure of the $\alpha\mu^-e^-$ pseudo hydrogen atom. Presumably effects connected to the polarizability of the muon distribution are much larger than previously expected.

/1/ K.N.Huang, PH.D.Thesis, Yale University (1974)
/2/ P.A.Souder et al., Phys. Rev. Lett. 34, 1417 (1975)



Schematic view of the ($\alpha\mu^-e^-$)-apparatus

SUBNATURAL LINEWIDTH RESOLUTION OF 2 $S_{1/2}$ AND 2 $P_{1/2}$ LEVEL CROSSINGS OF HYDROGEN IN A MAGNETIC FIELD

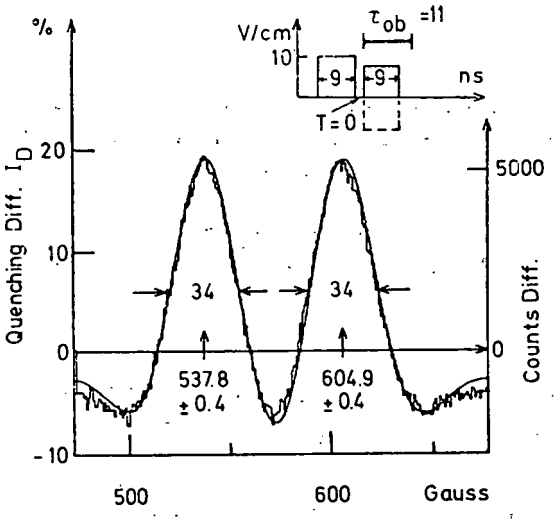
W. Hartmann and A. Oed
Phys. Institut der Universität, 7400 Tübingen, Germany

In 1965 Robiscoe determined the position of the $2S_{1/2}(m_J=-1/2)$ $2P_{1/2}(m_J=+1/2)$ level crossings of hydrogen in a magnetic field. These crossings have been observed as resonances in the intensity measurement of a thermal metastable hydrogen beam, with a small static electric field applied perpendicular to the scanned magnetic field.

We have modified this experiment as follows: The static electric field is replaced by a pulsed electric field and instead of the beam intensity, the L_α-radiation which is produced by the pulsed quenching field is detected in time correlation with the electric pulses. These modifications produce several advantages. The detection of the L_α-quenching radiation and the use of the coincidence technique make it possible to measure only the signals of those atoms which are in the homogeneous areas of the electric and magnetic fields. Also, the detection of the emitted radiation instead of the beam intensity yields signals with a better signal-to-noise ratio which holds mostly true of emission experiments compared to absorption experiments.

Moreover, if pulse sequences of two (or more) pulses are used, quenching signals can be obtained with a narrowed linewidth less than the natural width similar to the well-known Ramsey method. In place of the spatially separated oscillatory fields of the Ramsey technique, we apply time-separated electric fields at zero frequency.

The lineshape of the quenching signal in pulsed electric fields as function of the timing of the pulse sequences, of the polarity and of the time position of the observation window will be reported.



Measured difference signal of the two HFS crossings with time-separated electric fields at zero frequency, for two pulse sequences with inverted and not inverted polarity of the second pulse, without waiting-time between the pulses. The observation-time window was longer than the second pulse. The smooth line is the theoretical signal.

A first measurement is shown in the figure.

The experimental curve is the difference signal of two different pulse sequences: one with two pulses of the same polarity and another with an inverted polarity of the second pulse. The measured resonance lines due to the two HFS crossings with $\Delta m_I=0$ at 538 G and 605 G are clearly resolved. They have a width of 34 G (FWHM), i.e. two thirds of the natural width. The application of this method to a precision measurement of the Lamb shift will be discussed.

HIGH PRECISION SATURATION SPECTROSCOPY AND LINE SHAPE STUDIES IN I_2 WITH ARGON LASERS AT 5145 Å AND 5017 Å. APPLICATION TO OPTICAL FREQUENCY STANDARDS.

by C.J. BORDÉ, G. CAMY, B. DECOMPS, J.P. DESCOUBES,
Laboratoire de Physique des Lasers - L A. 282, Université Paris-Nord
Avenue J.B. Clément - 93430 - Villetaneuse.

and J. VIGUÉ,
Laboratoire de Spectroscopie Hertzienne de l'E.N.S.,LA.18, Université Pierre et Marie Curie, 4, Place Jussieu. 75230 Paris CEDEX 05.

Four strongly interacting domains of interest have motivated this work :

- the development of optical frequency standards in the visible spectrum.
- an improved quantitative understanding of line shapes and intensities in saturation spectroscopy.
- a better knowledge of the relaxation processes in iodine.
- a refined test of the hyperfine hamiltonian for I_2 {1}

For those purposes a high accuracy saturation spectrometer has been constructed, which uses two commercial Ar^+ lasers prestabilized on the peaks of confocal Fabry-Pérot interferometers. Each of these lasers illuminates a ring interferometer which can be used to monitor either saturated absorption or dispersion. One of these devices, locked to an iodine peak is used as a frequency reference. The other one may either be locked in turn to the different peaks whose frequencies are to be measured or be locked with a tunable frequency offset with respect to the first laser for line shape studies.

The following results have been obtained {2}{3}{4} :

- *In the spectroscopy domain* , hyperfine splittings have been measured for the v = 0 - 43 P(13) and R(15) rovibronic transitions at 5145 Å and for the v = 0 - 62 R(26) transition at 5017 Å with an accuracy of the order of 200 Hz in the first case and 10 kHz in the second one. By a careful study of the crossover resonances we were able to demonstrate their

recoil shift and to reach the higher and lower state hyperfine splittings. This provides an independent determination of the coupling constants for both states. We have also performed a detailed comparison of the theoretical and experimental intensities of the various resonances.

- The previous study also brings some insight in *the relaxation domain* : the relaxation rates of both states can be compared and a new evidence is brought for hyperfine predissociation. The non-linear pressure dependence of the broadening and of the shift of the resonances demonstrates the strong influence of weak elastic collisions and gives an estimate of the relaxation rate of the optical dipole.

- The previous spectroscopic results and insight in the line shape are of fundamental importance for *metrological applications*. The accuracy is presently limited to ±5 kHz by pressure, recoil and curvature shifts but the stability (Allan variance) is close to 5.10^{-14} for 10 sec. counting times.

{1} M. BROYER, J. VIGUÉ, J.C. LEHMANN, J. de Physique 39, 591 (1978).

{2} G. CAMY, thèse Université Pierre et Marie Curie, Paris 1979.

{3} C.J. BORDÉ, G. CAMY, B. DECOMPS, Phys. Rev. 1979 (in press).

{4} G. CAMY, B. DECOMPS, J.L. GARDISSAT, C.J. BORDÉ, Metrologia 13, 145 (1977).

HYPERFINE SPECTROSCOPY OF 199 Hg^+ IONS CONFINED IN A RF CYLINDRICAL TRAP

M. JARDINO, F. PLUMELLE, M. DESAINTFUSCIEN and C. AUDOIN

Laboratoire de l'Horloge Atomique
Equipe de Recherche du CNRS associée à l'Université Paris-Sud
Bât. 221 - Université Paris-Sud
91405 ORSAY - France

A three dimensional quadrupole RF field can be created by hyperbolic or cylindrical electrodes. For some values of the amplitude and frequency of the voltage applied to the electrodes [1][2], ions can be trapped in this field. These values define the stability diagram of the trap.

When trapped, the ions undergo a periodic motion, whose coherence time is limited by collisions with other ions, with neutral gases or with the electrodes of the trap. It can be shown that, in such conditions, the hyperfine transition (whose wavelength is of the same order than the amplitude of the ion trajectories) is neither shifted nor broadened by the first order Doppler effect [3][4]. The other perturbations can be made very small and the ions can be observed during a long time, of the order of 1 s. It is then possible to measure the hyperfine frequency with great accuracy [5].

$^{199}Hg^+$ ions have been trapped in a cylindrical trap. Ions in the ground state have been selectively pumped with a ^{202}Hg lamp, from the F = 1 hyperfine state to the F = 0 state via an upper excited state. The florescence intensity from this last level at 194 nm is proportional to the ion number in the F = 1 state and serves to probe the hyperfine transition induced by a high spectral purity microwave signal. The hyperfine line have been recorded at 40.5 GHz with a linewidth of 7 Hz.

The hyperfine signal depends upon the pumping rate, proportional to the light intensity, and upon the relaxation rates, which are strongly affected by the residual gas in the trap (neutral mercury, light buffer gas). These rates have been determined from fluorescence measurements.

REFERENCES

(1) W. Paul, O. Osberghaus and E. Fischer, Forschungber. Wirtsch. Verkehrsministeriums Nordrhein-Wastfalen n° 415 (1958)

(2) M.N. Benilan and C. Audoin, International Journal of Mass Spectrometry and Ion Physics 11 (1973) p. 421

(3) R.H. Dicke, Phys. Rev. 89 (1953) p. 472

(4) F.G. Major and J.L. Duchêne, Journal de Physique 36 (1975) p. 953

(5) F.G.Major, NASA Report n° X-521-69-167 (1969)

Blank

LIFETIME OF THE METASTABLE 5 $D_{3/2}$ STATE OF Ba^+

R. Schneider und G. Werth
Institut für Physik, Universität Mainz, D-6500 Mainz, FRG

Ba^+-Ions are suspended in a rf-quadrupole trap. Under UHV conditions the storage time exceeds several minutes. The 6 $P_{1/2}$ state, excited by a pulsed tunable dye laser, decays partially into the metastable 5 $D_{3/2}$ state (Fig. 1). The amount of fluorescence radiation at the $P_{1/2}$ - $D_{3/2}$ transition, monitored perpendicular to the laser beam (Fig. 2), depends on the population of the different states. The equilibrium fluorescence intensity will be reached after a certain number of laser pulses, depending on the $D_{3/2}$ decay rate and the laser repetition frequency (Fig. 3). Measurements at different background pressure M and extrapolation to p=0 results in the natural lifetime of the state. A number will be given at the conference.

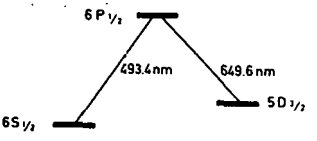


Fig.1. Energy levels of Ba+

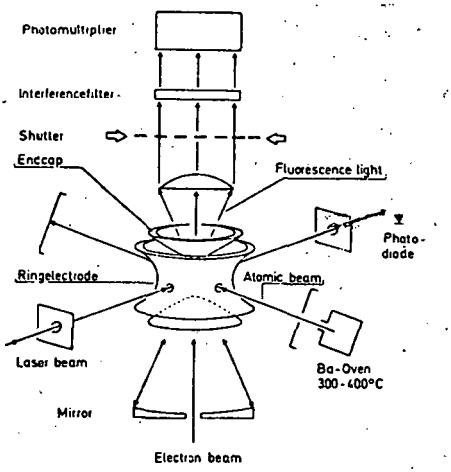


Fig. 2. Sketch of the apparatus

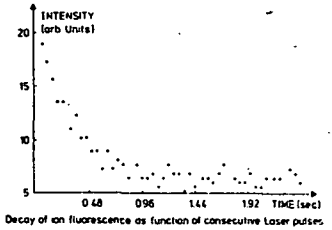


Fig. 3

SYNCHRONOUS PUMPING OF DYE LASERS UP TO 1095NM

Michèle LEDUC

Laboratoire de Spectroscopie Hertzienne de l'ENS
24, Rue Lhomond 75231 Paris Cedex 05
France

In 1978 the tuning range of CW dye laser emission was extended up to 1020nm with several cyanine dyes [1]. For the purpose of ^3He optical pumping and spectroscopic applications requiring laser light further in the infra-red we investigated the tuning possibilities of these dyes under synchronous pumping with picosecond pulses emitted from a mode locked Kr^+ laser source. The idea was that the lasing threshold of the dyes should be much lower in mode locked than in C.W. operation, provided that $\Delta t >> \tau$, where τ is the lifetime of the excited level of the dye and Δt the delay between the pump pulses. In the case of carbocyanine dyes such as IR 140, τ is of the order of 1ns or shorter [2], whereas Δt is 13ns in our case. So we mode locked the IR line of the Kr^+ laser at 752 nm and obtained 0,5 watt of average power in short pulses of 220ps width. We excited several carbocyanine dyes with a dye laser cavity of exactly the same length as the Kr^+ one (synchronous pumping). Formulae for these dyes are given in [1] and [3]. The main results are given in table 1. As expected all thresholds are decreased by the mode locked operation and the wavelength tuning ranges are consequently extended. All these dyes have a good stability except IR 143 which lasts only a few days.

We think this extension of the dye laser tuning range may be of some importance for many applications in atomic and solid state physics.

	Threshold (mWatt)	Maximum output power(mWatt)	Upper limit Wavelength
IR 140	< 2	90	1030
IR 137	< 2	100	1027
DaTTec	35	30	1058
IR 143	10	50	1095
IR 132	30	30	1048

(1) M. LEDUC, C. WEISBUCH, Optics Com. 26, p.78 (1978)

(2) J.P. FOUASSIER, D.J. LOUGNOT and J. FAURE
Jour. Chimie Physique 1, p 23 et 32 (1977).

5) J.P. WEBB, F.G. WEBSTER and B.E. PLOURDE
Eastman Organic Chemical Bulletin, 46, (1974).

FREQUENCY STABILIZATION OF AN AR^+ LASER TO SYMMETRIC I_2 LINES - A REFERENCE FOR THE SPECTROSCOPY

Frank Spieweck

Physikalisch-Technische Bundesanstalt,
Bundesallee 100
D-3300 Braunschweig

The most precise frequency values in the visible part of the spectrum are based upon iodine hyperfine components at 474 THz or 633 nm and 582 THz or 515 nm. These values are the two fixed-points in the iodine spectral atlas of Gerstenkorn and Luc [1].

Now, using an Ar^+ laser of the PTB the wavelength ratio $\lambda_{515}/\lambda_{633}$ has been measured at BIPM, yielding the value

$$\lambda_s = 514.673467 \text{ nm}$$

for the s-component of the $^{127}I_2$ line P(13) of the 43 - 0 band. The s-component is separated by >55.9 MHz from the neighbouring components [2]. The symmetry of the components s and t was tested with a system resolution of $\pm 4 \cdot 10^{-13} \nu$; no asymmetry could be detected within these limits [3].

As the frequencies of two hf components at 474 THz have been determined via different measurements [4, 5] of the wavelength ratio $\lambda_{633 \text{ nm}}/\lambda_{3.39 \mu m}$, the frequency of the 515 nm line can be evaluated as well.

A third iodine stabilized gas laser line of highest accuracy is the orange He-Ne laser line at 612 nm [6]. Because of their high signal to noise ratio the iodine absorption lines at 515 nm and 612 nm should be the best references for the spectroscopy in the visible part of the spectrum; e.g., the accuracy of wavemeters was tested with I_2 stabilized Ar^+ lasers at 515 nm [7, 8].

1. S. Gerstenkorn et P. Luc: Atlas du spectre d'absorption de la molécule d'iode, Ed. CNRS, Paris 1978

2. G. Camy: Spectroscopie de saturation de $^{127}I_2$ avec un laser à Ar^+ stabilisé en frequence; application à la recherche d'un étalon dans le visible. These, Centre Scientifique et Polytechnique de l'Université Paris-Nord, 1979

3. F. Spieweck: IEEE Transact. Instrum. & Measurem. IM-27, 398, (1978)

4. H.P. Layer, R.D. Deslattes, and W.G. Schweitzer,Jr.: Appl.Opt. 15, 734, (1976)

5. Document CCDM/78-4: Reply to CCDM questionaire, National Physical Laboratory, January 1978

6. P. Cerez and S.J. Bennett: IEEE Transact. Instrum. & Measurem. IM-27, 396, (1978)

7. F.V. Kowalski, R.E. Teets, W. Demtröder, and A.L. Schawlow: J. Opt. Soc. Am. 68, 1611, (1978)

8. K. Wickert: Aufbau eines digitalen Interferometers zur Absolutmessung von Laserwellenlängen mit hoher Genauigkeit (Lambda-Meter), Diplomarbeit, Universität Kaiserslautern, Januar 1979

HIGH PRECISION HIGH ENERGY FLASHLAMP PUMPED DYE LASER

F. TREHIN, F. BIRABEN and B. CAGNAC
Laboratoire de Spectroscopie Hertzienne de l'ENS, Université Pierre et Marie Curie, 4 place Jussieu, 75230 PARIS cedex 05.

In order to investigate very precisely some non-linear optical effects there is an important need for a tunable laser which combines the high monochromaticity, which is usually provided by a c.w. dye laser, and the high intensity obtained with a flashlamp-pumped dye laser.

We describe here an experiment in which the light emitted by a single mode c.w. dye laser is injected into the cavity of a ring flashlamp-pumped dye laser, in order to synchronize the pulsed emission on the c.w. frequency.

A preliminary experiment with a standing-wave flashlamp-pumped laser, i.e. a linear cavity, gave some encouraging results but the laser was not single-mode for any duration of the flash (1).

We have considerably improved these results by using a travelling-wave flashlamp-pumped dye laser, i.e. a ring cavity (see figure 1). With a well defined direction of the c.w. laser beam into the cavity, only one of the two possible oppositely propogation modes occurs in the ring cavity ; and a perfect single mode operation is achieved throughout the flash duration.

Using this technique we have obtained 2 kW of laser light of linewidth less than 10 MHz over a duration of 500 n.sec.

(1) F. TREHIN, G. GRYNBERG et B. CAGNAC - Revue de Physique Appliquée, t. 13, 307 (Juin 1978)

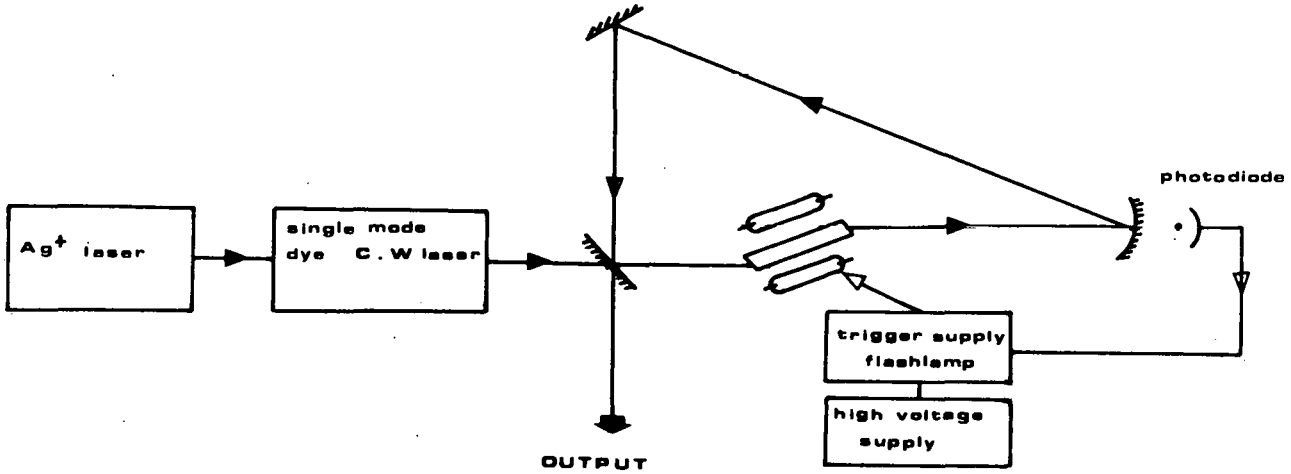

Ag+ laser
single mode
dye C.W laser
photodiode
trigger supply
flashlamp
high voltage
supply
OUTPUT

FIGURE : 1

Blank

DETECTION OF BEAT FREQUENCIES IN THE 80GHz RANGE BETWEEN LASERS IN THE VISIBLE

B.Burghardt, H.Hoeffgen, G.Meisel, W.Reinert, and B.Vowinkel

Institut für Angew.Physik and Radioastronomisches Institut, Universität, D-5300 Bonn, Fed.Rep.Germany

Precise frequency determination of lasers in the visible can be performed by heterodyning thechniques. For this purpose a method is required to generate beat oscillations between such lasers. Since there are only few reference lasers with well known frequencies in the visible, the frequency differences to be measured are very large. To measure such large differences a multistep procedure is discussed which requires the beating of two lasers with smaller frequency differences. In order to reduce the number of steps the beat frequency must be high.

We have successfully performed experiments to beat a HeNe and a cw dye laser with 79 GHz frequency difference. A GaAs Schottky barrier dicde is used as fast light detector to pick up the beat signal between the lasers. The diode is mounted inside a mm waveguide light mixer. The beat signal was 15 dB above noise for a detection bandwidth of 10 kHz.

SHIFT OF TUNABLE LASER MODES BY EFFECT OF INTRACAVITY WAVELENGTH SELECTORS AND SHORT DURATION PULSES

E. BERNABEU, F. MORENO, J.M. ALVAREZ and J.C. AMARE

Departamento de Física Fundamental, Cátedra de Optica.
Universidad de Zaragoza, España.

In laser spectroscopy it is essential to know how to control the wavelength tuning of laser modes and to know as well the frequence stability of these modes. This is important too in metrologic applications, where a stability of cavity frequency modes is required.

A tunable laser cavity consists of a resonator and intracavity wavelength selectors (tuning Fabry-Perot or equivalents). This cavities can be used with short pulses of dye emission. The purpose of this work is to analize the influence of these two aspects on the mode wavelength situation of a dye laser cavity.

The effect of an internal FP etalon on the modes of a resonator has been analyzed for infinite duration pulses[1]. A shift ($\delta\sigma_n$) of the modes has been obtained and the wavelength intervals ($\Delta\lambda_n$) between the Q_oth mode in coincidence with the FP resonance peak at λ_o and $Q_o \pm n$ modes are changed (Fig. 1).

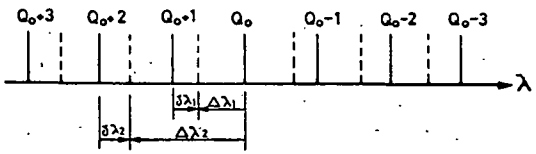


Fig. 1.- Scheme of resonator modes and their shift by effect of internal tuning elements.

The spectral selection for short pulses in dye laser with Fabry-Perot has been studied recently[2], but the influence on the modes of a dye laser cavity, consisting in a resonator with an internal FP, has not been considered up till now. In Fig. 2 we show the shift of the three first modes as a function of the duration of a short rectangular pulse.

The duration is specified by $m\tau$, where m is a positive integer and $\tau = \frac{2\eta d}{c}$, (η is the refractive index inside FP and d is the mirror spacing). A calculation method has been developed by us for pulses with other profiles.

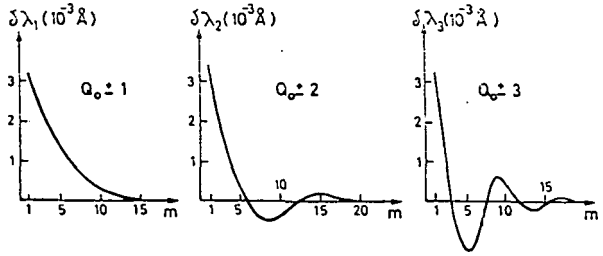


Fig. 2.- Shift of the three first modes as a function of the duration of a short rectangular pulse (η=1, d=4.35 mm, R=.8, resonator length l=10 cm, and λ=6000 Å).

We have studied also the effect of multiple intracavity wavelength selectors -tuning wedge (TW), and tuning etalons (TE)- considering the different phase changes introduced by each intracavity selector. The non-sintonization effect of the finest tuning FP etalon (FTE) has been studied, and the results are plotted in Fig.3 against the continous phase change produced by a scanning of the finest tuning FP.

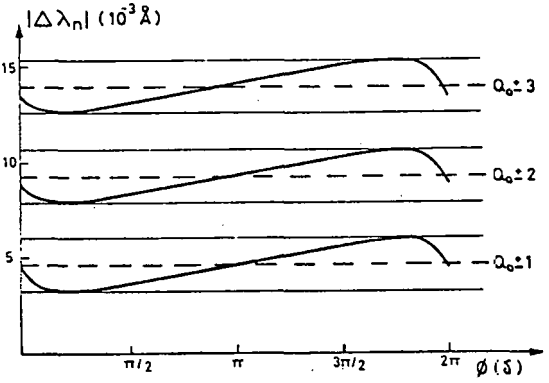


Fig. 3.- Non-sintonization effect of the finest tuning FP on the dye laser cavity modes. (η_{TW}=1.43, $d_{TW}\simeq 2.10^{-3}$ mm, $R_{TW}\simeq .2$; η_{TE}=1.36, d_{TE}=.11 mm, R_{TE}=.3; η_{FTE}=1, $d_{FTE}\simeq 2$ mm, R_{FTE}=.8; l=38.5 cm, and λ=6000 Å)

REFERENCES

(1) D.D. Bhawalkar, L.G. Nair and S.C. Mehendale, Opt. Comm. 23, 427 (1977).
(2) A. Kastler, Nouv. Rev. Opt., 5, 133 (1974).
C. Roychoudhuiri, J. Opt. Soc. Am., 65, 1418 (1975).
E. Bernabeu and J.M. Alvarez, Proc. ICO-11. Madrid, 11, 671 (1978).
H. Daussy, R. Dumanchin and O. de Witte, Appl. Opt. 17, 451 (1978).

Blank

HIGHLY EXCITED LEVELS OBSERVATIONS IN BARIUM VAPOR USING LASER MULTISTEP EXCITATION AND OPTOGALVANIC DETECTION

P. Camus, M. Dieulin, and C. Morillon
Laboratoire Aimé Cotton, C.N.R.S. II, Bâtiment 505, 91405 - Orsay, France.

It has been demonstrated that large changes can be induced in the voltage of a gas discharge plasma by optical [1] and laser [2,3] irradiation at wavelengths corresponding to resonant transitions between excited states of atoms present in the discharge. Recording these changes when the laser is tuned is a non optic detection of the absorption spectra, called optogalvanic detection.

This report describes the preliminary results obtained with this method in the neutral barium using a pulsed dye laser. The Ba plasma is produced by using a dc discharge 400 V - 20 mA through a vapor maintained by a heat-pipe [4].

Two-step transitions from the metastable levels $5d6s\ ^3D_{1,2,3}$ populated in the discharge allow investigations of highly excited even $5dn\ell$ configurations, via $5d6p\ ^3P_{0,1,2}$, $^3D_{1,2,3}$, $^3F_{2,3,4}$ intermediate levels. Below the first limit the 5d7d levels perturb the neighbouring members of the $6sn'\ell'$ series allowing the observation of the J=1 and 3 levels. Optogalvanic signals are recorded up to the second limit, in the autoionized spectrum, in order to study the $5dn\ell$ even configurations converging to the $5d\ ^2D_{3/2,5/2}$ levels. Experimental results and interpretation are in progress.

[1] K. W. Meissner, and W. F. Miller, Physical Review 92, 896 (1953).
[2] R. B. Green, R. A. Keller, G. G. Luther, P. K. Schenk, and J. C. Travis, Appl. Phys. Lett. 29, 727 (1976).
[3] W. B. Bridges, J. Opt. Soc. Am. 68, 352 (1978).
[4] P. Camus, J. Phys. B 7, 1154 (1974).
[5] M. Aymar, P. Camus, M. Dieulin, and C. Morillon, Phys. Rev. A 18, 2173 (1978).

BEHAVIOUR OF LINES FROM A COPPER HOLLOW-CATHODE LAMP

G H C FREEMAN

Division of Quantum Metrology, National Physical Laboratory, Teddington, Mdx.TW11 OLW, U.K.

Copper lines (Cu I and Cu II) have been used for many years as wavelength standards. Freeman and King [1] have looked at the suitability of some of the Cu II lines in the VUV for use as standard lines, and those that are symmetrical and narrow enough appear to be stable to 0.1 mÅ (10 fm) provided the conditions are within limits.

Freeman and King [1] used a 10 mm diameter hole in a copper block. Liquid nitrogen cooling and helium carrier gas were used. Miss B Jeffery (student) and I, in 1977, investigated the intensity variation of Cu I and Cu II lines as a function of pressure and discharge current for other conditions:-

Gas	Cathode hole sizes in mm	
	Length	Diameter
Helium	40	10, 15, 5
	20	10
	10	10
Neon	40	10
Argon	40	10

To obtain the complete Cu II spectrum down to λ120 nm (our lower limit of observations) as listed by Ross [2], helium carrier gas must be used and the 10 mm diameter, 40 mm long cathode hole is the most suitable. The low level states are more intensely excited by neon and argon, but the higher states are not excited at all. In general, the line intensity increases with current density in the cathode but the 5 mm diameter cathode can only be used over a limited pressure range. At each current there is an optimum pressure for each spectrum. For a discharge current of 500 mA the pressures, in torr (133 Pa = 1 torr), are:-

Gas	Cu I	Cu II	Cathode diameter
A	5	2	10 mm
Ne	2	3	10 mm
He	<1	7	10 mm
He	5	>10	5 mm
He	9 <1	2.5	15 mm

These values are for poor imaging of the cathode on to an 8 mm long slit with the spectrometer producing astigmatism, i.e. they probably represent an average over the complete cathode diameter. Freeman and King[3] using a good imaging system on a different instrument, plotted the intensity variation across the cathode for the Cu II line at λ205 nm. At low
sures the visible glow and Cu II emitting region are in the centre of
cathode, while at high pressures the cathode dark space (Crook's) is
ow and the emitting region (negative glow) is an annulus with a dark hole in the centre (Faraday dark space). The pressure for maximum uniformity in the centre of the cathode is between 2.5 and 3.0 torr (350 to 400 Pa).

D. Stone (student 1979) and I have run a hollow-cathode lamp with a discharge current of 500 mA with liquid nitrogen cooling and water (280k) cooling. The striking feature about the lamp when it is cooled by water is the high level of impurities (CO, CI, OI and HI) and the presence of many more intense lines. If the cathode is run at higher temperatures (470K), the voltage drop across the lamp increases above the maximum voltage of the constant current supply unit (normal lamp voltage is about 200V and at high temperature it is above 600V).

Freeman and King[3] found that two hollow-cathode lamps which were only nominally identical in fact gave lines at λ205 nm and λ154 nm, which were identical to $\pm$ 2 fm (0.02 mÅ) even though the intensity of the lines from the two lamps were very different. This was for 200 mA discharge current, 3 torr (400 Pa) of helium and liquid nitrogen cooling. At other pressures and currents the wavelength of the lines shifted, but stayed within $\pm$ 0.1 mÅ provided the pressure was between 2 and 8 torr (270 and 1060 Pa).

Stone and I are comparing the wavelength and width of more lines from lamps run under different conditions such as those listed above. We will also check whether or not the copper atoms have the same distribution within the cathode as the copper ions.

(1) Freeman, G H C and King, W H, J. Phys. E, 1977, 10, 894 - 897.

(2) Ross, C B., 1970. Report LA-4496, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, USA.
Freeman, G H C and King, W H, J. Phys. E, 1979, in press.

MICROWAVE EXCITED ELECTRODELESS GAS DISCHARGES IN THE VUV

M. OUTRED, Department of Physics, The Polytechnic of North London, Holloway Road, London, N7 8DB

G.H.D. FREEMAN, Division of Quantum Metrology, National Physical Laboratory, Teddington, Middlesex, TW11 CLW.

- - - - - - -

Microwave excited electrodeless discharge tubes have been used for many years as a convenient method of producing the spectrum of many gaseous elements and of metals which can be obtained in the vapour state either by their intrinsicly high vapour pressure or by the use of a suitable volatile halide. In the majority of applications the electrodeless tube is used with the commercially available A antenna, the three-quarter wavelength Broida cavity or the quarter wavelength Evenson cavity. When these cavities are used to excite the spectrum of an inert gas it is the first spectrum that is produced very intensely (particularly the resonance lines). However, to obtain the second spectrum low pressures must be used and most of the available cavities will not maintain discharges at the required pressures.

Hammond and Outred (1976) and Hammond (1978) have described a slab line cavity in which it is possible (a) to alter the cavity geometry, and (b) to excite the second spectrum of He, Ne and Ar. This cavity has now been used, on a flowing gas system, to excite discharges in He, Ne, Ar, Kr, Xe and N. The spectra of these gases were recorded down to approximately 50 nm using a 1 m normal incident monochromator (Ditchburn type).

The effect of coupling the microwave power into the discharge was studied by varying the cavity geometry, different discharge tube diameters and shapes. From this work the optimum conditions which produce maximum line intensity, for a given gas and spectrum, were determined.

In general it was found that at the higher pressures the atomic resonance lines were predominant. As the pressure was reduced more of the first spectrum was excited together with the resonance lines of the second spectrum, and at the lowest pressures the complete second spectrum was observed with increased intensity whilst the intensity of the first spectrum was reduced. For some of the gases, at the lowest pressures, a few lines of the third spectrum have been observed.

Table 1 shows the lowest pressures at which spectra were recorded for the various gases.

Gas	Pressure	
	m torr	Pa
He	600	80
Ne	20	2.7
Ar	5	0.6
Kr	8	1.0
Xe	5	0.6
N_2	60	8

Table 1

References:-

Hammond, C.B., and Outred, M., 1976, Physica Scripta, 14, 81-84

Hammond, C.B., 1978, Ph.D. Thesis, University of London.

PHOTOCELL COMPARISON IN THE VUV

G.H.C. FREEMAN
Division of Quantum Metrology, National Physical Laboratory,
Teddington, Middx. TW11 OLW, UK.

With the advent of space astronomy, electron storage rings for syncrotron radiation and accurate work on absolute intensity measurements in the VUV, the demand for photocell calibration has increased. The NPL is using its large reflectometer for photocell comparisons so that large devices, such as 250 mm long image intensifier tubes, can be measured. Most of these devices have magnesium fluoride windows.

In the reflectometer several devices can be mounted on the carriage and moved through a parallel beam of radiation. This allows (1) semi-transparent and opaque cathodes, which are at different distances from the window, to be compared using the same size of beam and (2) scans across the cathode can be made to determine the spatial uniformity. Errors caused by the use of moving mirrors are not incurred. The electrometer amplifiers are also mounted on the carriage so that movement does not induce voltages in the high impedance part of the circuit (100 M ohms and 10 to 100 pA of signal).

Solar blind cells (Cs_2Te) with opaque cathodes and an anode ring (part of the magnesium fluoride window mounting) 12 mm from the cathode, electrically saturate well below the 60 V at which we use them. Unfortunately they can take up to half an hour to produce a steady photocurrent (better than 1% of the final value), particularly when first used after evacuation.

Image intensifier tubes with windows mounted after Freeman and Moore[1] have semi-transparent cathodes on the inside of the window and an anode/phosphor between 50 and 100 mm away depending on tube type. For this work the focusing electrodes are connected to the anode and to the amplifier input. They saturate at below 10 V and the photocurrent settles within a few seconds. The dark current of devices with caesium present (trialkali or S20) often take hours to become constant enough for measurements to be taken. Bialkali cathode tubes do not suffer from this.

Photodiodes with 25 mm diameter semi-transparent cathode behave differently. Caesiated trialkali (S20) cathodes with approximately 50 mm anode-cathode separation do not saturate until 400 V when the background noise is very large due to electrical leakage.

Cathode uniformity can be very good, less than 5% variation along a diameter, but usually it is poor with several maxima and minima symmetrically placed about the centre, similar to an optical interference effect. This phenomenon is most noticeable at the shortest wavelengths.

The reproduceability for any one comparison of two photocells is good, usually about 0.1%. If the cells are recleaned and re-compared, the reproduceability is poorer, especially at shorter wavelengths. This is probably associated with problems of cleaning the windows, particularly the solar blind cells as the part of the window seal is made with a solvent soluble adhesive.

The experimental assistance of K.D. Russel (Student) and M. Ohly (EMI Electron Tubes, Ruislip) for parts of this work is gratefully acknowledged. Thanks are due to EMI and ESA for permission to publish.

(1) FREEMAN, G.H.C. and MOORE, P.J., J. Phys. E., 11, 980-981, 1978.

NEW EMISSION BANDS IN Na_2 GENEPATED BY DIFFERENT LASER EXCITATIONS

M.ALLEGRINI, L.MOI

LABORATORIO DI FISICA ATOMICA E MOLECOLARE DEL C.N.R.
VIA DEL GIARDINO, 3 - 56100 PISA - ITALY

The more detailed study of the alkali molecules and the extension either of the excitation or of the detection towards unexplored spectral regions permitted , in the last few years, the observation of new absorption as well as fluorescence bands.

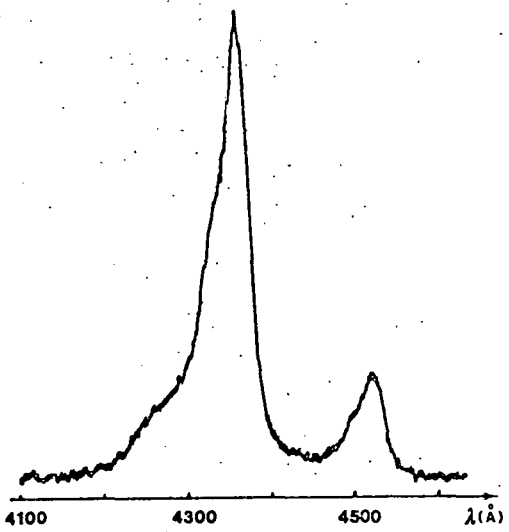
These bands are to be ascribed to transitions between molecular electronic energy levels which cannot be excited, through one photon absorption, from the ground state and which are completely unknown. For this reason the interest in this study is great even if it is extremely difficult owing to the numerous levels implied.

The experimental set-up was the usually one of laser induced fluorescence with the laser beam chopped to allow phase-sensitive detection. The temperature of the cell was 398°C , corresponding to $\simeq 5 \cdot 10^{15}$ atoms/cm^3 and to $\simeq 10^{14}$ molecules/cm^3.

Two new bands are reported in figures 1 and 2.

These bands were obtained: i) upon excitation of the vapour with a cw Kr^+ laser tuned at 6471/6764 Å (fig.1) ; ii) upon resonant excitation of the atomic 3S-3P transition with a cw dye-laser (fig.2).

Fig. 1 : fluorescence spectrum excited by the 6471/6764 Å lines of a cw. Kr^+ laser.
Laser power ≃ 3 W.



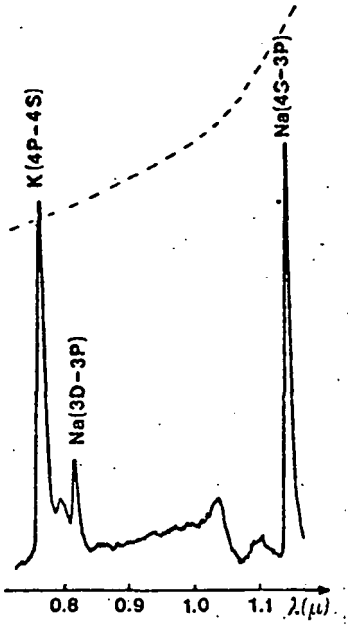


Fig. 2 : fluorescence spectrum upon excitation of the 3P-3S atomic transition.
Laser power ≃ 40 mW.
The response of the photocell is indicated by the dashed curve.

QUANTUM BEAT SPECTROSCOPY IN THE $A^1\Sigma^+$ STATE OF BARIUM OXIDE

H. Büsener, A. Hese, A. Renn and H.S.Schweda

Institut für Strahlungs- und Kernphysik
Technische Universität Berlin, Rondellstr. 5, D-1000 Berlin 37

The electric dipole moments of several vibrational levels in the electronically excited $A^1\Sigma^+$ state of the Barium oxide molecule have been measured using the method of Stark quantum beats under pulsed dye laser excitation (1). The BaO molecules were produced by the gasphase chemical reaction
$Ba + SO_2 \rightarrow BaO + SO$ (2).
The J = 1 levels of the vibronic states v'= 0,1,2,3 have been excited and the decay signals following the exciting laser pulses were measured using the standard technique of delayed coincidences. The observed modulations on the decay signal exhibit the electric field induced level splitting ΔE of the excited state which is connected to the dipole moment μ_v by

$$\Delta E = \frac{3}{20} \frac{\mu_v^2}{B_v \cdot h \cdot c} \cdot \varepsilon^2$$

Fig. 1 shows two quantum beat signals obtained by observing different polarisations and the difference signal. The solid lines are computer optimized fit curves corresponding to a modulation frequency of 12.2MHz. The method of QBS will be compared with the Electric Field Levelcrossing technique using cw Laser excitation performed by other groups and also in our laboratory (3). The results obtained by the methods of QBS and LC are listed in table 1. Moreover lifetime measurements have been done in the v'=0,1,2,3,5 levels in order to get information about the electronic transition moment. In case of a strong perturbation by other electronic states via spin-orbit interaction lifetimes may change dramatically caused by mixing of the molecular wave functions. In the $A^1\Sigma^+$ state several perturbations due to the neighbouring $b\,^3\pi$ and $A'\,^1\pi$ states are known. Lifetime measurements as a function of the rotational quantum number reveal the influence of the perturbing states.

The lifetimes of the v'=3 rotational states show an increase from 341ns at the bandhead to 485ns at the J'=19 level and 1027ns in the perturbing J'=19 state. Mixing coefficients of the wave functions could be derived. The observation of Zeeman beats following the excitation of the R(18) and the accompanying line also leads to values for the mixing coefficients and moreover to information about the Landé g_J factors of the perturbing states.

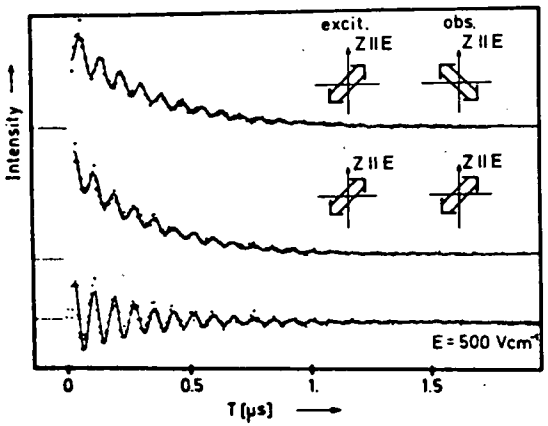


Fig.1:
Quantum beats after excitation of the $A^1\Sigma^+$ v'=2 J'=1 state obtained at different polarisations in observation and difference signal.

v'	μ_v (Debye)	τ (ns) this work	τ (ns) Johnson (4)
0	2.98 (7)	285 (8)	356 (7)
1	2.66 (7)	322 (9)	363 (7)
2	3.15 (6)	313 (9)	335 (13)
3	3.19 (7)	341 (10)	293 (23)
5		328 (9)	303 (12)
7	2.2 * (1)		

Tab.1:
Summary of measured dipole moments and lifetime compared with other measurements.

* This value was determined by Wharton et.al.using the method of microwave optical double resonance (5)

Referenaes:
(1) A.Hese,A.Renn,H.S.Schweda:Opt.Comm.20, 385 (1977)
(2) G.P.Smith,R.N.Zare: J.Am.Soc.97 1935 (1975)
(3) S.J.Silvers,T.H.Bergemann,W.Klemperer:J.Chem.Phys.52,4385 (1970)
G.Dohnt,A.Hese,A.Renn,H.S.Schweda: to be publ.in Chem.Phys.
(4) S.E.Johnson: J.Chem.Phys.56, 149 (1972)
(5) R.F.Wormsbecher,S.L.Lane,D.O.Harris:J.Chem.Phys.67,2745(1977)

FIRST OBSERVATION OF HYPERFINE PREDISSOCIATION IN IODINE TRHOUGH LINEWIDTH MEASUREMENTS.

C. MAN, P. CEREZ and A. BRILLET

Laboratoire de l'Horloge Atomique
Equipe de Recherche du CNRS associée à l'Université Paris-Sud
Bât. 221 - Université Paris-Sud
91405 - ORSAY - France

Hyperfine predissociation in the $B^3\pi_{0^+_u}$ of iodine has been predicted and observed by Broyer and Vigué, but no measurement of the predissociation constants has never been made through linewidth measurements of the hyperfine components. We report here the first successful experiment of this kind.

We realized saturated absorption experiments in iodine at 612 nm with a He-Ne laser. Narrow resonances belonging to the $^{127}I_2$ molecular lines R(47)9-2, P(48)11-3 and R(48)15-5 were observed in a low pressure iodine cell. The observed linewidths range between 220 and 770 KHz (HWHM). They can be interpreted as the sum of the contributions of a constant transit-time effect (100 KHz) and of the lifetime. In particular, the R(47)9-2 hyperfine components show strong amplitude and linewidth differences (250 KHz to 700 KHz), due to hyperfine predissociation. The predissociation constants a_v and c_v have been measured for v' = 9. The results are $a^2_v = (2.24 \pm .7)\ 10^5\ s^{-1}$ and $c_v = (11.7 \pm 2.5)\ s^{-1/2}$, compatible with Vigué's results.

The experimental technique deserves some comments. The source is a 612 nm He-Ne laser, with an internal iodine cell. The strong saturation of the iodine absorption in this cell produces an hysteresis effect, ensuring single frequency operation and tunability of the laser over more than 1 GHz, although the free spectral range of its cavity is only $\frac{c}{2L}$ = 200 MHz. The output power is 200 µW and relatively flat over the 1 GHz range (saturated absorption signals from the internal cell are very weak and broad due to the low pressure and very high saturation). The signals come from a second iodine cell, external to the laser cavity, but put inside a high finesse Fabry-Perot resonator, mode-matched to the laser beam. When the laser fre-

quency is tuned, the Fabry-Perot is kept in resonance with a servo-loop, and non linear resonances appear as variations of the transmission (or reflection) factor of the Fabry-Perot.

This set-up has two advantages : energy storage in the Fabry Perot provides enough intensity to saturate the transitions even with an input power as low as 30 μW, and the contrast of the non linear resonances is greatty increased by the fact that the transmission (or reflection) of a high finesse Fabry Perot is very sensitive to small variations of its losses. This gain in sensitivity is as large as 50 in our experiment and provides a very good signal to noise ratio (Fig. 1). This technique may find an application in the field of wavelength standards, where high signal to noise ratio and narrow linewidths are needed.

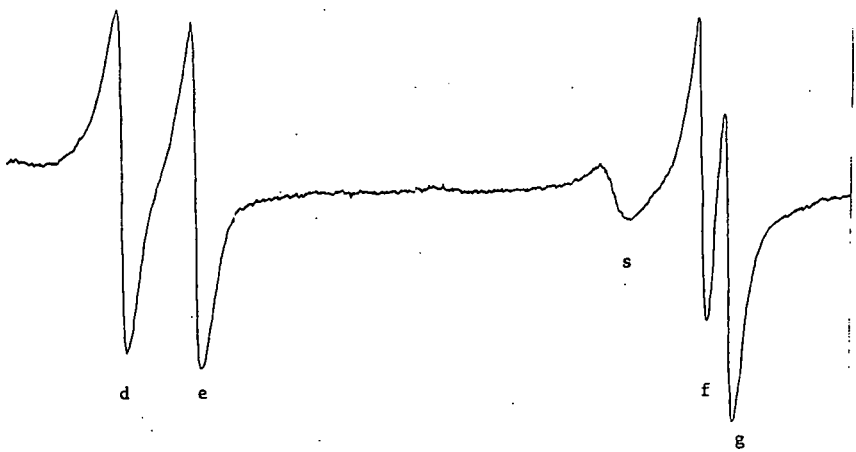


Fig. 1 : First derivative of the d, e, f, g components of the P(48)11-3 line and the s component of R(47) 9-2. The full frequency sweep is 25 MHz.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

DISPERSION EFFECTS IN DISSOTIATION OF THE MOLECULES OF $^{80}Se_2$

M. Stankiewicz, T. Dohnalik, L. Frasiński

Institute of Physics, Jagellonian University
ul. Reymonta 4, 30-059 Kraków, Poland

A Pulse Dye Laser System, pumped by Nitrogen Laser /1 MW, 10 ns/ with second harmonic generation /on KDP crystal / is used to excite the $^{80}Se_2$ molecule to a higher vibrational state of $^3\Sigma_u^-$ electronic state or to dissociate this molecule.
Selenium, contained in a quarz cell, is placed in strong magnetic field / up to 0.6 T / from electromagnet and illuminated by linearly polarized light beam parallel to the field.
We can observe the Faraday rotation or forward scattering curves given by interaction of a discrete ground state and a continuum.

The results of the measurements will hopefully be presented at the conference.

SPECTROSCOPIC INVESTIGATION OF BALMER LINES EMISSION IN CONTROLLED ELECTRON IMPACT INTERACTION WITH CH_3Cl MOLECULES

J.M.Kurepa and J.M.Marendić

Institute of Physics, Studentski trg 12/V, POB 57, 11001 Beograd, Yugoslavia

Spectroscopic investigations of hydrogen halides and logen substituted simple hydrocarbons have been extensively carried out in the last few years. They are important species for astrophysics, radiation chemistry, atomic and molecular spectroscopy, and of special interest for laser physics. Their spectroscopic studies are necessary for the development of excimer high power lasers and chemical lasers, too. So, gas discharge, controlled electron impact and photoexcitation investigations of such gases have lately attract the interest of many investigators |1||2|.

This contribution deals with optical investigation of halogen substituted hydrocarbon, methyl chloride, CH_3Cl, at low gas pressure in collision with electrons of medium energy. Our aim was to investigate the type of emitted radiation of this target when the primary excitation by electrons has been performed into superexcited states of the molecule, i.e. excited states above the first ionisation potential of the molecule|3|. We wanted to learn more about these states and their importance to emission spectra of the molecule.

The details of the used experimental apparatus have been described elsewhere |4||5|. It mainly contains crossed electron and molecular beams in high vacuum chamber where electron energy could be changed in interval of 70-700 eV, quartz optical elements, optical monochromator with reciprocal dispersion of 20 Å/mm, cooled RCA C 31034 photomultiplier, ORTEC photon counting system and specially designed multiscaling photocounting system for low level optical signal detection.

For above cited electron energies, under the conditions of binary collisions of electrons with CH_3Cl molecules, we have investigate optical emission in the 350-900 nm wave length range. According to previous investigations in other molecules |6|, the resulting optical emissions for cited electron impact energies originate from dissociated fragments of parent molecules which are free excited radicals of atomic or more complex nature. Our measurements of emitted spectral radiation have confirmed these predictions |6|, and we have obtained in 350-900 nm region the following spectra: Balmer lines have been found as the most prominent feature, CH bands, ClI and ClII lines, too. Under our impacting conditions no trace of expected $A^2\Sigma^+ - X^2\Pi$ transition of HCl^+ band has been detected. In 350-900 nm region also, the prominent molecular continuum spectra have not been found.

Firstly, we have concentrated our attention to investigation of optical characteristics of Balmer lines. So, the optical excitation functions for H_α, H_β, H_γ, H_σ and H_ε have been

obtained for energy interval of 70-700 eV. They all exhibit the same structure, i.e. broad maxima between 100-120 eV, and their shapes do not differ mutually within 3% of accuracy. These data then have been compared with Bethe theory and presented in Fano plot representation |7|. This has been done with the aim to investigate the same parameters of directly excited superexcited states of the CH_3Cl molecules, analysing the radiation of products of these unstable excited states. The analysis of such presentation of the data for H_α, H_β, H_γ, H_δ and H_ε led us to the following conclusions:

The first five investigated Balmer lines originate from the excited H fragments obtained after dissociative excitation of the same unstable superexcited states of parent CH_3Cl molecules. For electron impacting energies from 70-120 eV, the obtained superexcited states of CH_3Cl molecules have been formed by optically allowed transitions from ground state of molecules. In this energy interval Fano plot exhibit linear dependence, and by the least square fitting procedure the existence of one effective superexcited state is shown. Its effective optical oscillator strength, f_n could be obtained from the Fano plot presentation. Above 120 eV Fano plot of the data shows that the excitation to superexcited states of CH_3Cl molecules occurs mainly via symmetry forbidden excitation processes, which value for f_n tends to zero.

Our investigated effective values for f_n obtained for allowed superexcited state, formed in 70-120 eV interval of CH_3Cl molecules, compared with the tabulated values |8| for H atoms show the considerable influence of dissociative excitation processes on Balmer line emission from CH_3Cl in comparision with the emission of H excited atoms.

|1| M. Toyoda, T. Ogawa, N.Ishibashi, Bull.Chem.Soc.Japan, 49 (1976), 384.

|2| H.A. van Sprang, H.H.Brongersma and F.J.de Heer, Chem. Phys. 35 (1978) 51.

|3| R.L. Platcman, The Vortex 23 (1962) 372.

|4| J.M.Kurepa and M.D.Tasić, Chem.Phys. 1979 (in press)

|5| J.M.Kurepa, B.J.Levi, B.M.Panić, Spectrochem.Acta 32B (1977)

|6| G.R.Mölhmann and F.J. de Heer,Chem.Phys. 19 (1977) 233.

|7| M.Inokuti, Rev.Mod.Phys. 43 (1971) 297.

|8| W.L.Wiese, M.W.Smith and B.M.Glennon, "Atomic Transition Probabilities" NSRDS-NBS 4, Vol. 1, 1966.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

MULTICHANNEL QUANTUM DEFECT ANALYSIS OF RYDBERG SERIES OF NEUTRAL YTTERBIUM

M. AYMAR, A. DEBARRE, O. ROBAUX

Laboratoire Aimé Cotton, C.N.R.S. II, Bâtiment 505, 91405 ORSAY, France.

We report here an interpretation of the even J = 0 and J = 2 bound spectra and of the odd J = 1 bound spectrum of neutral ytterbium [1,2] by using the multichannel quantum defect theory (M.Q.D.T.). Although this atom is very complex, it presents Rydberg series $4f^{14}6\,snl$ same as those of barium, but the perturbers now pertain as well to configutations with two excited valence electrons ($4f^{14}5d6p$, $4f^{14}6p^2$) as to configurations where one electron of the 4f shell is excited ($4f^{13}5d6s6p$, $4f^{13}5d^26s$). Then, the spectra are more complex than in barium [3] . However, a parametric study of the perturbing configurations performed by Wyart and Camus [4] allowed us to identify the different perturbers.

With relatively simple M.Q.D.T. models (number of channels smaller than 7), the main perturbations of the different Rydberg series are clearly interpreted. A new value of the first ionization limit of neutral ytterbium has been obtained.

References :

[1] Débarre, A., thèse de 3ème cycle, Orsay (1979)
Camus, P., Débarre, A., Morillon, C., J. Phys. B : Atom. Molec. Phys., 11, n° 13, L395 (1978)

[2] Camus, P., Tomkins, F.S., J. Phys. (Paris), 30, 545 (1969)

[3] Aymar, M., Robaux, O., J. Phys. B : Atom. Molec. Phys., Vol. 12, n° 4 (1979)

[4] Wyart, J.-F., Camus, P., Phys. Scripta, to be published (1979).

AN ALN EXPERIMENT BETWEEN ATOMS OF TWO DIFFERENT SEPCIES.

J.-L. Picqué and R. Vetter
Laboratoire Aimé Cotton, Centre National de la Rechérche Scientif:
Bâtiment 505, 91405-Orsay, France.

An experiment analogous to an ALN experiment has been performed between atoms of two different species connected by a resonant excitation transfer. ^{86}Kr and ^{136}Xe atoms are hold in a discharge tube cooled at liquid nitrogen temperature. An intense laser beam provided by a single-mode dye laser saturates the Kr transition at $\lambda = 557$ nm , whose lower level $4p^5 5s[3/2]_2$ is metastable. A weaker laser beam provided by a Xenon gas laser monitors the absorption around the infrared Xe line at 3.68 μm , whose upper level $5p^5 5d[1/2]_1$ almost coincides with the Kr metastable level. Under these conditions, we have observed (Fig. 1) that the probe linewidth (typically 35 MHz) is significantly lower than the width of the Voigt profile (50 MHz) which would be obtained in a conventional linear absorption experiment. This means that the hole burned in the longitudinal velocity distribution of Kr metastables is transferred to Xe atoms (without complete thermalization) through excitation-exchange collisions.

For the theoretical interpretation, we have found convenient to define a "cross" collision kernel $W(V_z \rightarrow v'_z)$. This kernel represents the probability density per unit time for a donor (here, Kr) of longitudinal velocity V_z to give rise through an excitation-exchange collision to an acceptor (here, Xe) of longitudinal velocity v'_z . The calculated lineshape is then similar to that of an usual three-level system, without the coherence term. Moreover, the expression of the signal depends directly on the shape of the kernel.

Both from systematic studies of the experimental lineshapes and from physical arguments, we have been led to choose a simple gaussian form for the cross kernel. The profiles recorded over a wide range of Kr partial pressures are found consistent with this model. In particular, we have verified that the width of the kernel deduced from profile analysis is pressure-independent. From its value, one infers that the collision-induced velocity dispersion is two third of the width of the thermal velocity distribution of Xe at $T = 77$ K .

With the saturating beam out of resonance ($V_z \neq 0$) , we have observed that the probe profiles are slightly shifted. The shift is much less than the one expected in a true three-level system. However, this effect shows that the transfer collisions do not destroy completely the memory of the donor's velocity. In conclusion, the ALN-type experiment described here has revealed the importance of velocity effects in excitation-exchange phenomena.

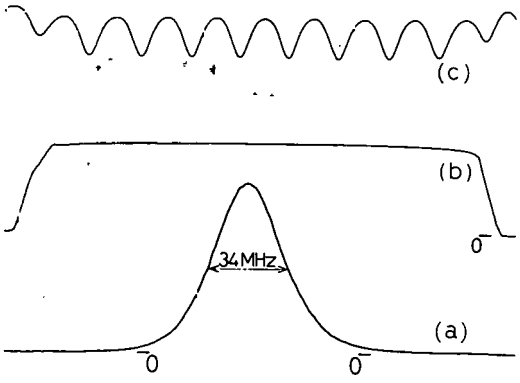


Fig. 1 - Trace (a) : Typical experimental recording of the probe signal (temperature : 77 K ; Kr pressure : 17 mT). Trace (b) : Output level of the frequency-scanning Xe laser. Trace (c) : Reference fringes, separated by 20.85 MHz.

Blank

OPTICAL PUMPING STUDIES OF ^{3}HE NUCLEAR RELAXATION

V. LEFEVRE, P.J. NACHER and F. LALOË
Laboratoire de Spectroscopie Hertzienne de l'E.N.S
24, Rue Lhomond 75231 Paris Cedex 05

Optical pumping can be used to nuclearly polarize ^{3}He atoms in the ground state (1). Since direct optical pumping of the ground state is not possible (the resonance wavelength is 580 Å), an indirect pumping at λ=1.08μ through the 2^3S metastable state has to be used (the latter is populated by a weak gaseous discharge). Metastability exchange collisions transfer the orientation from the metastable to the ground state level. After a stationary nuclear orientation is obtained, it is possible to switch off the discharge and to use N.M.R. techniques in order to monitor the nuclear polarization which decays with a time constant T_r. This time constant depends essentially on the relaxation induced by atom-wall collisions. Measuring Tr therefore amounts to studying atom-surface interactions.

This experiment has been done at low temperatures ($2K < T < 4.2K$), the internal wall of the cell being coated with a solide hydrogen film. Measuring T_r as a function of the static magnetic field B gives various informations on the correlation time of the random magnetic perturbation acting on the spins and therefore on the structure of the H_2 film, the mobility of the adsorbed atoms, etc... This technique allows one to detect the evolution of a very small proportion of atoms (adsorbed phase), in opposition to N.M.R. methods directly applied to ^{3}He adsorbed phases where a much larger adsorbate area is needed.

(1) F.D. Colegrove, L.D. Schearer and G.K. Walters, Phys. Rev 135A 353 (1964).

THE USE OF LOW PRESSURE RING DISCHARGE EMISSION SPECTROSCOPY FOR THE DETERMINATION OF Hg-TRACES IN WATER

Henryk Zbigniew Wrembel
Pedagogical University
Słupsk, P o l a n d

The pollution of natural waters with mercury copounds is an increasingly serious problem. In recent years several spectrometric analytical methods for determining mercury traces were evaluated. Table 1 presents a survey of application ranges of some most important spectrometric determination methods for mercury analysis in water.

Table 1. Detection C_L and determination C_D limits for mercury in aqueous solutions obtained with some spectrometric methods

Method	C_L, g/l	C_D, g/l
Atomic Absorption Spectrometry	10^{-12}	10^{-9}
Atomic Fluorescence Spectrometry	10^{-11}	10^{-8}
Atomic Emission Spectrometry ICP	10^{-12}	10^{-8}
Radio-Isotope Techniques	10^{-15}	10^{-10}
Activation Analysis	10^{-16}	10^{-8}
Mass Spectrometry	10^{-15}	10^{-12}

Note: ICP - inductive coupled plasma

Low pressure ring discharge emission spectroscopy is a suitable method for the investigation of Hg-traces in water. In Table 2 results obtained by the method in pure water, synthetical Baltic water and synthetical sea water are shown.

Table 2. Some values of C_L, the Hg-determination and C_D, the Hg-detection limits in low pressure ring discharge

Kind of water	C_L, g/l	N_L, cm^{-3}	C_D, g/l	N_D, cm^{-3}
pure	3.10^{-12}	9.10^{6}	3.10^{-10}	2.10^{12}
synthetical Baltic	1.10^{-11}	3.10^{7}	2.10^{-9}	3.10^{13}
synthetical sea	5.10^{-10}	2.10^{9}	1.10^{-8}	3.10^{14}

Note: N_L, N_D-density of Hg-atoms in the plasma

Using low pressure ring discharge emission spectroscopy the loss of mercury from the solution, due to sorption phenomena in glassware, polythelene and quartz, were investigated. In Table 3 some observationes of mercury losses due to sorptic phenomena are shown.

Table 3 Mercury Losses from a 10^{-9} g/l aqueous solution in 24 hours

Container of	mercury-loss, %
glasware	31
siliconized glass	26
polyethylene	21
quartz	12

It was shown that in the analytical process of determining of mercury there is a considerable danger of increasing rando errors due to sorption and desortpion phenomena in the contai This can expecially occur when glassware and polyethelene are used.

N° 140

VELOCITY SELECTIVE OPTICAL PUMPING

M. PINARD, C.G. AMINOFF and F. LALOË

Laboratoire de Physique de l'E.N.S.
24, rue Lhomond, 75231 PARIS CEDEX 05 - France

Velocity Selective Optical Pumping (V.S.O.P.) is a Doppler free spectroscopy method which combines the ideas of Zeeman optical pumping, velocity selective excitation and detection, and possibly magnetic resonance or modulated excitation in an absorbing gas. It is also strongly related to saturated absorption, "polarization spectroscopy" ([1]), or "polarization labeling" of molecular spectra ([2]). The main difference between these methods and V.S.O.P. lies in the fact that essentially no optical saturation of the optical resonance line is required, in a similar way to ordinary optical pumping. A circularly polarized laser beam, expanded over several cm^2 to avoid optical saturation, is used to induce anisotropy in the gas. Since the laser is very monochromatic (single mode), a strong correlation is introduced between the atomic velocities and internal variables (orientation, alignment, etc...), unlike conventional optical pumping. For detection, a weak collimated beam is injected as a counterpropagating probe. Its polarization is modulated at a low frequency so that a lock-in amplifier allows one to isolate the contribution of orientation or alignment of the atoms.

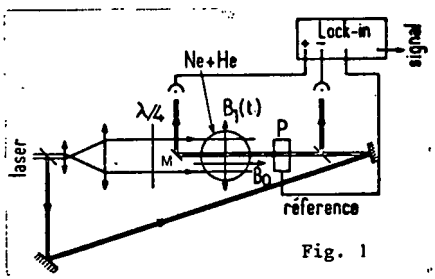


Fig. 1

Fig. 1 shows a scheme of the experiment. The method has been applied to Neon metastable atoms ([3]). The curves obtained by sweeping the laser frequency exhibit a narrow Doppler-free peak superimposed on a broad backgrounds (Fig.2a), which is due to velocity changing (but orientation conserving) collisions. The sign of the peaks depends in general on the collision rate. This is for example the case when opposite orientations are given by a full Kastler-type optical pumping cycle or depopulation pumping, as shown in Fig. 3. Magnetic resonance inside the metastable level allows one to reduce the background intensity (Fig. 2b). Another variant of the method consists in modulating the pump polarization at a frequency Ω of several KHz, in order to study the response of the orientation inside the Doppler

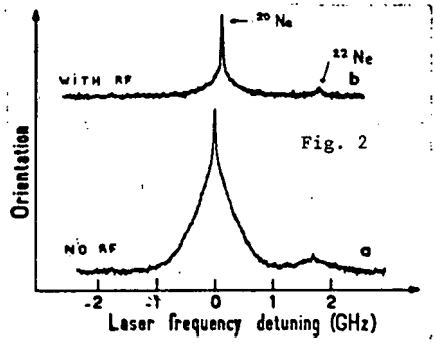


Fig. 2

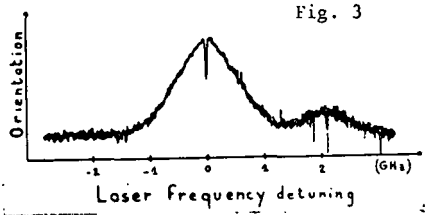


Fig. 3

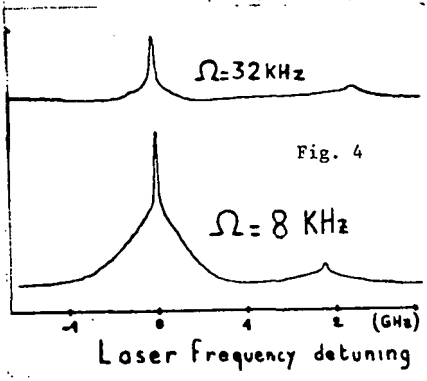


Fig. 4

profile as a function of Ω (Fig. 4). This is particularly useful to obtain collision rate constants and selecting between various collision models (strong collisions without memory or weak collisions resulting in a velocity diffusion inside the Doppler profile). The method seems to be well adapted to studies of collisions in well defined conditions (one observable inside one level is observed, simple geometrical conditions, no effect of the optical coherences, etc...).

([1]) C. WIEMAN and T.W. HANSCH, Phys. Rev. Lett. 36, 1170 (1976)

([2]) R. TEETS, R. FEINBERG, T.W. HANSCH and A.L. SCHAWLOW, Phys. Rev. Lett. 37, 683 (1976)

([3]) M. PINARD, C.G. AMINOFF, F. LALOE, "Velocity selective optical pumping and Doppler free spectroscopy", Phys. Rev. A, submitted in August 1978.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

DISCREPANCIES BETWEEN BEAM-FOIL LIFETIMES AND THEORETICAL LIFETIMES IN THE Mg I SEQUENCE

A. Lindgård and E. Veje
H.C. Ørsted Institute
Universitetsparken 5
DK-2100 København Ø
Denmark
and
L. Liljeby, S. Mannervik and J. Jelenkovic
Research Institute for Physics
Roslagsvagen 100
S-10405 Stockholm
Sweden

Lifetime measurements using the beam-foil technique have been made for 10 levels in Mg I. Lifetimes have been calculated for the same levels using the numerical coulomb approximation method (Lindgård and Nielsen 1977), and the results are compared with experimental data. Whereas good agreement exists for some of the low lying levels, there are large and unexpected disagreements for some of the higher lying levels. There is good agreement between Hartree-Fock lifetimes (Weiss 1967, Froese Fischer 1975a, 1975b) and numerical coulomb lifetimes as the effect of configuration interaction is rather week (Lu 1974).
For the higher ionized members of the Mg I sequence there is generally good agreement between experiment and theory for the resonance transitions. For higher lying states the agreement between different experimental values is so poor that nothing can be said about agreement between theory and experiment.

References:

Froese Fischer C.
Can. J. Phys. 53 184 (1975a)

Froese Fischer C.
Can. J. Phys. 53 338 (1975b)

Lindgård A. and Nielsen S. E.
At. Data & Nucl. Data Tables 19 533 (1977)

Lu K. T.
J. Opt. Soc. Am. 64 706 (1974)

Weiss A. W.
J. Chem. Phys. 47 3573 (1967)

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

The angular distribution of p shell electrons from the inert gases and methane

G.V. Marr and R.M. Holmes

Abstract

The spatial distribution of photoelectrons from a random distribution of free atoms or molecules by plane polarized electromagnetic radiation can be described by

$$\frac{d\sigma_\ell}{d\Omega} = \frac{\sigma_\ell}{4\pi}\left[1 + \frac{\beta_\ell}{2}(3\cos^2\theta - 1)\right]$$

where θ is the angle between the direction of the emitted photoelectrons and the electric vector of the radiation, $d\Omega$ is the element of solid angle involved and σ_ℓ is the cross section for photoionization from the neutral atom of an electron ℓ. The angular distribution is characterised by the asymmetry parameter β_ℓ and experiments will be described using the polarized radiation from an electron synchrotron to measure β_ℓ as a function of energy.

Comparisons will be drawn between the "p" shell β values for the inert gases Ne, Ar, Kr and Xe to show the effect of inter and intra shell interactions. New data will be presented on similar measurements made on the symmetric molecule CH_4 which are at variance with published calculations but which can also be explained on similarities with a neon like system.

NUCLEAR STRUCTURE STUDIES IN HEAVY ELEMENTS: ISOTOPE SHIFT OF RADIOACTIVE ^{202}PB

O. Redi, F. Moscatelli, R.L. Wiggins, H.H. Stroke, New York University*,

and

R.A. Naumann, Princeton University**

In a continuing program to study the magnetic and electric structure of nuclei of heavy atoms, we are measuring the spectra of radioactive lead by classical high-resolution optical spectroscopy[1], level-crossing[2] and optically excited atomic beam techniques[3], and have initiated work with our tunable ring dye laser system. The isotope shifts in this region are particularly interesting because they reflect largely the variations in the nuclear charge radius through $\delta\langle R^2\rangle$, the mass-dependent effects having expectations of the order of one percent. Our data, particularly in mercury, as extended substantially by the work of the group of Otten in Mainz, has revealed a detailed picture of deformations of nuclei both in their ground and isomeric levels.[4] The lead experiments are expected to complement these studies.

We have measured the isotope shift of ^{202}Pb (3×10^5y) in the 2833-Å resonance line with the use of our 9.1-m focal length Czerny-Turner monochromator (resolving power $\approx 10^6$). Photographic as well as photoelectric detection, which incorporates our multiply-scanned averaging system[5], were used. The isotope was produced in a (p, xn) reaction using natural thallium as a target at the Princeton University cyclotron and Brookhaven National Laboratory linear accelerator. Radiochemistry and isotope separation were used to yield a final sample in the cell of about 1 nanogram.

The result of our measurement for the ^{208}Pb-^{202}Pb isotope shift is 0.209(6) cm^{-1}.

Following the procedure used by Otten et al.[6], with the use of B(E2) data[7] for ^{204}Pb and ^{206}Pb we determined the deformation contribution to the isotope shift, and then the spherical volume term. From this we can then obtain the deformation effect for ^{202}Pb, $\beta_o^2 = 0.007$. This can be

used to predict a value of B(E2) (0 - 2) = 6.6 x 10^{-49} cm^4. As one goes into the neutron deficient region, the shift due to dynamic deformation is thus found to become comparable to the spherical volume shift.

*Work supported by the National Science Foundation Grant PHY76-21099 A01.
**Work supported by the U.S. Department of Energy.

1. R. Wiggins, O. Redi, H.H. Stroke, S. Lis, and R.A. Naumann, Bull. Am. Phys. Soc. 21, 626 (1976); F. Moscatelli, R.L. Wiggins, O. Redi, H.H. Stroke, and R.A. Naumann, id. 24, 17 (1979).
2. R. Wiggins, O. Redi, and H.H. Stroke, Fifth International Conference on Atomic Physics, 26-30 July 1976, Berkeley, Abstracts, p. 312.
3. O. Redi and E. Wang, Bull. Am. Phys. Soc. 18, 120 (1973).
4. J. Bonn, G. Huber, H.-J. Kluge, L. Kugler, and E.-W. Otten, Phys. Lett. 38B, 308 (1972); H.H. Stroke, D. Proetel, and H.-J. Kluge, Phys. Lett. 82B, 204 (1979).
5. G.F. Fulop, C.S. O, and H.H. Stroke, Rev. Sci. Instr. 48, 1550 (1977).
6. J. Bonn, G. Huber, H.-J. Kluge, and E.W. Otten, Z. Physik, A276, 203 (1976).
7. P.H. Stelson and L. Grodzins, Nuclear Data Tables 1, 21 (1965).

Blank

INDEX ALPHABETIQUE

REMERCIEMENTS

Les organisateurs de la Conférence tiennent à remercier les organismes officiels qui ont contribué à la préparation de cette manifestation :

La Direction des Recherches, Etudes et Techniques
Le Centre National de la Recherche Scientifique
Le Commissariat à l'Energie Atomique
La Direction des Relations Universitaires Internationales
La Délégation Générale à la Recherche Scientifique et Technique
l'Université Pierre et Marie CURIE (PARIS VI)
L'Université Paris-Sud (PARIS XI)

---

et les Sociétés Industrielles qui ont également apporté leur soutien :

Centre de Recherche de la C.G.E.
Coherent Radiation
Jobin Yvon
Matra-Seavom
Oriel
Philips
Schlumberger
Sopra
Spectra Physics
Thomson-CSF

IMPRIMERIE AUGUSTIN - PARIS 742 41 17