SAND2007-3771C

STUDY OF EUV SPECTRA FROM AL X- PINCH AND WIRE ARRAY IMPLOSIONS PRODUCED ON THE 1 MA " ZEBRA" AT UNR

P.G. Wilcox, A. S. Safronova, V. L. Kantsyrev, U. I. Safronova, K. Williamson
University of Nevada, Reno, NV USA
K. Struve, B. Jones, C. Deeney*, P.D. LePell**
Sandia National Laboratories, Albuquerque, NM USA

ICOPS 2007 , 17-22 June, Albuquerque ,NM

ABSTRACT

It is well known that implosions of X-pinches and wire arrays produce powerful laboratory x-ray sources. X-ray spectroscopy is a very useful tool for diagnostics of X- and Z-pinch plasmas at stagnation while EUV spectroscopy seems to be an appropriate tool of diagnosing the plasma before and after the stagnation. Though x-ray spectra that characterize the stagnating plasmas are intensively used for X- and Z-pinch plasma diagnostics the EUV spectra are not yet studied in detail.

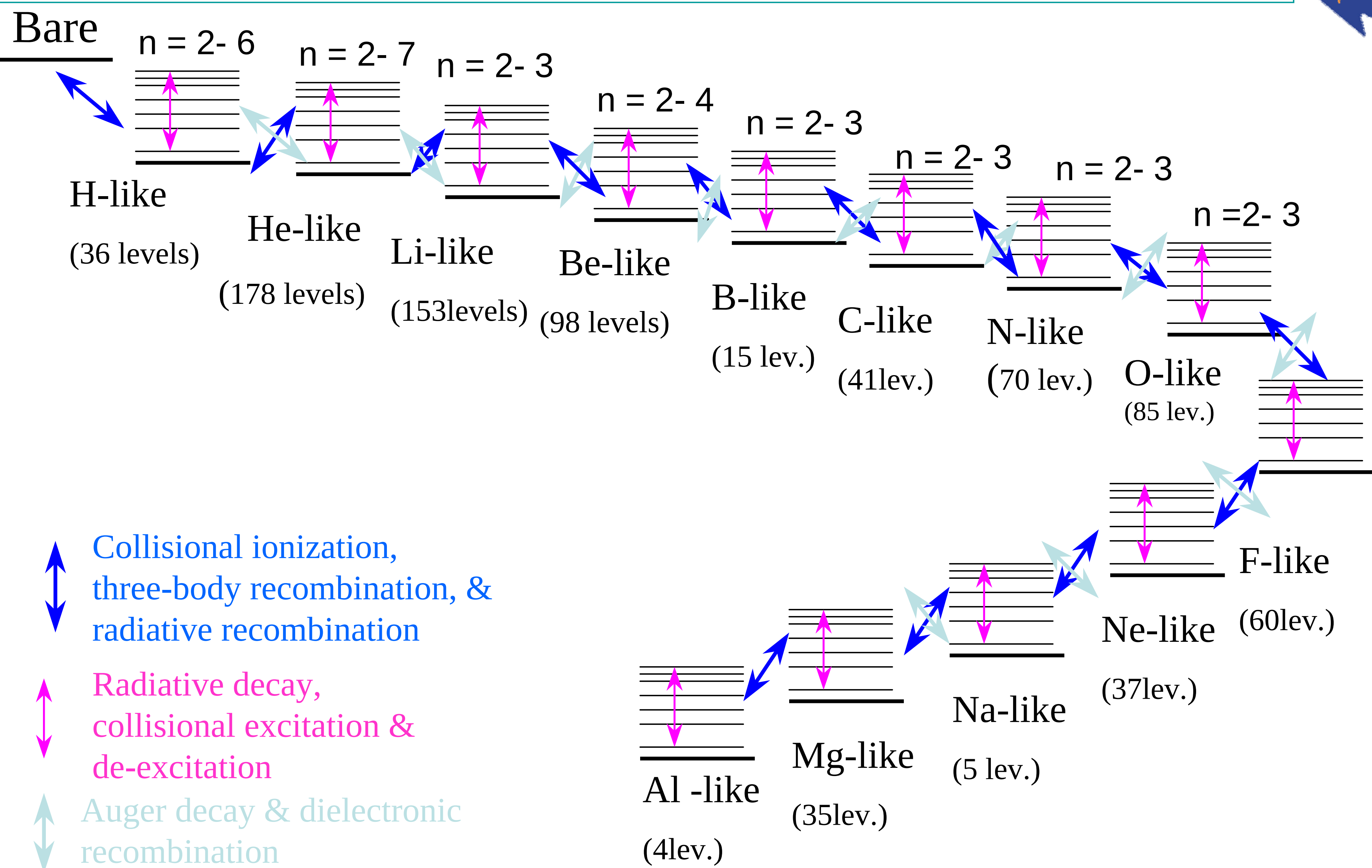
In the present work a collection of EUV spectra from implosions of very different X- and Z-pinch loads on the 1MA Zebra generator at UNR is presented for the first time. Specifically, the loads were Al X - pinches, cylindrical wire arrays (with a small portion of NaF coating), and planar wire arrays (see [1-2] for the details of the experiments).

Non-LTE kinetic model of Al that was recently used to model X-ray K-shell Al spectra from the planar wire arrays[3] was applied here to calibrate and identify the EUV spectra. Preliminary plasma parameters were computed. Similar and different features of the EUV spectra from the above-mentioned loads were identified and analyzed. Future work is discussed.

Kinetics Modeling

- The kinetics modeling of Al spectra depends on the plasma conditions (parameters T*e* , *Ne).*
- The atomic dataset was generated for the new Al model and used as an input to SCRAM (non-LTE collisional –radiative kinetics code [4])to model first x-ray spectra in [3] and the EUV spectra (present work) from Z-pinches.
- It includes the ground states of all ions from neutral to bare nucleus.
- Energy level structures and complete radiative and collisional coupling data are calculated by the *FAC* atomic structure code [5].
- The levels are fully coupled by radiative decay and radiative recombination, collisional excitation and ionization, Auger decay and their reverse rates.
- All collisional rates are calculated by integrating collision cross sections over a Maxwellian electron distribution function.

Aluminum kinetics model

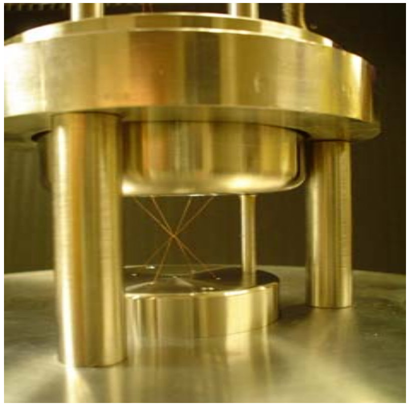


Atomic data is generated using the FAC atomic structure package developed by M.F. Gu[5]

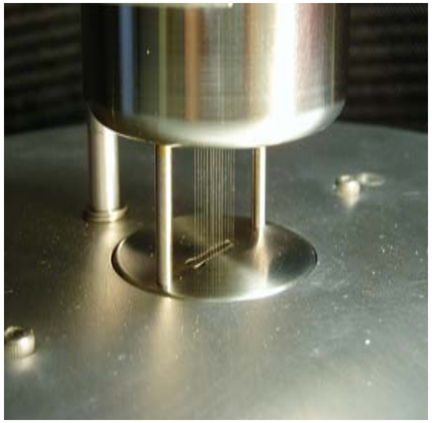
The X- and Z-pinch loads used in experiments on 1 MA “Zebra”at UNR

- Al X-pinches with 2 and 4 wires from Al 5056 (95% Al and 5% Mg) and Al 1100 (99% Al) alloys
- Cylindrical wire arrays with NaF coating
- Planar wire arrays

Shot #	Load	Material
432	X pinch,2w	Al(1100)
785	Cylindrical Array, 8 w	Al(5056) + 5 %NaF
796	Planar Array, 10w	Al(5056)
787	Cyl.Arr.,8w	Al(5056) + 5 %NaF



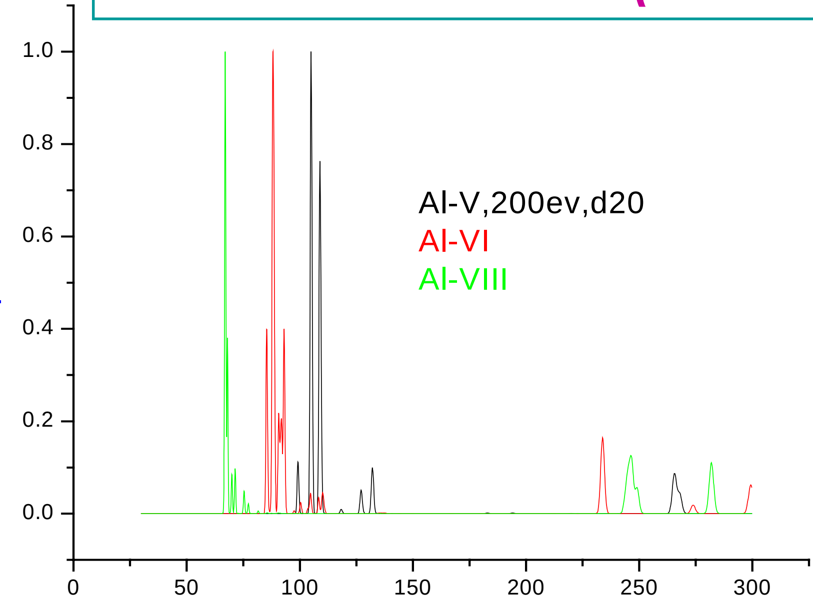
X-Pinch

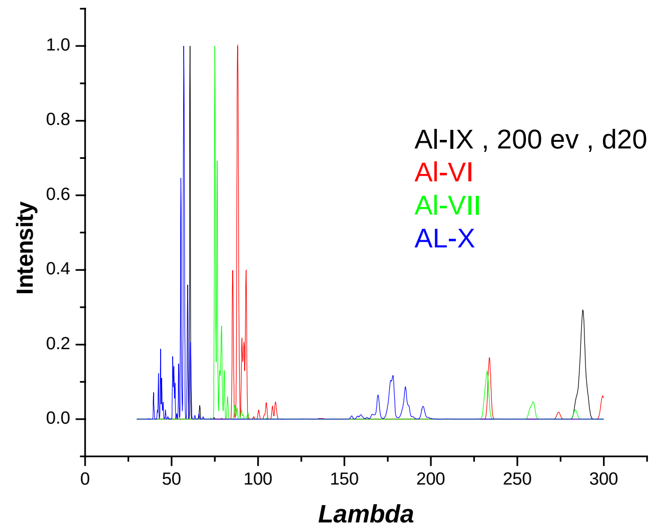


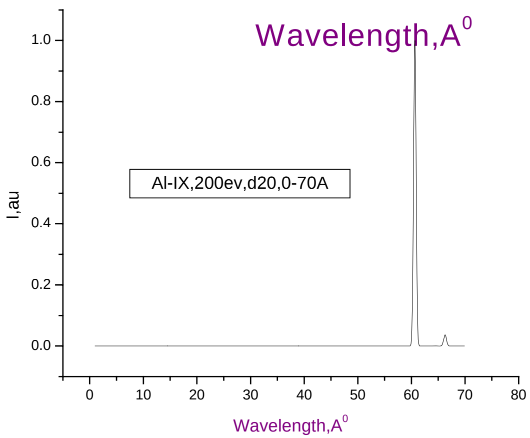
Planar Array

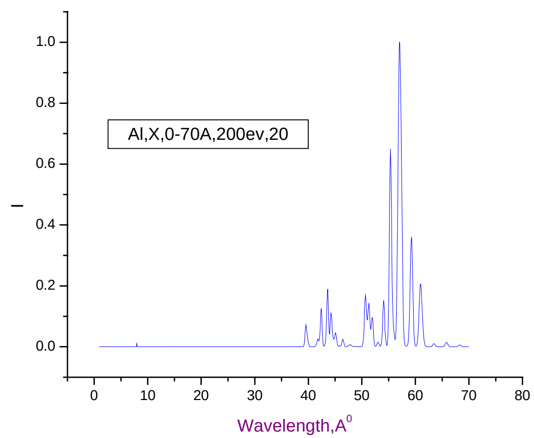
Modeling of EUV spectra from different Aluminum Ionization Stages

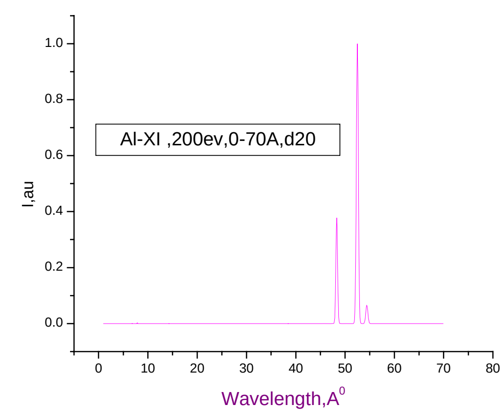
(Te = 200ev , Ne = 10^{20} /cm³)





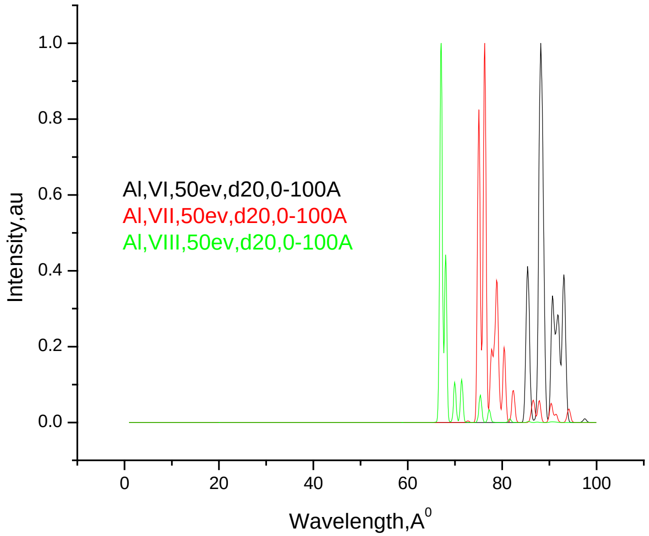


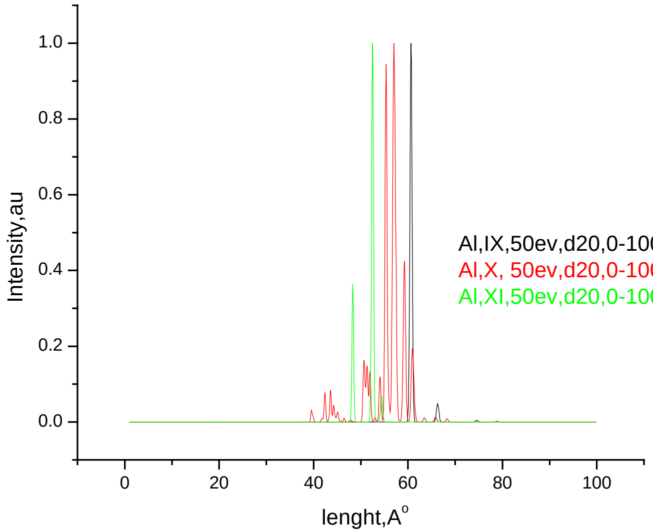


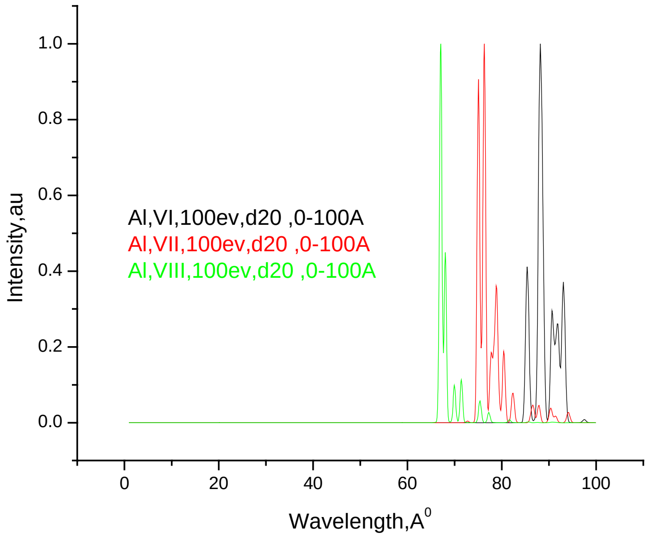


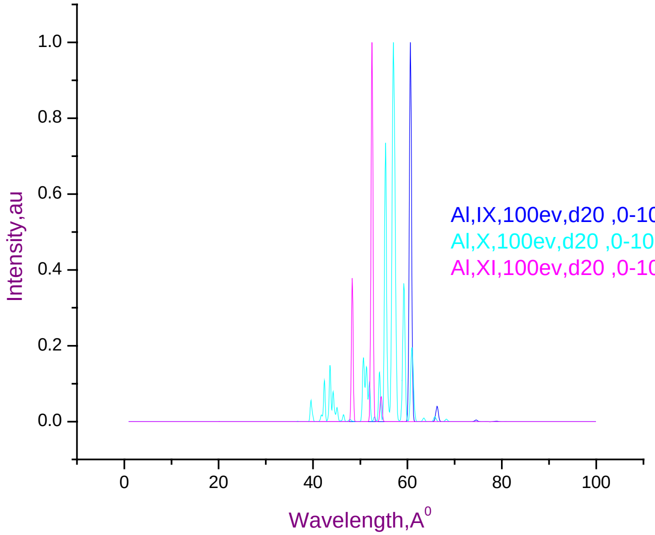
Modeling of EUV spectra from Aluminum VI-XI

(Te = 50ev ,100ev ; Ne=10^{20} cm^{-3})



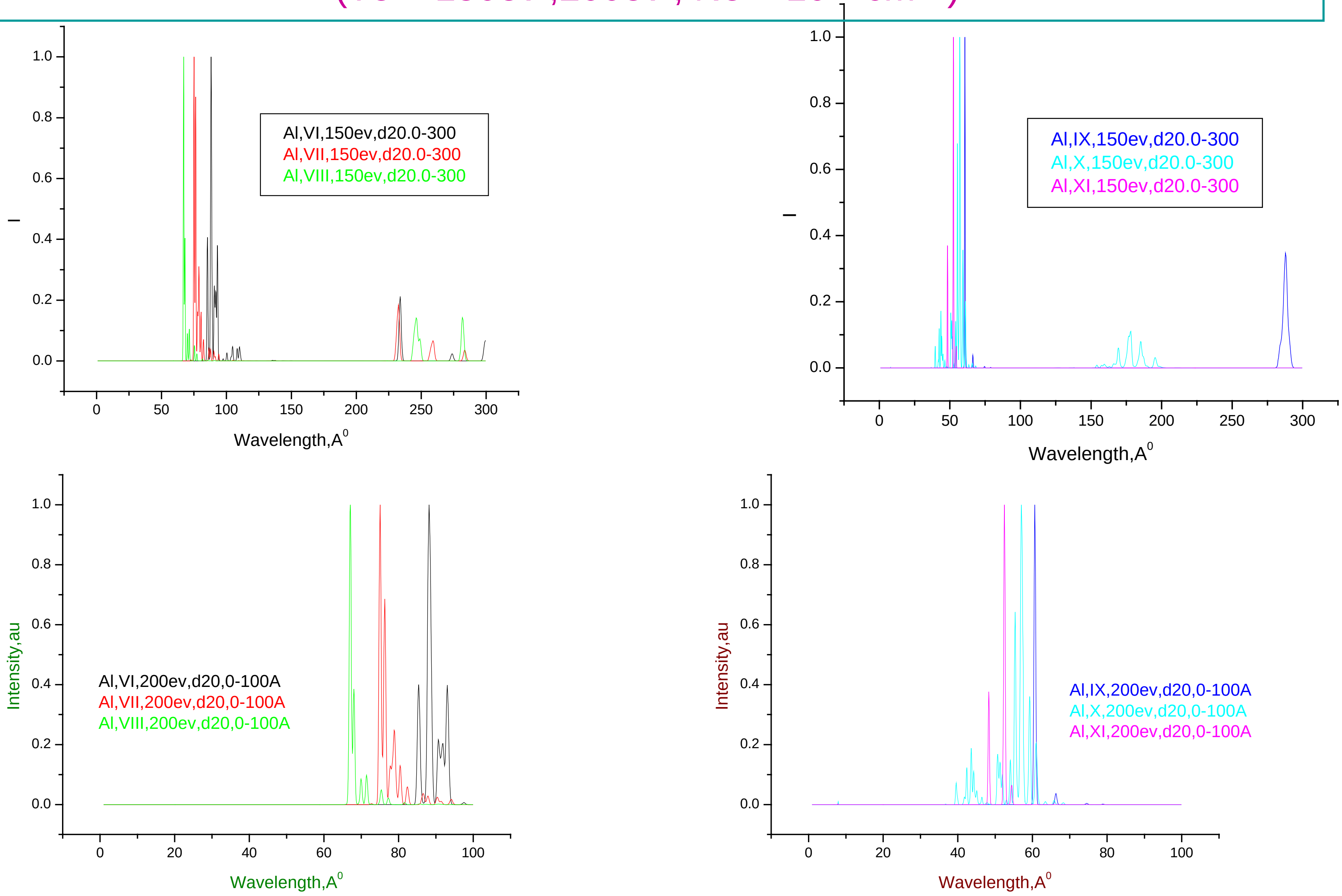






Modeling of Ionization Stages in Aluminum

(Te = 150ev ,200ev ; Ne = 10^{20} cm^{-3})



Reference sources for the Identification

6. R. Kelly,Atomic and Ionic Spectrum Lines below 2000 Å ,Vol. 16 (1987)

7. NIST -- http://physics.nist.gov/asd3.

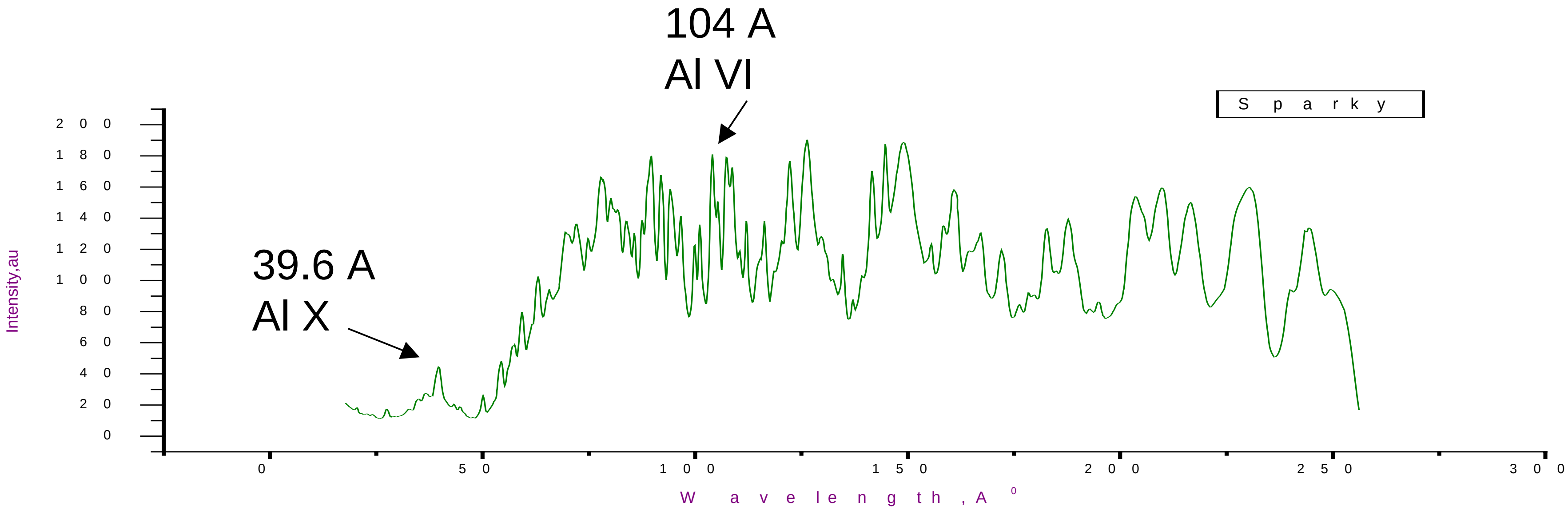
8. Non-LTE Al modeling

9. A.Shevelko,L.Shmaenok et al, Physica Scripta,vol. 57, pp 276 – 282 (1998).

10. S.Hoory,U.Feldman at al,Journal of the Optical Society of America, vol.60, #11 (1970)

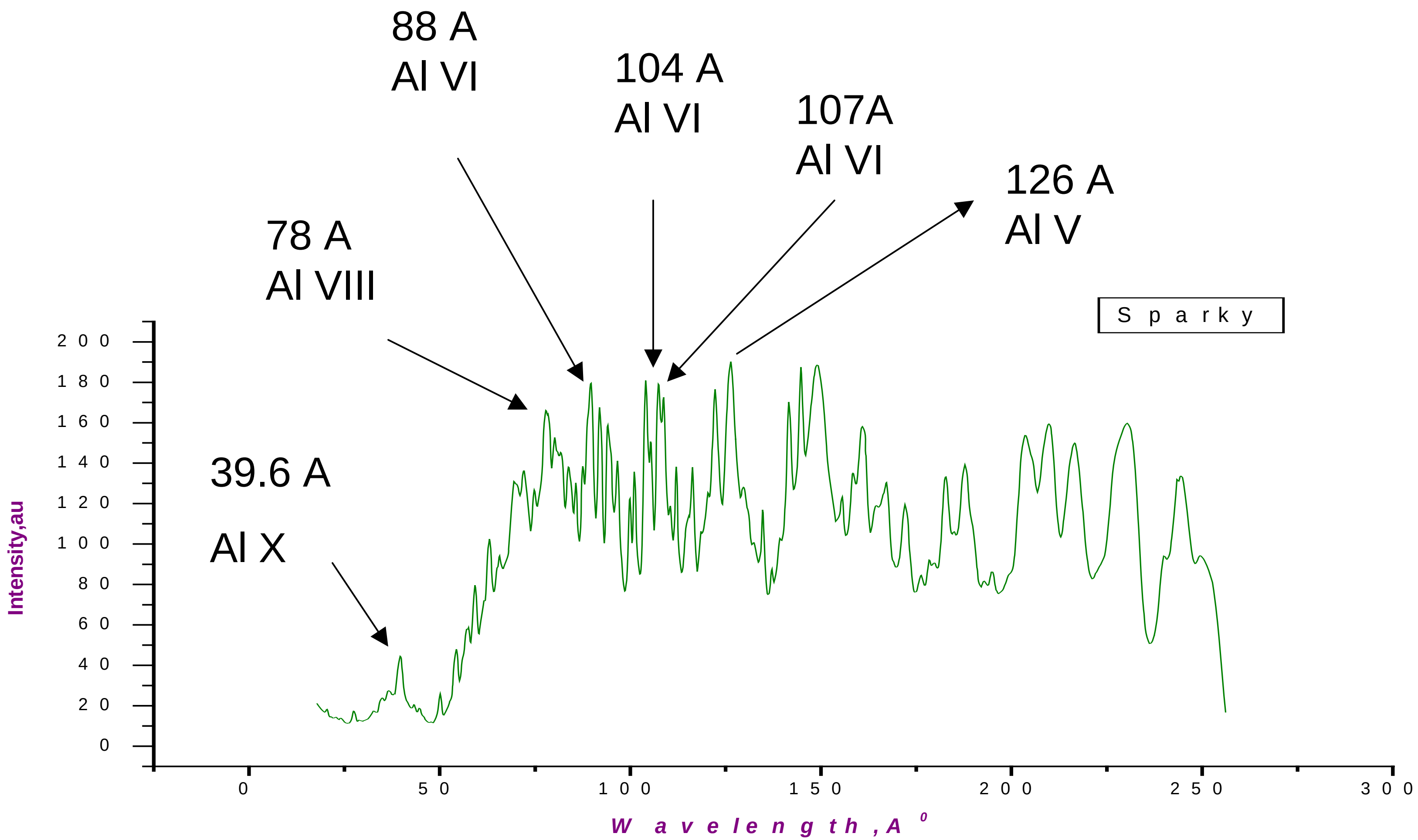
11. R. Stuik , PhD Thesis , Tech. University, Eindhoven, The Netherlands

Al EUV spectrum from "Sparky" *

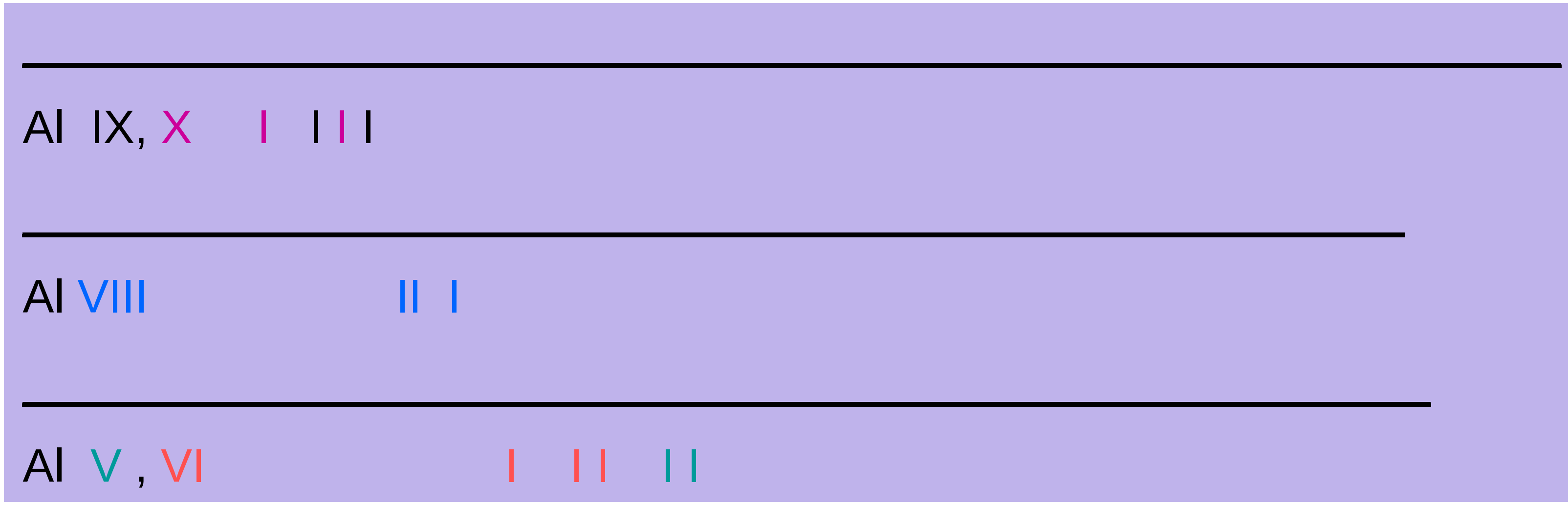


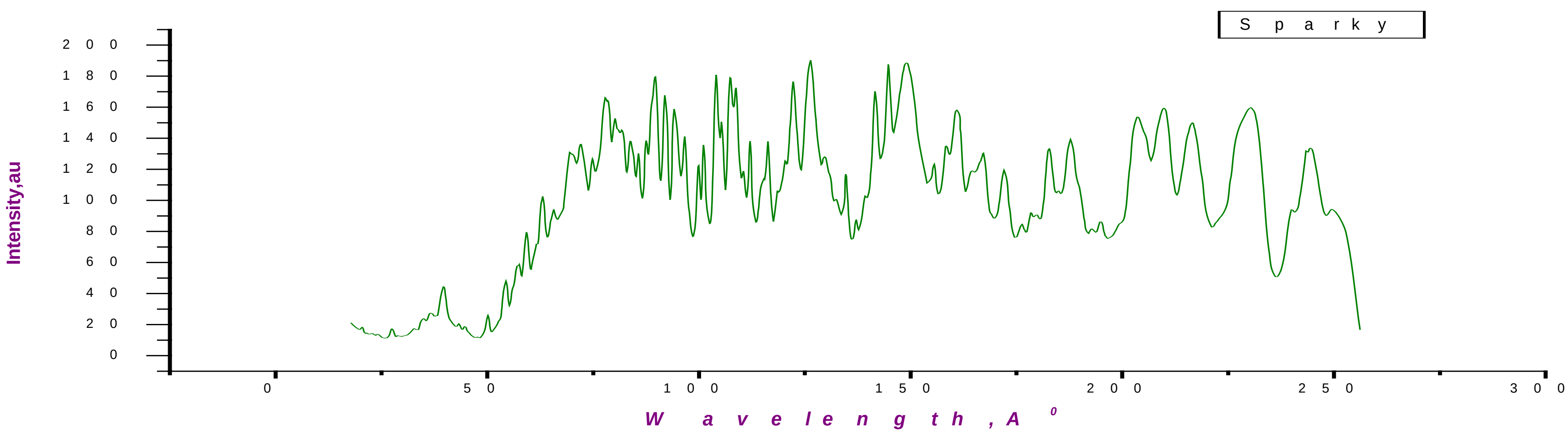
* For details about UNR table-top Z-pinch & laser-plasma facility see [12]

Al EUV (“ Sparky”) line identification



Al EUV (“ Sparky”) line identification





List of the Identified Lines

AL X	Ref.
2s2p – 2p4p	6,7,8,9,10
2s2p – 2s3d	6,7,8,9,10

AL IX	
$2s2p^2$ - 2s2p3d	6,7,8,9

AL VIII	
$2s^22p^2$ – $2s^2$ 2p3d	6,7,8,9
$2s2p^3$ – $2s2p^23s$	6,7,8,9

AL VI	Ref.
$2s^22p4$ - $2s^22p^33d$	6,7,8,9,11
$2s^22p4$ - $2s^22p^33s$	6,7,8,9,11

Al V	
$2s^22p5$ - $2s^22p4(^1D)3s$	6,7,11
$2s^22p5$ - $2s^22p4(3P)3s$	6,7,11

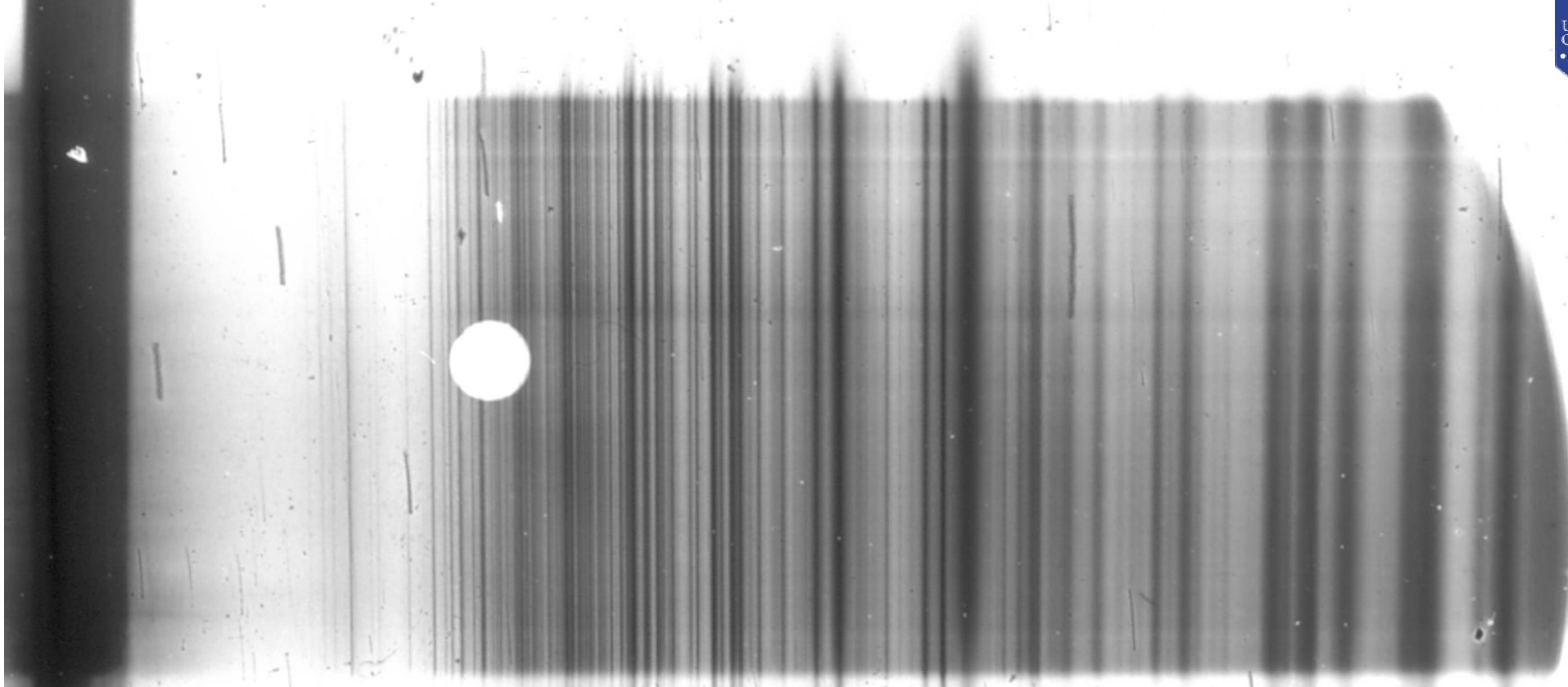
Comparison and Identification

of Al EUV spectra

from

“Zebra” Shots

Sparky



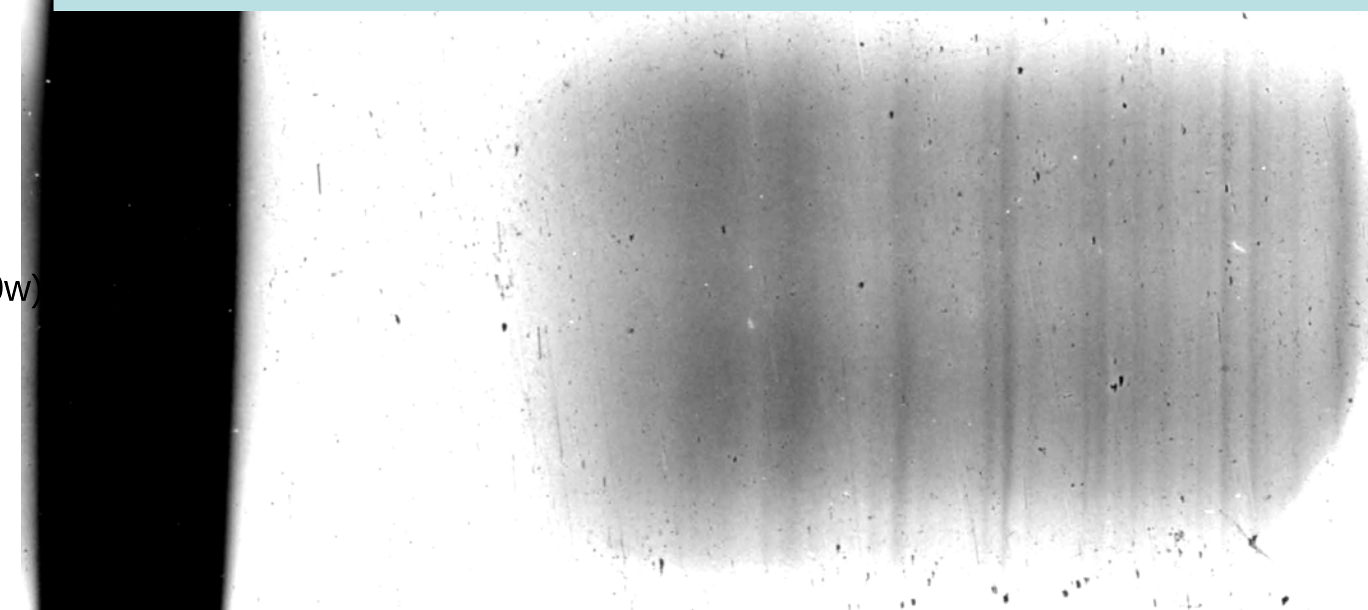
Wavelength, A 50 ________100_A_____150________200_________>

Al V,VI ,VIII I I I I II II

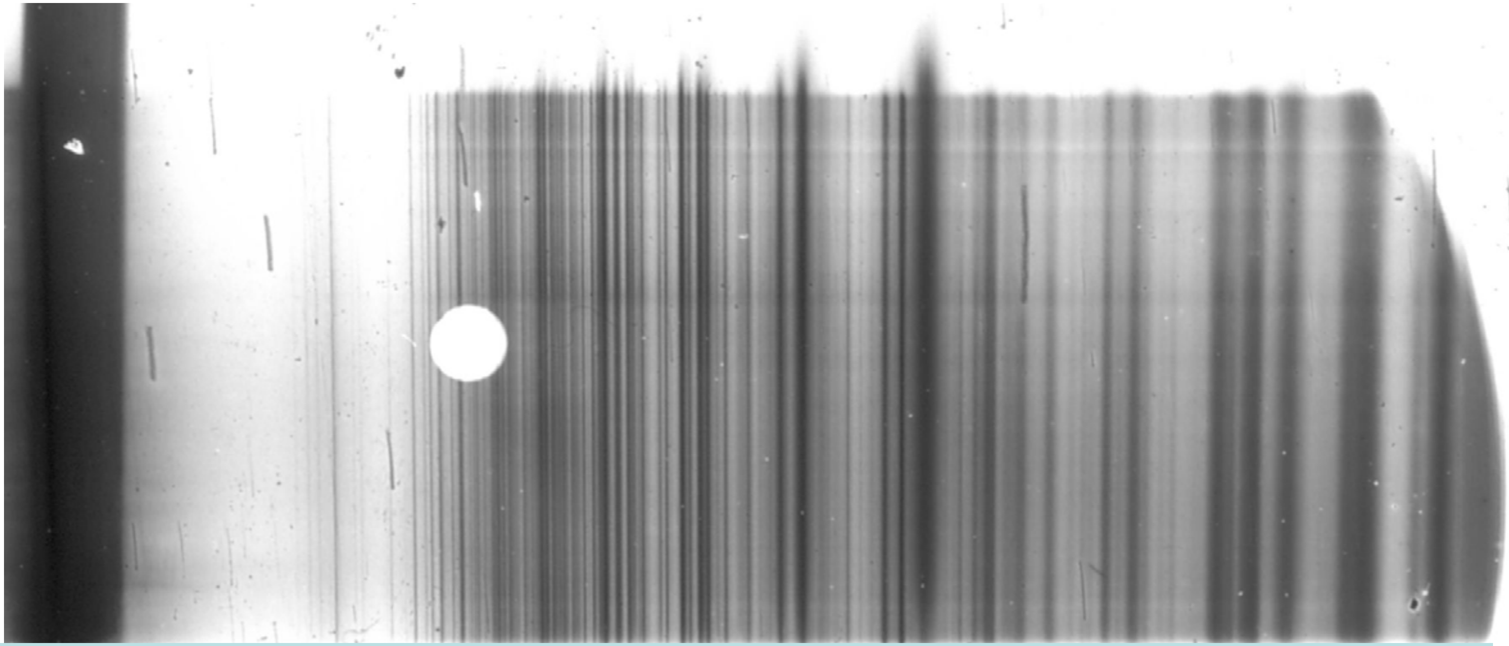
Zebra

796

(Pl.Ar.,10w)

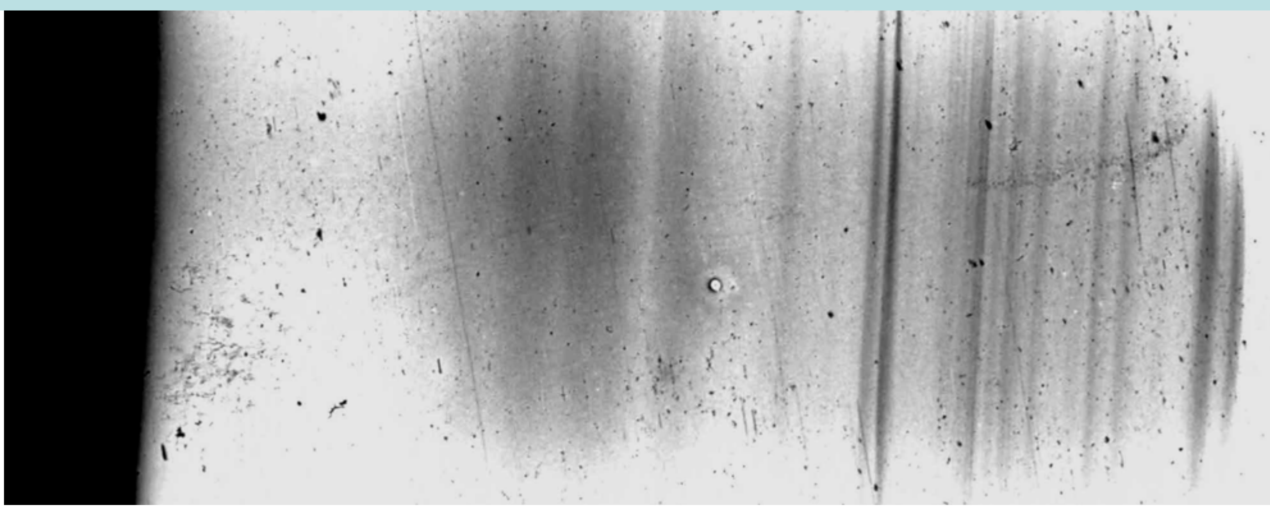


Sparky



_Wavelength, A_____50__________100_A___________150 __________________>

Al V,VI ,VIII I I I I II II



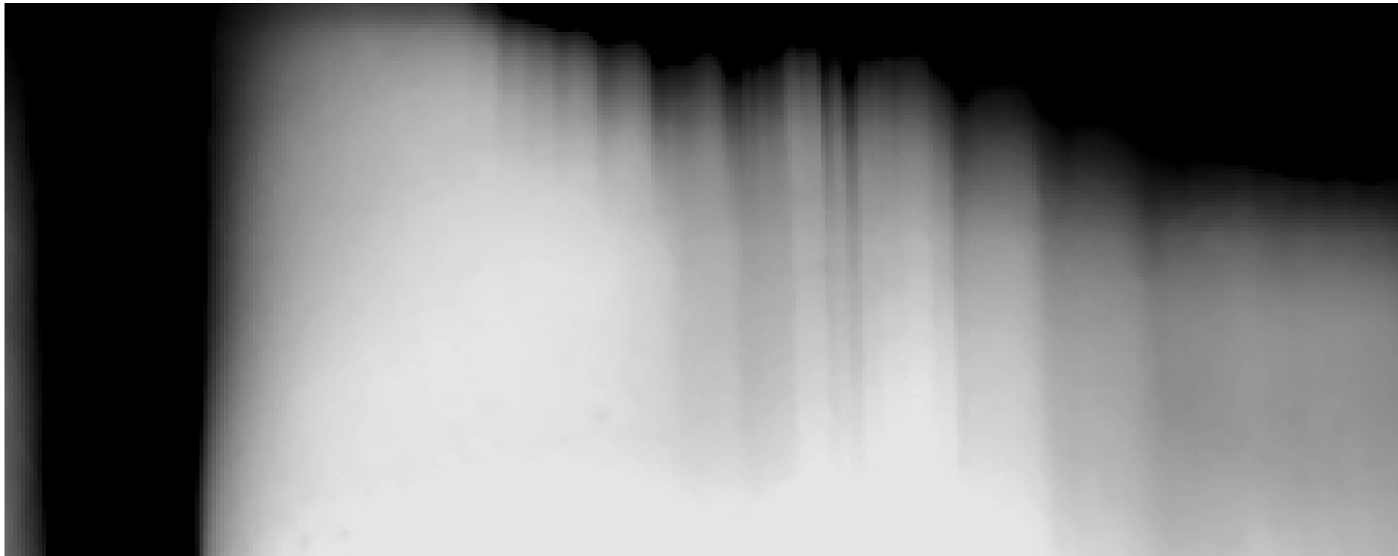
Zebra
787

(Cyl.Arr.,8w)

Zebra

432

(X,2w)



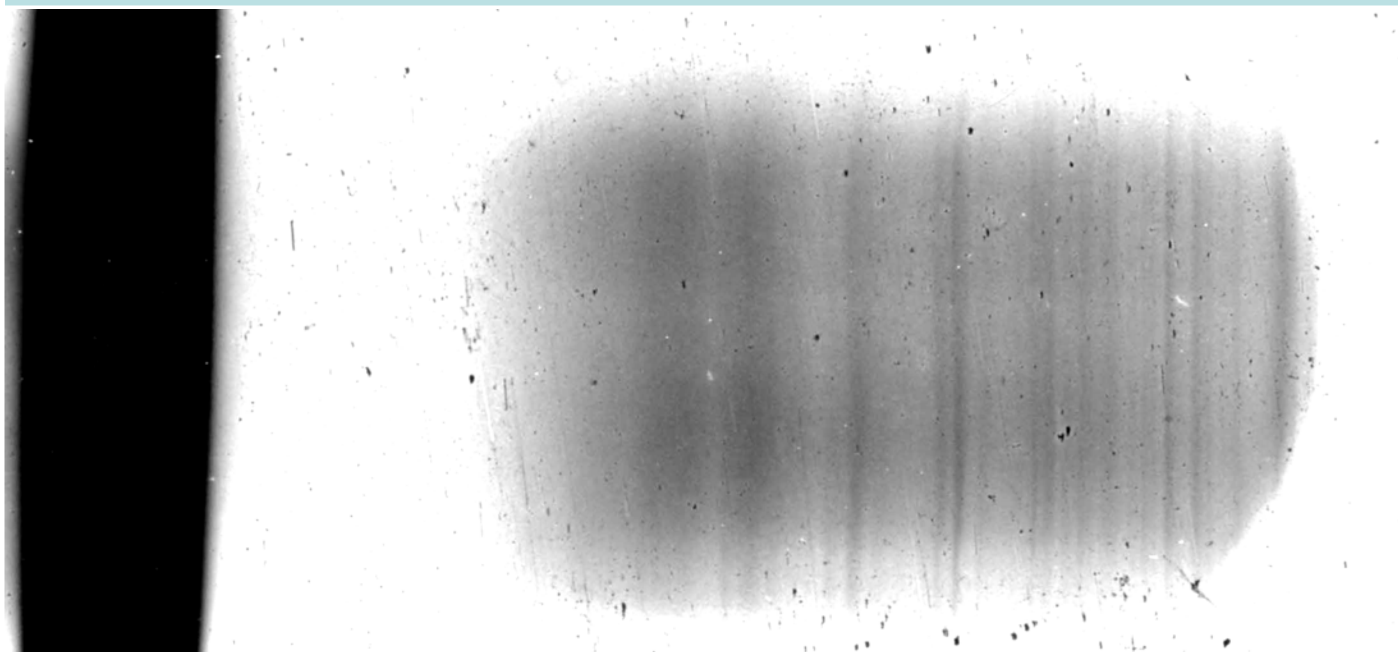
_Wavelength, A___ __50_______100_A______150 _____________>

Al V,VI ,VIII I I I I I I II

Zebra

796

(Pl.Ar.,10w)



Zebra

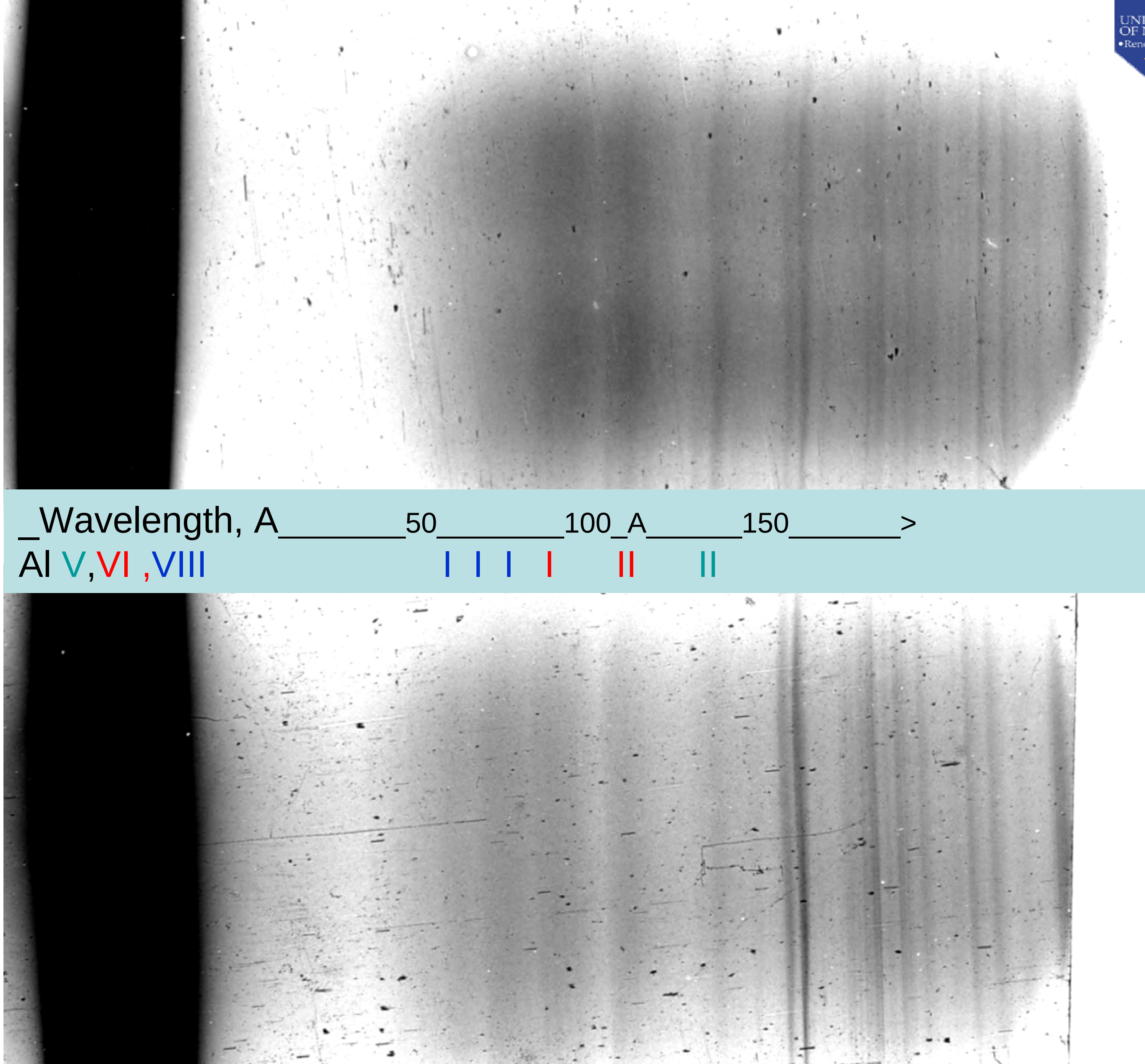
796

(Pl.Ar.,10w)

Zebra

785

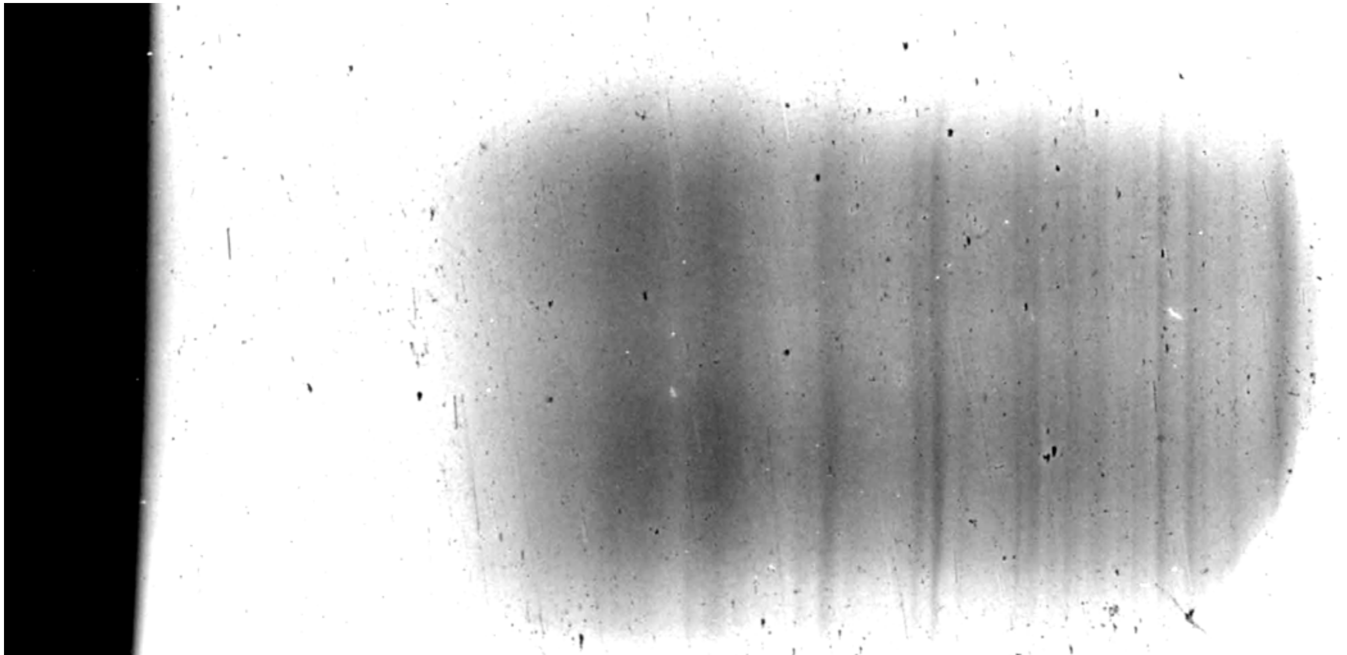
(Cyl.Arr.,8w)



Zebra

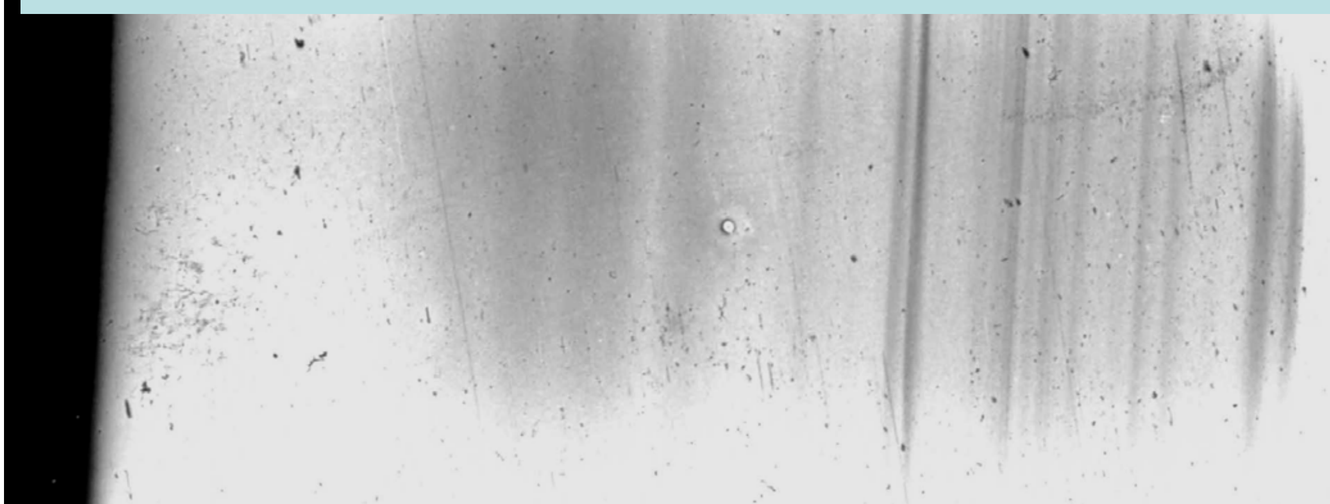
796

(Pl.Ar.,10w)



Wavelength, A_50________100_A_______150___________>

Al V,VI ,VIII I I I I I I II



Zebra

787

(Cyl.Arr.,8w)

Conclusions

- Non - LTE kinetic model of Al is used to model EUV Al spectra.
- Preliminary plasma parameters (Te =150-200ev, Ne=10^{20} /cm^3) are computed.
- The different spectral features of EUV spectra from the Aluminum loads in experiments on "Zebra" are identified and analyzed .
- Predominantly low ionization stages that we found in "Zebra" shots indicate relatively lower Te than on "Sparky" (150-200 vs 300-350 eV).
- Higher ionization stages lines are widely broadened due to the increased number of collisions in denser "Zebra" plasma (in comparison with "Sparky").

Future Work

- Modification of the model to include high Rydberg states for Li-, B-, and C-like Aluminum.
- Modeling of EUV spectra from “Zebra” and analysis of plasma parameters with connection to the type of load.
- Analysis of EUV spectra from other Z- and X- pinch loads.

References and Acknowledgments

1. V.L. Kantsyrev, A. S. Safronova et al, IEEE transactions on plasma science , vol. 34, No.2 (Apr. 2006).
2. B. Jones, C. Deeny, V.Kantsyrev et al, ICOPS 2006, CP808.
3. A.S.Safronova, V.L. Kantsyrev et al , HEDP 3 pp.237-2415 (2007)
4. S.B. Hansen. PhD Dissertation, University of Nevada,Reno (2003).
5. M.F. Gu. , AIP conference proceedings; 730: 127 (2004).
6. R. Kelly,Atomic and Ionic Spectrum Lines below 2000 Å ,Vol. 16 (1987)
7. NIST -- http://physics.nist.gov/asd3.
8. Non-LTE Al modeling
9. A.Shevelko,L.Shmaenok et al, Physica Scripta,vol. 57, pp. 276 – 282 (1998).
10. S.Hoory,U.Feldman at al,Journal of the Optical Society of America, vol.60, #11 (1970)
11. R. Stuik , PhD Thesis , Tech. University, Eindhoven, The Netherlands
12. V.L. Kantsyrev, D. A. Fedin et al,Proc. of SPIE, vol. 59180W, pp. 1-7 (2005).

* This work was supported by NNSA under DOE Cooperative Agreements DE-FC52-06NA27588, DE-FC52-06NA27586,and DE-FC52-06NA27616.
Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04- 94AL85000 .