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FINAL REPORT

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ATOMIC STRUCTURE OF NI-LIKE SOFT X-RAY LASING IONS

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The object of this research was to use the GDL laser at the Laboratory for Laser Energetics at the University of Rochester to determine the atomic structure of ions of the nickel isoelectronic sequence for which lasing in the soft x-ray region has been observed.

To accomplish this goal, two experiments were carried out at the Laboratory for Laser Energetics (LLE). The first experiment was carried out from 19 June 1991 to 4 July 1991. In preparation for this experiment a portable 2.2-m grazing-incidence spectrometer was carefully aligned at the National Institute of Standards and Technology (NIST) to produce excellent spectra throughout the region 10 - 300 Å. A target chamber and hardware to interface this chamber to the GDL focussing lens assembly were fabricated at NIST.

A series of test plates was made at NIST with a low-inductance vacuum spark to determine the point in the center of the target chamber that corresponded to the entrance optical axis of the spectrometer. A special template was then fabricated that could be used to position laser targets correctly in the target chamber.

After vacuum testing all components, the spectrograph and associated hardware were shipped to LLE and set up in the GDL target room. The GDL laser was configured to direct frequency-doubled light (532 nm) to the NIST spectrometer. A target of pure iron was positioned in the chamber with its flat surface vertical and lying along the entrance axis of the spectrometer, as determined by the mentioned template. This position was then fine-tuned for optimal illumination of the spectrometer by taking a series of photographic spectra in which the target and GDL focussing lens were moved in synchronism along the axis of the focussing lens. The position of the lens relative to the target was then fine-tuned by taking a series of spectra with a molybdenum target in which only the lens was moved along its axis. These exposures produced the following results, which according to previous experience were totally unexpected:

1. With optimum focussing, very high stages of ionization could be achieved with the GDL laser operating at an energy of about 60 J in green light (532 nm). For example, for iron strong spectra of stages of ionization up to Fe^{23+} were easily obtained. For molybdenum, strong

spectra for stages up to Mo^{33+} were obtained. Stages of ionization could be distinguished by taking spectra at different positions of the lens.

2. Of much greater surprise was the finding that by positioning the focussing lens so that the focal point would lie about 1.5 mm in front of the target, extremely sharp spectra could be achieved without significant reduction of maximum ionization stage. It seems clear that this method can yield laser-produced spectra of higly-ionized atoms that have higher resolution than previously possible. This technique was used to acquire subsequent data plates for the desired Ni-like ions.

Using the above techniques excellent spectra were photographed for Ni-like ions of the following atoms: Gd, Tb, Dy, Er, Yb, Lu, and Hf. The wavelength scales for these spectra were determined by overlaying a laser-produced spectrum of Fe as well as a spectrum of a sliding-spark of Mo on the spectrum of the Ni-like ion.

Thousands of spectral lines were observed in these exposures. The plates are now in the process of being measured and analyzed at NIST.

With an eye toward possible future research with the GDL laser system, a test exposure was made to determine the ability of the laser to generate Na-like ions. These ions are currently of great interest for evaluating quantum electrodynamic effects in heavy ions. To this end a spectrum of the Na-like ion Ag^{36+} was photographed. Measurement of the spectra have produced the following comparison with previous measurements and with several theoretical predictions of the wavelengths. As can be seen from Table 1, the new results show a clear preference for the calculations of Kim et al.

Table 1. Wavelengths in Å for Na-like Ag^{36+}

Transition	Previous Meas.	Calculated		New Meas.
$3s\text{-}3p_{1/2}$	150.78 ±0.050[a]	150.286[b]	150.793[c]	150.800±0.010
$3s\text{-}3p_{3/2}$	97.263±0.015[d]	97.108[b]	97.278[c]	97.279±0.010

[a] E. Hinnov et al., J. Opt. Soc. Am. B 3, 1288 (1986).
[b] J. F. Seely et al., At. Data Nucl. Data Tables 47, 1 (1991).
[c] Y.-K. Kim et al., Phys. Rev. A 44, 148 (1991).
[d] J. Reader et al., J. Opt. Soc. Am. B 4, 1821 (1987).

The second experiment was carried out at LLE from 8 - 14 December 1991. In this experiment the 2.2-m grazing-incidence spectrometer was again set up with its target chamber in the GDL target room. Spectra of the following atoms were photographed with a laser energy of about 45 J in green light: Fe, Cd, Ce, Sn, Mo, and Rh. The spectrum of Fe was particularly excellent, evidencing several strong, previously unobserved transitions at about 32 Å for the Li-like ion Fe^{23+}. These transitions are of the type n=3-4, which will be important for determining an accurate ionization energy for this ion. The measurements of the wavelengths for these transitions are being completed at the present time. They will eventually be combined with new measurements of the n=2-2 resonance lines obtained from tokamak observations to produce an improved set of energy levels for Fe^{23+}.

All equipment was shipped back to NIST in June 1992.

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