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K-SHELL AND L-SHELL PLASMA SPECTROSCOPY EXPERIMENTS

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Final Technical Report
K-Shell and L-Shell Plasma Spectroscopy Experiments
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Detailed atomic level populations in high temperature and dense plasmas have become increasingly important in laser generated plasmas. Certain spectral line intensity ratios are density-dependent while others are temperature-dependent. Both can be used to extract information concerning population kinetics and ion level populations. In order to be useful these dependencies must be characterized by independent means. In laser produced plasmas this can be done via holographic interferometry for electron density determinations[1] and via the slope of the H-like free-bound continuum of K-shell lines for electron temperature determinations[2]. The characterization of density- and temperature-dependent L-shell lines can be accomplished in ionization balance experiments in which laser irradiance is varied on targets which contain both K-shell and L-shell emitters. The K-shell free-bound continua provide the local temperature determination while holographic interferometry yields density profile information, from which the temperature and density dependent L-shell lines can be characterized.

The plasma spectroscopy ionization balance experiments were performed during the latter half of 1989 and into January 1990 on K-shell and L-shell elements. They constitute a refinement on a previous series of ionization balance experiments that were performed in 1987 at KMS[3]. The difference between the two sets of experiments consists in the degree of sophistication used in the recording of the time-resolved spectral data. In the earlier, 1987, series, two time-resolving instruments were employed: (1) a streak camera fitted with a low spectrally resolving KAP crystal spectrograph was used to record the time-varying x-ray emission at selected regions of the target plasma plume, and (2) a gated/micro-channel plate(MCP) framing camera spectrometer, also with a KAP crystal, was used to provide spatially resolved spectra at three different times.

In the present series, 4 gated/MCP framing intensified x-ray spectrometers (FIXS) (3 used simultaneously on any one experiment) provided by LLNL, were used to yield simultaneous high, medium and low resolution spectra of the plasma plume, utilizing ADP, Beryl, and KAP crystals, respectively. Electron density was measured using a 4-frame holographic interferometer. Additional target/plasma diagnostics included 3 pinhole cameras (2 time-resolved and one time-integrated), one with 3 filtered gated/MCPs yielding 18 timed target images, a spatial- and time-integrating KAP spectrometer, plus the usual energy-on-target and absorbed energy calorimeters and visible streak cameras for pulse length and shape measurements. A further refinement over the 1987 experiments was the use of wide band ($\Delta\lambda = 18\text{\AA}$) laser irradiation in conjunction with crossed etalon plates designed to induce spatial incoherence in the laser beam, thereby smoothing out focused beam hot spots caused by laser coherence. Fig.1 is a schematic of an axial view of the placement of the spectrometers in the KMS target chamber.

Twenty-five target types, listed in Table 1, were employed to accommodate the different target element emissions and spectrometer sensitivities. Al, Mg, P, and Cl, as K-shell emitters, provided information on the electron density and temperature of irradiated targets also containing L-shell emitting spectra of Mo, Br, Ge and Cu. A large number of the targets were provided by LLNL. Special composite targets using powder fabrication techniques were fabricated by KMSF. Previously prepared powders of the specified elements (pre-determined composition) were mixed, melted in a furnace, remelted, etc., until the composite was considered well-mixed. The powder mixtures were then tamped into pre-drilled depressions in polystyrene and then shaved at the surface to produce spots with diameters of 50 and 100 μm , as shown in Fig.2. Also shown in Fig.2 is a so-called 'Bulls-eye' target made by placing a washer of Mg around the spot, in order to provide added Mg emission for shots in which electron temperature could be more easily determined via the free-bound continuum of H-like Mg.[4]

The work was performed in five (5) experimental sub-series:

- A. Microdot target optimization of H-like and He-like free-bound recombination continuum measurements of the free velocity distribution and electron temperature. $Z = 12(\text{Mg})$ and $13(\text{Al})$

- C. Temporal and spatial measurements of K-shell and L-shell dielectronic satellite lines at high resolution for use as electron density and temperature diagnostics in laser produced plasmas.[5]
- D. Experiments to test the feasibility of x-ray lasing schemes in which lines of Al are used to photo-pump lines of Fe[6], Er[7], and Cu[8].
- E. Determination of T_e for exploding foil x-ray laser targets.

A typical L-shell spectrum of Molybdenum is shown in Fig.3, in which fluorine-like, neon-like, and sodium-like lines of Mo are indicated by F, Ne, and Na labels, respectively. As an example of the use of L-shell lines as a measure of density, the E2 transition indicated by the line labeled X is density sensitive[9]. When compared to the Ne-like line 3A, it can be used as a measure of the plasma electron density, especially under conditions where interferometric measurements of electron density are not practical.

Of a total of 250 targets fabricated, 173 were shot on target, 44 were thin foils and were irradiated on both sides while the remainder, being thick, were irradiated only from one side. Data reduced at KMS included (a) laser energy on target, (b) absorbed energy by the target, (c) laser pulse shape and length, (d) laser bandwidth, (e) equivalent plane measurements of the irradiated target spots, (f) photographic development of all films, and (g) reconstruction and recording of all (420) holographic interferometer images. Further scanning and reduction of the many spectrograms recorded (estimated at 480), will be carried out at LLNL by LLNL personnel.

References

- [1] Gar. E. Busch, C.L. Shepard, L.D. Siebert, and J.A. Tarvin, Rev. Sci. Instrum. 56, 879, (1985)
- [2] C. DeMichelis and M. Mattioli, Nucl. Fusion 21, 677 (1981)
- [3] G. Charatis, B.K.F. Young, Gar.E. Busch, C.J. Cerjan, W.H. Goldstein, A.H. Osterheld, T. Phillips, M.D. Rosen, R.E. Stewart, and R.S. Walling, Proc. SPIE 913, (1988)
- [4] B.K.F. Young, PhD Dissertation, 291-296 (1988); UCRL 53887
- [5] B.K.F. Young et al., Phys. Rev. Letts., 61, 2851, (1988)
- [6] J. Nilsen, Phys. Rev. A40, 5440 (1989)
- [7] Y.T. Lee, Wm. Howard, and J.K. Nash, to appear in JQSRT (Apr or May 1990)
- [8] J. Nilsen, LLNL Report UCRL-102608 (Jan 1990) submitted to Optics Communications
- [9] B.K.F. Young et al., Phys. Rev. Letts., 62, 1266 (1989)

Table

Target Type	Composition
1. Al slab	1 mm thick
2. Al dot/Lexan	50 μ m dia x 147nm thick Al on 151nm thick Lexan
3. Al dot/Lexan	100 μ m dia x 158n thick Al on 151nm thick Lexan
4. Al dot/Formvar	500nm thick x 530 μ m dia Al on 100nm thick Formvar
5. Al/Al 2-sided	43 μ m x 43 μ m Al dot on 1 mil Mylar with 53 μ m dia Al on back
6. 50 μ m Al sq.dot	100nm Al on 50nm Mg on 50nm Si on 2 μ m Al on 125 μ m Mylar
7. Al/Ge/Lexan	23nm Al on 34nm Ge on 150nm Lexan
8. Al/NaCl split	70x30 μ m NaCl crystal atop 50 μ m dia Al dot on 150nm Lexan
9. Layered Al/NaCl	50 layers alternating 15nm Al with 5nm NaCl on 125 μ m mylar
10. Fe/Al 2-sided	35x25 μ m Fe triangular dot on 5mil Mylar backed by 50 μ m dia x 12.5 μ m thick Al dot on opposite side
11. Er/Al 2-sided	50x25 μ m Er dot on 5mil Mylar backed by 50 μ m dia x 12.5 μ m thick Al dot on opposite side
12. Mg slab	4.5x6mm x 15 μ m thick Mg
13. Mg dots	70x70 μ m Mg dot on 5mil Mylar
14. Mo/Mg	50 μ m dia x 90nm thick Mo dot on 50 μ m dia x 140nm Mg dot on 150nm Lexan
15. 10%Mo/30%Mg	10%Mo/30%Mg mixture via MoO ₃ + MgO powders packed in 50 μ m dia hole in 5mil thick polystyrene
16. 10%Mo/30%Mg Bullseye	10%Mo/30%Mg mixture via MoO ₃ + MgO powders packed in 50 μ m dia hole in 5mil thick polystyrene with 125 μ m OD Mg washer around OD of hole
17. 11%Mo/11%Mg	11%Mo/11%Mg mixture via MoO ₃ + MgCO ₃ powders packed in 50 μ m dia hole in 5mil thick polystyrene
18. 2%Mo/10%Mg	2%Mo/10%Mg mixture via MoO ₃ + MgCO ₃ + NaHCO ₃ powders packed in 50 μ m dia hole in 5mil thick polystyrene
19. 2%Mo/10%Mg Bullseye	2%Mo/10%Mg mixture via MoO ₃ + MgCO ₃ + NaHCO ₃ powders packed in 50 μ m dia hole in 5mil thick polystyrene with Mg 125 μ m OD washer around OD of 50 μ m hole
20. 8:1 Mg/Mo dot	50 μ m dia 8:1 Mg/Mo on 160 μ m dia Mg on 5mil Mylar
21. 7%Mo/7%P	7%Mo/7%P mixture via Na ₄ P ₂ O ₇ + Na ₂ MoO ₄ powder packed in 50 μ m dia hole in 5mil thick polystyrene
22. MgF ₂ /NaBr	50 μ m dia x 110nm thick NaBr dot on 50 μ m dia x 100 μ m dia MgF ₂ dot on 150nm thick Lexan
23. 10%Br/40%Mg	10%Br/40%Mg mixture via C ₆ Br ₆ + MgO powders packed in 50 μ m dia hole in 5mil thick polystyrene
24. 10%Br/10%Mg	10%Br/10%Mg mixture via C ₆ Br ₆ + MgO + C powders packed in 50 μ m dia hole in 5mil thick polystyrene
25. Mg/Cu 2-sided	76x78 μ m Mg dot on 5mil mylar with 53 μ m dia Cu dot on back side

Fig.1 Axial view schematic of target chamber showing the placement of the spectrometers and other plasma diagnostics

Fig.2 Schematic drawings of powder spot targets and 'bullseye' targets

Fig.3 Preliminary lineout of a molybdenum L-shell spectrum showing the appearance of F-like, Ne-like, and Na-like lines. An E2 line labeled X can also be used as a ratio with the Ne-like 3A as a density diagnostic

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