Section 5
NATIONAL LASER USERS FACILITY NEWS

This report covers the activities of the National Laser Users Facility (NLUF) during the quarter October to December 1982. During this period five users conducted experiments on LLE facilities. The visiting scientists associated with these experiments represented UCLA, Yale University, the Naval Research Laboratory, the University of Maryland, the University of Pennsylvania, the University of Connecticut, and the University of Rochester.

Five user experiments were conducted in this quarter, compiling a total of 120 shots on the Glass Development Laser (GDL) and the OMEGA laser system. Table 2 gives a summary of the number of shots for each user experiment.

Research scientists from the following institutions participated in the experiments:

1. Francis Chen, Chan Joshi, and Humberto Figueroa (UCLA), and Nizarali Ebrahim (Yale University).
2. J. Kent Blaise, D. Pierce, Donatella Pascolini, and A. Scarpa (University of Pennsylvania).
3. Leo Herbette and Robert McDaniel (University of Connecticut).
4. James Forsyth and Robert Frankel (University of Rochester).

User System Shot Distribution
October 1 to December 31, 1982

USER (Principal Investigator)	FACILITY	NUMBER OF SHOTS
UCLA/Yale University (F. Chen)	GDL	48
University of Pennsylvania (J. K. Blaise)	GDL	14
University of Connecticut (L. Herbette)*	GDL	--
University of Rochester (J. Forsyth)	GDL	44
Naval Research Laboratory (U. Feldman)	OMEGA	14
	TOTAL	120

*Shared shots with the University of Pennsylvania

U65

Table 2
User system shot distribution from October 1 to December 31, 1982.

5. Uri Feldman and George Doschek (Naval Research Laboratory), Samuel Goldsmith (University of Maryland), and W. E. Behring (Goddard Space Flight Center).

This issue of the LLE Review highlights results from the Naval Research Laboratory experiment entitled "Spectral Lines of High-Z Ions" (principal investigator, Uri Feldman).

A laser-produced plasma is a very efficient and interesting source for the study of spectral lines of highly ionized atoms. The high irradiation intensities and the spherically uniform illumination obtained with the OMEGA laser at LLE produce a very dense hot plasma ($N_e \sim 10^{21} - 10^{22}$ cm^{-3}, $T_e \sim 0.5 - 2$keV). In such plasmas high-Z atoms (where Z is the nuclear charge) lose most of their electrons and the resultant ions are strongly excited, emitting rich line spectra in the x-ray and extreme-vacuum-UV (XUV) spectral region (5-300 Å). The study of the XUV spectra emitted by the plasma ions is of great interest as a diagnostic tool, determining the physical characteristics and parameters of the plasma. Furthermore, XUV spectroscopy is significant for the advance of atomic physics (specifically, the study of the atomic structure of high-Z ions) and for the possible development of x-ray and soft-x-ray lasers.

The work described here was motivated by the last two goals. First, known spectra of some high-Z ions were obtained to examine the properties of the XUV spectra emitted from laser-produced plasmas. For this purpose the spectra of highly ionized Fe, Ni, Cu, and Mo were obtained and compared with data found in the literature. Second, the less-known spectra of highly ionized Ge, Kr, and Ta were recorded and some new atomic levels were identified. In the present study, a particular effort was made to observe and identify new transitions in Ne-like krypton (Kr^{25+}).

Hot, dense plasmas were produced by focusing the 24 laser beams of OMEGA onto spherical glass-microballoon targets of ~1-μm thickness coated with layers of the elements to be studied. The microballoons usually contained no gas except when the spectra of gaseous elements were studied. Several spectra were also recorded from targets which were not prepared for our specific experiment, but for another study; in these cases, the targets generally had a complex multilayered structure. The diameter of a microballoon ranged from 200 μm to 630 μm, the duration of the laser pulse was about 1 ns, and the total laser energy varied between 500 and 2400 J. The intensity of radiation on the target varied in the range of $1\times10^{14} - 5\times10^{15}$ W/cm^2. Sometimes several shots, taken under relatively constant irradiation conditions, were integrated to obtain sufficient line intensity.

The spectra were observed with a 3-m grazing-incidence spectrograph at an incidence angle of 88°.[1] The grating was ruled with 1200 ℓ/mm, yielding a plate factor in the first order of 0.2 Å/mm at 16 Å. In order to enhance the radiation flux to the grating, the radiation from the plasma was focused onto the spectrograph entrance slit using a cylindrical concave mirror. The mirror was fabricated from a Be strip, coated by high-Z elements and bent to obtain a grazing-incidence reflection of the XUV region. The design of the mirror is given in detail by Underwood.[2] The spectra were calibrated by means of known lines of oxygen, silicon, carbon, and some known lines of the observed elements. The wavelength calibration may be affected by the relative mass motion of the various ionic components of the plasma. Though it is difficult to estimate the errors at present, we believe that they are somewhat below 5 mÅ for lines in the region of 10 to 90 Å.

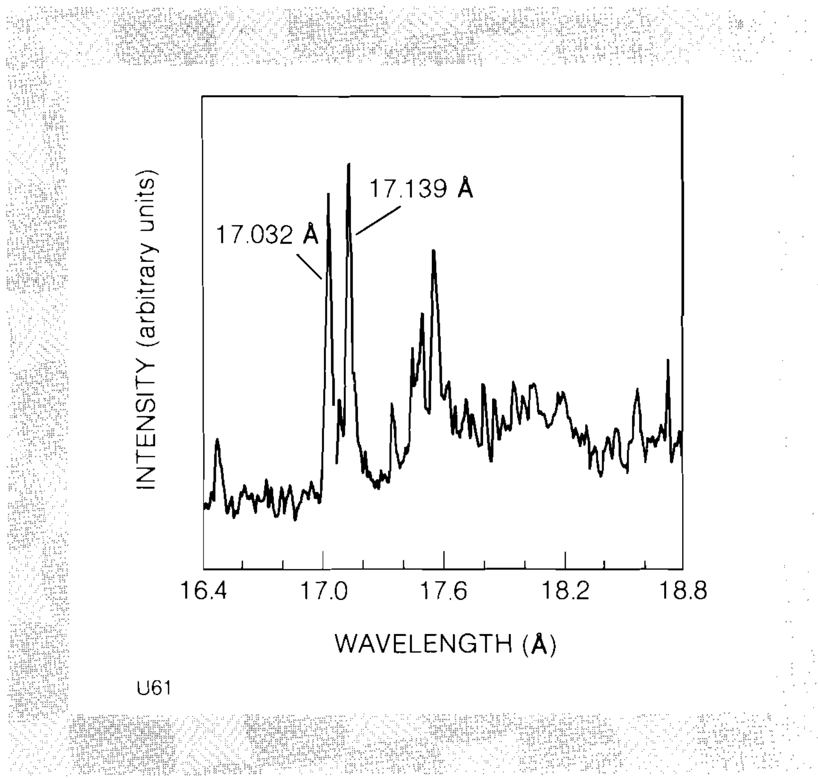

Fig. 34
Spectral lines of MoXXXII (Mo^{31+}) in the wavelength region of 17 to 18 Å.

The spectra of eleven elements (C, N, O, Al, Si, Ni, Cu, Ge, Kr, Mo, and Ta) were obtained in the region of 10 to 95 Å. We were particularly interested in the spectra of highly ionized Ni, Cu, Kr, Ge, and Mo. In Fig. 34, the spectrum of highly ionized Mo is shown in the region of 17 to 18 Å; the stronger line in Fig. 34 corresponds to MoXXXII (Mo^{31+}), Na-like Mo. Other spectral transitions in Mo^{31+}, Mo^{30+}, and Mo^{29+} are shown in Table 3. In the Kr spectra, lines of Kr^{25+} were identified for the first time. These lines are presented in Table 4. Excellent agreement between theory[3] and experiment was obtained. Some unidentified lines, which may be other Kr lines, are also listed in Table 4.

The observed spectra of most other elements (except for Ge and Ta) agree well with published data, but some noticeable irregularities in relative line intensities were observed in the spectra of Li-like Cu, Ni, and Si. The absence of some normally strong lines from these spectra is presently under study and an effort is being made to relate this observation to the physical properties of the plasma.

Table 3
Observed short-wavelength transitions in MoXXX-XXXII ($Mo^{29+}-Mo^{31+}$).

ION	CLASSIFICATION	J-J	λ(Å)	PREVIOUS MEASUREMENT[a]
MoXXXII	$3p^2P-4d^2D$	3/2-5/2	15.456	15.456
MoXXXII	$3p^2P-4d^2D$	3/2-3/2	15.505	15.504
MoXXX	$3p^2P-4d^2D$	1/2-3/2	15.630	15.627
			15.694	15.694
			15.755	15.756
			16.033	16.033
			16.273	
MoXXXII	$3p^2P-4s^2S$	1/2-1/2	16.481	16.480
MoXXXII	$3d^2D-4f^2F$	3/2-5/2	17.032	17.033
MoXXXII	$3p^2P-4s^2S$	3/2-1/2	17.088	17.086
MoXXXII	$3d^2D-4f^2F$	5/2-7/2	17.139	17.140
MoXXXII	$3d^2D-4f^2F$	5/2-5/2	17.161	17.165
			17.325	
MoXXX	$3p^2P-4s^2S$	1/2-1/2	17.355	17.355
MoXXXI	$3s3d^3D-3s4f^3F$	1-2	17.444	17.445
MoXXXI	$3s3d^3D-3s4f^3F$	2-3	17.493	17.500
MoXXXI	$3s3d^3D-3s4f^3F$	3-4	17.555	17.556
			17.812	17.815
MoXXXI	$3s3d^1D-3s4f^1F$	2-3	17.865	17.871
MoXXXII	$3d^2D-4p^2P$	5/2-3/2	18.573	18.573

a) P. G. Burkhalter, J. Reader, and R. D. Cowan, *J. Opt. Soc. Am.* 67, 1521 (1977).

TRANSITION	λ_{exp} (Å)	λ_{cal} (Å)
$3s^2S_{1/2}$ - $4p^2P^0_{3/2}$	21.181	21.183
$^2S_{1/2}$ - $^2P^0_{1/2}$	21.350	21.370
$3p^2P_{1/2}$ - $4d^2D_{3/2}$	22.255	22.256
$^2P_{3/2}$ - $^2D_{5/2}$	22.735	22.741
$3d^2D_{3/2}$ - $4f^2F_{5/2}$	25.605	25.618
$^2D_{5/2}$ - $^2F_{7/2}$	25.715	25.724
	22.195	
	23.877	
	37.762	
	37.859	
	37.926	

Table 4
Observed and calculated lines of Kr XXVI (Kr^{+25}).

Further information on the NLUF is available by writing to:

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REFERENCES

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3. L. L. Ivanov and E. P. Ivanova, *Atomic Data and Nuclear Data Tables* **24**, 95 (1979).