Section 4
NATIONAL LASER USERS FACILITY NEWS

This report covers the activities of the National Laser Users Facility (NLUF) during the quarter April to June 1982. During this period seven users conducted experiments on LLE facilities. The visiting scientists associated with these experiments represented UCLA, Yale University, the University of Maryland, the National Bureau of Standards, the Naval Research Laboratory, the University of Florida, the University of Illinois, and the University of Rochester. Also, during this period, the NLUF Steering Committee met to review and rank new proposals submitted by the users. Nine of the sixteen proposals were accepted, advancing the NLUF to a total of twenty-one user experiments.

Seven user experiments were conducted during this quarter, compiling a total of 317 shots on the Glass Development Laser (GDL) and the OMEGA laser systems. Table 1 gives a summary of the number of shots for each user experiment.

The GDL laser system accommodated four user experiments during the quarter. Typically, the laser system delivered 35 Joules of 0.35 μm laser light in a nanosecond pulse. The laser was focused onto flat targets for either plasma physics or x-ray diffraction experiments. Research scientists from the following four institutions participated in the experiments:

1. Francis Chen, Chan Joshi, and Humberto Figueroa (UCLA), and Nizarali Ebrahim and Hiroshi Azechi (Yale University).

2. Hans R. Griem and John Adcock (University of Maryland), Joseph Reader (National Bureau of Standards), and Uri Feldman (Naval Research Laboratory).

3. Anthony Burek (National Bureau of Standards) and Barukh Yaakobi (University of Rochester).

4. James Forsyth and Robert Frankel (University of Rochester).

User System Shot Distribution
April 1 to June 30, 1982

USER (Principal Investigator)	FACILITY	NUMBER OF SHOTS
UCLA & Yale University (F. Chen)	GDL	78
University of Maryland (H. Griem)	GDL	12
National Bureau of Standards (A. Burek)	GDL	19
University of Rochester (J. Forsyth)	GDL	65
Naval Research Laboratory (U. Feldman)	OMEGA	26
University of Florida (C. F. Hooper, Jr.)	OMEGA	55
University of Illinois (G. Miley)	OMEGA	60
University of Rochester (B. Yaakobi)	OMEGA	2
	TOTAL	317

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Table 1
User system shot distribution from April 1 to June 30, 1982.

The UCLA/Yale experiment accumulated 78 system shots during this quarter (in the previous quarter they received 17 experimental shots plus 25 diagnostic check-out shots). The objective of the experiment is to study the effects of specific instabilities in producing energetic electrons or scattering of the laser light. [The specific instabilities are Stimulated Raman Scattering (SRS) and two-plasmon decay.] These instabilities occur at densities less than or equal to quarter-critical (at an electron density of 2×10^{21} for 0.35 μm laser light). A long scale-length plasma is used to simulate the conditions expected in reactor-sized targets. The long scale-length is formed by focusing two pulses, separated by 1 ns, onto a foil target. The first pulse has an energy of approximately 7 J at 1.054 μm and forms the long scale-length plasma. The second pulse has an energy of 35 J at 0.35 μm and is used to study the instabilities. The spot size of the 1.054 μm beam was 1 mm, producing an irradiance of 5×10^{11}W/cm^2. The 0.35 μm beam was tightly focused to 70 μm diameter, yielding an irradiance of 10^{15}W/cm^2. This special optical arrangement was provided by members of the LLE scientific staff.

The diagnostics for the experiment consisted of a user-supplied, visible spectrograph to examine the Raman spectrum and two electron spectrometers for the angular distribution of hot electrons. Other diagnostics supplied by LLE included an additional visible spectrograph, and six calibrated photodiodes to monitor the angular distribution of $\omega_o/2$ light.

The University of Maryland experiment was completed with twelve shots in this quarter. (They had 32 shots in the previous quarter.) The goal of the experiment is to examine the broadening and wavelength shifts of the soft x-ray line emission from a laser-produced plasma. An understanding of these spectral features can be used to diagnose the plasma temperature and density.

The experimental configuration used a 0.35 μm laser pulse focused onto foils of different elements. A soft x-ray spectrometer, previously flown in solar physics experiments, was used to record the spectrum. The spectrometer was supplied by the Goddard Space Flight Center. The instrument is a 3 m, grazing-incidence spectrograph capable of covering a wavelength range of 8 to 780 Å. A single shot easily produced well-exposed spectra. Spectra were taken of carbon, oxygen, fluorine, iron, niobium, molybdenum, and silver.

The experiment by the National Bureau of Standards used 19 shots to test the application of a Laue-type, x-ray diffracting crystal for target-implosion diagnostics. In a Laue crystal, x-ray radiation passes through the crystal instead of reflecting, as in a Bragg Geometry. The entire spectrum goes through a "focus", allowing a reduction in the background radiation by appropriate placement of an aperture. Figure 26 shows the geometry of a Laue-type spectrograph.

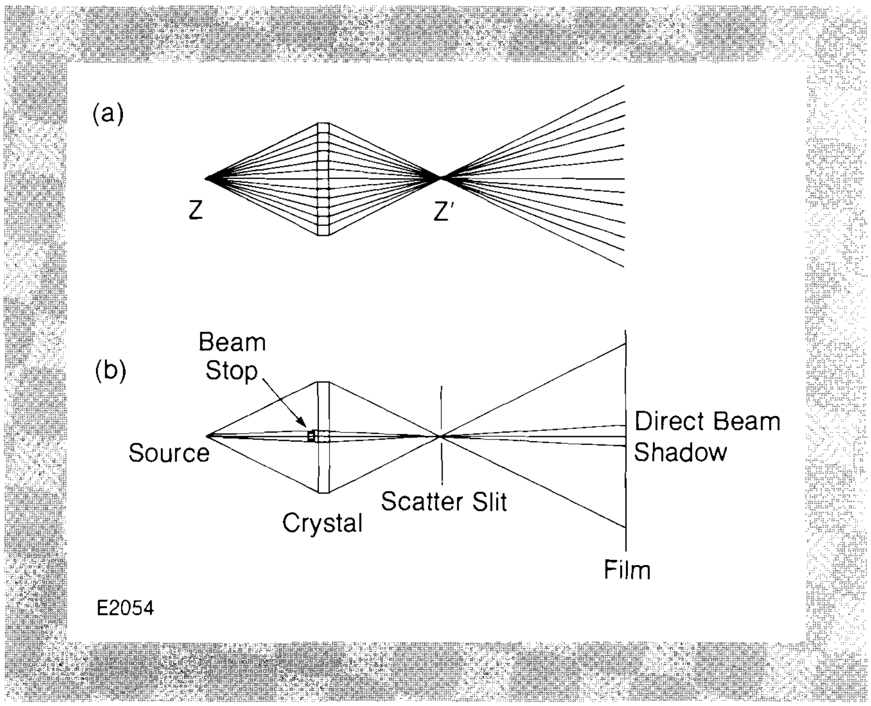

Fig. 26
Configuration of a Laue-type x-ray diffraction spectrometer.
a) a ray trace of x-rays diffracted by the crystal
b) compounds in the diagnostic

A Laue-type spectrograph was constructed by the National Bureau of Standards and used to examine a titanium spectrum produced from a laser plasma. Figure 27 shows typical titanium spectra recorded (on different shots) using Laue- and Bragg-type spectrographs. The spectra show both helium-like and hydrogenic spectra, including resonance lines and satellites. The line ratios are different in the two examples; the Laue experiment used a larger laser focal spot which produced a lower plasma electron temperature. Also, the spectral dispersion is different for the two examples; this accounts for the closer spacings of lines in the Laue geometry. In other respects the Laue spectrogram exhibits features comparable to the features in the Bragg spectrogram.

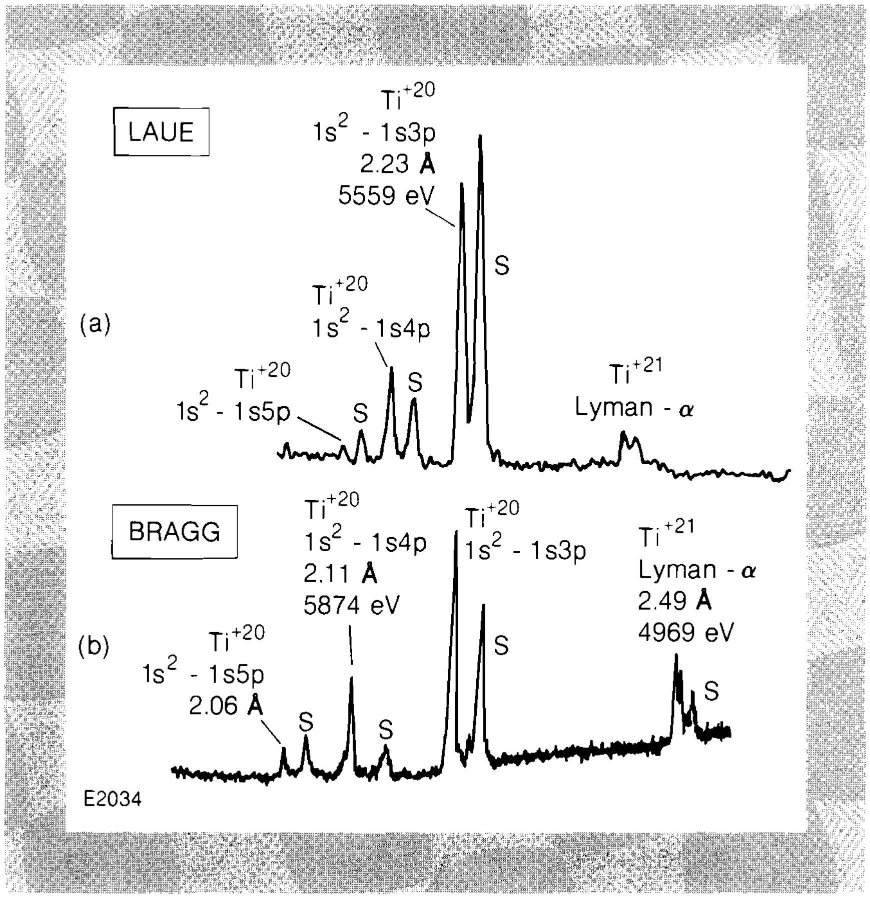

Fig. 27
A comparison of Laue and Bragg x-ray spectrographs.
a) spectrum of titanium using a Laue spectrograph
b) spectrum of titanium using a Bragg spectrograph

A Laue spectrograph may be used as a diagnostic for compression measurements in laser-fusion experiments. This application uses x-rays to backlight a fusion target and measure the x-ray transmission. An example of this technique is shown in Fig. 28. This figure shows the x-ray transmission of a 420 μm diameter CH_2 sphere placed at the Laue focus. The x-rays used for this example are at 4.750 keV from the $1s^2$-1s2p Ti^{+20} line. The measured x-ray transmission compares well with the calculation.

The University of Rochester experiment conducted by Jim Forsyth and Robert Frankel uses x-rays from a laser-plasma source for kinetic x-ray diffraction experiments. Preliminary results from this experiment were reported in LLE Review, Volume 8. During this quarter, target shots were used to test upgrades of the diagnostic equipment.

The remaining four user experiments were conducted on the OMEGA facility. The system was operated at a nominal pulse width of 100 ps and typically delivered 600 Joules on target. In most of the experiments, all

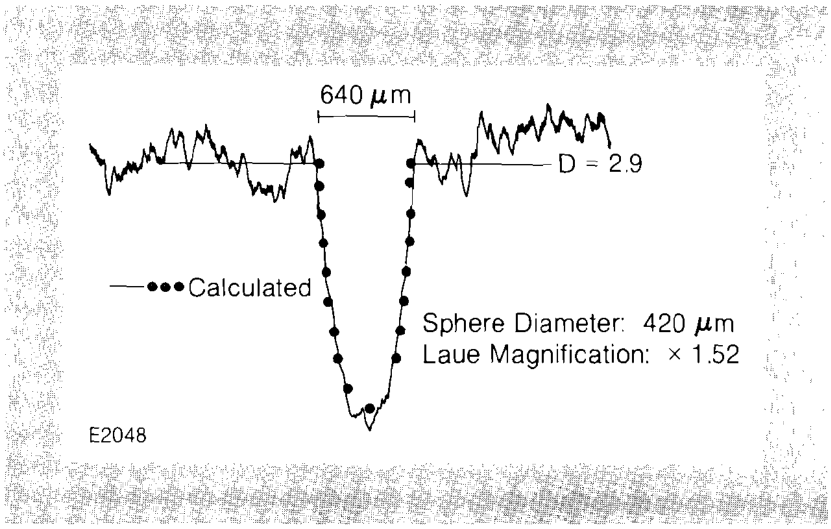

Fig. 28
Backlighting of a CH_2 sphere in a Laue geometry. A monochromatic image is shown using 4.750 keV x-rays produced from a titanium target.

24 beams of the OMEGA laser were focused onto thin-wall glass microballoons. Research scientists associated with the following institutions participated in the experiments:

1. Uri Feldman and George Doschek (Naval Research Laboratory) and W. E. Behring (Goddard Space Flight Center).
2. C. F. Hooper, Jr. (University of Florida); Natale Ceglio, Robert Kauffman, Gary Stone, and Gary Howe (Lawrence Livermore National Laboratory); Andrew Hawryluk (MIT); and Stan Skupsky and Barukh Yaakobi (University of Rochester).
3. George Miley, Chan Choi, Aaron Bennish, and David Harris (University of Illinois).
4. Barukh Yaakobi (University of Rochester) and H. W. Schnopper and P. O. Taylor (Smithsonian Institution).

The Naval Research Laboratory experiment received 26 shots in this quarter. Dr. Feldman and his colleagues studied the soft x-ray emission from spherical targets irradiated by the OMEGA laser system. The goal of the experiment is to identify the line emission from high-Z elements in order to develop an application of spectroscopic diagnostics of inertial fusion conditions. This application will be useful in examining the density and temperature in the lower temperature region of the plasma. X-rays emitted from the lower temperature plasma regions will tend to originate in lower ionization stages and the emission will tend to be concentrated in the soft x-ray region of the spectrum.

The configuration for the experiment was to focus all 24 beams from the OMEGA system onto spherical targets composed of different elements. The spectrograph is the same one used in the University of Maryland experiments. The targets were glass microballoons with coatings of titanium, copper, parylene, or gold. One type of target was filled with krypton gas. (Details of the target coating and filling procedures can be found in LLE Review, Volumes 7 and 8.) A soft x-ray spectrum was recorded for each of the above types of targets.

The University of Florida experiment received 55 shots to examine the physics of x-ray line profiles in laser fusion experiments. A measurement of these x-ray line profiles is useful in determining plasma conditions, such as density and fuel ρR.

The experiment consisted of irradiating spherical microballoons filled with either argon gas or a mixture of argon and neon. Various pressures of the gas mixtures were used to examine the effects of argon cooling in the implosions. Diagnostics for the experiment examined the x-ray emission from both the gas and the glass components.

Several of the diagnostics were supplied by Lawrence Livermore National Laboratory, including a zone-plate-coded image camera,[1] and transmission x-ray gratings. The total x-ray diagnostic complement included (1) a zone-plate-coded image camera to evaluate the sphericity of the implosion (the diagnostic covers a range of approximately 3 to 30 keV, in five distinct energy bands, with a spatial resolution of 4-8 microns); (2) time- and spatially-resolved x-ray spectroscopy measurements using transmission x-ray gratings (covering a range of 500 eV to 5 keV) employed with an LLE-supplied x-ray streak camera for temporal resolution, and with an LLE-supplied grazing-incidence reflection microscope for spatial resolution; and (3) two flat crystal (LLE) x-ray spectrometers to examine the line emission of silicon, neon, and argon.

The University of Illinois experiment was completed in this quarter with 60 shots on the OMEGA facility. This experiment was designed to examine the energy loss of fusion-reaction products as they passed through the outer parts of the expanding plasma. These fusion products act as "test particles" since they are emitted in a short time, compared with the time taken for the total target implosion.

The experimental diagnostic was a particle time-of-flight spectrometer capable of measuring the 3.5 MeV alpha particles emitted in DT reactions and the 3.0 MeV protons emitted from DD reactions. Spherical microballoons were filled with a mixture of deuterium and tritium in the ratio of 95% deuterium to 5% tritium at a pressure of 20 atmospheres. This mixture was chosen to enhance the 3 MeV proton signal since the DD reaction rate is approximately 1/100 of the DT reaction. Data was recovered for a variety of target diameters and wall thicknesses to examine the particle energy losses as a function of target mass.

The University of Rochester experiment consisted of two dedicated and fourteen shared shots to test a focusing x-ray crystal spectrometer. This curved-crystal, x-ray spectrometer is a "Von-Hamos" type, designed to focus the x-ray emission, and hence provide increased sensitivity over flat crystals. Thus, reduced amounts of a tracer gas can be added to the target while still recording the tracer x-ray emission.

The experiment attempted to record the emission from a variety of elements in typical implosion experiments. Elements of krypton, germanium, silicon, and copper were used. Krypton gas was filled inside a glass microballoon, and the other elements were coated onto the glass. A preliminary examination of the x-ray spectra shows lines from all of the elements. Especially interesting is the ability to record the Lyman-α hydrogenic line (1s-2p) and heliogenic lines of copper and germanium. The heliogenic $1s^2$-1s2p line of krypton was also recorded.

These experiments were supported by contracts with the U.S. Department of Energy, except for J. M. Forsyth's work, which is supported by the National Science Foundation and the National Institutes of Health.

The targets used by the Naval Research Laboratory (Uri Feldman), University of Florida (C. F. Hooper, Jr.), University of Illinois (George Miley), and the University of Rochester (Barukh Yaakobi) were supplied by KMS Fusion, Inc. and by the University of Rochester's Laser Fusion Feasibility Project. The targets used by the University of Maryland (Hans Griem) and the National Bureau of Standards (Anthony Burek) were supplied by the University of Rochester's Laser Fusion Feasibility Project.

Future issues of the LLE Review will highlight additional results from user experiments performed in this quarter.

During this quarter, on June 4, 1982, the NLUF Steering Committee had their third meeting, to review and approve proposals, and to recommend funding of approved proposals to the Department of Energy. The Committee membership remained the same as that at the previous meeting, consisting of scientists from a broad range of areas, including laser fusion, atomic physics, plasma physics, astrophysics, biophysics, and materials research. The Committee membership consists of Dr. David T. Attwood, Jr. (Lawrence Livermore National Laboratory), Dr. Michael Bass (University of Southern California), Dr. Manfred A. Biondi (University of Pittsburgh), Dr. Thomas C. Bristow (non-voting Executive Secretary, University of Rochester), Dr. Donald L. D. Caspar (Brandeis University), Dr. Lamar W. Coleman (absent, Lawrence Livermore National Laboratory), Dr. Gordon P. Garmire (Pennsylvania State University), Dr. Hans R. Griem (University of Maryland), and Dr. Brian J. Thompson (Chairman, University of Rochester).

The Committee approved 9 of 16 proposals for user experiments. The approved experiments are in areas of laser fusion, plasma physics, and x-ray biophysics. These new proposals are from the following investigators:

1. NLUF Proposal 36: R. Elton (Naval Research Laboratory), "Gain Measurements for a Soft X-Ray Laser High-Density Plasma Probe."
2. NLUF Proposal 40: Leo G. Herbette (University of Connecticut), "Time-Resolved X-Ray Diffraction of Acetylcholine Receptor Membranes."
3. NLUF Proposal 41: J. K. Blasie (University of Pennsylvania), "Time-Resolved Structural Studies of the Ca^{2+}-ATPase of Sarcoplasmic Reticulum Membranes Utilizing a Laser Plasma X-Ray Source."

4. NLUF Proposal 42: U. Feldman (Naval Research Laboratory), "Measurements of Spatially-Resolved High-Resolution Spectra of Laser-Produced Plasmas Using the OMEGA Laser Facility at the University of Rochester."
5. NLUF Proposal 43: T. Blue (University of Illinois), "Measurement of D-^{3}He Proton Yield With CR-39 as a Diagnostic for Inertial Confinement Fusion Experiments."
6. NLUF Proposal 44: H. Griem (University of Maryland), "Shifts and Widths of Hydrogenic Ion Lines: Experimental Proposal for Continuation of Measurements at the University of Rochester Laser Users Facility."
7. NLUF Proposal 46: B. Henke (University of Hawaii), "Development and Evaluation of a Streak-Camera-Coupled Elliptical-Analyzer Spectrograph System for the Diagnostics of Laser-Driven X-Ray Sources (100-10,000 eV Region)."
8. NLUF Proposal 48: F. Chen (UCLA), "Studies of the Two-Plasmon Decay and Stimulated Raman-Scattering Instabilities in Hot, Long Scale-Length Plasmas."
9. NLUF Proposal 49: C. F. Hooper, Jr. (University of Florida), "Implosion Dynamics of the Fuel, Pusher, and Fuel-Pusher Interface."

Further information on the NLUF is available by writing to:

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1. N. M. Ceglio, D. T. Attwood, and J. T. Larsen, *Phys. Rev. A* **25**, 2351 (1982); N. M. Ceglio, A. M. Hawryluk, and R. H. Price, *Proc. SPIE* **316**, 134 (1982).