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HIGH ENERGY LASER FACILITIES AT LAWRENCE LIVERMORE NATIONAL LABORATORY

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ABSTRACT

High energy laser facilities at Lawrence Livermore National Laboratory are described, with special emphasis on their use for equation of state investigations using laser-generated shockwaves. Shock wave diagnostics now in use are described. Future Laboratory facilities are also discussed.

INTRODUCTION

In support of the nation's inertial confinement fusion (ICF) effort, Lawrence Livermore National Laboratory (LLNL) has built a series of high-energy lasers. Recently, each has also been used for ultra-high pressure shock-wave research, as part of the Laboratory's program of equation-of-state (EOS) investigations. I will briefly describe the three largest lasers, with special emphasis on their use as shock-wave drivers; the special diagnostics for shock wave studies using lasers will also be described. Finally, I will discuss the use of new lasers soon to be in operation at LLNL.

LASER FACILITIES AT LLNL

Each of the three high-energy lasers at LLNL were designed as multiple beam systems using Nd: glass as the active amplifying medium at a wavelength of 1.06 μm. The three lasers - Janus, Argus, Shiva - differ mainly in size, energy output, and the sophistication of their operating systems. Table I provides a comparison of the performance specifications for these laser systems.

Table I High Energy Lasers Used at LLNL

Facility	Janus	Argus	Shiva
Energy	100 J	2 kJ	10 kJ
Pulselength	30-300 ps	0.1-1 ns	0.1-30 ns
Wavelength	1.06 μm	1.06 μm	1.06 μm
Beams	1	2	20
Output Aperture	8 cm	28 cm	15 cm

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Janus, while originally a two-beam system for ICF research, is now operated as a single beam laser dedicated solely to EOS research and related experiments. Janus experiments provided the first conclusive evidence that lasers could produce shock pressures over 1 TPa without significant preheat.[1] In other experiments Janus was used to measure preheat,[2] which provided a basis for normalization of target design simulation codes, and tests of analytical preheat models.[3-5] Janus is now being used for a systemmatic study of impedance-match techniques using lasers.[6]

The ultrafast recording technique we use at Janus to measure shock velocities is depicted in Fig. 1. Simply put, a streak camera is used to record an image of the luminosity emitted from the stepped rear surface of a metallic target as a function of time. We can measure the time difference of shock arrival across the two levels of a small (∿5 μm) step to an accuracy of roughly 20 ps. A typical shock transit time of a 10 Mbar shock in aluminum across a 5 μm high step is 200 ps. More advanced streak cameras now becoming available should improve our accuracy to roughly 2-3 ps.

A fiducial signal, derived from the main laser pulse, is also recorded by the camera and provides absolute timing of shock arrival relative to the target irradiation pulse. This allows us to measure the transit time of the shock after passing through the bulk of the target. Diagnostics of similar design are now installed at both Argus and Shiva as well.

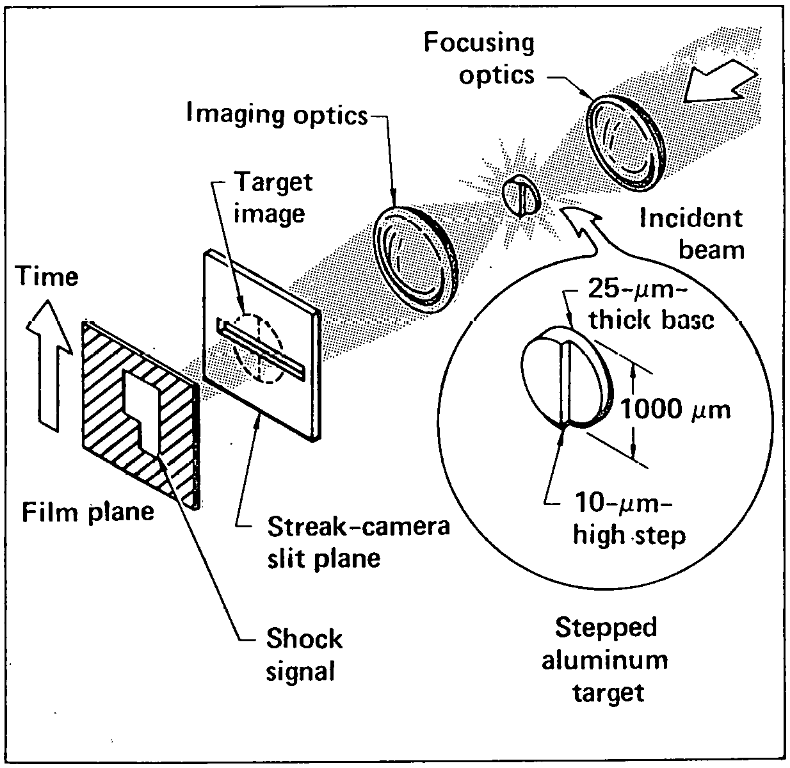

Fig. 1 An ultrafast streak camera is used to measure the velocity of a laser-generated shock wave in a stepped metal target.

The Argus laser is now principally used for laser-matter interaction studies. Starting in mid-1980, Argus was converted to operate at the second harmonic wavelength (532 nm) and after a series of target interaction experiments was converted to the third harmonic (355 nm) in late 1980. Shock wave experiments using the third harmonic capability showed that much lower preheat levels and somewhat higher shock pressures can be achieved using short wavelength irradiation.

Shiva, the world's most powerful laser, is used mainly for fusion target experiments. Experiments using Shiva have produced both the highest recorded neutron yield from a D-T filled target, and also the highest compression, to roughly 100 times liquid density. As a shock wave driver, Shiva can produce very uniform irradiation to drive planar shocks, and its high energy allows relativey large samples to be used. In an experiment in 1980, a pressure over 3 TPa was inferred from the shock velocity measured in a gold target with negligible preheat.

FUTURE LASER FACILITIES

As laser energy is increased, longer pulse irradiation over large samples can be maintained at very high laser intensities, over 10^{15} W/cm^2. This allows increased accuracy in the experiments by providing longer shock transit times across larger steps. Also, the use of short wavelength irradiation can reduce preheat levels. With thinner targets required to provide preheat shielding, shock stability should also be enhanced. Two new lasers are soon to be operating at LLNL; they will provide high energy, long pulses, and irradiation at harmonics of the basic 1.06 µm wavelength.

Shiva will be upgraded in two stages to become the Nova laser. Its 20 beams will provide an output energy of about 250 kJ in 1-3 ns pulses at 1.05 nm, and will also be able to operate with about 150 kJ output at 527 nm. Argus is to be rebuilt using two Nova beams, and will be renamed Novette. It is expected to have the capability of doing target experiments at three wavelengths: 1.05 µm, 527 nm, 351 nm. The expected performance of these two new lasers is specified in Table II.

Table II Performance Specificaions for Nova and Novette

Facility	Novette	Nova I	Nova II
Energy	10 kJ	100-150 kJ	200-300 kJ
Pulselength	1-3 ns	1-3 ns	1-3 ns
Wavelengths	1.053 µm 527 nm 351 nm	1.053 µm 527 nm	1.053 µm 527 nm
Beams	2	10	20
Output Aperture	46 cm	46 cm	46 cm

Using these new facilities for shock wave research should allow reduction of experimental errors to roughly the 1% level at pressures of 5 TPa and above, which will significantly extend our knowledge of material properties under extreme conditions of pressure and temperature.

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