Section 2
PROGRESS IN LASER FUSION

2.A Initial Long-Pulse Experiments on OMEGA

During the months of August and September the first multi-beam experiments were performed on OMEGA with laser pulses approaching 1 nsec in duration. Our goal was to conduct a preliminary examination of some of the requirements necessary for the uniform ablative drive of spherical targets for direct-drive laser fusion.

A considerable effort was made to first characterize the performance of the OMEGA laser in the long pulse width regime. Measurements were performed to determine the passive and active transmission factors for all driver line and beamline optical components. Near and far-field energy distributions and beam phase front distributions taken with a grating interferometer[1] were used to gain confidence in the predictive capabilities of the two-dimensional beam propagation code MALAPROP. In addition, with the knowledge of the output intensity distribution and the relative phase front distribution, it was also possible to predict, with the aid of the code BEAMPROP, the expected intensity distribution in the target plane, and to compare this with the measured equivalent target plane distribution recorded in the BDP (beam diagnostic package) structures. Figure 9a shows a radially-averaged plot of the measured output near-field intensity profile which, when coupled with the measured radial extent of spherical aberration (Fig. 9b) gives, through the code BEAMPROP, a predicted intensity distribution in the target plane of the form shown in Fig. 9c. This can be compared with the actual measured distribution, a two-dimensional intensity plot of which is shown in Fig. 9d. Apart from the periodicity in the annular ring struc-

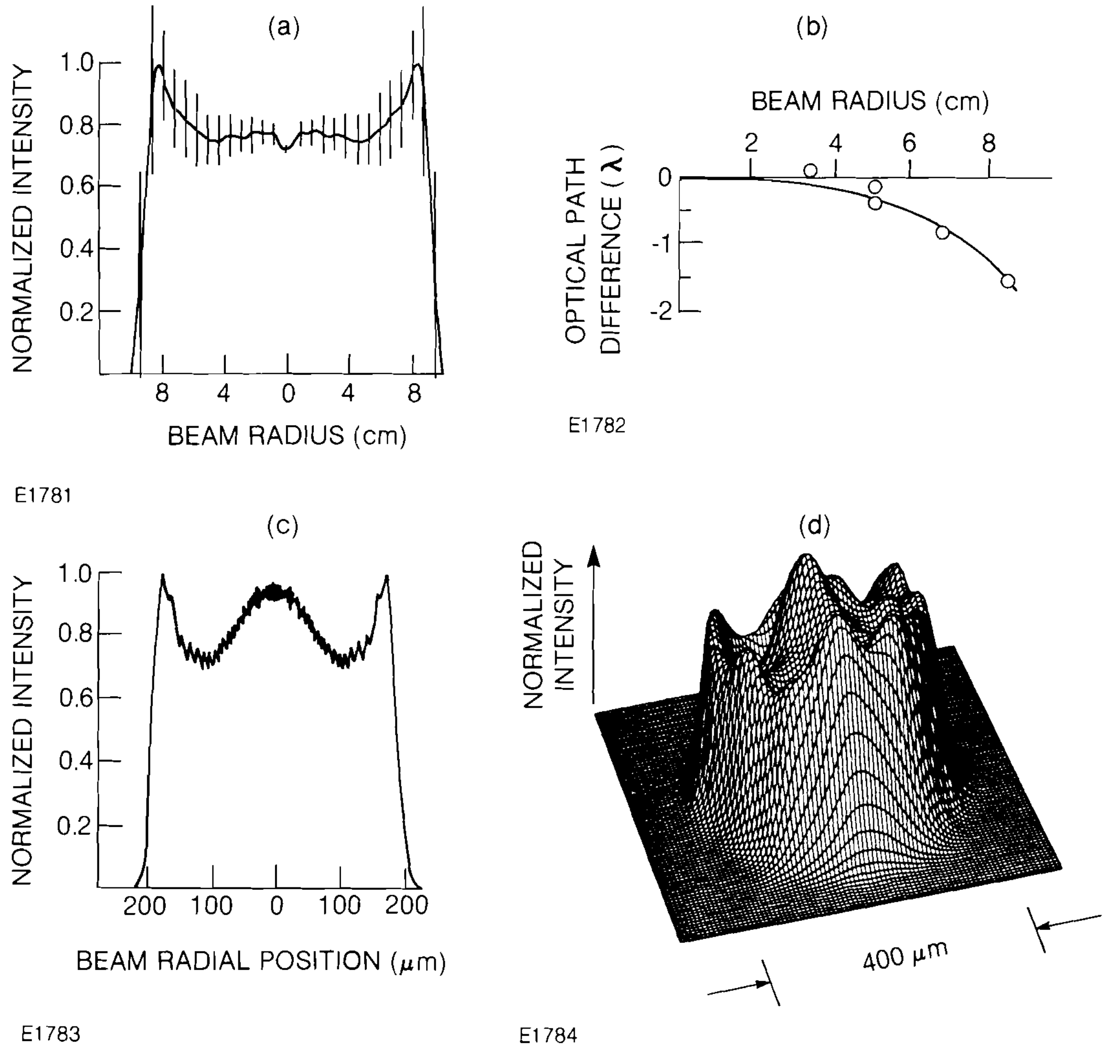

Fig. 9

Comparison of actual and computed beam distributions in the target plane. From the actual radially-averaged near-field intensity profile (a) and the measured spherical aberration across the output beam (b), the code BEAMPROP predicts an intensity distribution in the target plane 1200 μm from best focus, of the form shown in (c), for a 17 cm beam focussed by a 600 mm lens. This can be compared with the equivalent target plane distribution measured in the BDP, shown in (d).

ture seen in the equivalent target plane data of Fig. 9d (possibly caused by phase distortions resulting from the twelve-flash-lamp arrangement in the final amplifiers), there is good agreement between this measurement and the code prediction.

Target experiments with twelve well-characterized beams of OMEGA were conducted at 700 psec in a spherical irradiation geometry to compare the predictions of the one-dimensional hydrodynamic code, *LILAC*, and the two-dimensional Eulerian code, *SAGE*, with measurements of absorption in the intensity range between 10^{14} and 10^{15} W/cm^2. Laser absorption depends on target Z at 10^{14}W/cm^2, where the dominant mechanism is inverse bremsstrahlung. As the intensity is increased to the 10^{15}W/cm^2 level, the collisionless process of resonance absorption becomes important. This latter process results in the copious generation of super-thermal electrons, which redistribute energy to regions of the target remote from the interaction zone, couple a significant fraction of their energy into fast ion expansion, and perhaps more seriously, preheat the core fuel to undesirably high temperatures.

Measurements of the variation in overall absorption for high Z (Ti) and low Z (CH) spheres 400 μm in diameter were performed with an array of 20 plasma calorimeters symmetrically distributed within the OMEGA target chamber. The results are shown in Fig. 10. From Fig. 10a it can be seen that peak absorptions of 70% are measured for Ti spheres at intensities around 10^{14}W/cm^2. This absorption fraction drops to 50% as the intensity is increased. Similar behavior is observed for CH spheres (see Fig. 10b), except that the low intensity absorption is predictably lower in

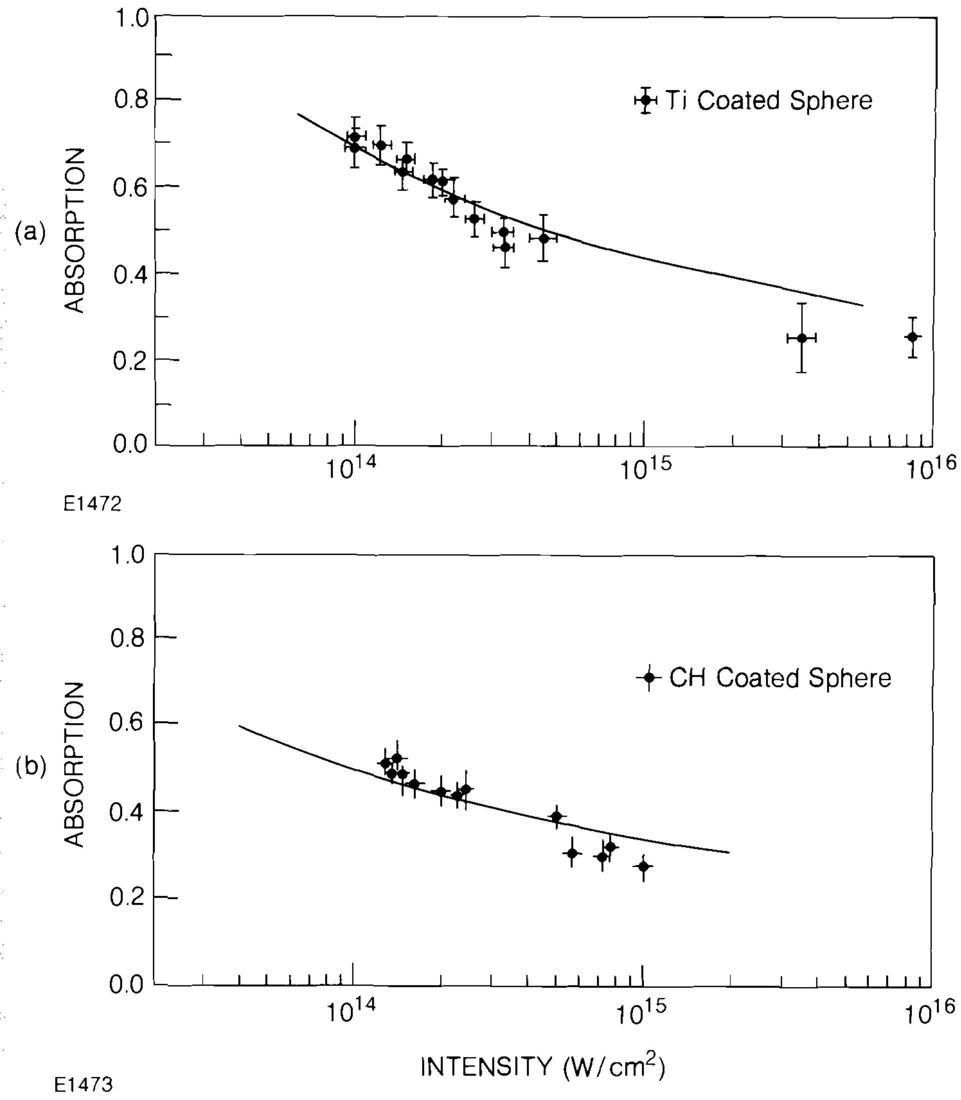

Fig. 10
Variation of absorption with intensity for 700 psec pulses incident uniformly on 400 μm diameter spheres of (a) Ti and (b) CH. The solid line represents comparative calculations made with the code SAGE, assuming inverse bremsstrahlung absorption, flux inhibition (f = 0.03) and a 15% deposition of energy reaching the critical surface into fast electrons.

CH versus Ti, because it is a low Z target material. The solid lines in Fig. 10 represent *SAGE* calculations, taking into account both inverse bremsstrahlung and resonance absorption. The *SAGE* code correctly models the lack of a strong Z dependence to absorption at intensities approaching 10^{15}W/cm^2. Predictions from the one-dimensional hydrodynamic code *LILAC* show a similar dependence.

The transition between absorption mechanisms was further investigated by measuring the spectrum of high energy ions using two Thompson parabola ion spectrometers equipped with CR-39 track detectors. This diagnostic permits the determination of absolute fluence and the energy spectrum for specific ionic species emitted from CH targets. The absorbed energy that was coupled into these ions (protons and ionized carbon C^{6+}, C^{5+}, C^{4+}, and C^{3+}) was determined as a function of laser intensity and compared to predictions from the *LILAC* code. The variation of the normalized energy partition to ions having energies in excess of 100 keV, as a function of intensity is shown in Fig. 11. The shaded area represents one-dimensional *LILAC* simulations of these experiments under the assumption of thermal flux-inhibition (f = 0.05) and 10%-15% deposition of energy at the critical density into super-thermal electron emission.

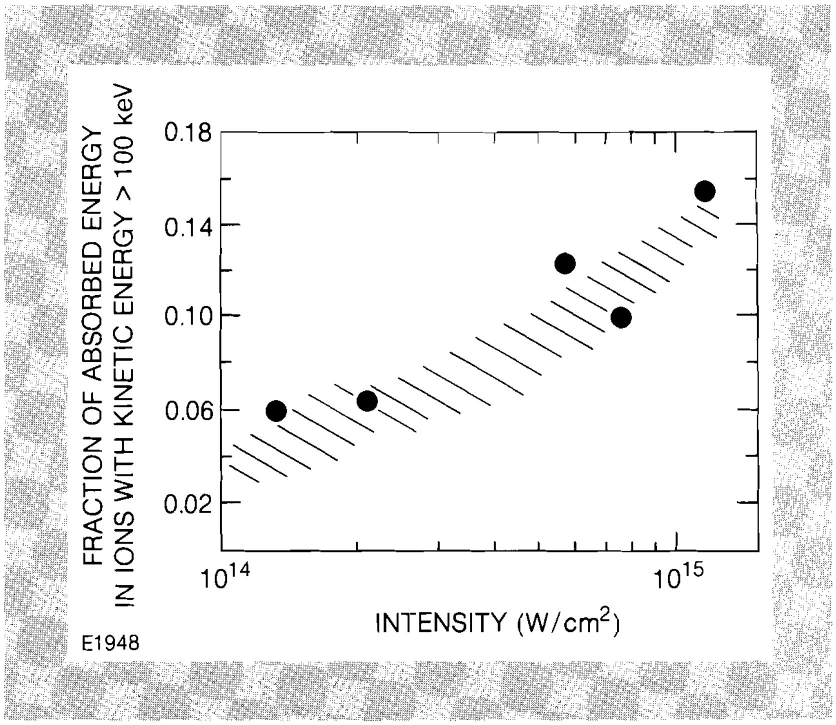

Fig. 11
Variation of the partition of energy into ions having an energy in excess of 100 keV, as a function of intensity.

The experiments described above have given us a preliminary look at the physics of symmetric implosions produced by long laser pulses. Much additional work in this area is planned for the coming months, and a concentrated effort will be directed toward measuring and understanding the limitations of thermal electron transport in this ablative regime.

REFERENCES

1. S. Kumpan, Preliminary LLE Report, June 1981.