NEWS AND VIEWS

Physics at very high pressures with laser-driven shock waves

from M.H. Key

RECENT papers by Trainor *et al.* (*Phys. Rev. Lett.* **42,** 1154; 1979) and by Veeser *et al.* (*Appl. Phys. Lett.* **35,** 761; 1979) highlight the fact that in relatively simple experiments laser-driven shock waves can be used to study the propagation of shocks in solids for shock pressures up to terapascals (1 TPa $= 10^7$ bar $= 10^{13}$ dyne cm^{-2}). In view of the fact that the only demonstrated alternative for studying such high pressure shock waves requires a nuclear explosion (Ragan *et al. JAP* **48,** 2860; 1977) the simplification provided by the laser approach is considerable.

Laser irradiation of a solid surface in vacuum creates a high pressure surface plasma. The pressure exerted on the solid by this 'ablation plasma' is shown in Fig. 1 as a function of laser irradiance I and for two laser wavelengths $\lambda = 0.53$ and $1.05 \mu m$. The ablation pressure acts as a 'piston' driving a shock wave into the undisturbed solid. Accurate shock velocity measurements were obtained by Trainor *et al.* and Veeser *et al.* by recording the differential time of transit of the shock through ~ 30 μm thick foil targets with a step variation in thickness as in Fig. 2. The arrival of the shock at the rear surface was signalled by a fast ($\sim 10^{-11}$ s) rise in luminosity detected by an electron optical streak camera with time resolution $\sim 10^{-11}$ s.

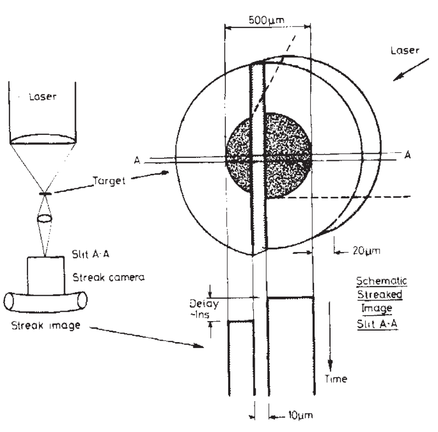

Fig. 2 Schematic diagram showing how streak photography is used to measure shock velocity in a planar foil target with a thickness discontinuity.

The maximum shock pressure for which these techniques are useful is limited by the saturation in the rate of increase of ablation pressure with intensity (Fig. 1) and the associated increasing depth and magnitude of target preheating due to energetic electrons generated in the process of absorption of the laser light in the surface plasma. Where pressure due to this preheating becomes significant relative to the ablation pressure and the preheat penetration depth becomes comparable with the target thickness the process no longer results in a simple shock propagating in an undisturbed medium. Investigation has shown that the preheating depth is a function of $I\lambda^2$ and that the maximum value of $I\lambda^2$ for simple shock generation in these targets is of the order of 3×10^{14} W cm $^{-2}$ μm^2 (Hares *et al. Phys. Rev. Lett.* **42,** 1216; 1979). Thus shock pressures up to 1.8 TPa were reported by Trainor *et al.* using 1.06 μm radiation while Fig. 1 suggests that with $\lambda = 0.53$ μm pressures up to about 10 TPa should be attainable.

The motivation for these studies is that the equation of state of compressed solids is not well known in the interval between a few tenths and a few tens of terapascals. At lower pressures extensive experimental data from static high pressure and chemical explosive experiments are available while at higher pressures the relatively simple Thomas Fermi (TF) theoretical model is valid (Ragan *et al. op. cit.*). The TF model neglects all atomic structure and quantum mechanical binding force between atoms and treats only the compressibility of a degenerate electron gas in the field of positive nuclei. At the opposite extreme a solid at zero pressure is in equilibrium between the degenerate electron repulsive forces and interatomic binding forces. Theoretical analysis for conditions where the applied pressure is not large relative to the binding forces is complex and experimental studies are needed.

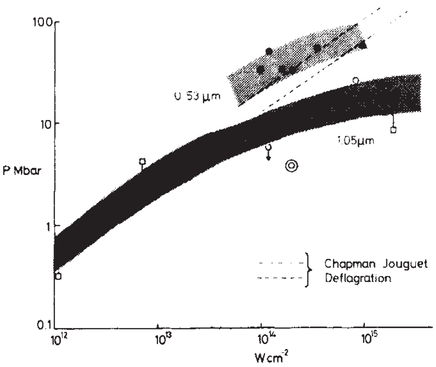

Fig. 1 Ablation pressure in units of megabar as a function of laser irradiance for 0.53 and 1.05 μm laser wavelength. (Dashed lines theoretical model). Unpublished results obtained by research groups from Imperial College London and Queen's University, Belfast working at the SRC Central Laser Facility, Rutherford Laboratory.

The laser technique of shock generation extends the upper pressure limit for such measurements since measurement of any two of the five shock parameters (material density, pressure, internal energy, flow velocity and shock front velocity) allows solution for the other three (from the conservation of energy momentum and mass flow across the shock front) and hence gives the equation of state relationships between pressure, density and internal energy (Ragan *et al. op. cit.*).

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