L.7: Enhancement of laser generated shock-pressure using low density coatings on Al-foil targets

The laser-driven dynamic compression of matter under extreme pressure conditions (on the order of tens of megabars to gigabars) is a subject of significant interest in various fields of physics, including phase transformations, materials science, astrophysics, geophysics, and high energy density physics applications. Such extreme conditions can be generated in laboratory environments using high-energy, high-power (HEHP) laser systems.

The low-density target was fabricated by depositing carbon aerogel (CA) onto an aluminium (Al) foil substrate using an air spray gun with a 0.3 mm nozzle aperture. The morphology of the resulting CA was characterized using field-emission scanning electron microscopy (FESEM) (Fig. L.7.1). The thickness of the coated film was measured using a profilometer and was approximately 20 µm. The density of the fabricated carbon on the Al-foil (density~2700 mg cm^{-3}) is approximately 300 mg cm^{-3}.

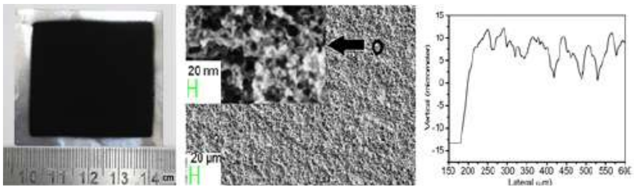

Fig. L.7.1 Morphology of the coated CA.

A schematic of the experimental setup is shown in Fig. L.7.2. The experiments were conducted using a high-energy, high-power Nd:glass laser system in the laboratory, delivering laser energies in the range of ~5–20 J. The laser (with pulse ~0.5 ns duration) was focused onto the target using a plano-convex lens (f = 55 cm), resulting in intensities on the order of 10^{13}-10^{14} W cm^{-2}. The targets were mounted on a motorized translation stage inside a plasma chamber maintained at a vacuum of ~5×10^{-5} mbar.

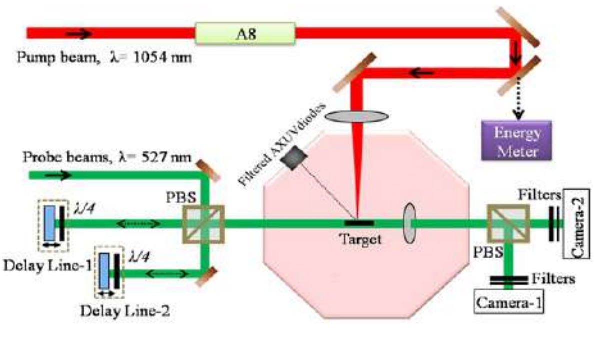

Fig. L.7.2 The experimental setup.

The probe beam was derived by tapping a portion of the main beam and converting it to its second harmonic using a KDP crystal. Two temporally separated second-harmonic probe beams were then generated via polarization discrimination, producing orthogonally polarized components (Fig. L.7.2). The relative optical delays between the main beam and the two probe pulses were independently controlled using delay lines 1 and 2. A plano-convex lens (f = 5 cm) was used to image the plasma plane. The orthogonally polarized probe beams were separated using a polarizing beam splitter and directed onto DSLR cameras positioned at the image plane.

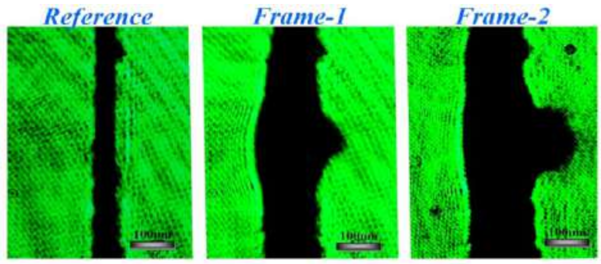

Fig. L.7.3 Typical shadowgrams of a reference, frame-1(2ns) and frame-2(3.5ns).

The particle velocities in both the targets were measured using two-frame shadowgraphy. Experiments were conducted over a range of laser intensities (~7.5×10^{13} to 2.3×10^{14} W cm^{-2}). Fig. L.7.3 shows typical shadowgrams obtained for the CA-coated Al-foil targets. Similar shadowgrams were also recorded for Al-foil targets.

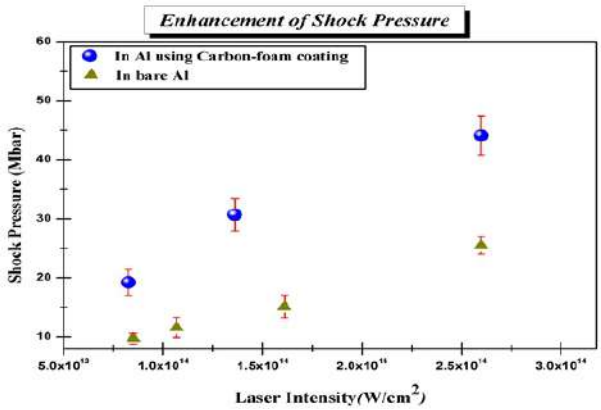

Fig. L.7.4 Variation of shock pressure with laser intensity in Al and CA coated Al.

The shock pressure (P) in the foil target of initial mass density (ρ_0) was estimated from measurements of particle velocity (U_p) using the Hugoniot relation, $P=\rho_0(a+bU_p)U_p$, where a and b are material-specific constants. Fig. L.7.4 illustrates the variation in shock pressure as a function of laser intensity. As a laser-driven shock propagates from a low-density medium to a higher-density material, shock amplification occurs due to the impedance mismatch between the two media. The results indicate that the CA coating on the Al-foil enhances the laser-driven shock pressure by approximately a factor of two compared with the uncoated Al-foil.

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