Direct measurement technique for shock wave velocity under super high pressure

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Ignition targets planned for the laser fusion require a pulse shape with a low power foot designed to send a carefully timed series of shocks through the frozen DT (deuterium–tritium) shell [1-3]. To achieve ignition, both the strength and timing of the shock and compression waves must be accurately set. To achieve optimal shock conditions, experiments using optical diagnostics will detect the shock-velocity temporal profiles, providing both the strength and timing of the various shocks within the capsule fuel. For the basic experiment, the technique which can measure the shock front directly in the transparent material has been developed in SGIIIYX of China. All insulators are expected to transform into metals at high enough compression due to closing of the energy gap in the density of states separating occupied and unoccupied states[4，5]. Such pressure-induced gap closure will be preceded by a stage when thermal excitation can excite substantial numbers of electrons across the reduced gap into unoccupied states.

The plan for achieving the proper shock timing (that is, the proper pulse shape) for a laser fusion ignition capsule relies on a diagnostic instrument called VISAR. At its simplest level the active shock breakout (ASBO) diagnostic is a high resolution optical imager that projects a two-dimensional magnified image of the target onto a pair of streak camera detectors (Fig. 1). In somewhat more detail, the system can be divided into a cascade of image relays leading from the target chamber through a 150mm diagnostic manipulator and then into the detection paths. The signal passes through a pair of velocity interferometers before being recorded on the streak cameras. The interferometers superimpose a sinusoidal spatial modulation on the image: Doppler shifts in the reflected probe are manifested as shifts of these fringes at the interferometer outputs. The streak cameras record the central chord of the field of view and sweep this signal in time across the output detector.

The probe light is delivered to the diagnostic system through a large-core-diameter multimode fused silica optical fiber, the output of which is collimated and injected into the optical system through a 50% beamsplitter. Light reflected from the target returns to this beamsplitter, from which it is reflected into the detection paths. The probe laser is 7ns full width at half maximum (FWHM) with 40kHz line width which is produced by the fiber laser. After accounting for losses the energy levels, required to produce good exposure on a streak camera during a time window of a few nanoseconds

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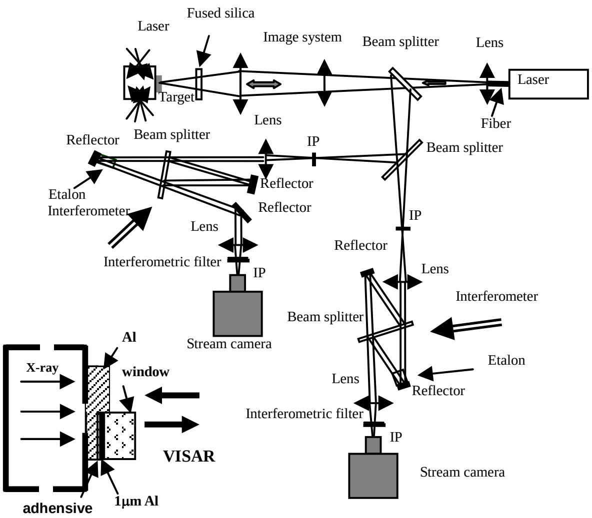
can exceed 3mj. The probe laser light is delivered to the diagnostic station through a multimode fused silica optical fiber with 1 mm core diameter and 0.22 numerical aperture.



(a) (b)

Fig.1 (a) Schematic of target (b) Schematic of IVISAR system

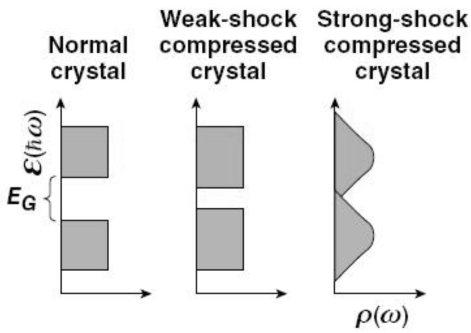


Fig.2 Difference of band gap under shock pressure

The F number (focal length/diameter) of collecting lens in the chamber is 4.5 which is a compromise result about the collecting efficiency and Doppler shift between the edge of collecting lens and center of that. The time resolution of the streak camera is 30ps, and the space resolution is 8μm. The wavelength of laser pulse is 351nm, and the wavelength of probe laser is 532nm which can avoid the scattering interfering from the 526.5nm in the chamber with 2nm FWHM interfere filter.

Figure 1(a) show the diagram of *Hohlraum* target. The 8 lasers enter into the hole, and the diagnostic aperture is about 400×600μm on the side of *Hohlraum* target. The ablation layer is aluminum with the different thickness in this paper. In order to shield the effect of adhesive (there are the blank effect even if the radiation temperature is about 150eV), there is 1μm aluminum (Al) coated on the rear side of transparent window before the transparent window was adhered to the Al base. Therefore the interface of aluminum step and the transparent window is the Al-adhesive-Al-transparent material, otherwise Al-adhesive-transparent material. The thickness of adhesive is less than 2μm which has little effect for shock wave measurement.

Shock front reflectivity is much greater than a few percent are a clear indication that delocalized electrons are present in the shocked liquid. Fresnel reflectivities (due to bound electron contributions) are estimated to be only 0.1% based on extrapolations of the scaling found in previous experiments. To understand the origin of such delocalized electrons we first note that for strong shocks, the thermal energy increases much more rapidly than the compressive energy. This process can be explained in the figure 2. When the shock is less than 1Mbar, the band gap become small, and the reflective of shock front is a few percent. From the VISAR, the reflective signal of shock front is very small. The interface of Al and quartz will be the reflective surface. As the shock pressure increasing, the band gap will be overlap. So the reflective of shock front will rise from a few percents to 50% which can be measured easily for VISAR.

The complex index of refraction, given by $n=\sqrt{\varepsilon}$, can then be used to calculate the reflectivity from $R=|(n-n_{00})/(n+n_{00})|^2$, where n_{00}= 1.547 is the index of unshocked quartz (z-cut). The optical reflectivity of the shock at 532 nm, defined as the fraction of energy reflected by the moving shock front, is shown in figure 3.

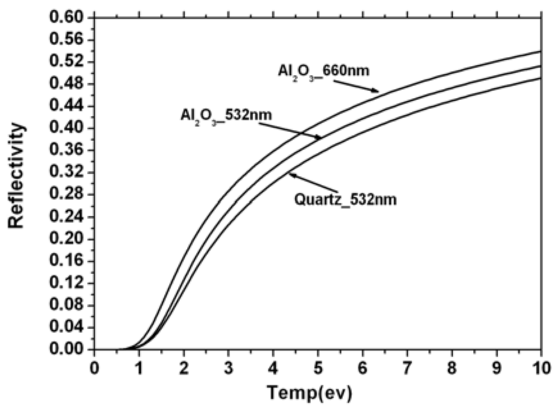


Fig.3 Shock reflectivity in quartz and Al2O3 shown as a function of temperature

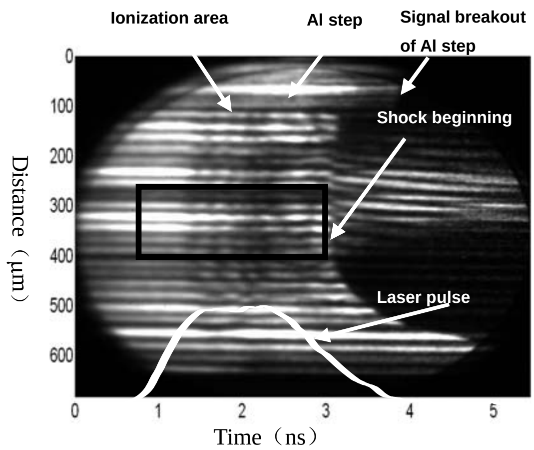


Fig.4 Experimantal data of quartz window with Tr=180eV (shot9)

Figure 4 show the experimental signal data from the streak camera with quartz window. The Al step (60/80μm) was mounted on the diagnosis aperture of 400×600μm with ~1μm adhesive. The quartz window with 200μm thickness coated 1μm Al on the rear surface was glued on the low step of Al (60μm). From the experimental data, it is found that there is a dark area in the time scale. The width of dark area is longer than 1ns which is the width of laser pulse. At 2.8ns, the shock wave transmitted to the interface of Al layer and quartz material. Since the pressure of shock wave is so high that the delocation electronic can reflect the probe laser, the fringe jump suddenly and shift continuously. The moving direction of fringe indicates that shock wave has been in the decreasing state. The etalon of two arms in VISAR is 4mm and 7mm with fused silica material, then the fringe sensitivity is 8.32km/s/Fr and 4.75km/s/Fr. The shock velocity when the shock arrive the interface of Al and quartz is 36km/s, and the reflectance ratio is 50% based on the 85% reflectance ratio for Al.

Reference:

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