Adapting ASBO/VISAR for Foam Targets

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Abstract:

The scattering properties of foams were analyzed to investigate whether the Velocity Interferometer System for Any Reflector (VISAR) could be used with foam targets, or whether the scattering of the probe beam would reduce fringe contrast to an unusable level. A mock-up of the VISAR system was constructed using a HeNe laser as the light source. CH foam samples were tested, and it was determined that good fringe contrast can be achieved by adding a pinhole to the system to reduce the collection of scattered light. This pinhole, however, can lead to additional difficulties.

Drive uniformity is very important to Internal Confinement Fusion (ICF) experiments. Nonuniform irradiation of the target leads to hotspots and deformation of the target, therefore decreasing the efficiency of the target implosion. It has been proposed that a thin (~100 μm) coating of foam over the target might increase the thermal uniformity on the target. The theory is that lower-density foams will turn into plasma faster than the traditional CH plastic shells and conduct the heat rapidly and evenly over the entire target.

Three foam types have been considered: CH foam, silica foam (aerogel), and carbonized silica foam (carbon resorcinol foam, CRF). These materials, however, have not yet been well characterized. Equation-of-state (EOS) measurements are crucial to better understand their properties. ASBO/VISAR (Active Shock Break Out / Velocity Interferometer System for Any Reflector) is an optical diagnostic used for EOS experiments, and there is interest in performing ASBO/VISAR experiments with foam targets. The largest potential problem with measuring the EOS of foam is that foams strongly scatter light and scattering reduces VISAR fringe contrast, which is essential for accurate velocity measurements. The goal of this project is to determine the feasibility of adapting ASBO/VISAR for use with foam EOS experiments.

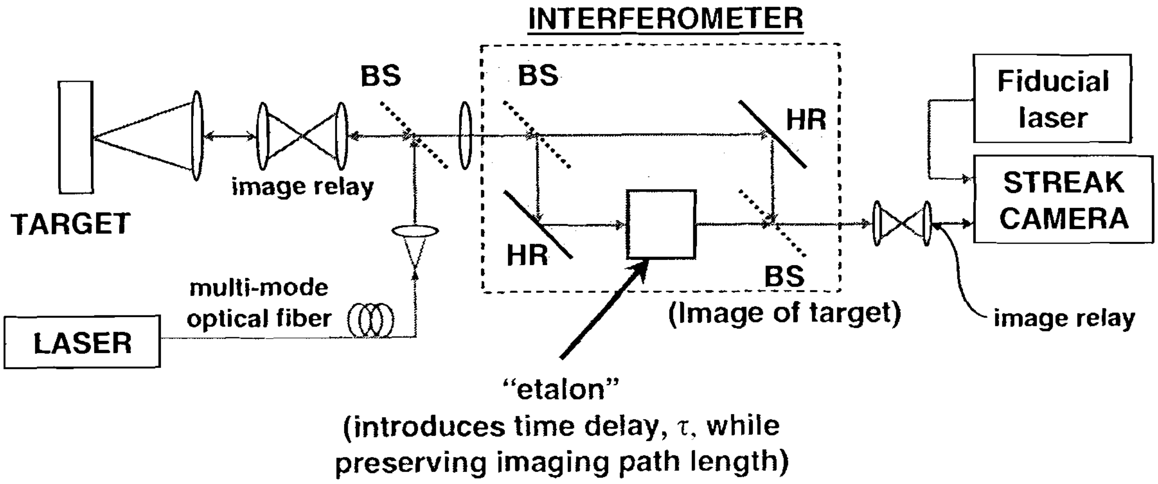

Fig. 1 - ASBO/VISAR with Mach-Zender interferometer as set up in OMEGA target bay. The beam splitters (BS) are coated with 50% reflectivity coatings on one side and antireflection coatings on the other. The etalon is antireflection coated on both sides.

ASBO/ is an Equation of State (EOS) diagnostic used in OMEGA to measure the velocity of a shock front propagating through a transparent target. (Fig. 1) VISAR employs a temporal shearing interferometer with a pulsed 532 nm laser beam. The beam illuminates the target and is reflected off of the propagating shock front, then enters a Mach-Zender interferometer with an etalon that introduces a time delay placed in one of its arms. The moving shock front induces a Doppler shift of the light based on the velocity of the shock front, so the interference pattern, which is collected by the streak camera, describes the change in velocity of the shock front through the material over time.

A typical planar target for measuring the EOS of a sample with VISAR is illustrated in Figure 2. The material to be tested is mounted on a stepped reflective "pusher," which is usually made of aluminum. The back of the pusher is illuminated with several high-energy UV OMEGA beams. The force of these pulses generates a shock wave in the aluminum that is then launched into the target material under study. The shock front ionizes the target material, thus creating a reflective surface travelling through the target. The VISAR beam reflects off of this surface and undergoes a Doppler shift back towards the interferometer.

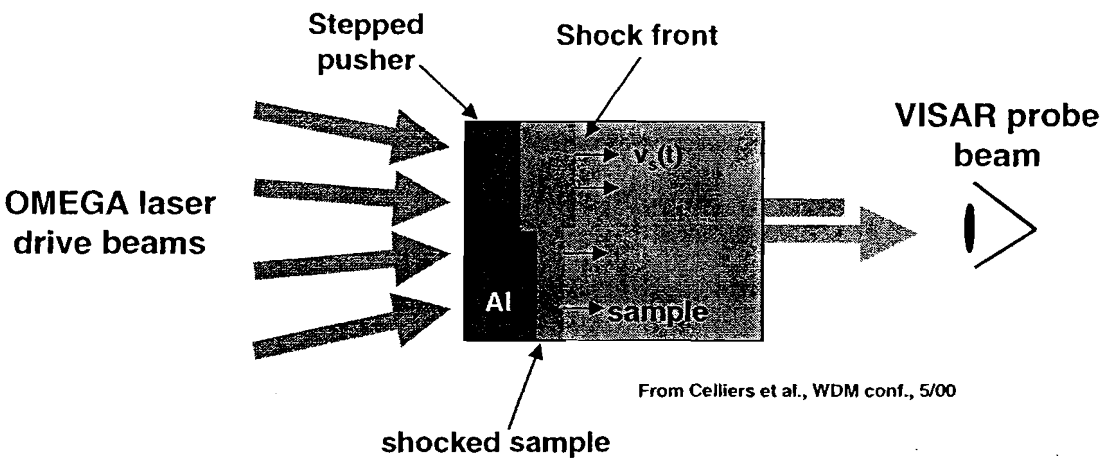

Fig. 2 - Planar VISAR target. OMEGA beams illuminate the aluminum, generating a shock wave. When the shock wave "breaks out" of the Al into the sample, the wave front ionizes and turns into plasma. This creates a moving reflective surface off of which the VISAR beam reflects, experiencing a Doppler shift.

A VISAR mockup was built to evaluate its performance with foam samples. The mockup differed from the VISAR installation in OMEGA in several ways. First, the mockup used a red helium-neon (HeNe) laser (λ = 632.8 nm) instead of the green frequency-doubled Nd:YAG (λ = 532 nm) used in the OMEGA system. Additionally, the HeNe laser in the mockup is spatially coherent, whereas the 531-nm beam is delivered by a multi-mode optical fiber. Neither leg of the interferometer contained an etalon, as there was no change in wavefront characteristics over time. Lastly, a foam sample was placed in front of a 100 % reflectivity mirror, used to retro-reflect the VISAR probe beam.

Despite some potential difficulties, it was shown from the VISAR mockup that good fringe contrast can be achieved with the addition of a pinhole, as shown in Figure 3.

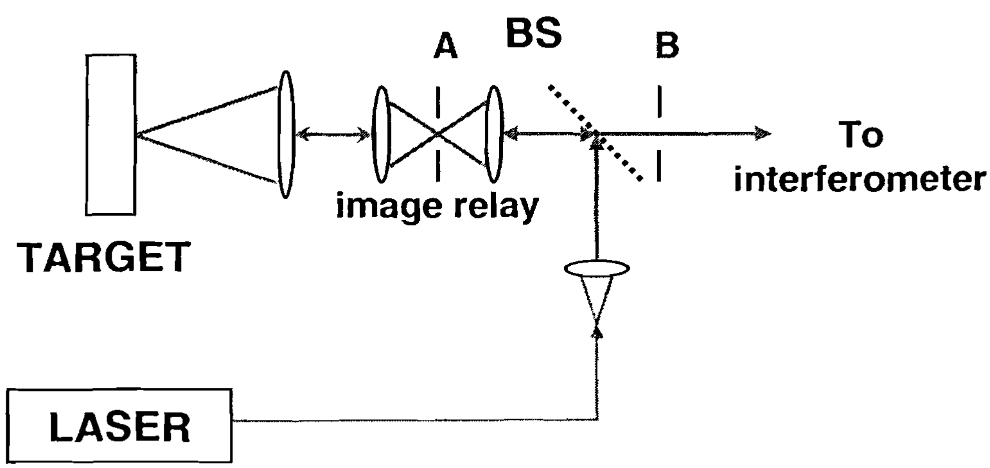

Fig. 3 - Pinhole placement: (A) represents the placement of the pinhole at the focal point of the image relay in the mock-up. (B) represents a possible pinhole location in on-line ASBO/VISAR. Placing the pinhole after the beam splitter means the beam only passes through the hole once, minimizing reduction of signal.

Figure 4 shows the fringes obtained from the VISAR mockup. The fringes in Figure 4(a) were collected with no foam sample interrupting the beam. The speckle pattern present in Figure 4(b) occurred when a nominally 50 mg/cc, 50 μm thick sample of CH foam was inserted directly before the mirror, where the beam is collimated, but with no pinhole. The speckle occurred due to the random nature of the light emerging from the foam sample and entering the interferometer, which obliterated the fringe pattern. Figure 4(c) shows the fringes obtained with the same sample, but with a 0.405 mm pinhole added at the focal point of the beam relay (point A shown in figure 3). To obtain the same signal strength, the filters on the camera were adjusted to allow approximately 33 times more light through.

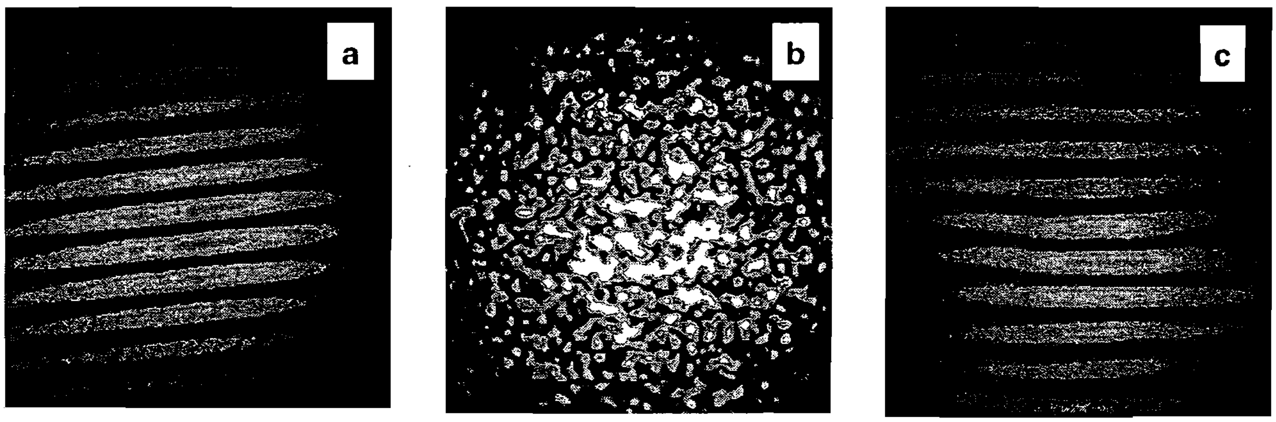

Fig. 4 - Fringes produced by interferometer in LDL mock-up.
(a) No foam sample in beam. (b) 50 mg/cc, 50 μm thick (nominal) CH foam sample, no pinhole. (c) 50 mg/cc, 50 μm thick (nominal) CH foam sample, with 405 μm pinhole, 33x amount of light needed for same output intensity.

Introducing a pinhole reduces scattered light collected by the VISAR system and allows only directly reflected light to be collected, but this scheme introduces several other problems. The first of these is increased alignment sensitivity. The beam and target must be aligned much more precisely than without the pinhole so it does not miss the pinhole altogether which could might be operationally impractical in OMEGA. Another problem is reduced signal. The scattering in the foam reduces the amount of light that actually enters the interferometer. Thus, if only unscattered light is collected, the signal is much weaker. It was found in these experiments that when a nominally 50 μm thick, 50 mg/cc CH foam sample was inserted in the beam, the filters on the camera needed to be adjusted to allow 33x more light into the camera. The signal in the OMEGA ASBO/VISAR installation may or may not be able to afford such a reduction.

A second problem caused by a pinhole is reduced spatial resolution. The size of the smallest resolvable target feature depends upon the wavelength of the light, the diameter of the pinhole, and the focal length of the beam relay by the equation

$$x_{obj} \geq \left(\frac{x_{freq}}{\lambda \cdot f} \right)^{-1} = \left(\frac{D_{pinhole}/2}{\lambda \cdot f} \right)^{-1} = 317\,\mu m$$

Using the measurements from the mock-up (λ = 0.633 nm, f = 100 mm, and $D_{pinhole}$ = 400 μm), the smallest resolvable feature is calculated to be about 317 μm. For a target with a diameter of about 1 mm, only three resolution units of this size fit across the target. The stepped nature of the target causes a step in the shock front, as shown in Figure 5. With reduced spatial resolution, details such as this step would be lost and only an average velocity value can be obtained. Since edge effects will affect two of those, only one measurement will be useful. It may be noted that the shorter-wavelength green light used in the OMEGA ASBO/VISAR system will result in a slightly smaller resolution unit; the shorter wavelength, however, it will also suffer more scattering in the foam.

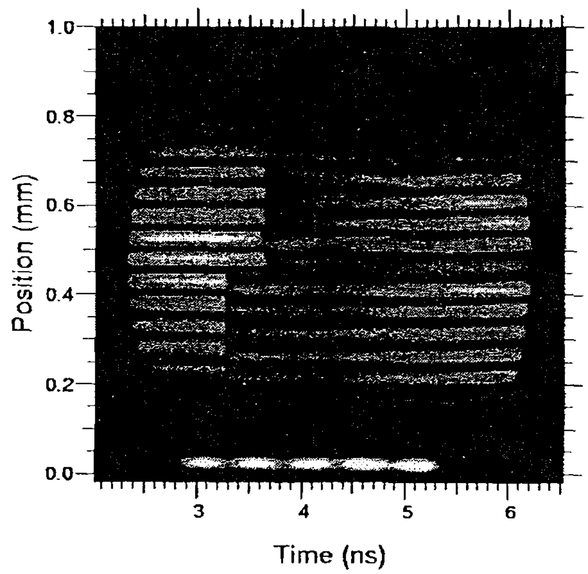

Fig. 5 - ASBO/VISAR streak camera image. Note the step. From Celliers et al, Warm Dense Matter conference (May 2000).

Spectrophotometer scans of an aerogel sample (a silica foam, also under consideration) were done to determine the relationship between the wavelength of light passing through the sample and the amount of scattering that occurred. Figure 6 shows the results of one scan, with wavelength plotted on the x-axis and absorbance on the y-axis. Since the aerogel is translucent, any loss of signal through the sample can be attributed to scattering, rather than actual absorbance. The results of these measurements showed that scattering of light increases exponentially with shortening of wavelength.

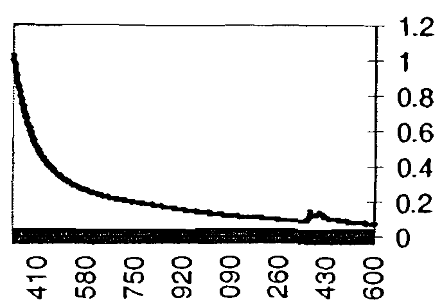

Fig 6 – Spectrophotometer scan of aerogel sample. X-axis shows wavelength, Y-axis shows the amount of scattering that occurred in the sample.

In conclusion, good fringe contrast can be achieved in foam ASBO/VISAR experiments, but trade-offs must be made. Further investigation is planned to continue to research the problem, including investigation of other types of foam and computer modeling.

Many thanks to Dr. Stephen Craxton for admitting me to the program and assigning me to this project. I would also like to thank Devon Battaglia for helping me out, particularly in the beginning. Thanks to Doug Smith for the loan of his fiber-optic spectrophotometer and to Matt Pandina for assisting me with my presentation. Finally, I would like to thank Jon Zuegel for being the best advisor I could have asked for. Thank you for a great experience and many memories.

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