ATLAS LINE-IMAGING ORVIS DIAGNOSTIC [*]

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Abstract

Many pulsed-power facilities used for high energy density experiments require diagnostics that can measure the velocity histories of shocked materials. The Atlas pulsed-power z-pinch machine [1] (located at the Nevada Test Site) is a 23-megajoule capacitor bank capable of delivering 28 mega-amperes in an approximately 5 microsecond rise time pulse into a cylindrical imploding liner. Experimental data is needed for the hydro-modeling of dynamic friction. For this set of experiments, shocks in two adjacent materials will produce differential shear velocities.

An optically recording velocity interferometer system (ORVIS) [2,3] has been designed to measure the differential velocity from the inner surface of a load after shock breakout. The moving target surface located inside an imploding load is illuminated with an f/10 laser pulse at 532 nm, focused down to a 12-mm long line. An optical relay collects light from the middle 8-mm of this line at f/15. Relay lenses pass collimated light through a two-arm interferometer, in the same fashion as VISAR (velocity interferometer system for any reflector). Different thicknesses of etalons in one arm allow recording of different velocity ranges. After the interferometer, a dove prism rotates the line image into the slit of the recording streak camera. Alignment techniques are discussed and test calibration data from laser-driven mini-flyer plates are presented.

I. INTRODUCTION

In this ORVIS setup, a Q-switch-gated, continuous wave probe laser illuminates a moving surface. The ensuing Doppler shift of the light collected off the surface causes fringe motion after passing through the interferometer, which is then recorded by a streak camera. Data analysis of the fringe motion yields information about the target velocity with respect to time.

The ORVIS diagnostic will be used for a series of liner-target implosion experiments designed to test the validity of a new interface-friction model developed by Hammerberg, et al. [4,5]. Key features of this model are that the retarding frictional force will increase “linearly” from very low interface slipping velocities up to a critical value. At higher velocities, a large number of molecular dynamics calculations have indicated a near-universal decrease in the friction force. The liner-target implosion Friction series of experiments on Atlas will test the high-velocity scaling of this model in regimes that are virtually impossible to reach by other experimental techniques. The interface materials in this first series will be a Ta-Al-Ta “sandwich.” ORVIS will provide the relative velocity measurements of the Ta/Al interface.

II. OPTICAL SYSTEM

A perspective view of the optical imaging system underneath the Atlas machine is shown in Fig. 1. Optical relay lenses are used to both illuminate the target and to collect light from the target and relay its image safely inside a shielded enclosure. Because of the immense operational energy of the Atlas machine, all optical elements along the downward vertical axis (from mirror M1 to mirror M2) may need to be replaced after each experiment. The interferometer sits on an upper shelf, and the recording streak camera on a lower shelf. Total distance from target to the streak camera slit is 8.75 meters. The optical system can resolve 1 part in 500 of the 8-mm target line. This initial ORVIS diagnostic uses a single interferometer, and a future upgrade to dual-leg interferometry will allow us to track complex shockwave velocity jumps in the target.

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14. ABSTRACT
Many pulsed-power facilities used for high energy density experiments require diagnostics that can measure the velocity histories of shocked materials. The Atlas pulsed-power z-pinch machine [1] (located at the Nevada Test Site) is a 23-megajoule capacitor bank capable of delivering 28 mega-amperes in an approximately 5 microsecond rise time pulse into a cylindrical imploding liner. Experimental data is needed for the hydro-modeling of dynamic friction. For this set of experiments, shocks in two adjacent materials will produce differential shear velocities. An optically recording velocity interferometer system (ORVIS) [2,3] has been designed to measure the differential velocity from the inner surface of a load after shock breakout. The moving target surface located inside an imploding load is illuminated with an f/10 laser pulse at 532 nm, focused down to a 12-mm long line. An optical relay collects light from the middle 8-mm of this line at f/15. Relay lenses pass collimated light through a two-arm interferometer, in the same fashion as VISAR (velocity interferometer system for any reflector). Different thicknesses of etalons in one arm allow recording of different velocity ranges. After the interferometer, a dove prism rotates the line image into the slit of the recording streak camera. Alignment techniques are discussed and test calibration data from laser-driven mini-flyer plates are presented.

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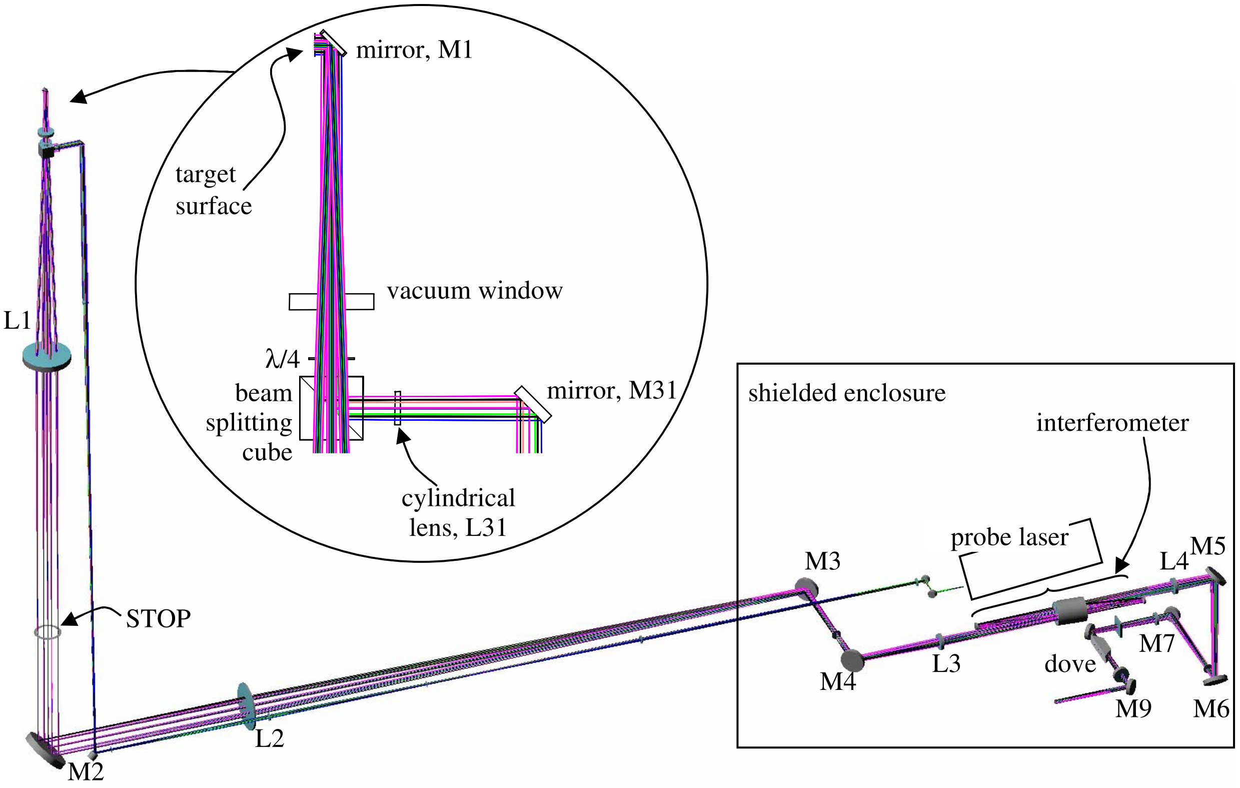

Figure 1. Optical layout of ORVIS line-imaging system for the ATLAS machine. All components from mirror M3 to the streak camera are located inside of a shielded enclosure. Optical components inside the ATLAS machine are seen in the insert to this figure.

The optical design must be flexible to allow for changes to the turning mirror placements. For example, different target packages will position mirror M1 at different rotations and heights. The dove prism, located in front of the streak camera, allows the line-image to be correctly rotated at the streak camera slit to account for image orientation.

If the interferometer is perfectly aligned, a "bull's-eye" fringe pattern is superimposed upon the image. To track parallel fringes with the streak camera, the fringe pattern is shifted by about 20 fringes from the "bull's-eye" center to find a location where the fringes are roughly parallel. Tilting the interferometer's end mirrors (M11 and M12) allows for both adjustment of the fringe spacing and rotation of the fringes relative to the line image. For consistent data collection, care is taken to always operate on the same side of the "bull's-eye." This is checked by using an alignment laser inserted before the intermediate image plane (IP1), and monitoring the orientation of two laser dots (produced by each interferometer arm) at the dove prism location.

The probe laser sits on the upper shelf of the interferometer enclosure, next to the interferometer optics. Separate relay optics send probe laser light into a beam-splitting cube located as close as possible to the target. To achieve a uniform illumination of the target, Fourier relay lenses are used to image the second harmonic generator of the probe laser at the target. This provides a top hat illumination profile on the target surface rather than a Gaussian profile.

The insert on Fig. 1 shows the beam splitting cube located as close to the target as possible. A double pass of the laser light through the λ/4 plate will rotate its polarization for transmitting through the beam splitting cube.

It is important to illuminate the target with the lowest possible f/# light because, after shock breakout and subsequent target launch inward, the surface becomes curved [5]. As the target curvature increases under shock pressure, the field points from the edge of the line image show higher vignetting than the center field points [6]. Since the cube beam splitter must be physically located outside a vacuum window, the probe laser illuminates the target with f/10 light. The cylindrical lens (L31) is used to collapse the laser illumination into a 12-mm-long line at the target. The ORVIS collects the center 8-mm of this light at f/15.

III. OPTICAL ALIGNMENT

To inspect the optical alignment [7], two lasers with differently colored beams provide counter propagating light passing through the interferometer. One alignment laser (543 nm) is injected before the first intermediate

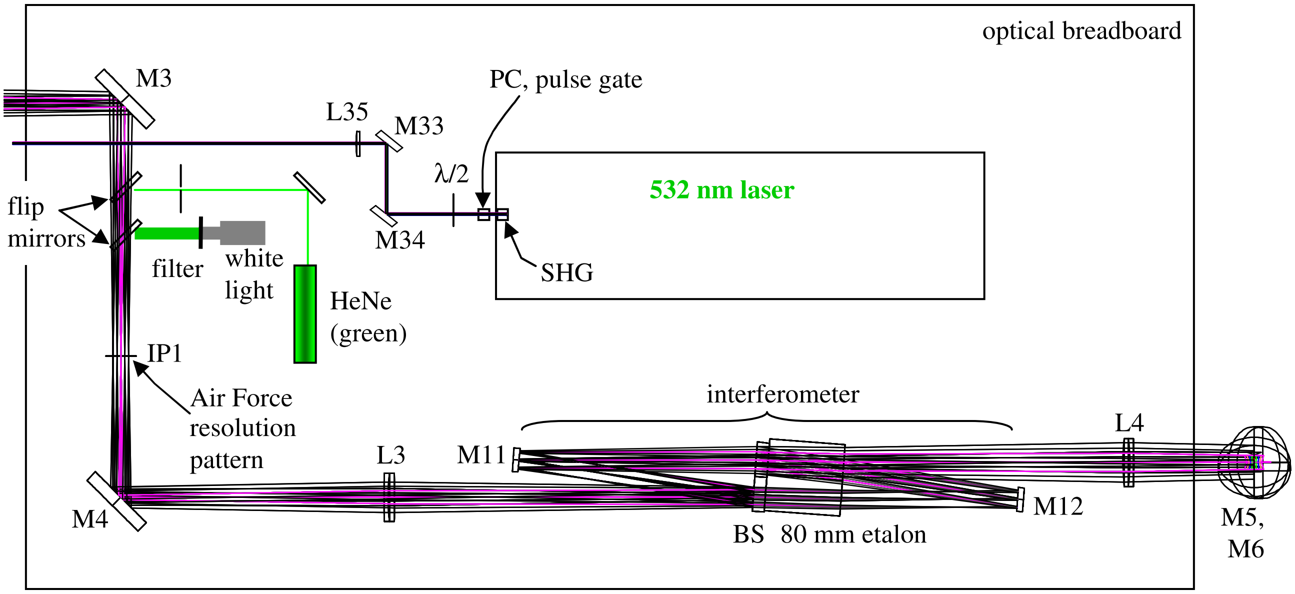

Figure 2. Breadboard layout on the upper shelf of the interferometer enclosure.

image plane (IP1), passes forward through the interferometer, and illuminates the streak camera slit (Fig. 2). The second laser (633 nm) is injected just in front of the recording streak camera, passes backward through all the optical elements, and illuminates the target center (Fig. 3). All optical components are mounted on kinematic plates. By using both reflections and transmissions of each colored laser beam, one can precisely align each optical component.

Light from the target is relayed to an intermediate image plane (IP1) placed before the interferometer, shown in Fig. 2. Lenses L3 and L4 are used to collimate the light through the interferometer. This configuration differs from the normal operation of ORVIS diagnostics [2], where the exit surface of the interferometer's beam splitter is an image plane. If the f/# of the light passing through the interferometer is large (it is 50.5 for the ORVIS discussed in [2]), this may be acceptable. For the Atlas ORVIS interferometer, the f/# is 30.8. At this f/#, astigmatism produced by the tilted etalon would have to be corrected for with a tilted plate. Additionally, different ray angles from the same field point would have significant variations in their optical path lengths (traveling through the etalon) that would limit the accuracy of the velocity measurement. By collimating the light through the interferometer, the different ray angles from the same field points have identical optical path lengths. The 80 mm etalon shown in Fig. 2 is the longest delay etalon and is used for the slow velocity measurements. We could stack etalons to give slower velocity, but we would have to increase the f/# collection.

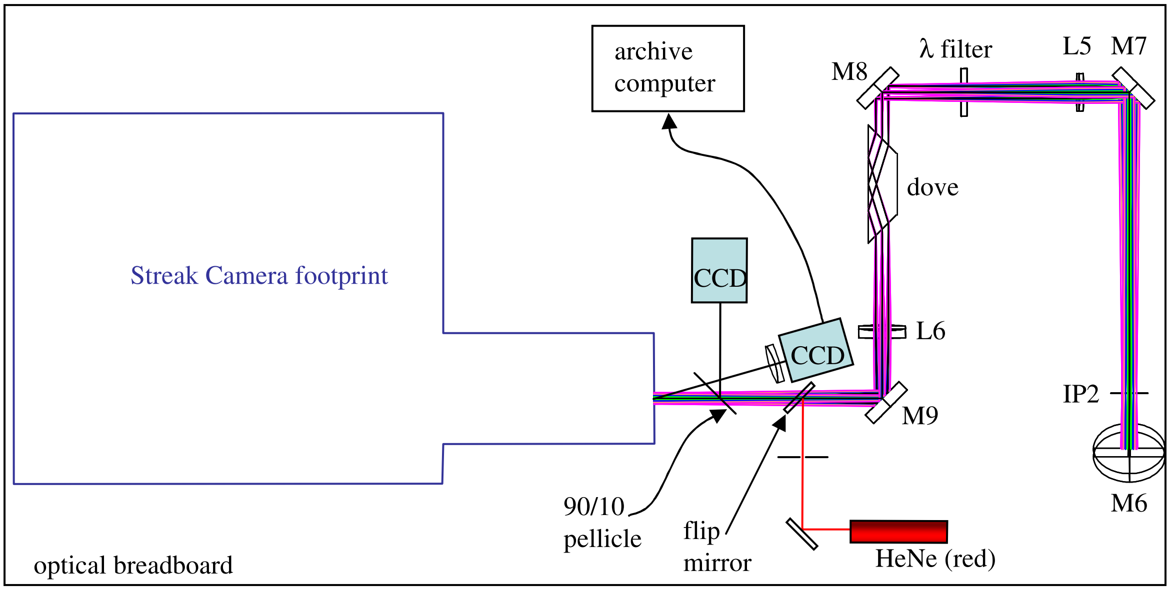

Figure 3. Breadboard layout on the lower shelf of the interferometer enclosure.

IV. LASER-DRIVEN MINI-FLYER PLATES

Testing of this ORVIS system is performed with a laser-driven mini-flyer plate launch system [8]. An 8-nsec-pulsed, 1.5-joule, Nd:YAG laser ablatively drives a shock into the flyer plate. We are using the substrate structure shown in Figure 2 of Reference 8, with a 0.5-µm thick aluminum layer. The flyer, also aluminum, is 3 mm in diameter and 100 microns thick. With this laser pulse drive energy, the peak flyer velocity will be ~1.2 km/sec. Sample fringe data is shown in Fig. 4.

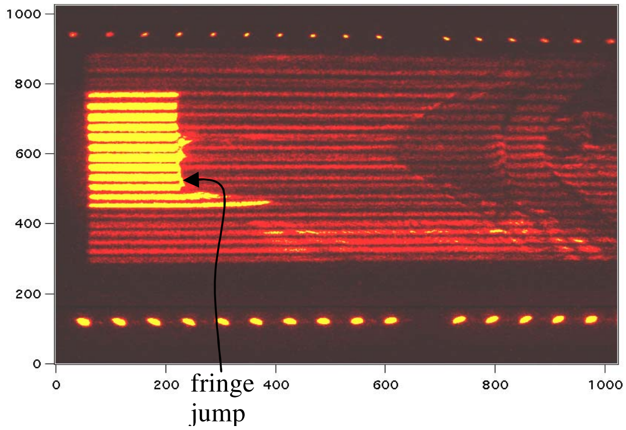

Figure 4. Sample VISAR data. Uniform fringes are seen up until shock breakout. Fringes can shift an arbitrary number of times at shock breakout. As the reflector becomes curved, the light from the edge of the field can be attenuated. Lighter fringes are from a window placed 740 µm from reflector. Window shocks are seen late in time. Comb lights are spaced by 100 ns.

V. SUMMARY

We have designed a spatially-resolved line-ORVIS velocity measurement diagnostic for pulsed power hydrodynamic experiments. The system is designed to be portable and flexible to view arbitrary orientations of a target. Resolution of the optical relay system exceeds the limiting resolution of the recording streak camera.

VI. ACKNOWLEDGEMENT

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