Line-imaging Laser Interferometers for Measuring Velocities

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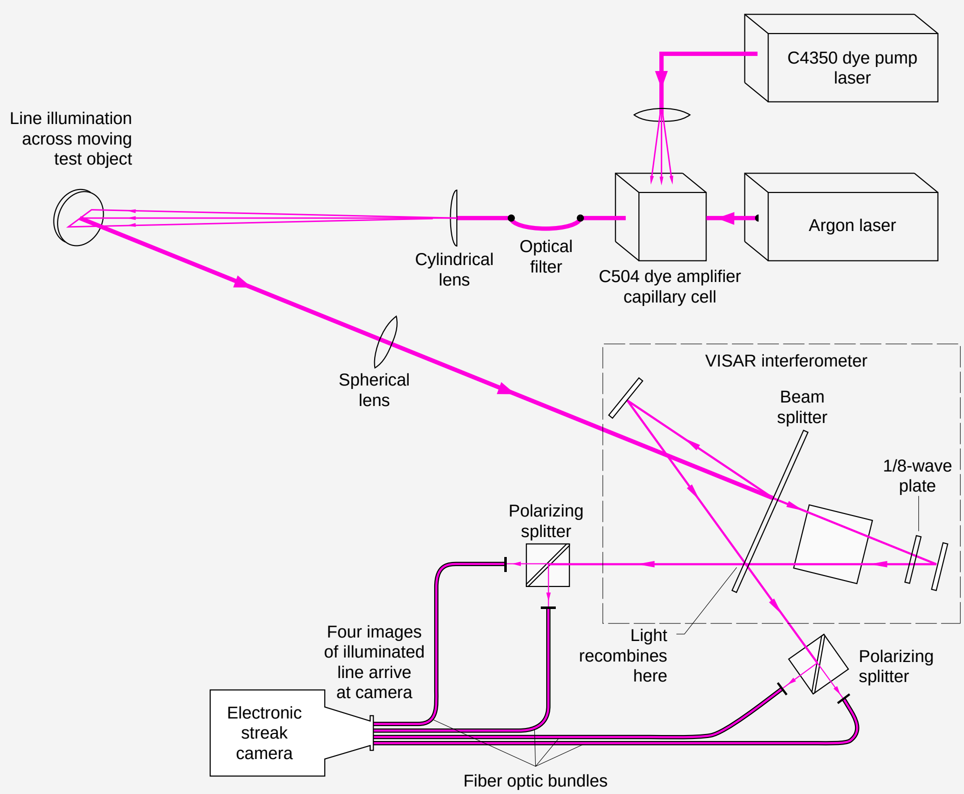
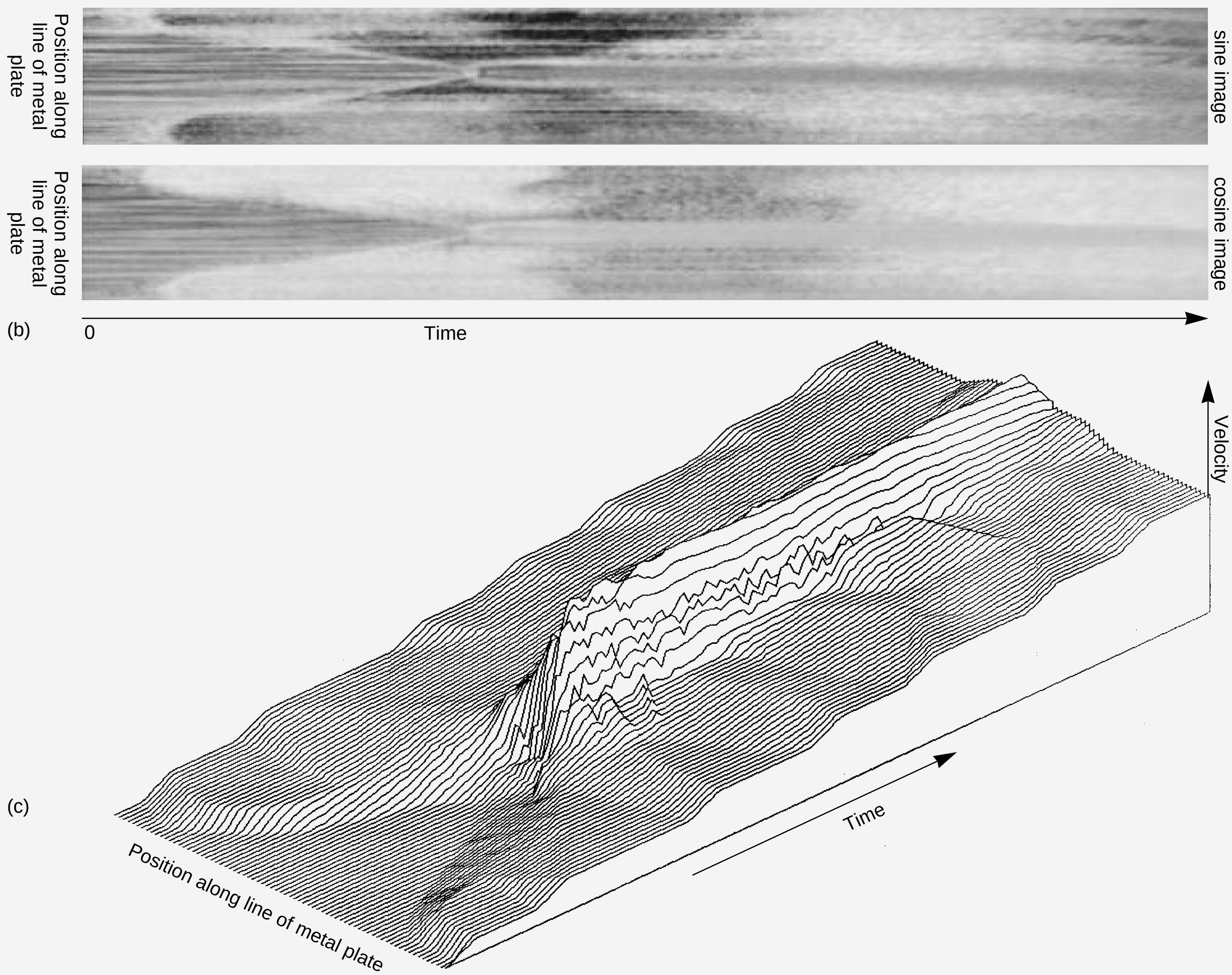
Hydrodynamic tests create hostile conditions in which high pressures can easily compress solids and accelerate materials to velocities of several kilometers per second. Among the advanced diagnostics for hydrodynamic tests at the Laboratory is our line-imaging VISAR (Velocity Interferometer System for Any Reflector). The VISAR measures the velocities of points along an illuminated line on a fast-moving test object. The instrument exploits the fact that when laser light is reflected from a moving surface, the wavelength of the light is Doppler-shifted in proportion to the velocity of the point that reflects it. The VISAR employs optical interference to generate bright and dark bands of light called interference fringes. The fringes oscillate between bright and dark as the test object accelerates. The VISAR measures velocity by accurately determining the number of whole and partial oscillations that occur as the test object accelerates. Its useful product is a continuous velocity history for all the points that are visible in the image.

(a) Our line-imaging VISAR uses a cylindrical lens to focus laser light onto a line on the test object. Conventional optics image the illuminated line through a special wide-angle Michelson interferometer, where a retardation plate delays the vertical polarization component of one beam by a quarter of a wavelength. As a result, when the beams are recombined to produce interference, the fringes of the vertical polarization component are shifted and their oscillations lag behind those of the horizontal component. Specifically, the intensities of corresponding points in the horizontal and vertical components depend on the sine and cosine, respectively, of the velocity at each point on the target. Polarizing beam splitters separate the horizontal polarization component from the vertical component where light exits from each side of the interferometer. This separation produces two pairs of images of the interference intensities along the illuminated line. The two images for each polarization are simply negatives of each other.

Fiber-optic bundles transmit the four images to the photocathode of an electronic streak camera. The

(a)





camera rapidly sweeps the images across a charge-coupled device that digitizes them into a microcomputer. Later, we subtract one image of each polarization from its negative to double the signal and cancel optical noise. Analysis of the images yields the velocity histories of many points in the line as a continuous function of time.

The VISAR's sensitivity to acceleration, instead of to velocity alone, best accommodates measurements of velocities from 100 meters per second to over 20 kilometers per second. Its recording time can vary from milliseconds to nanoseconds; the length of the line it observes can range from 0.3 to 30 millimeters across the target surface. Because it records pictures with their great capacity to store information, our line-imaging VISAR can capture many times more data than conventional VISARs. We have found its ability to simultaneously record large quantities of information relating different points on a test object extremely advantageous. This is most useful in measurements in which velocity gradients are important, and in tests that destroy expensive hardware, especially when test-to-test variations are important. Although our line-imaging VISAR is versatile, its use is precluded when smoke blocks its optical path or when the test-object surface loses light reflectivity.

(b) The sine and cosine interference images from an experiment in which two converging detonation waves, produced by an explosive initiated at two separate points, drove a metal plate. Triangles extending across the left third of the images are the edges of interference fringes as they responded to the acceleration of the plate. A change from dark to bright, corresponding to an increase in velocity of 200 meters per second, is visible in the cosine image.

(c) An isometric plot of velocity, deduced from the photograph in (b), as a function of position along the illuminated line and time. The "cliffs" at the lower left indicate the acceleration of the metal as it was driven by the two converging pressure waves. The ridge extending from the center to the upper right is a region of high velocity caused by the pressure enhancement where the waves collided. □