4. Laser Interferometry

Interferometric measurements provide the highest time and space resolution currently attainable. For these methods a laser is not only convenient as a coherent light source but is necessary in order to achieve the requisite high light intensities.

Two schemes have been reported; both of them were developed by Barker.[16,36] The first of these uses the laser in a conventional Michelson interferometer arrangement and is shown schematically in Fig. 8. The portion of the laser beam reflected from the mirror surface of the specimen is compared with that reflected from a stationary mirror. Interferometric fringes are thus formed, each of which corresponds to a displacement of the surface of one-half wavelength and the spatial resolution is therefore of the order of 0.3 micron.

The laser beam is focused on the specimen mirror surface in order to minimize the effect of projectile tilt. This surface can either be a polished free surface, in which case the problems of relating free-surface velocity to mass velocity are the same as in many of the techniques mentioned above, or it may be a mirror surface plated on an internal surface of a transparent specimen. In this case a direct measure of mass velocity is obtained. In either case impact stresses must be limited to those for which the mirror retains its integrity.

When measuring the displacement of an internal surface a correction is required for the change of index of refraction of the shocked "window". The relation that best fits current data is the Gladstone-Dale formula:[36]

$$d\rho/\rho \;=\; dn/(n-1)$$

where ρ is density and n is the index of refraction.

The uncertainty introduced by lack of complete independent knowledge of the density in the shock (which is one of the parameters one wishes to determine) does not produce serious errors because the density changes involved are usually small.

The principal disadvantage to the technique described above is that the spatial resolution is generally too high. Consequently, for mass velocities greater than about 0.2 mm/μs the fringe frequency exceeds the capabilities of current recording systems (approx. 600 MHz).

By means of a clever modification of the above technique the space and time resolution can be adjusted over a wide range; moreover, the fringe frequency is proportional to the acceleration of the mirror rather than to its velocity.[36] Each fringe then corresponds to a velocity increment of predetermined magnitude.

In this modification, the "velocity interferometer technique," interference fringes are formed by superposition of two portions of the laser beam reflected from the specimen surface at different times. The earlier signal is delayed a predetermined amount with respect to the later signal. The arrangement is shown in Fig. 9.

The operation can be understood by referring to Fig. 10. If the time through the delay leg is $\tau = t_2 - t_1$ and the distance travelled by the mirror surface in that time is S, then

$$S = \overline{u}\tau$$

where $\overline{u}$ is the average surface velocity over the interval τ. The signal reaching the photomultiplier at time $(t_2 + t_c)$, where t_c is constant, is thus composed of the signal reflected at time t_2 plus that reflected at time t_1. If the velocity of the surface is constant in time the separation of the surfaces, $S = x(t_2) - x(t_1)$, is constant and the fringe frequency is zero. If the surface accelerates, however, fringes will appear at the rate

$$(\lambda/2)(dn/dt) = (dS/dt) = \tau(d\overline{u}/dt)$$