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TITLE
INTERFEROMETRY AND HIGH SPEED PHOTOGRAPHY OF LASER-DRIVEN FLYER PLATES

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Interferometry and high speed photography of laser-driven flyer plates

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ABSTRACT

Laser-driven thin (2-10-μ thick) plates of aluminum and copper are accelerated to velocities ≥5 km/s by a 1.06-μ wavelength Nd:YAG 8-10 ns FWHM laser pulse at power densities 0.7-4.0 $\mathrm{GW/cm^2}$. Accelerations $\geq 10^9\ \mathrm{km/s^2}$ have been achieved. The acceleration and velocity of these 0.4-1.0-mm-diameter plates are experimentally recorded by velocity interferometry (VISAR)[1] and the planarity of impact by streak photography.[2]

1. INTRODUCTION

Metals of controlled thickness (2-10 μ) are vacuum deposited on UV-fused quartz substrates. A Nd:YAG laser is focused through the substrate and on the metal foil (plate). The laser energy is deposited in a few skin depths[3] (~10-50 Å) in the foil at the substrate interface. The metal at this interface is converted to a metal plasma at high temperature and pressure resulting in the acceleration of the remaining plate thickness (Figure 1).

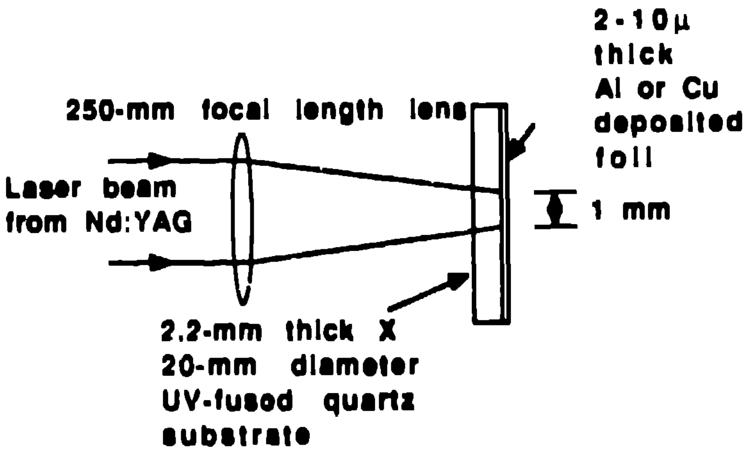

Figure 1: Technique for launching high velocity flyer plates

2. VELOCITY MEASUREMENT TECHNIQUE

An argon ion laser (514.5 nm) beam from the VISAR is focused on the free surface of the metal foil (plate) to be accelerated. The 1.06-μ Nd:YAG laser beam (~1-mm diameter) used to accelerate the plate and the argon ion beam (<0.3 mm diameter) are collinearly aligned with a HeNe laser (Figure 2). By properly synchronizing the two lasers and the VISAR electronics, the dynamic interferometric fringes containing velocity information are recorded (Figure 3). The reduced VISAR data from Figure 3 produce a velocity profile (Figure 4). Velocity profiles have been recorded with various metals, thickness, beam diameter, and power densities (Figure 5). Similar experimental techniques by various experimenters[4,5,6] have used pulsed lasers to generate one-dimensional shocks in materials or launch one-dimensional flyer plates. Our technique (Figure 1) uses thinner foils that are attached by physical vapor depositon (PVD) eliminating a bonding material and improving coupling efficiency to ≥30% and has produced relatively high velocities (≥5 km/s) with conventional, commercially available lasers. All of these modifications reduce laser energy requirements and improve plate velocity and planarity.

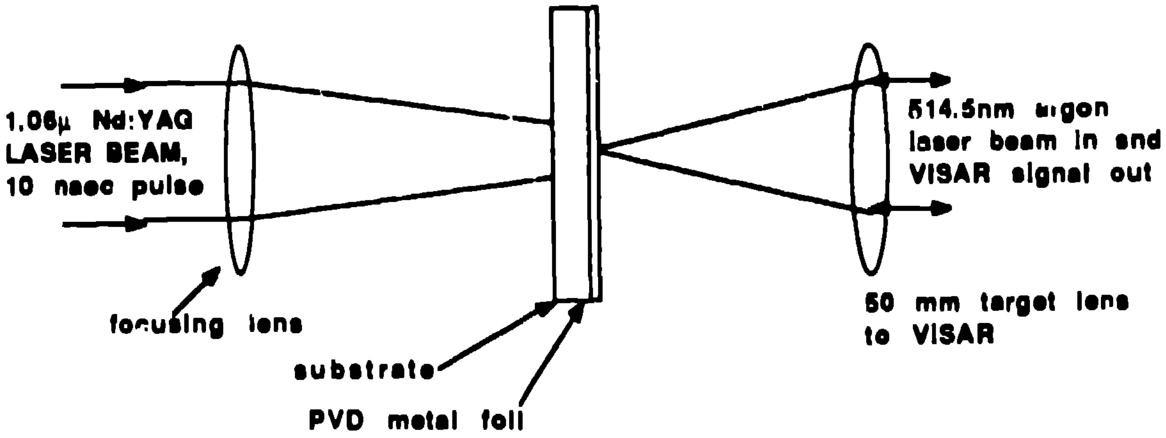

Figure 2: VISAR and Nd:YAG optical axes are colinearlly aligned

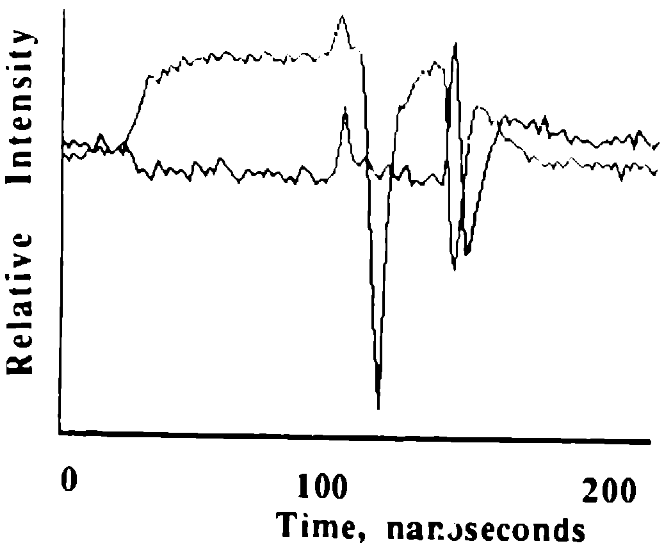

Figure 3: VISAR signals with superimposed fiducials and 10-ns laser pulse that accelerates the plate

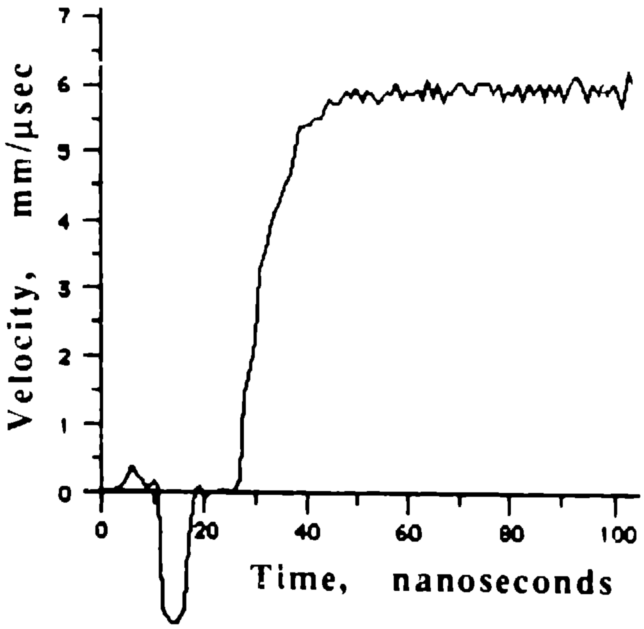

Figure 4: Reduced VISAR velocity data from Figure 3 with negatively superimposed 10-ns laser pulse

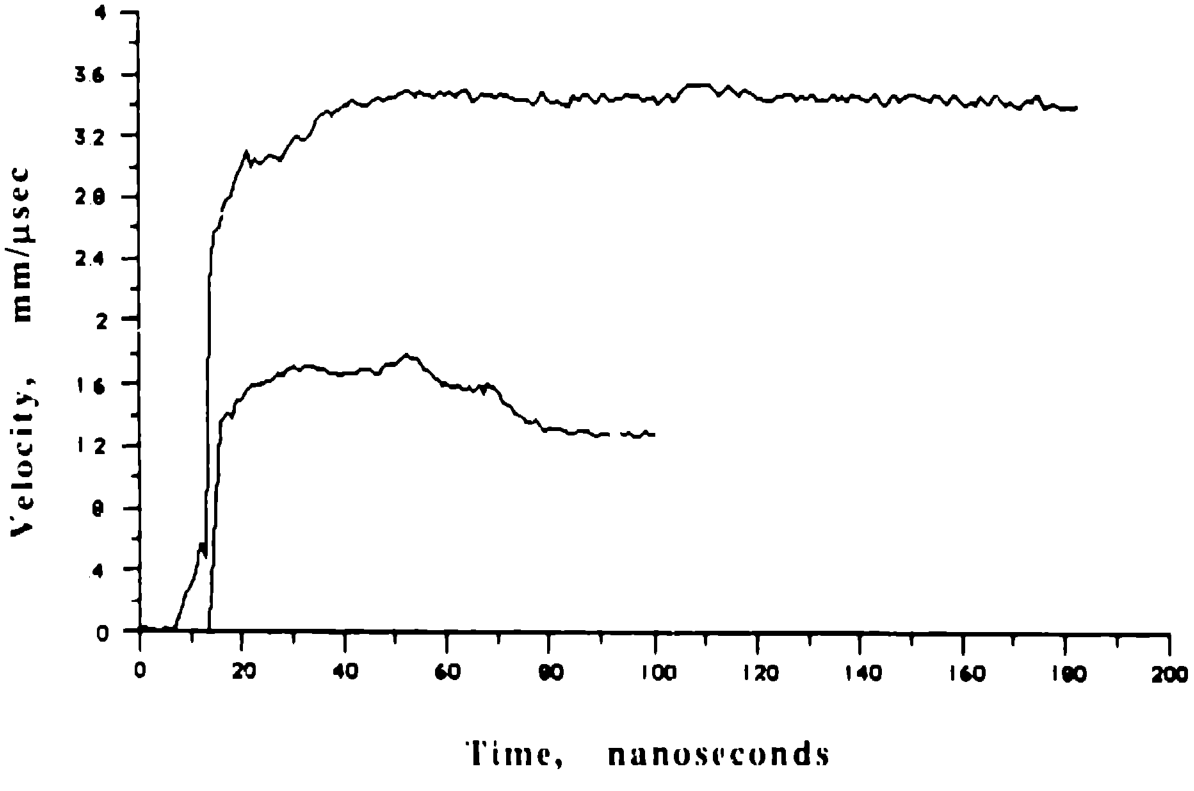

Figure 5: A comparison of several different velocity profiles for plates of different thicknesses

3. EXPERIMENTAL METHOD FOR PLATE PLANARITY AND INTEGRITY

Most applications of plate impacts to generate shock waves require a high degree of planarity i.e., minimum tilt, bow, or ripple in the plate surface at impact. Actual quantative requirements depend on numerous experimental parameters and material properties. To quantify plate impact planarity, a target of transparent material, i.e PMMA (Lucite®), is positioned 75-100 µ from the free surface of the plate surface with its parallel to the plate and perpendicular to the flyer plate velocity vector (Figure 6). As the flyer plate impacts the PMMA a bright flash is generated by the shock and recorded with an electronic streak camera.(Figure 7). The planarity can be correlated with plate thickness, flight length, laser power/energy density uniformity , or other experimental parameters. To synchronize the Nd:YAG laser pulse that accelerates the plate with the impact time of the plate on the Lucite® target, a small portion of the laser beam is sent through an optical fiber and placed on the streak camera. The time difference produces an average velocity over a fixed distance.

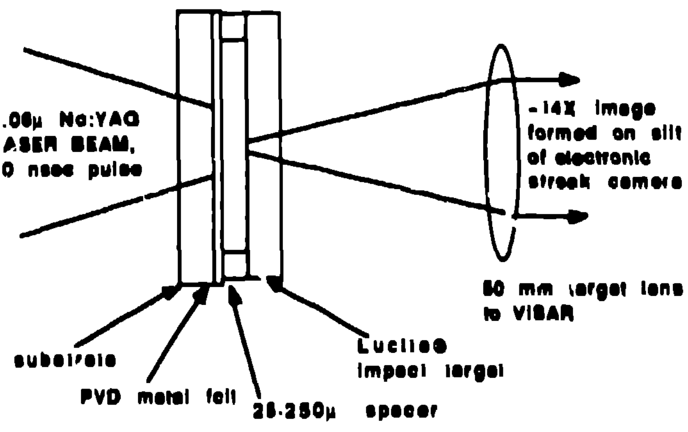

Figure 6: Electronic streak camera technique for recording impact of flyer plate on transparent target

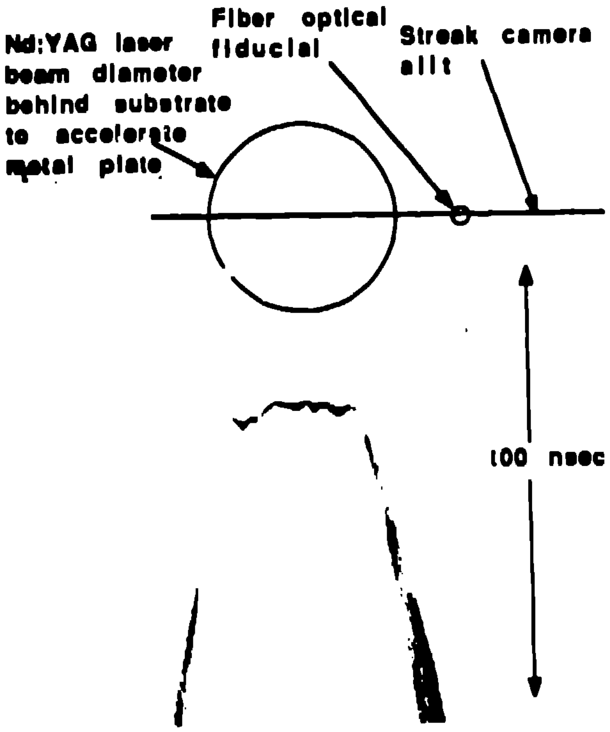

Figure 7: Static and dynamic streak record from technique in Figure 6.

4. CONCLUSIONS

Miniature flyer plates (<1-mm diam) can be accelerated (10^9 km/sec^2) to high velocities (>5km/s) with good planarity with conventional laboratory lasers. The velocity and planarity can easily be measured and controlled to provide a miniature high velocity shock physics laboratory on a standard optical table. Velocity interferometry and electronic streak photography can be used to quantify flyer plate parameters.

5. ACKNOWLEDGEMENTS

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