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TITLE **Laser-Driven Miniauture Flyer Plates for Shock Initiation of Secondary Explosives**

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LASER-DRIVEN MINIATURE FLYER PLATES FOR SHOCK INITIATION OF SECONDARY EXPLOSIVES

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Miniature flyer plates (<1-mm diameter X < 5-micron thick) of aluminum and other materials are accelerated by a 10-ns pulsed Nd:YAG laser to velocities >5 km/s. Velocity profiles are recorded by velocity interferometry (VISAR) techniques and impact planarity by electronic streak photography. Techniques for improving energy coupling from laser to flyer plate will be discussed. Flyer plate performance parameters will be compared with material properties. The $P^n t$ criteria for shock initiation of explosives will be compared for various flyer materials, pressure, and pulse duration. Performance of secondary explosives (PETN, HNS, HMX, various PBX, others) will be reported. These data will detail the experimental effect of t (in $P^n t$) approaching values of a few nanoseconds.

1. INTRODUCTION

Current laboratory techniques to generate high-pressure shocks for initiation of explosives rely on one of three traditional methods: laboratory (powder or gas) guns, exploding-foil electric guns,[1] or less commonly, laser-driven shock-waves.[2-5] Laboratory guns are usually large and cannot easily accommodate free-standing 2-micron-thick targets or impactors. Electric guns require a nonconducting flyer plate (usually Mylar® or Kapton®) or at least a dielectric layer be placed between the exploding foil and a conducting flyer plate, in which the dielectric constitutes the back of the flyer. This results in a flyer of two distinct materials. Laser-driven shock waves deposit the laser energy in a few skin depths[1] of the target material that is being shocked, ablating a plasma of material off the laser pulse side of the target and depositing a shock wave in the remaining target material. To generate these high-pressure pulses over a 0.01 cm^2 area requires 10^{12}-10^{14} GW/cm^2 at 300 J[3] that is currently available in only large high-energy laser installations. We have modified a method by Sheffield et al[6,7] to improve optical coupling and launch thinner (2-10 μ) to near one-dimensional metal flyer plates to velocities ≥5 km/sec with a high degree of planarity, reliability and repeatability.

2. EXPERIMENTAL METHOD

Using a Spectra-Physics DCR 3G laser, we are able to accelerate 2-10 μ thick, 400-1000 μ diameter aluminum and copper flyer plates to velocities ≥5 mm/microsecond with 30-300 mJ at 1.06 μ wavelength in a 10 ns FWHM laser pulse. We accomplish these velocities by improving the coupling coefficient from the laser pulse to the flyer plate by confining the laser-beam side of the flyer plate with a high-impedance transparent material (Figure 1),

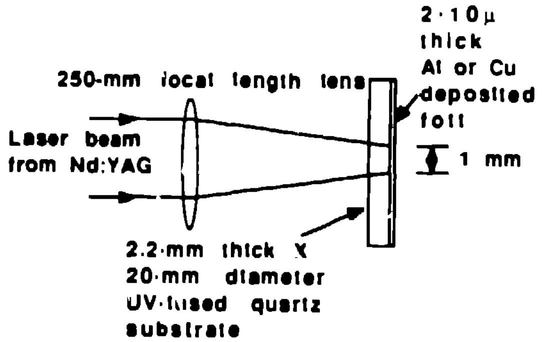

Figure 1
Technique for launching high velocity flyer plates

such as UV-fused quartz, and lowering the power density below the breakdown of the quartz. The quartz receives only surface damage during the launch of the metal flyer plate. The flyer-plate material is physically vapor deposited (PVD) on the quartz substrate by standard techniques resulting in a flyer plate of controlled thickness and good attachment with no voids between the flyer plate and UV-fused quartz substrate. Using a long focal-length lens lessens the tolerance in placing the substrate/flyer plate assembly at a desired beam diameter and delivering the same power density shot-to-shot. The flyer-plate diameters tested have been: 400, 600, and 1000 micron. These diameters are much greater (40-500) than the 2-10-µ flyer thickness, and launch techniques ensure a high degree of planarity at impact. The aluminum and copper are within a few percent of their bulk density. Efficiency (K.E. of the flyer plate/laser energy on target) ≥50% has been achieved by controlling the mass of the flyer that can be converted to a metal plasma by depositing a dielectric material (≤0.25 µ) between two separate metal deposits. The metal deposit on the substrate can be converted to a metal driving plasma but not the metal intended as a flyer plate. By depositing a dielectric (typically, Al_2O_3), a composite with a higher shear strength or an inhibited thermal diffusion is anticipated, resulting in a higher pressure before shearing out a metal flyer plate. This technique increases kinetic energy efficient by ~30%.

3. VISAR-VELOCITY PROFILES OF FLYER PLATES

To determine the velocity history of these 2-10 micron flyer plates, we use a velocity interferometer (i.e. VISAR).[6] The 1.06-µ Nd:YAG laser to accelerate the flyer plate and the argon laser beam of the VISAR are optically collinearly aligned (Figure 2) and ancillary electronics are synchronized for data acquisition. Accelerations $>10^9$ g's have been achieved with ~90% of maximum velocity attained in 20 ns (~2 X FWHM of the laser pulse). Figures 3 represents typical velocity profiles for flyer plates.

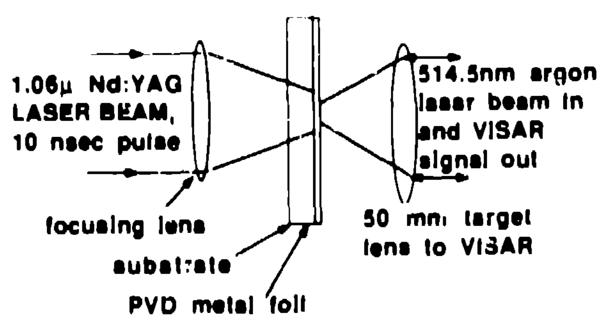

FIGURE 2
VISAR and Nd:YAG optical axes are colinearly aligned

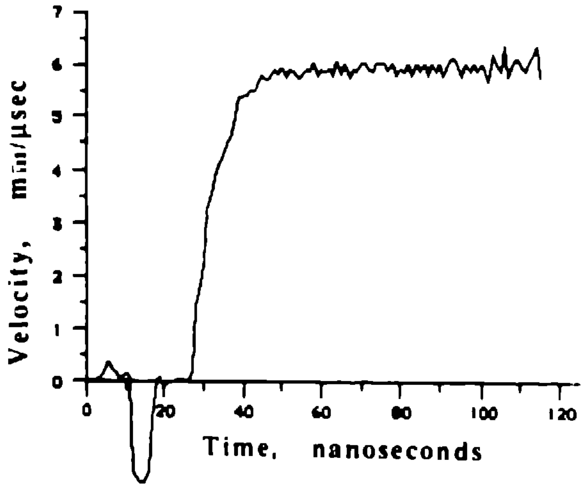

FIGURE 3
VISAR velocity profile with negatively superimposed 10-ns laser pulse

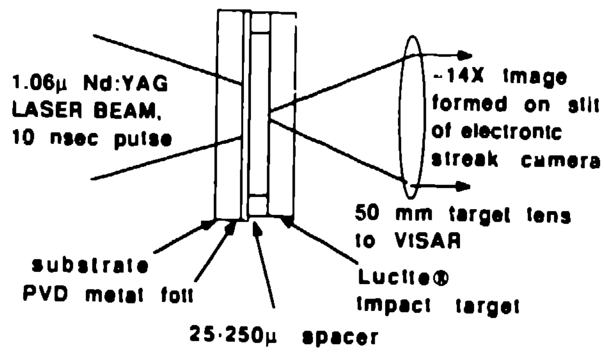

FIGURE 4
Electronic streak camera technique for recording impact of flyer plate on transparent target

4. ELECTRONIC STREAK CAMERA-PLANARITY AND INTEGRITY OF PLATE IMPACTS

To determine that a near one-dimensional flyer plate is launched and at what distances the plate will remain one-dimensional, we have performed experiments impacting flyer plates on PMMA (Lucite®) where an explosive sample would normally be placed (Figure 4). These data (Figure 5) confirm the degree of planarity, diameters of the flyer plates, and give a distance vs time that can be correlated with velocity profiles. A fiducial pulse is added to the streak record by placing a small sample of the Nd:YAG laser beam on the streak camera. The spatial beam profile for each test is recorded with a charge injection device (CID) camera and evaluated with Beamcode® software. The FWHM of the flat top beam profile closely correlates with the diameter of the flyer launched. In tests with optimum parameters, the impact time variation over 70% of the impact diameter is ≤4 ns.

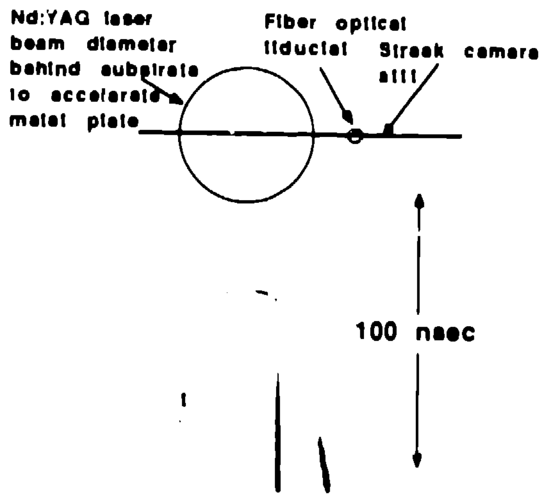

FIGURE 5
Streak record of flyer plate impacting a PMMA witness target

5. PROMPT DETONATION OF FINE GRAIN HNS

Numerous experimenters[8,9] have found that fine-grain (small hot spots) explosives exhibit small critical diameters for strong shocks of short duration ($\sim 10^{-7}$-10^{-8} s). By using our laser-driven 2-μ-thick aluminum flyer plates, we have been able to promptly detonate fine grain HNS of specific surface ~14 m^2/g and at densities 1.55 and 1.6 g/cm^3 at velocities as low as ~1.8 mm/μs resulting in ~8 GPa with a pulse duration of <1 ns. This pressure, but not pulse length, is in basic agreement with threshold of initiation by exploding foil-driven plastic flyer plates by other experimeters.[8,9] Our pulse durations are much shorter (~1 nsec vs ~20-100 nsec).

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