OMEGA Supersonic Gas-Jet Target System Characterization

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Gas-Jet Overview

- The jet is imaged using a 453-nm continuous wave laser.
- Rapid opening and closing.
- Nozzles may be customized for specific Mach numbers and jet sizes.
- Uses an electromagnetic valve controlled by an electronic pulser unit.
- High-repetition-rate, consistent, and flexible gas targets.
- Windowless gas target with excellent access to plasma.
- The gas target has a long-range density profile, is flat topped, and has a steep density gradient.

Characterizing the Gas Jet

- The gas jet density profile is characterized using a Mach-Zehnder interferometer.
- 532-nm continuous wave/linearly expanded and collimated to a 1-cm beam.
- PI-MAX 3 provides fast gating.
- The jet is imaged using a 450-mm optical system.

Image Analysis

- The jet’s refractive index ($n$) depends on the gas density.
- The beam passing through the jet will accumulate phase ($\phi$) relative to the unobstructed beam.
- An Abel transform is used to invert the integral that gives density as a function of phase delay and radius, assuming cylindrical symmetry.

Supersonic Nozzle

- Utilizes a convergent-divergent de Laval geometry.
- Ratio of nozzle exit area ($A_e$) over throat area ($A_t$) determines the Mach number ($M$) for a given gas with an adiabatic index ($\gamma$).
- In a converging section, the gas velocity increases as the area decreases.
- The Mach number determines the density at the nozzle exit.
- In a diverging supersonic section, the velocity increases as the area increases.
- The phase is extracted from the measured fringe shifts using an Abel inversion; phase is then converted to atomic number density.

Expansion Cone

- The jet continues to expand radially at $M=1$ once it leaves nozzle, forming a cone geometry.
- The expansion cone’s angle is determined by the nozzle’s Mach number.
- The jet’s number density decreases as the area of the cone it fills increases.

Results

- Density is measured along the central axis and compared to the density predicted by the expansion cone.
- Variations away from expectations are largely attributed to the assumption of constant expansion at $M=1$.
- Density is measured perpendicular to the gas flow to measure the jet density profile.
- Profiles with steep density gradients and flat tops were found.

Plasma Density

- The phase is extracted from the measured fringe shifts using an Abel inversion; phase is then converted to atomic number density.
- Density is measured perpendicular to the gas flow to measure the jet density profile.
- Profiles with steep density gradients and flat tops were found.

Pressure

- Pressure is measured at a location over the entire valve opening and closing cycle to find valve speed and steady-state behavior.
- The length of open time is controllable with the voltage of the electrical input pulse.
- Charging the pulser to 400 V gives an ~1-\(\mu\)s steady-state jet.