ABSTRACT

Two-photon laser induced fluorescence (TALIF) is a non-perturbative spectroscopic diagnostic that can provide direct measurements of neutral atom temperature, velocity, and absolute density in krypton gas. A new TALIF system has been installed at the U.S. Naval Research Laboratory (NRL) to diagnose these properties in two-dimensions near the exit orifice of a resistojet thruster nozzle. A Quantel Q-switch dye-laser system generates ultraviolet (UV) light at 205 nm with 5 ns pulses at 10 mJ energy to excite the resistojet’s plume of krypton gas from its ground state. To navigate the complex injection pathway from the exterior of the vacuum vessel to the exhaust plume, the intention is to inject the UV light through a large core, multi-mode fiber mounted in a custom vacuum feedthrough. Light exiting the fiber is collimated in situ with two cylindrical lenses to create a 1 cm wide, 200 µm thick sheet beam to pump the neutral krypton to the 5p[4/2] state. An Andor Newton ICCD camera images the 826 nm fluorescence emission through a fiber bundle. We present the status of the TALIF experiment.

MINIATURE ELECTRIC PROPULSION

Opportunities for scientific research, education, and exploration by use of miniature satellites in Earth’s orbit are expanding rapidly. The miniaturization of satellites has reduced costs for launching small payloads into orbit. Micro-satellites called CubeSats are a popular option for educational space research and can be as small as 10 x 10 x 10 cm³. However, CubeSats lack maneuverability once in orbit, limiting the lifetime of their scientific missions and the regions of space accessible for study. Micro-propulsion systems on CubeSats would eliminate these constraints.

A potential candidate for CubeSat propulsion is a micro-resistojet thruster. The micro-resistojet operates by the expansion of electrically heated gas through a nozzle of about 1 or 2 mm in diameter. A small amount of heat energy from the CubeSat would supply a relatively small amount of energy to provide heat in the stagnation chamber of the resistojet. Axial thrust is provided by the expulsion of pressurized gas from the expansion chamber of the nozzle. Due to the small scale of these thrusters, resistojets can be positioned on each face of a CubeSat to provide thrust for all degrees of freedom.

FLOW RESOLUTION CALCULATION

Krypton TALIF data from ORNL was artificially blunted by the laser linewidth. The linewidth at absorption corresponds to a spread in velocity values of ~2.7 km/s in 205 nm space. A schematic labeling components of the resistojet thruster and it’s mechanisms for thrust. Experiment flows will be measured up to 100 scm, with upstream nozzle pressures up to 10 psig, and jet pressures around 100 mTorr.

The flow uncertainty from a Gaussian fit (black dashed line) corresponds to ~180 m/s resolution with 10 discrete wavelength steps (left) and ~42 m/s resolution with 30 discrete wavelength steps (right). Velocity resolution increases with number of discrete wavelength steps as seen above, and is significantly more precise than the laser linewidth.

An alternative method to determining the number of discrete wavelength steps needed to resolve a change in bulk flow of 60 m/s would be to calculate the required population size, such that, the standard error of the mean of the laser linewidth is 60 m/s. This results in a requirement of 2025 discrete wavelength steps.

PULSED POWER UV DYE LASER SYSTEM

Quantel Q-switched Nd:YAG custom tunable dye laser system:
- Frequency doubling and tripling stage produces 205 nm light
- Pulse length: 5 ns
- Energy output: 10 mJ
- Repetition rate: 10 Hz
- Laser Linewidth at 615 nm: 0.06 cm⁻¹

NRL TVAC CHAMBER SYSTEM

Cameras and Wave meter

Camera and Wave meter

Thrust Experiment and Sheet Beam Location

Above: NRL’s TVAC chamber system along with the thrust stand and laser table. The chamber is 2 m in diameter and 2.3 m tall. It is pumped with a 48 inch NIK oil diffusion pump having a nominal pumping speed of 100000 L/sec of air. The base pressure at high vacuum is less than 1 x 10⁻⁸ Torr.

OPTICAL SCHEME - PLANAR TALIF

Above: ZEMAX spy drawing for planar injection optics design.

Above: Injection and collection optics mount design. The double injection optics design enables data collection parallel and perpendicular to thruster gas flow.

EXPERIMENT GOALS:
- Use planar TALIF to excite ground state krypton flow from the resistojet thruster.
- Image krypton fluorescence using an Andor ICCD camera.
- Generate flow maps from velocit y distribution functions near the nozzle orifice.

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