ABSTRACT

Two-photon Absorption Laser Induced Fluorescence (TALIF) is a non-perturbative spectroscopic technique that provides direct measurements of the temperature, bulk flow, and absolute density of neutral hydrogen in fusion-class plasmas. Recently, TALIF has been added to the suite of diagnostics on the Prototype Material Plasma Exposure xExperiment (Proto-MPEX) at Oak Ridge National Laboratory. Since TALIF is typically used to interrogate energetic ground state transitions, high intensity ultra-violet (UV) light is required. Here we generate 4 mJ, 8 ns pulses of 205 nm light with a Sirah Cobra-Stretch dye-laser. Laser light is injected in Proto-MPEX through high UV transmission sapphire vacuum windows. Implementation of TALIF on Proto-MPEX necessitates an injection beam path length of ~ 20 meters. We present measurements in Proto-MPEX using both free space injection and fiber coupled injection. For both beamline options, measurements in krypton and xenon calibration gases as well as the targeted neutral deuterium atoms were obtained confocally. Neutral deuterium measurements were made upstream of the helicon source region of Proto-MPEX for a range of D2 fuel gas pressures.

Preliminary Deuterium Measurements: Radial Scan

- Later times (~ 500 ms) produce reliable signal and show weak trend of increasing density towards edge of plasma and decrease outside of plasma
- \( r = 3 \sim 5 \text{ cm} \) inaccessible by confocal system
- Density increase with decrease discharge power, in good agreement with edge pressure gauge

Confocal Collection Requires One Line-of-sight

- UV beam compressed and passed through hole in mirror
- Single axis injection/collection requires single diagnostic access point
- Injection between magnets 1 and 2 (upstream of source)
- Translation stage allows radial profile measurements

Two-Photon Absorption Laser Induced Fluorescence (TALIF)

- TALIF signal is proportional to \( E^2 \), providing highly localized measurements
- \( S(T) = n_e \frac{\Delta \eta G^2(\Delta) G}{4\pi} \frac{G(\Delta)}{\eta} \frac{G^2}{\eta} \frac{G}{\eta} \eta_{det} \)
  - \( n_e \) — species density
  - \( \Delta \) — Solid angle of collection
  - \( \eta \) — Quantum efficiency
  - \( T_c \) — Transmission of collection
  - \( G(\Delta) \) — TALIF statistical factor
  - \( \eta(\Delta) \) — TALIF cross section
  - \( E/\text{photon count} \)
  - \( a \) — branching ratio
  - \( \eta_{det} \) — detector gain

- Absolute density requires calibration with second gas (usually krypton or xenon)

- \( \frac{S(T)}{S(\text{cal})} = \frac{G^2(\Delta) G}{4\pi} \frac{G^2}{\eta} \frac{G}{\eta} \eta_{det} \)
  - \( n_e \) — species density
  - \( \Delta \) — Solid angle of collection
  - \( \eta \) — Quantum efficiency
  - \( T_c \) — Transmission of collection
  - \( G(\Delta) \) — TALIF statistical factor
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- \( n_e \) for Proto-MPEX: Pmex \leq 140 mTorr, P \text{avg} = 30 – 90 kW, \( r = 0 \sim 7 \text{ cm} \)

Pulses are Grouped by Time Resolve Plasma Dynamics

- 5 laser pulses averaged to time resolve at 250 ms
- Detectable signal present at times later than 500 ms

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Optical Configurations

- Signal collected perpendicular to injection
- Signal collected confocally with injection

TALIF Laser System Generates 205 nm Light

- Approximately 500 mJ of 532 nm light is converted to 4 mJ of 205 nm light at 20 Hz

CONCLUSIONS

- Two-photon laser induced fluorescence has been demonstrated at a distance of ~ 20 meters at different radial locations and discharge powers
- Plasma dynamics has been resolved in time throughout the plasma discharge
- Signal is detectable at later times—higher densities
- Weak trends observed are inconclusive and more data points are needed to confirm trends

Future Work

- Update confocal system to allow for more radial measurements
- Improve beamline to maximize laser energy to plasma
- Increase signal to noise to probe plasma at higher RF discharge powers

REFERENCES