Use of Thomson Scattering for Plasma Characterization in the Embry Riddle Aeronautical University Plasma Jet Experiment

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Abstract

Plasma diagnostics play a crucial role in understanding the behavior and properties of plasmas, especially in high-energy applications such as fusion research. Thomson scattering, a widely used diagnostic technique, provides valuable insights into electron density and temperature. We present the setup and utilization of a laser system for Thomson scattering measurements in a MHD driven plasma jet experiment. The experimental setup consists of a high-energy laser system, a plasma jet generator, and a collection optics system. The 10 Hz, 400 mJ YAG laser generates a 10 ns pulse width beam that is carefully focused onto the center of the plasma jet inside the chamber. The scattered light from the electrons is collected into a 1-D optical fiber and a 1-m spectrometer for analysis. The spectrum is expected to show a collective Thomson scattering signal as the parameter ranges are within the collective regime. The collective Thomson spectrum allows us to extract valuable information about the plasma's electron density and temperature. We discuss the key components of the laser system, including the laser source, optics, and detectors, highlighting their roles in achieving accurate and reliable Thomson scattering measurements.

Experiment Setup

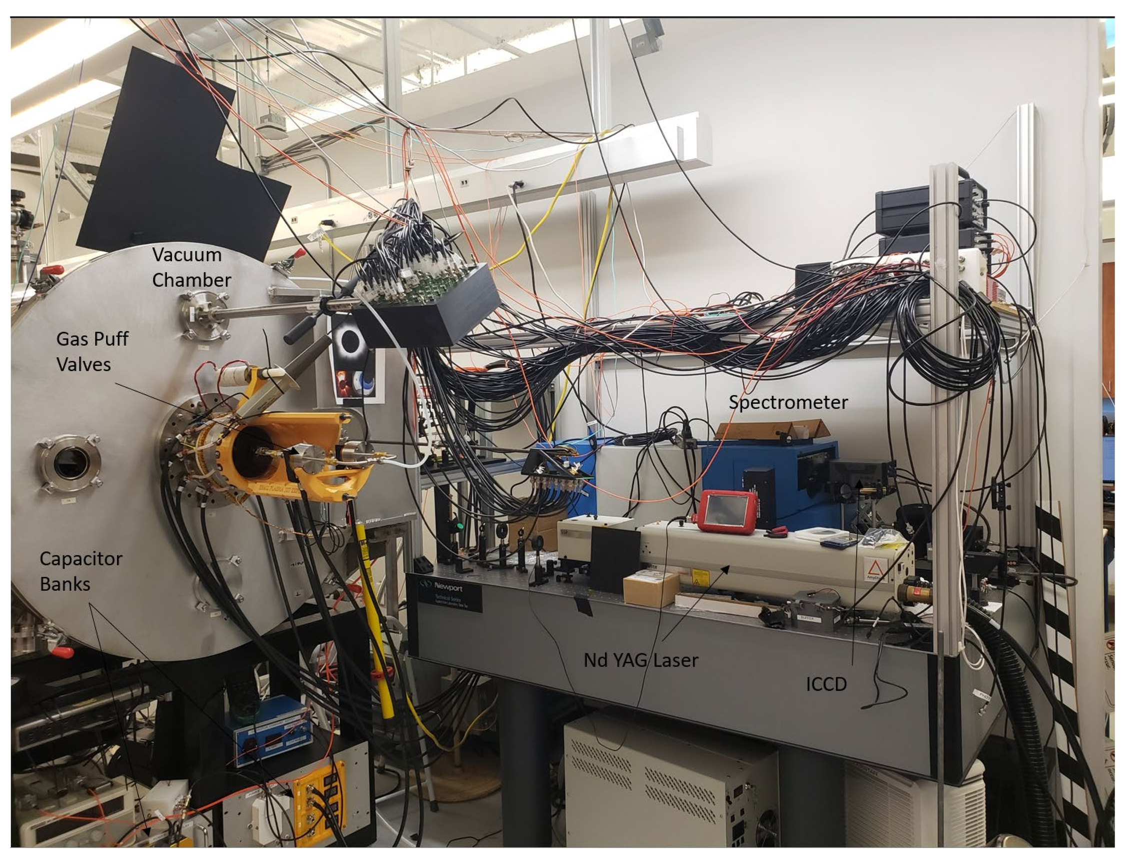

Figure 1. Setup image of chamber, laser, and spectrometer.

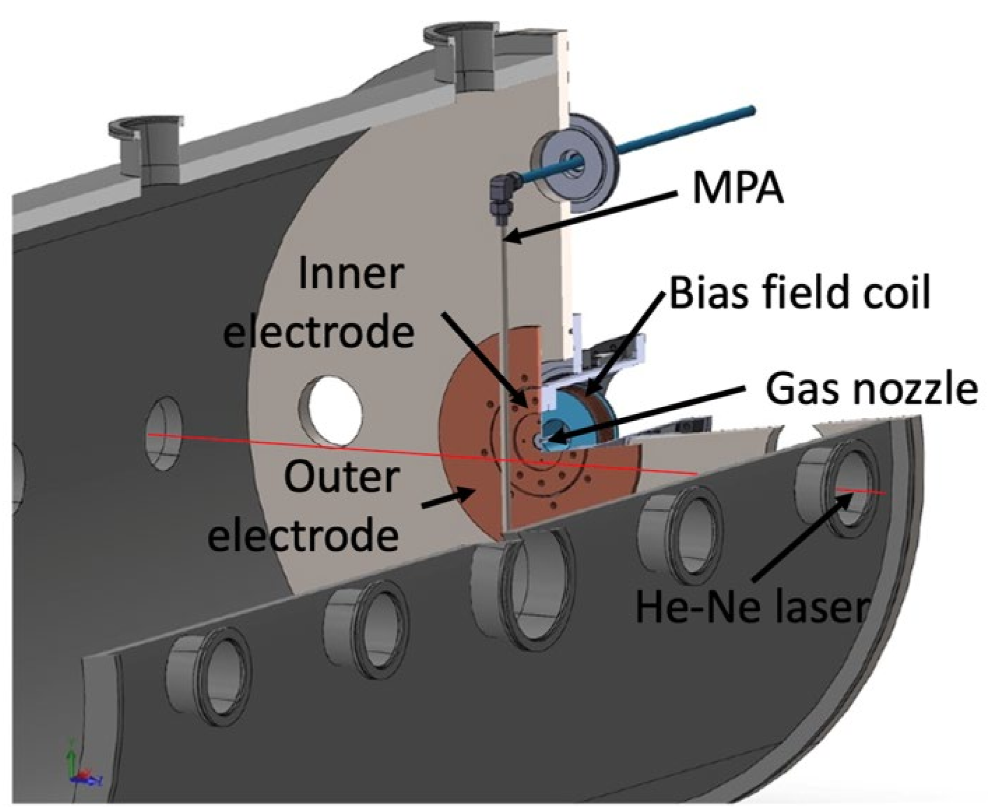

Figure 2. Plasma generation setup diagram.

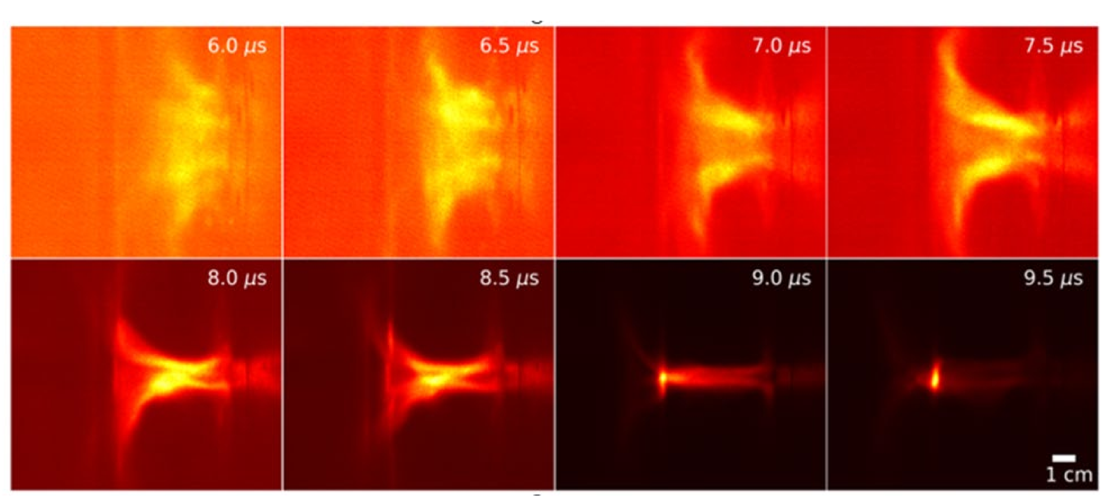

Figure 3. Development of plasma bursts.

- Plasma is generated from either Nitrogen or Argon gas.
- Current laser energy used is 250 mJ, 532 nm with plans to use 300 mJ for Thomson scattering data.
- Temperature and density measurements can be taken with 1-D optical fiber setup.
- The plasma electron temperature will be measured from the Doppler shifted scattered spectrum and density from the total scattered intensity.
- Thomson scattering will be in relation to MHD instability and magnetic reconnection experiments.

Data Collection System

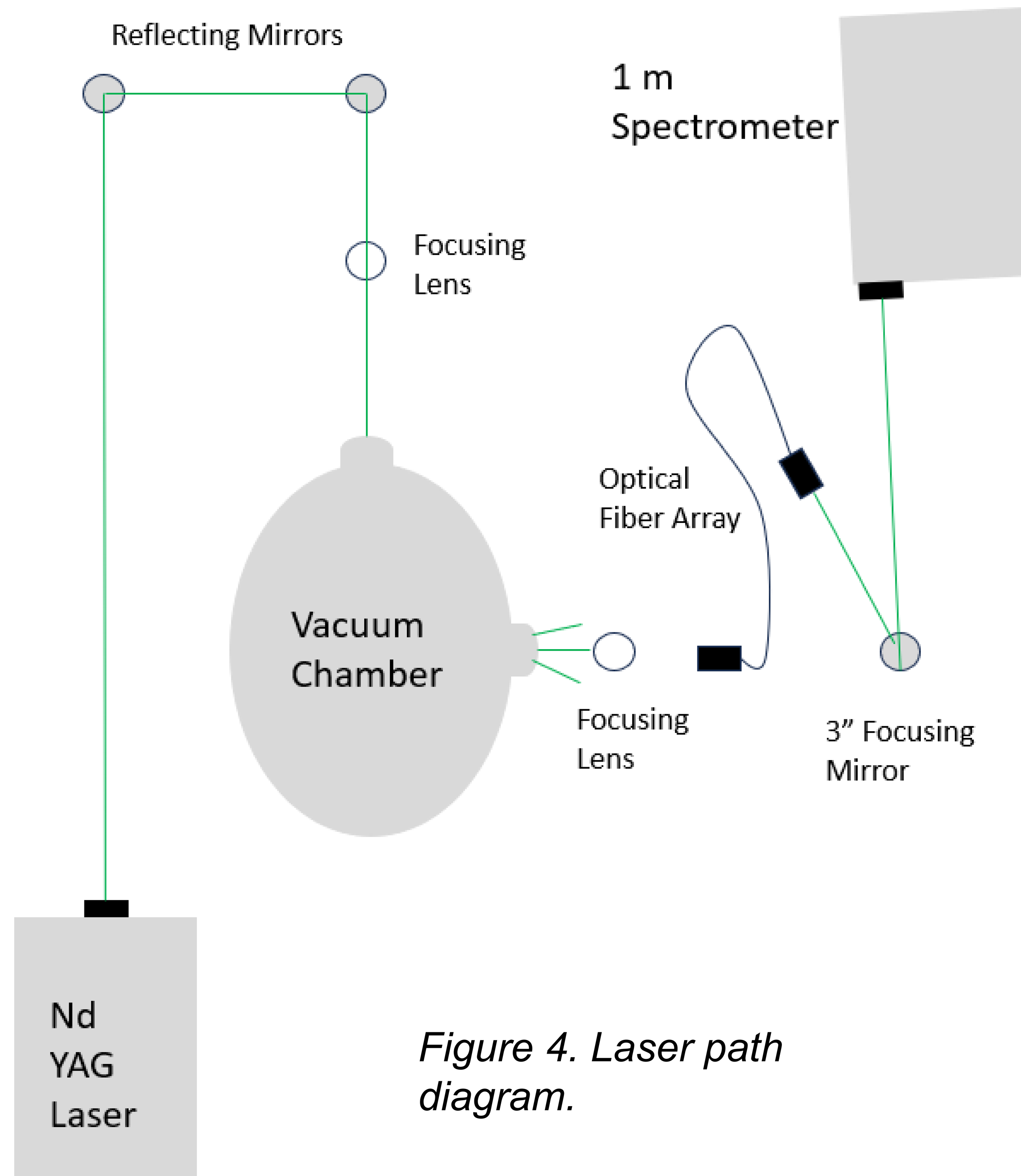

Figure 4. Laser path diagram.

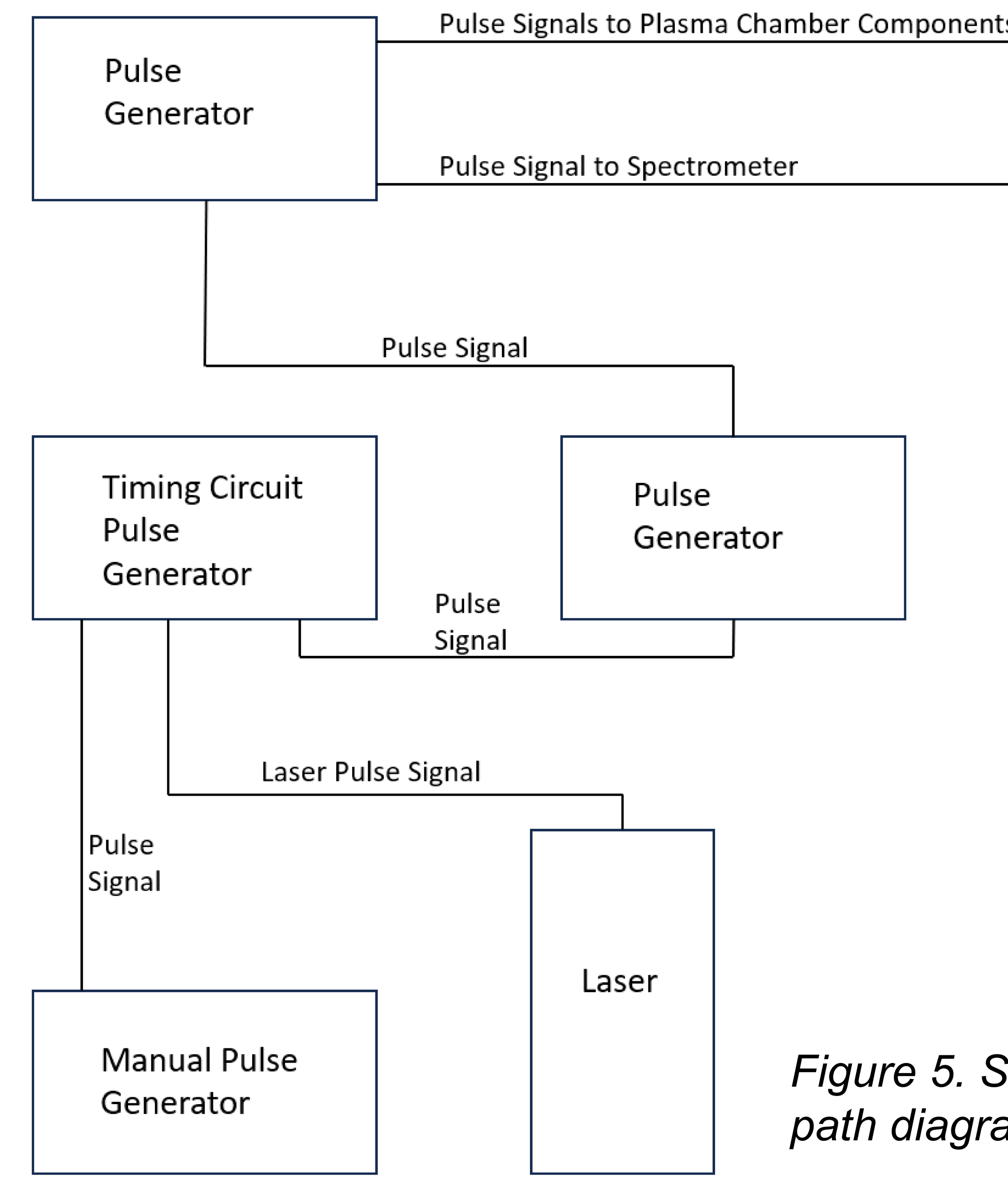

Figure 5. Signal path diagram.

Data Analysis

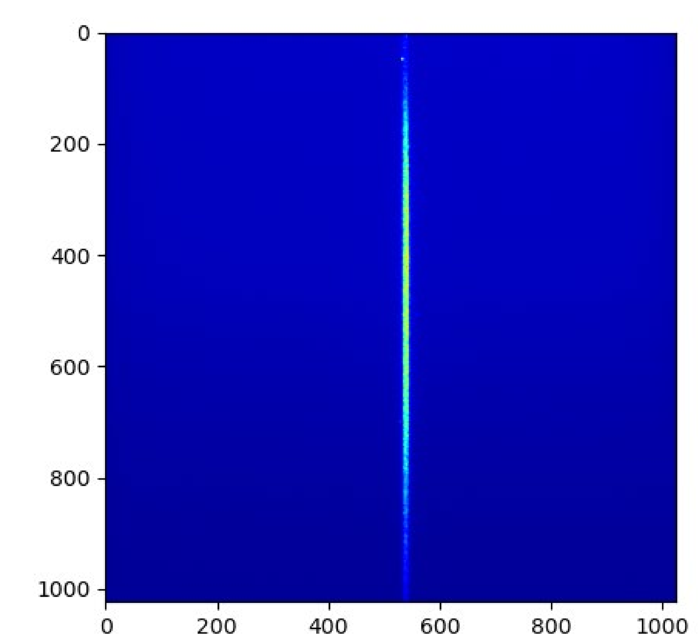

Figure 6. Rayleigh scattering in 1D

- Rayleigh scattering data has been taken to help characterize the chamber and laser system.
- Currently, significant noise (stray light) levels come from non scattering sources.
- Power levels are consistently higher than predicted by models.
- Further work is needed to reduce the noise level for Thomson scattering.
- Data taken with a laser power level of 20 mJ at atmospheric pressure (Figs. 6 and 7).

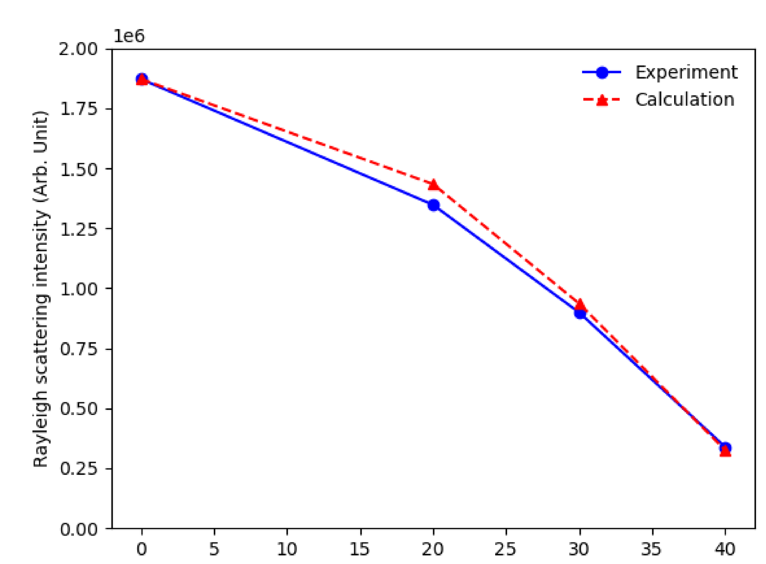

Figure 7. Polarization angle dependent Rayleigh scattering

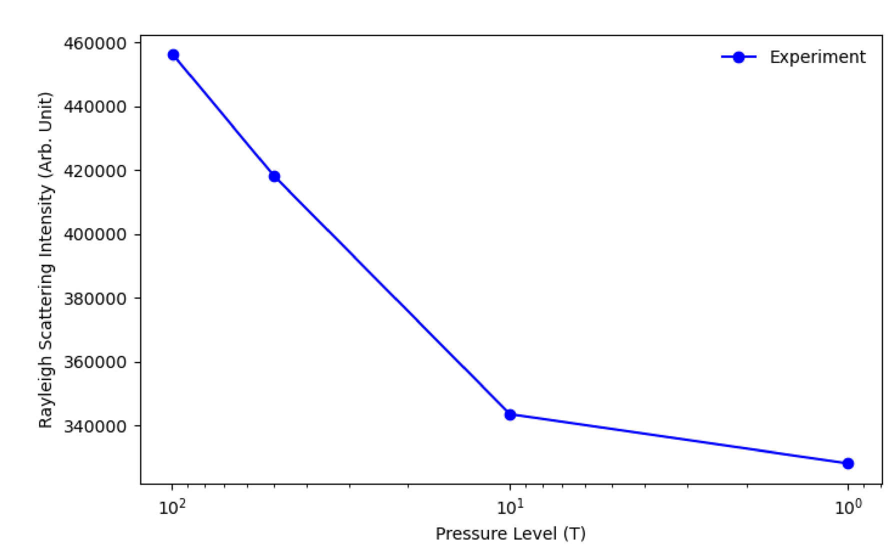

Figure 8. Pressure dependent Rayleigh scattering

Acknowledgement

Supported by DOE (DE-0022952), Florida Space Grant Consortium (80NSSC20M0093, no. 16, FSGC-3), ERAU Faculty Innovation grants, Center for Space and Atmospheric Research at ERAU, ERAU spark travel grant, and APS GPAP travel grant.