Study of a Supersonic, Magnetized Plasma Jet with a Heterodyne Interferometer

Connor Castleberry[1], Byonghoon Seo[2]
[1]Castlec6@my.erau.edu, [2]Seob1@erau.edu

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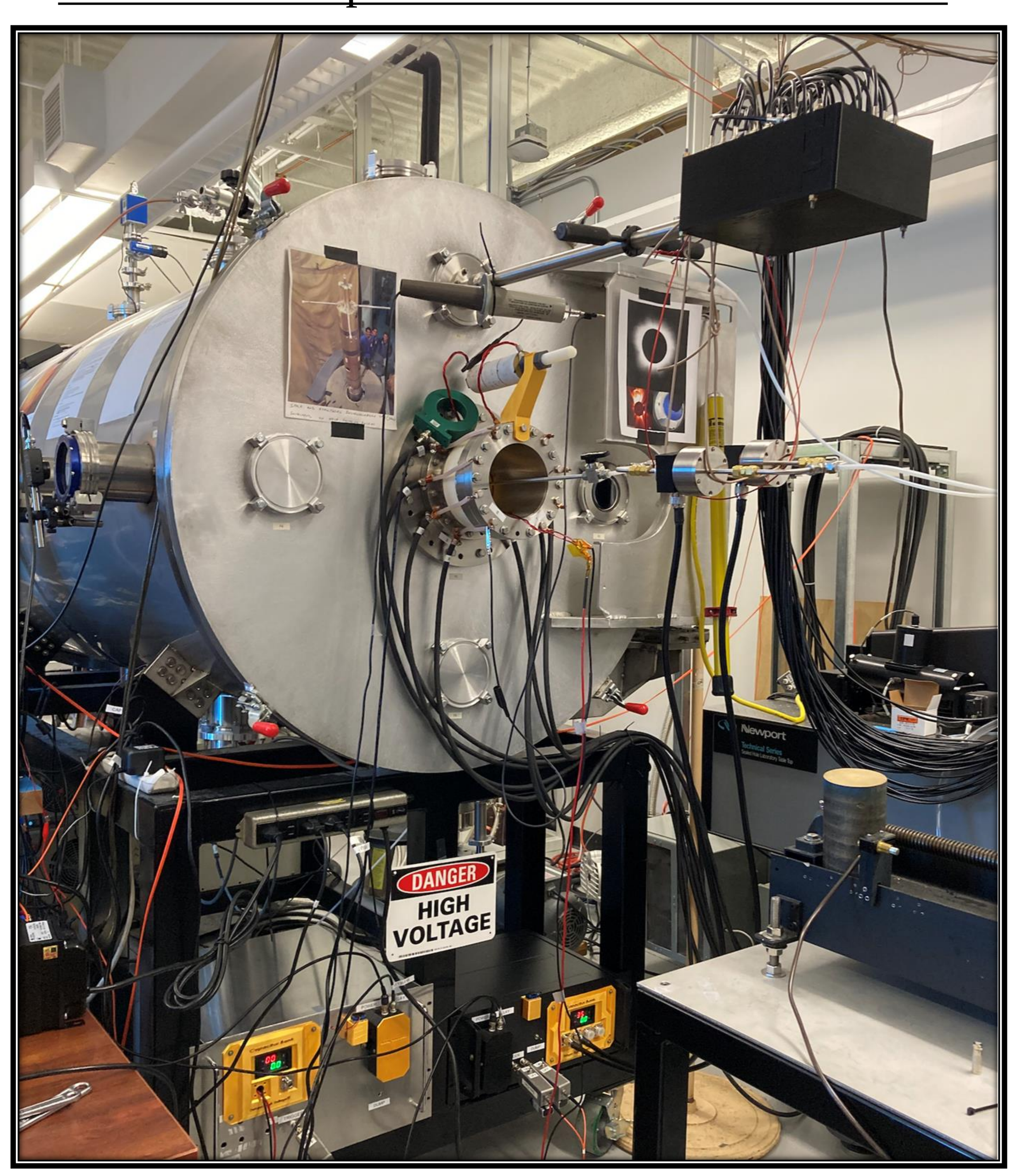
Abstract

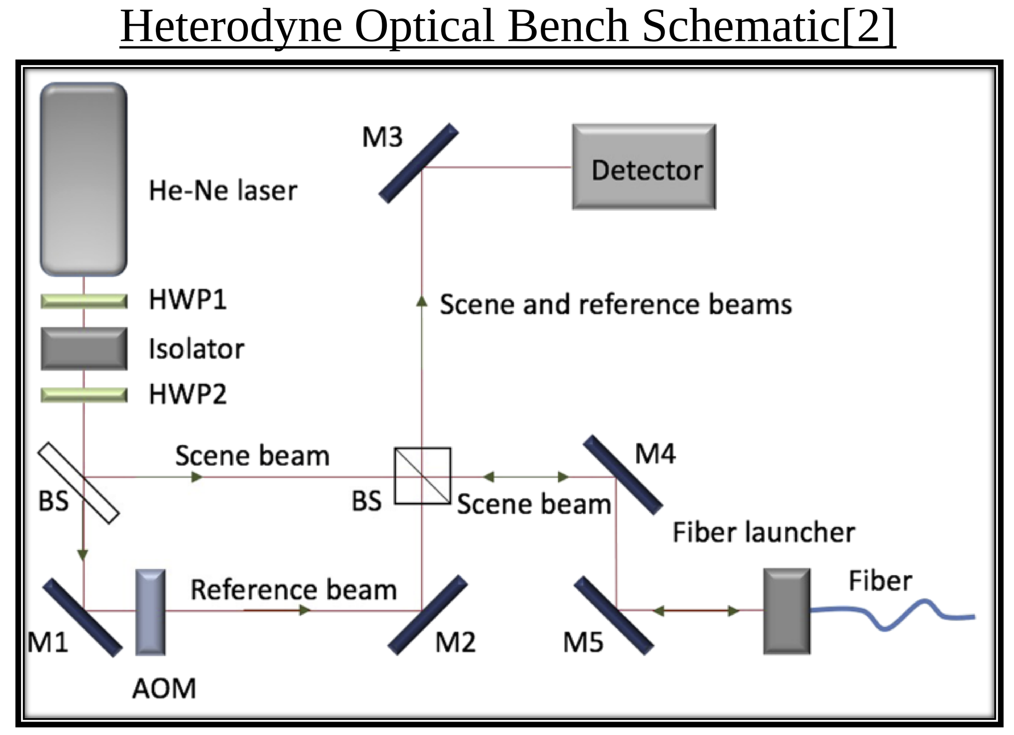
Presented is a method to measure the line-averaged electron density and velocity of a plasma jet generated by a pulsed plasma source, using a heterodyne interferometer. This source will produce a plasma jet that exhibits instabilities and magnetic reconnection [1] inside Embry-Riddle's two meter long, cylindrical plasma chamber. Magnetic reconnection is a process by which a portion of magnetic field energy is transferred into kinetic or thermal energy of plasma [1]. A heterodyne interferometer is similar to a Michelson interferometer, with the difference that the non-plasma beam is passed through an acoustic-optical modulator that isolates the 1st harmonic of the beam. The Interferometer measures the change in the index of refraction of the plasma chamber, this enables the determination of the change of the line-averaged electron density of the plasma jet. By interpreting this data over system parameter variations, changes in the density of the plasma jet over the course of the experiment will be studied. This study will investigate fundamental plasma physics and applications, such as the drivers and patterns of reconnection and may lead to improved fusion energy generation and pulsed plasma propulsion.

Experimental Setup

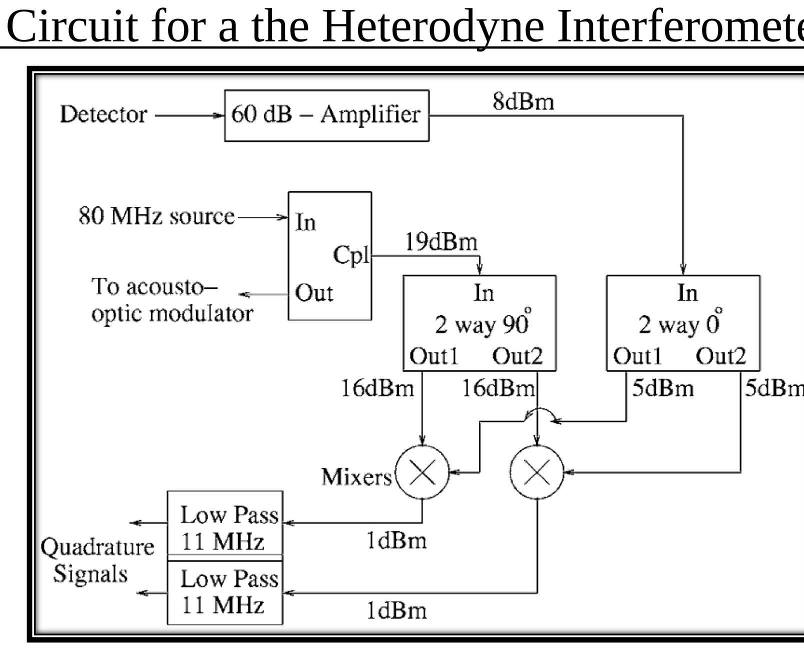
View of the Experimental side of the Chamber

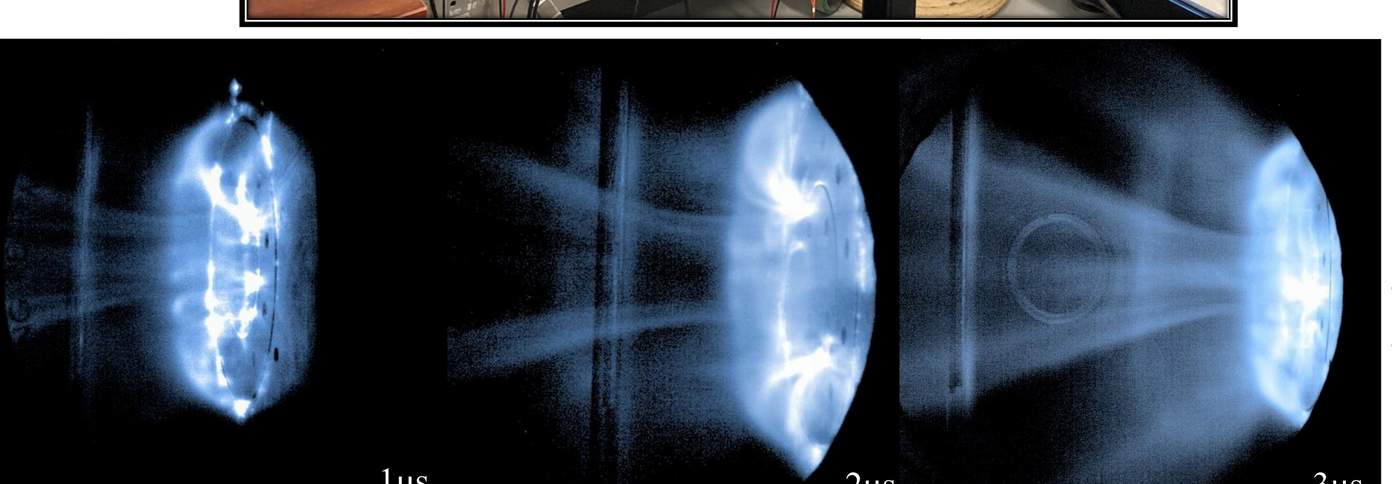


Heterodyne Optical Bench Schematic[2]

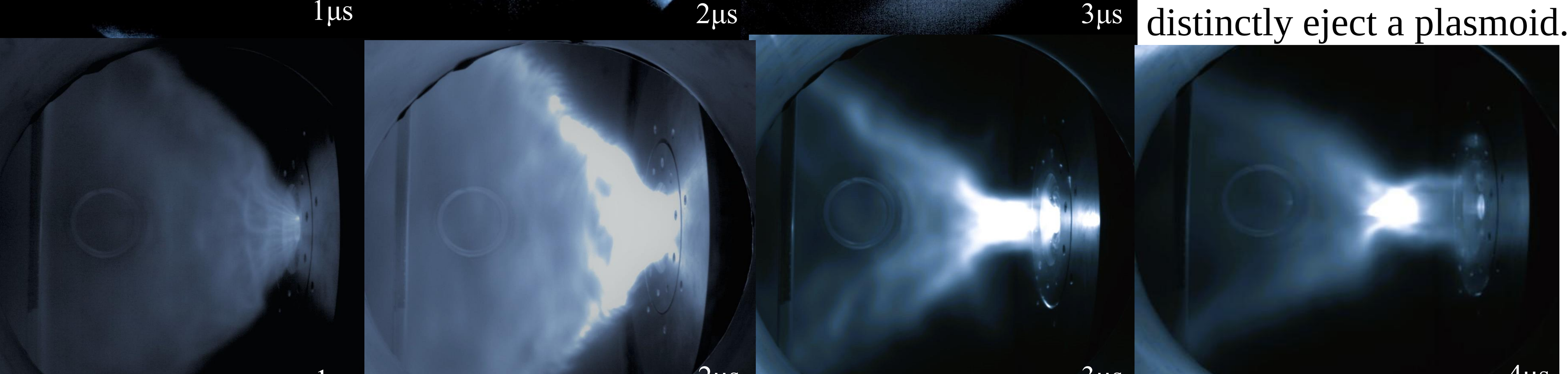


RF Circuit for a the Heterodyne Interferometer[4]





High Speed Camera Imagery – Evolution of the Plasma – Configuration 1:
Here, the gas injected is slowed down by a port cap. This method doesn't seem to distinctly eject a plasmoid.



High Speed Camera Imagery – Evolution of the Plasma – Configuration 2:
Preliminary data indicates this method ejects a plasma

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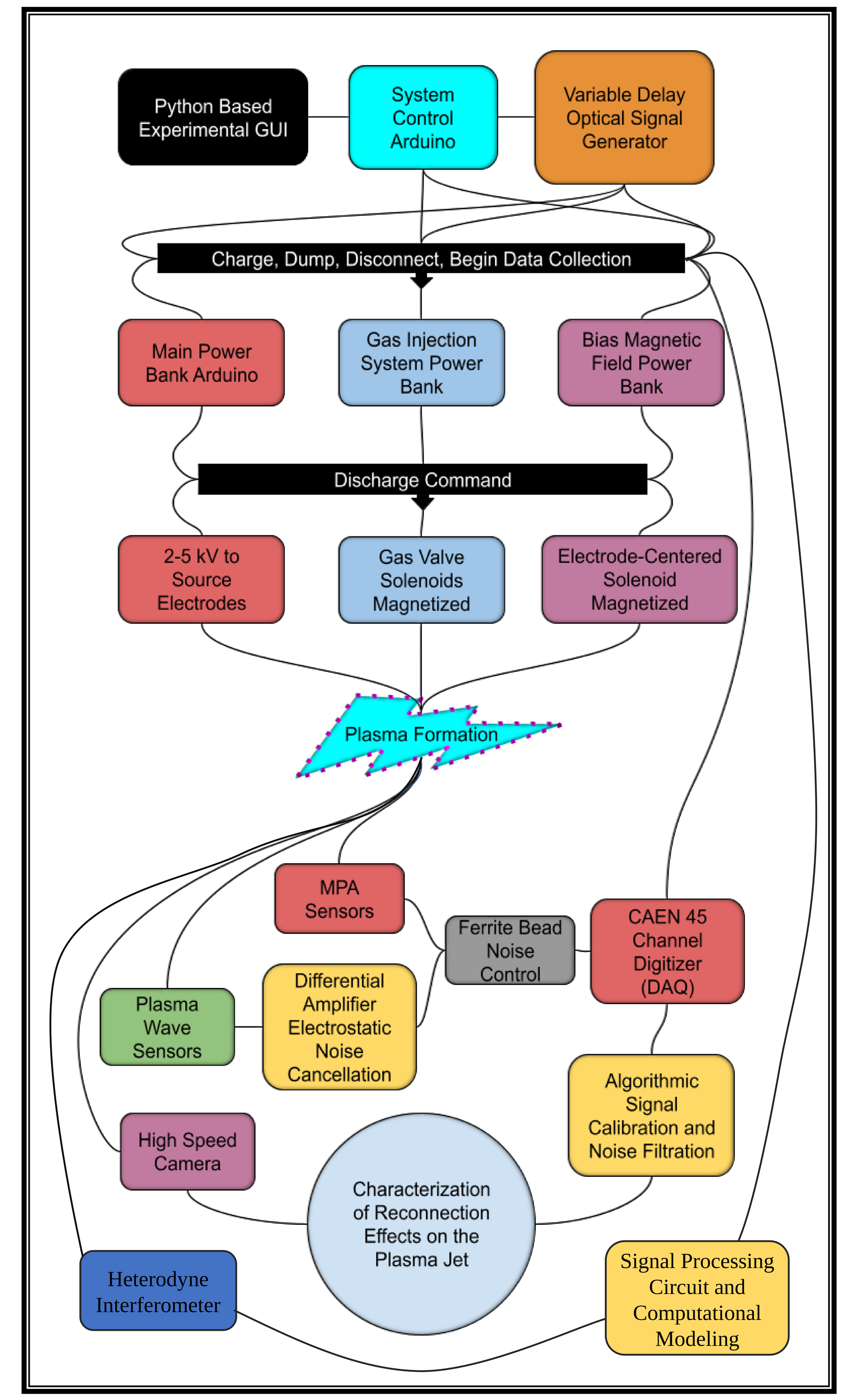
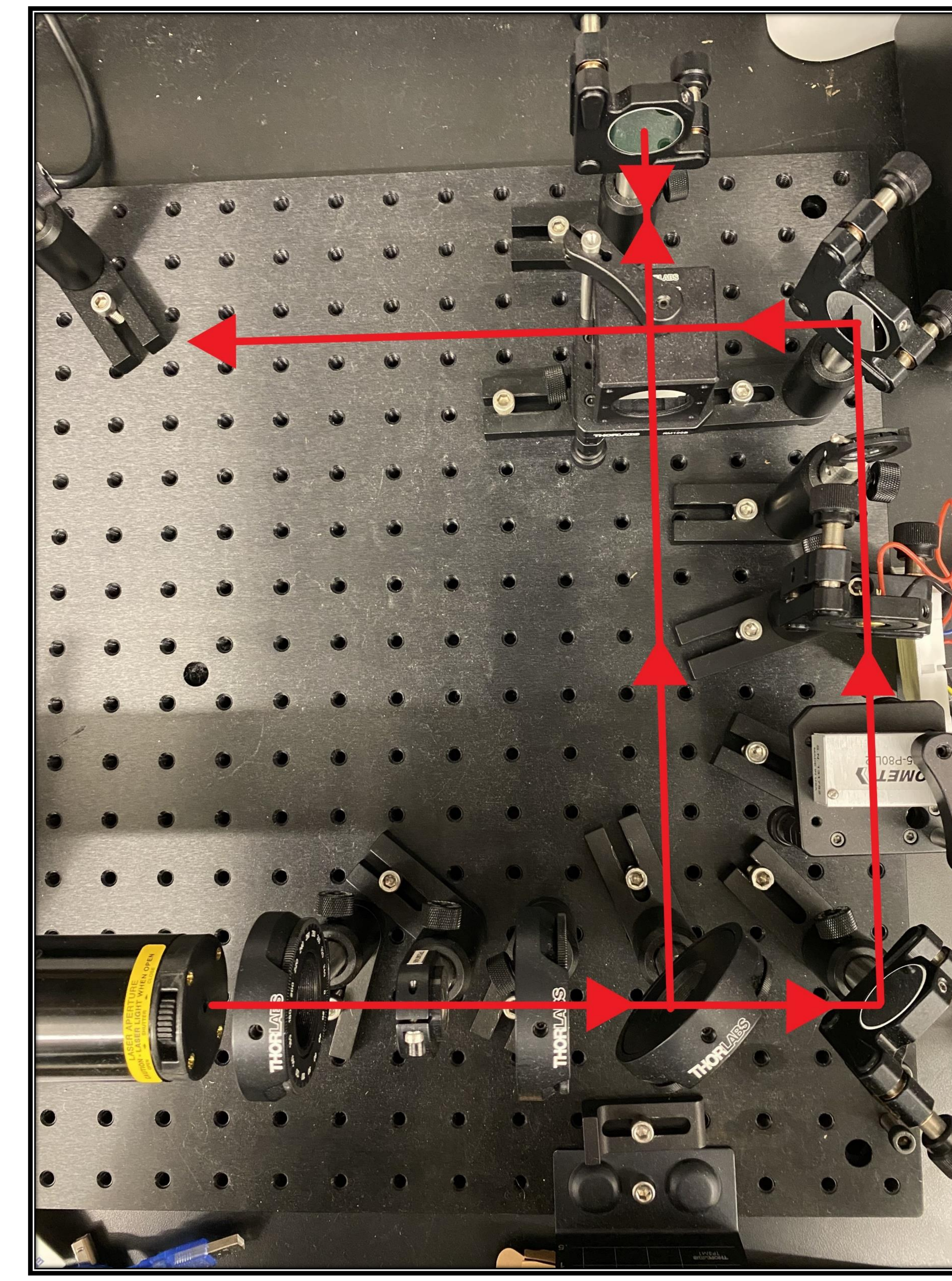
Data Collection

Experimental Flowchart



Heterodyne Interferometer Optics Bench Setup



Data Analysis

Scene beam which passes through the plasma, is interfered with the modulated beam on the detector. The detector's signal is passed through a RF Circuit(shown to the left) where it is mixed with the modulated signal, to produce two quadrature signals which is used to determine the phase shift in the laser beam caused by passing through the plasma. The plasma density can be determined by the phase shift observed in the quadrature signal compared to the phase before plasma jet is initiated, using the equation below. Where $\Delta\varphi_p$, is the phase-shift induced by the plasma, m_e is electron mass, c is the speed of light, ε_0 is the permittivity of free space, e is electron charge, L is the length of plasma the laser beam travels, and λ_0 is the wavelength of He-Ne laser[4].

Equation to Find Plasma Density from Change in Phase-Shift of Quadrature Signal

$$\int_0^L n(x)\,\mathrm{d}x = \frac{4\pi c^2 m_e \varepsilon_\circ}{e^2 \lambda_\circ}\Delta\varphi_p,$$

References

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