# Spatial Distributions of Excited Atoms in Argon Plasma

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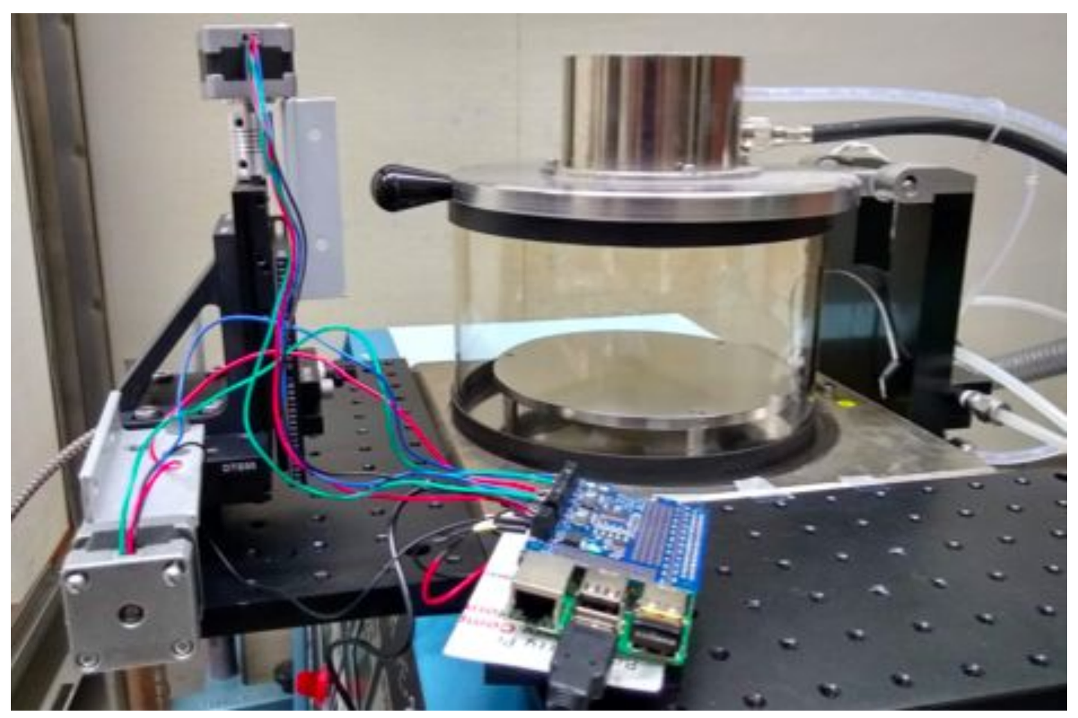
## INTRODUCTION

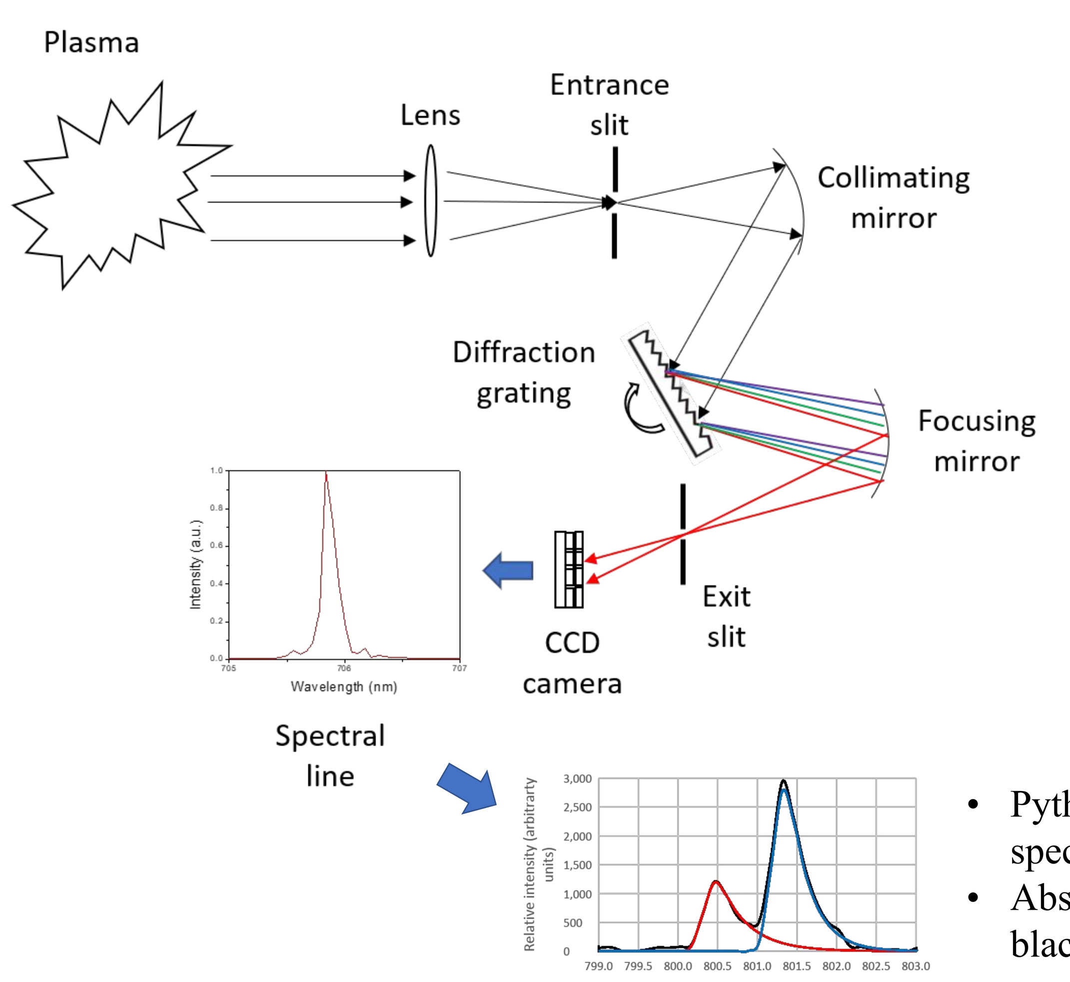
The interests in low-temperature plasma have been increasing over the years for uses in the biotech and semiconductor industry, making it essential for modern technology. Though it has become more commonly used in the industry the fundamental characteristics of plasma are still being researched, thus improving on understanding and controlling it is essential for the industry, which is why we have tried to observe and understand plasma characteristics. We developed a robust 2D plasma tomography method to find spatial distributions of excited argon levels, as well as calculating the average of various levels. Through our measurement methods, we are able to collect the light of various wavelengths emitted from the plasma, through this we are able to determine plasma intensities, the population densities, graph robust two angle tomography, and electron configurations.

## Experimental Setup

**Radio Frequency Argon Plasma**



- RF frequency – 13.56 MHz
- Pressures: 15 – 50 mTorr
- Powers: 15 – 100 W



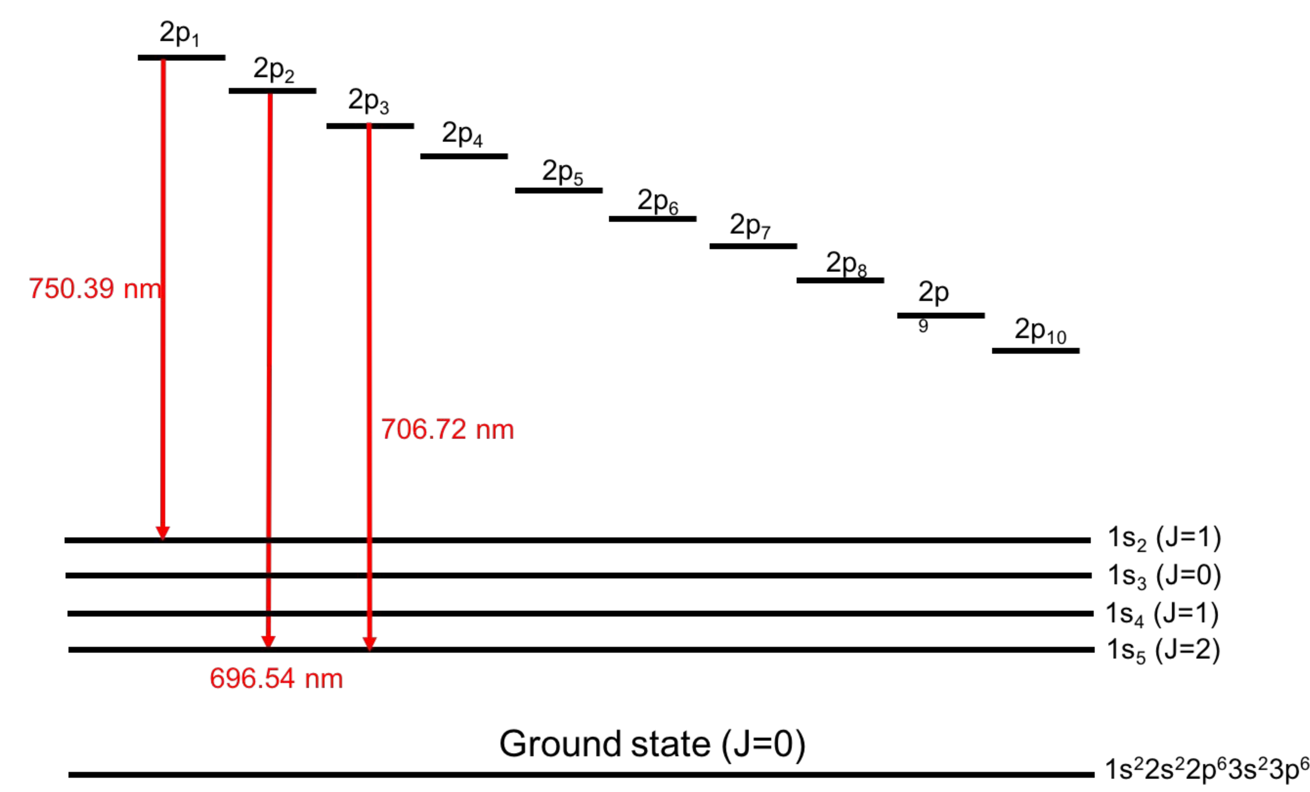

Detection system driven by Raspberry Pi computer

- 2 stepper motors – submillimeter precision
- Avasoft spectrometer – synchronized with the motors

- Python code for spectral resolution of spectral lines
- Absolute populations by applying the black body calibration

## Results

### Optical Emission Spectroscopy




### 2D Plasma Tomography

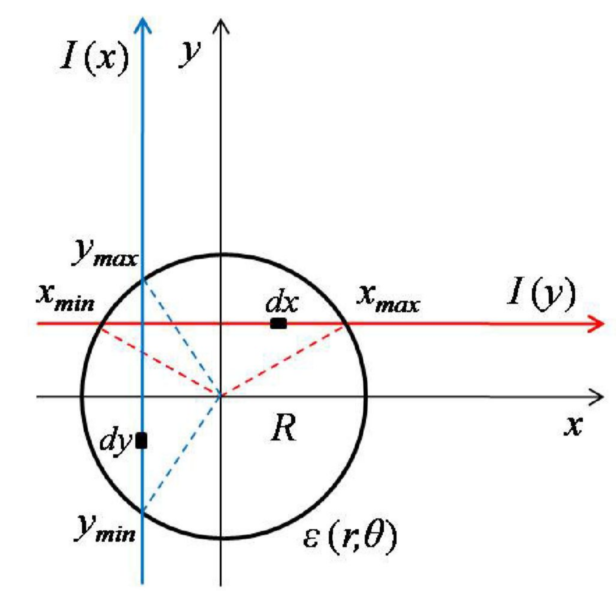
$$\varepsilon(r,\theta) = H(r) + K(r)\cos\theta + L(r)\sin\theta$$

Measured line intensities [1]

$$I(y) = 2\int_y^R \frac{\varepsilon(r)r}{(r^2-y^2)^{1/2}}dr$$

Inverse integral provides spatial distributions

$$\varepsilon(r) = -\frac{1}{\pi}\int_y^R \frac{dI(y)}{dy}\frac{1}{(y^2-r^2)^{1/2}}dy$$




$$\frac{1}{2}(I(x)+I(-x)) = 2\int_x^R \frac{H(r)rdr}{(r^2-x^2)^{1/2}}$$

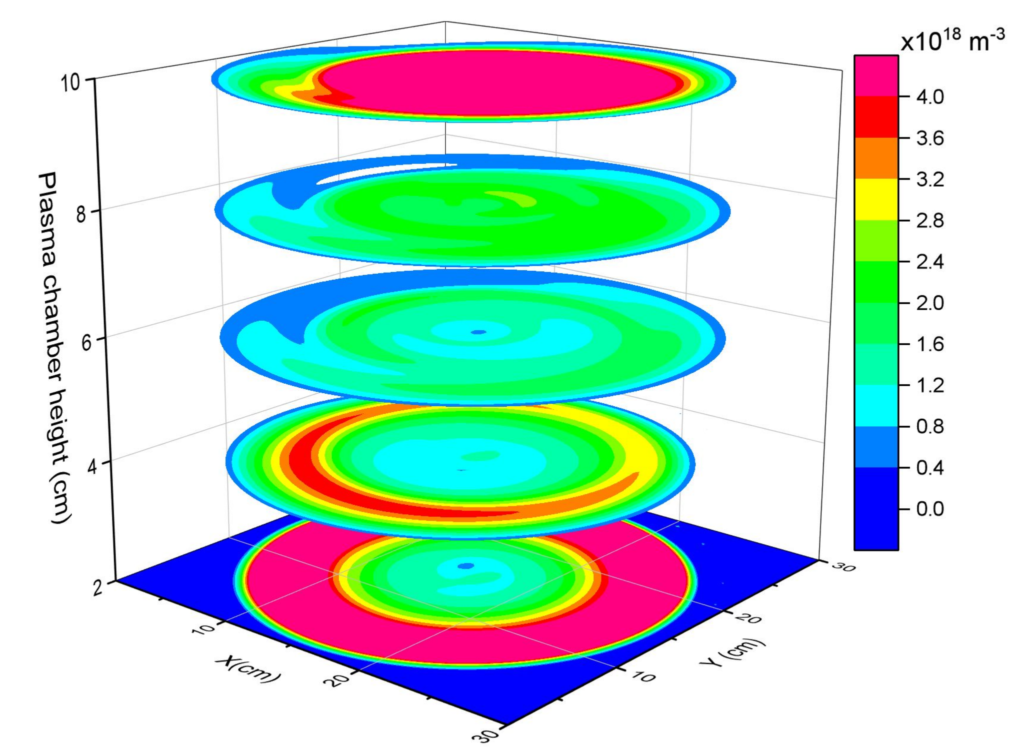
$$\frac{1}{2}(I(x)-I(-x)) = 2\int_x^R \frac{L(r)}{r}\frac{rdr}{(r^2-x^2)^{1/2}}$$

$$\frac{1}{2}(I(y)+I(-y)) = 2\int_y^R \frac{H(r)rdr}{(r^2-y^2)^{1/2}}$$

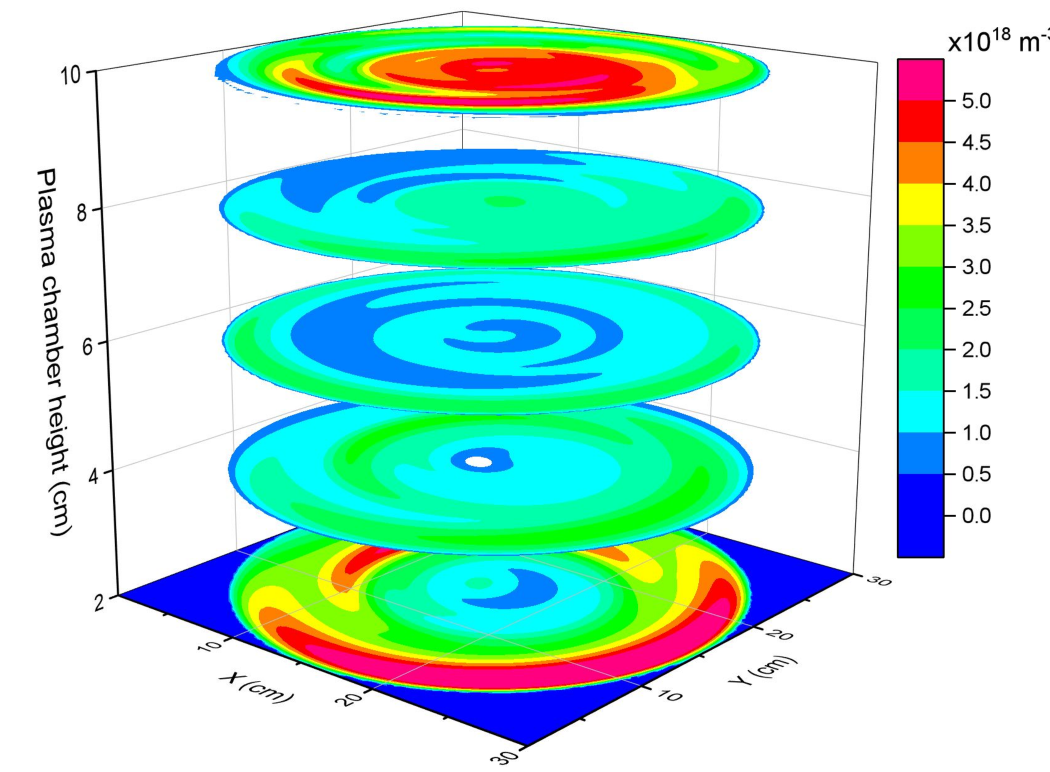
$$\frac{1}{2}(I(y)-I(-y)) = 2\int_y^R \frac{L(r)}{r}\frac{rdr}{(r^2-y^2)^{1/2}}$$

- Pressure 30 mTorr
- Power 50 W

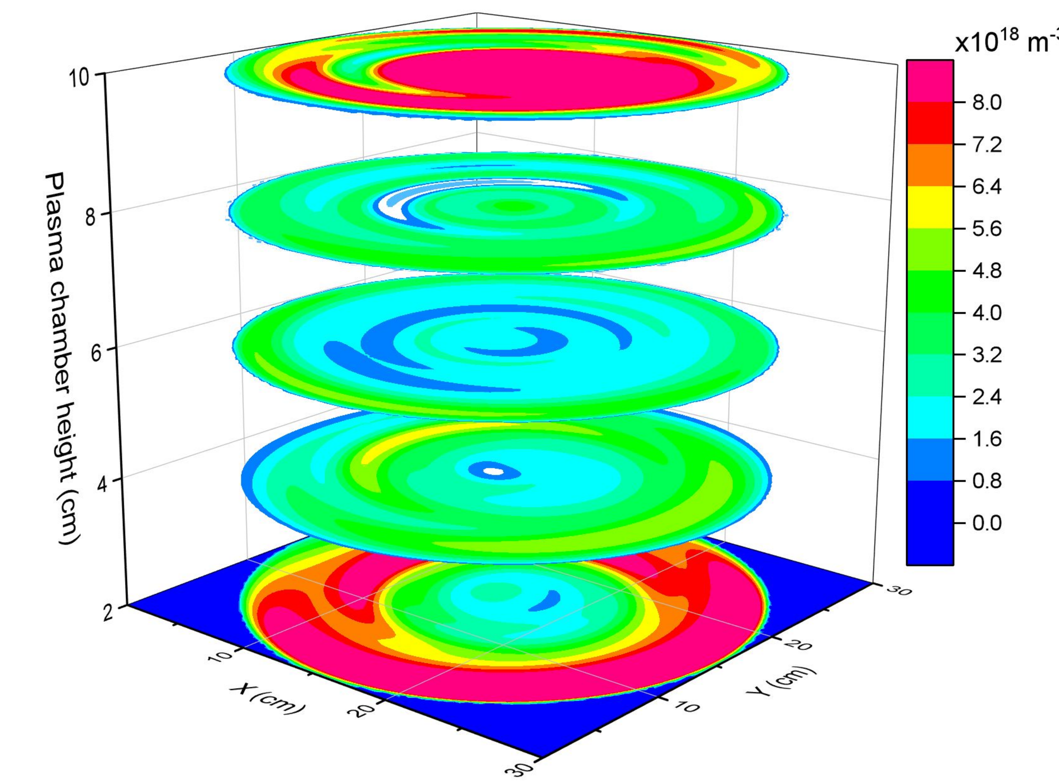
Ar I $2p_1$ population density at 750.39 nm




Ar I $2p_2$ population density at 696.54 nm




Ar I $2p_3$ population density at 706.72 nm




**References**
[1] M. P. Freeman and S. Katz, J. Opt. Soc. Am. 53 (1963) 1172.

**Acknowledgements**
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## Conclusion

The experiment was conducted using pure Argon in a radio-frequency cavity discharge, using a commercial low-temperature RF generator operating at a frequency of 13.56 MHz, at powers of 30-100 W, and the working pressure in the quartz chamber of 15-50 mTorr. We created an automated optical measurement system for distance measurements, using two high precision stepper motors and translational stages operated by a Raspberry Pi. Using an optical emission spectrometer (OES) we were able to detect the various excited energy levels higher than ground and metastable states. We developed a robust 2D plasma tomography method to find the spatial distributions of excited argon levels. We observed that the atoms are centered towards the lower and higher levels in the plasma chamber, whereas the middle of the chamber is less densely populated.