Two Dimensional Laser-Collision Induced Fluorescence in Low-Pressure Argon Discharges

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The development and implementation of diagnostics capable of providing spatial and temporal evolution of key plasma parameters such as excited state species, electric fields and electron densities are underlying needs of the plasma science community. Significant advances in plasma diagnostic development and implementation were realized through support of the Plasma Science Center program.

Laser-collision induced fluorescence (LCIF), a diagnostic method utilized for measuring the spatial and temporal distribution of electron densities and "effective temperatures" in helium, has been calibrated and implemented in argon discharges.[1],[2]. Central to the successful implementation of the LCIF diagnostic was identifying the appropriate spectroscopic pathway (Figure 1, upper plot) and the use of a double-pulse plasma method to generate and independently control both electron density (n_e) and reduced electric field (E/N). While not shown, several transitions are identified that demonstrate good sensitivity to the reduced electric field.

This achievement allows the ability to assess a broader range of plasma systems of interest beyond those generated in helium. The methods used during the calibration procedure can likewise be extended to other discharge gases and pressures. Current efforts are focusing on extending the LCIF method to higher pressure regimes.

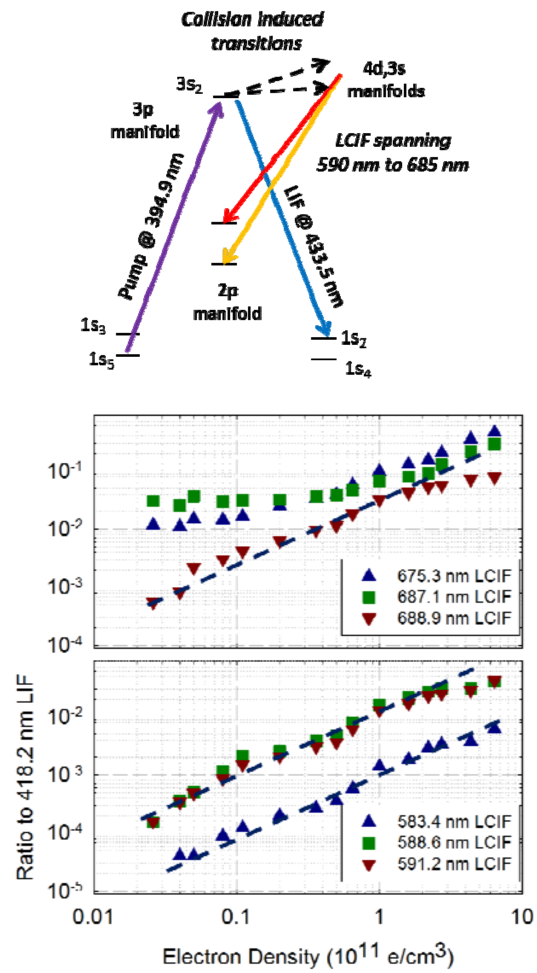


Fig. 1 –(upper plot) Excitation pathway utilized in argon and (lower plot) scaling trends of LCIF with electron densities.

References

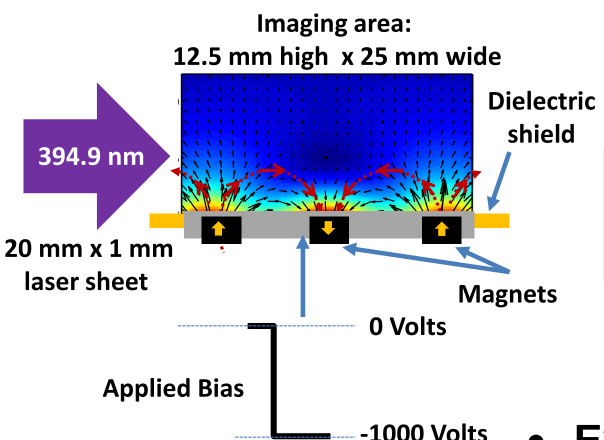
[1] E. V. Barnat and K. Frederickson, "Two-dimensional mapping of electron densities and temperatures using laser-collisional induced fluorescence", Plasma Sources Sci. Technol. **19,** 055015 (2010).

[2] E. V. Barnat and B. R. Weatherford, "Two dimensional laser-collision induced fluorescence in low-pressure-argon discharges" Plasma Sources Sci. Technol. (submitted).

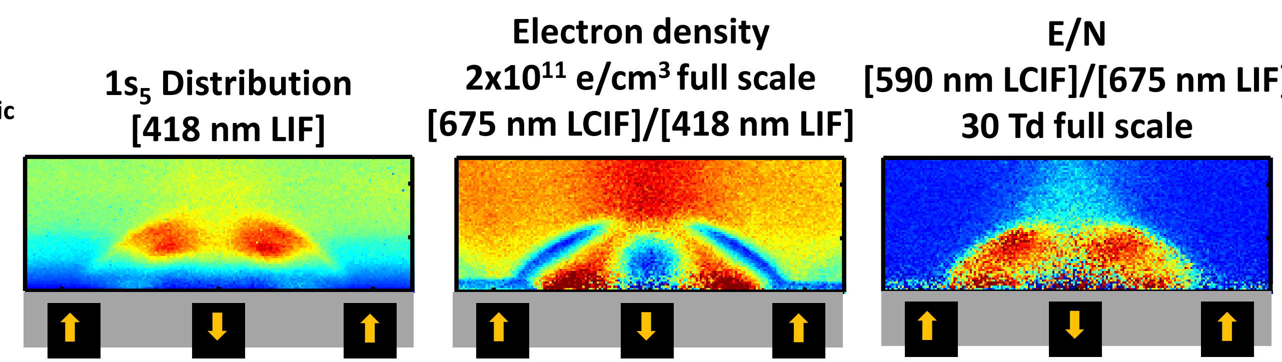
LASER-COLLISION INDUCED FLUORESCENCE IN ARGON DISCHARGES

- Laser-collision induced fluorescence (LFIC) was demonstrated and calibrated in low-pressure (< 1 Torr) argon discharges.
- Double-pulsed plasma generation and manipulation was utilized to independently control both electron density (n_e) and reduced electric field (E/N) in the plasma during calibration procedures.
- The calibrated LCIF technique was applied to transient magnetized plasma discharges to demonstrate this diagnostic capability.

Setup



Observed plasma properties



- Experimental setup and observed plasma properties measured in argon with newly calibrated LCIF diagnostic.

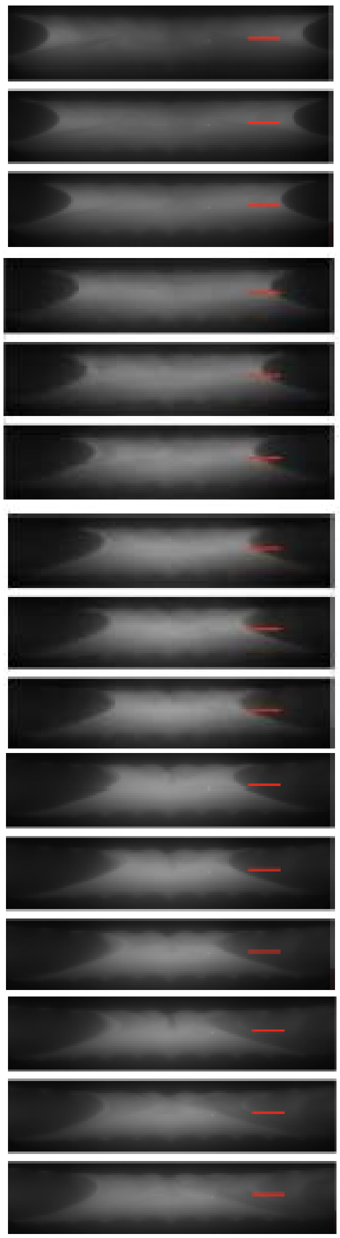


Fig. 1 – LLS from Si particles produced in a CCP as a function of time. (10s between frames.)

Laser Light Scattering Reveals Spatiotemporal Evolution of Silicon Particle Clouds in Dusty Plasmas

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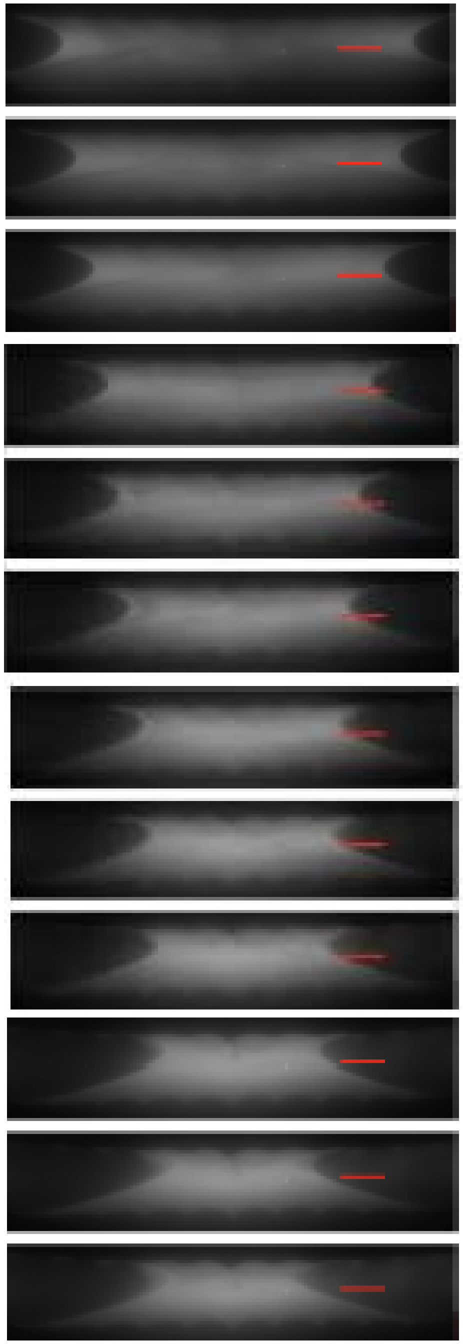
In many applications, small solid particles nucleate and grow in plasmas. These particles acquire negative charge and affect the behavior of the plasma in complex ways. The resulting mixture of ions, electrons and negatively charged particles are referred to as a "dusty plasma." Coupling between the ions, electrons and the particles leads to instabilities and waves that form unanticipated spatiotemporal patterns. We conducted laser light scattering (LLS) experiments in a 13.56 MHz dusty silane/argon capacitively coupled plasma (CCP) maintained between two parallel plate electrodes. The LLS experiments were complemented by optical emission and ion flux probe measurements. The space between the electrodes was illuminated with a sheet of red laser light produced by expanding a circular laser beam through a cylindrical lens. The laser light scattered from the nanoparticles was detected using a CCD camera.[1]

Silicon nanoparticles and nanoparticle agglomerates (~100s of nm) were produced *in situ* through reactions of silane radicals, forming a dust cloud with complex spatiotemporal structure. We observed distinct types of spatiotemporal evolution of the nanoparticle dust cloud and classified them into three regimes based on power and pressure. (See Fig. 1.) At low pressure (≈100 mTorr), Regime I, we observed periodically repeating radial expansions and contractions of a continuous dust cloud. At intermediate pressures (≈130 mTorr), Regime 2, we observed a large void appearing in the center of the electrodes. At still higher pressures (≈150 mTorr), Regime 3, we observed the same pattern as in Regime 1 but the periodic oscillations stopped and the void in Regime 2 slowly formed. We hypothesize that these patterns are a result of a delicate balance between electrostatic and ion drag forces which scale as R and R^2 (R=particle size) respectively. As particles grow with time this balance shifts to move the particles from the periphery to the center.

References

[1] Y. Qin, N. Bilik, S. L. Girshick, U. R. Kortshagen and E. S. Aydil, in preparation to be submitted to J. Phys. D: Appl. Phys. (2015).



SPATIOTEMPORAL EVOLUTION OF Si PARTICLE CLOUDS IN DUSTY PLASMAS

- **Laser light scattering (LLS) in SiH_4/Ar capacitively coupled plasmas (CCPs) between parallel electrodes revealed unanticipated patterns in the spatiotemporal evolution of silicon nanoparticle clouds.**
- **Distinctive classes of spatiotemporal evolution of the dust cloud were observed, and classified into three regimes based on power and pressure.**
- **At low pressure we observed periodically repeating radial expansions and contractions of a continuous dust cloud.**
- **At high pressure, the oscillations ceased and a void formed.**
- **These observations provide insights into the complexity of multi-phase plasmas.**

- **LLS intensity from silicon nanoparticles in a CCP, showing the contraction of the dust cloud. (10 s between frames.)**