Ultrafast Laser Diagnostics to Interrogate High Pressure, Highly Collisional Plasma Environments

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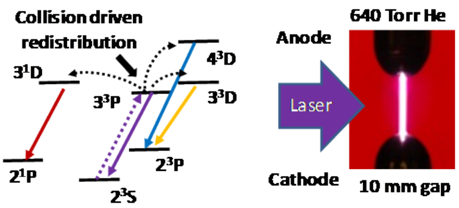
The implementation and demonstration of laser-collision induced fluorescence (LCIF) generated in atmospheric pressure helium environments is presented in this communication. As collision times are observed to be fast (~ 10 ns), ultrashort pulse laser excitation (< 100 fs) of the 2^3S to 3^3P (388.9 nm) is utilized to initiate the LCIF process. Both neutral induced and electron induced components of the LCIF are observed in helium afterglow plasma as the reduced electric field (E/N) is tuned from < 0.1 Td to over 5 Td. Under the discharge conditions presented in this study (640 Torr He), the lower limit of electron density detection is ~ 10^{12} e/cm^3. Spatial profiles of the 2^3S helium metastable and electrons are presented as functions of E/N to demonstrate the spatial resolving capabilities of the LCIF method.

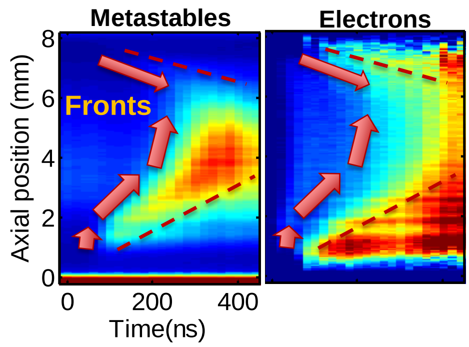
Diagnostics play a key role in assessing our understanding of processes that occur in low-temperature plasmas by benchmarking predictive capabilities as well as through discovering otherwise unexpected behaviors. As the perceived landscape of low-temperature plasma science evolve and challenges become more complex (high densities, shorter lifetimes, more reaction pathways), a broad range of diagnostic capabilities are needed to provide a sufficiently complete picture of the plasma. Therefore, new methods need to be developed and made available to facilitate research efforts of the low-temperature plasma community. In this presentation, we described continued efforts to further the state-of-the-art in plasma diagnostics.

To further the develop of the laser-collision induced fluorescence (LCIF) method [1] for use in such plasmas, a 640 Torr helium discharge, in a point-to-point configuration (Figure 1a) is studied. A key and potentially transformative element of the ongoing effort is the utilization of short pulse (~100 fs) laser to perform the initiation of the LCIF process (Figure 1a). For the presented data, LCIF is observed for 10 ns, starting ~ 1 ns before laser excitation.

To demonstrate the ability of the of the LCIF method to interrogate spatial and temporal evolution of a plasma, the evolution of a 640 Torr helium afterglow plasma in response to a 250 ns high-voltage excitation event (Figure 1b) is studied. It is observed that two excitation fronts are present during the formation of the plasma channel and that behind these fronts resides regions of higher electron density. As the electron density builds, the velocity of the front launched from the cathode (lower electrode) accelerates due to increased localized E/N. The successful development of the LCIF method in atmospheric pressure plasma environments will be presented in an upcoming fast-track communication [2].



(a)



(b)

Fig. 1 – (a) Laser-collision induced fluorescence concept and set-up utilized in studies. (b) Spatial and temporal evolution of helium afterglow plasma in response to 250 ns voltage pulse.

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[1] E. V. Barnat and K. Frederickson, Plasma Sources Sci. Technol. **19** (2010) 055015.

[2] E. V. Barnat and A. Fierro, J. Phys. D (accepted)