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Ultrasensitive E-FISH-based Picosecond DC Electric Field Measurements in Atmospheric Pressure Air

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The reduced electric field, denoted as *E/N*, where *E* represents the magnitude of the electric field within the plasma and *N* is the total gas number density is a crucial parameter influencing electron-impact driven energy processes and electron kinetics in electrical discharges. This parameter intuitively accounts for scaling the effects of accelerating electric fields by the number density of the available collisional partners. Collisional energy transfers from free electrons to other molecular and atomic species of the gas result in a complex chemistry featuring phenomena such as gas heating, rotational excitation of molecules within the gas, vibrational excitation of those molecules, electronic excitation of both atomic and molecular species, as well as dissociation and ionization. As highlighted in the 2022 Plasma Roadmap, the field of Low Temperature Plasma science and technology heavily relies on our capability to harness, engineer and control these complex energy transfers toward very diverse applications. The accurate measurement of the electric field magnitude, particularly in high-pressure conditions, becomes imperative due to the exponential dependence of rates for electron impact-driven processes on *E/N*. Furthermore, sub-nanosecond resolved E-field magnitude measurements are often needed under high-pressure conditions because of the very transient electric field dynamics when plasmas are generated using excitation voltages featuring a fast rise time.
In this context, we report on the development of a very sensitive Electric Field Induced Second Harmonic (E-FISH) generation diagnostic setup. This system is capable of measuring electric field magnitudes as low as 5 V/cm in room air and at the picosecond timescale. This advancement represents an improvement by over two orders of magnitude compared to most E-FISH systems encountered in the literature, where reported detection limits are typically around 500 V/cm –1 kV/cm. This enhanced capability is especially important when characterizing electric field reversals in plasma discharges. Through a comparative analysis with standard E-FISH systems, we explore necessary upgrades and discuss potential avenues for further advances.

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Low Temperature Plasmas

Keyword-2

Electric Fields

Keyword-3

E-FISH

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