1D Distribution Measurement of Electric Field in Streamer Discharge by E-FISH

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The electric field measurement of atmospheric-pressure nonthermal plasmas is essential for the fundamental understanding of the production mechanisms of the chemically reactive species utilized in wide ranging application fields. Recently, electric field induced second harmonic generation (E-FISH) has been reported as a promising method due to its technological superiority, e.g. versatility, setup simplicity, measurement sensitivity of ~ 0.1 kV/cm, temporal resolution of ~ 100 fs and spatial resolution of ~ 50 μm in the measurement plane vertical to the line of sight. However, the measurement accuracy of the E-FISH technique has not been accurately quantified. The measurement accuracy quantification requires the knowledge of the focused probe laser properties; such investigations have been conducted only for the spherically focused laser beam (0D measurement) and not for the cylindrically focused beam (1D measurement).

Here, the E-FISH method involving the cylindrically focused laser beam is demonstrated. The E-FISH signal generation is initially formulated and based on that, the spatial evolution of the E-FISH signal is analyzed along the laser propagation direction. Subsequently, the E-FISH signal analysis is conducted using model electric field profiles both with and without plasma. Comparison between the analysis data and the measured 1D E-FISH signal yields the 1D electric field distribution and the associated measurement accuracy. The measurement-accuracy-quantified E-FISH methodology captures the dynamic evolution of a single-filament streamer discharge in a primary-to-secondary transition phase generated in atmospheric-pressure air with spatiotemporal scales of ~ 1 ns and 100 μm. The precision of the experimental data in the transition regime is crucial to the development of a comprehensive numerical simulation model that links the primary and secondary phases.

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