Plasma-Induced Flow Instabilities in Atmospheric Pressure Plasma Jets (TOWNER_23)

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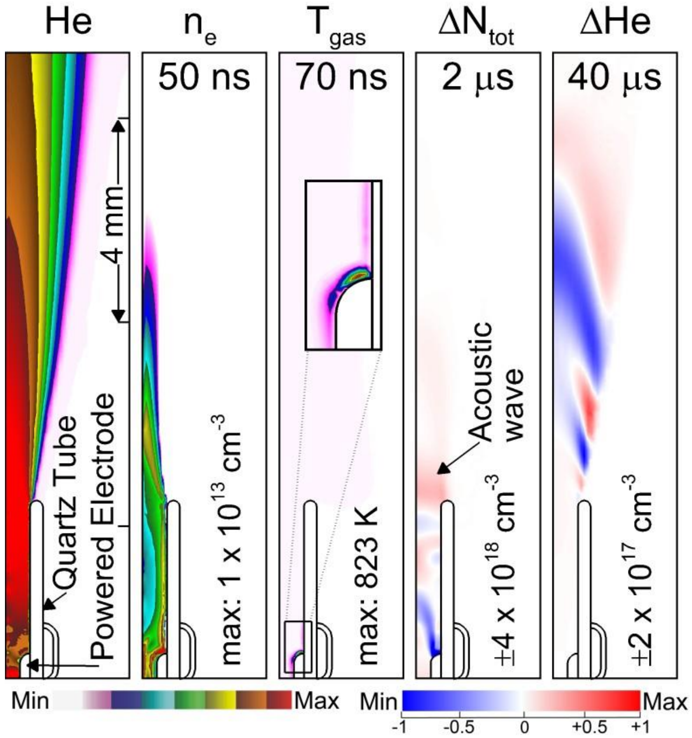
Atmospheric pressure plasma jets (APPJs) are a type of low temperature plasma source which produce fluxes of reactive species onto surfaces. These reactive species produce beneficial effects including cancer treatment, disinfection, and produce preservation. An APPJ typically consists of a dielectric tube through which a rare gas flows, with a high voltage electrode in or on the tube. The driving voltage is typically pulsed, generating plasmas that last hundreds of nanoseconds, initializing nonequilibrium chemistry can continues for minutes.

One challenge with these devices is producing a controlled, consistent, and well understood mixture of reactive oxygen and nitrogen species (RONS). Recently, experimental observations of flow instabilities have been made – previously laminar gas jets become unstable when the plasma is switched on. These instabilities can alter the RONS generation by changing the mixing of rare gas with the surrounding air. There have been many hypotheses regarding the physical mechanism of these flow instabilities, and understanding their cause is essential to controlling the RONS produced.



In this paper, the results from a 2-dimensional plasma hydrodynamics model of an APPJ are discussed. The device modeled consists of helium flowing through a 1 mm diameter quartz tube, with an annular high voltage electrode inside the tube, shown at the left. The plasma propagates in tens of ns as an ionization wave beginning at the powered electrode, producing the electron densities shown in the figure (n_e).

Highly localized gas heating near the powered electrode, shown by the plot of T_{gas}, produces temperatures of 823 K in a small region on the timescales of the discharge pulse (tens to 100 ns). After the pulse, the expansion of this heated gas produces an acoustic wave, shown as oscillations in the total number density (ΔN_{tot}). This acoustic wave initiates an instability in the shear layer where the rare gas meets the surrounding air. This shear instability grows and results in oscillations of the mixing region between the helium and surrounding air, shown by changes in He density (ΔHe). This mechanism is consistent with several experimental observations, including imaging which shows flow disturbances occurring at the discharge frequency and propagating with the flow velocity, which would be expected based on this mechanism.