Simulation of plasma bullet dynamics

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Cold atmospheric-pressure plasma jets, formed by barrier discharges in a gas flow (usually helium, argon or their mixtures) in thin dielectric tubes and injected into ambient air, are actively studied as an effective source for production of non-thermal plasmas. High-speed photographs have revealed that the jets are typically composed of bullet-like plasma volumes traveling with velocities in the range 10^6-10^8 cm/s (e.g. [1-3]). It has been assumed [1] that plasma bullets propagate like ionization waves – streamers.

Although plasma bullets are similar to streamers, some specific features of plasma bullets propagating in a jet column differ from those of streamers in a free space (in a uniform gas). In particular, experiments [2] have revealed a ring-shaped radiation profile of plasma bullets. Measurements [3], in helium plasma jets, of the radial profile of the density of metastable helium atoms have shown that its maximum is at some distance from the axis. This pattern is untypical for streamers propagating in a uniform gas where the densities of charged and excited species are maximal on the streamer axis. Simulations [4] of streamer propagation in a helium jet injected into ambient air has showed that depending on the jet width and the initial radial distribution of electron number density the streamer structures of two types can be formed: one with maximums of electric field and electron density at the jet axis and another with maximums of these parameters near the boundary between the jet and surrounding air. The latter structure is similar to observed ring-shaped structures of plasma bullets.

Note that in [4] streamer modeling has been performed in assumption that a sharp boundary exists between helium (inside the jet) and air (outside the jet). In the given work the plasma bullet dynamics is simulated with account of mixing of helium jet with surrounding air. It is shown that plasma bullets typically have a ring-shaped structure. The calculated ring radius decreases with growth of the distance from the tube end, in qualitative agreement with experimental data [3].

References

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