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Capillary Discharge Plasma Channels for Laser Pulse Guiding and Active Lensing of Charged Particle Beams

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Dissipative magnetohydrodynamics is used to develop theory and computer simulation to investigate the capillary discharge dynamics. Plasma discharges in the capillaries are of interest for x-ray lasers, waveguides for high power laser pulses, and as active plasma lenses to focus high energy charged particle beams. The discharge dynamics of a waveguide for high-intensity laser pulses in the gas-filled capillary discharge was investigated in [1]. A method of creating plasma channels with controllable depth and transverse profile for the guiding of short, high power laser pulses for efficient electron acceleration was proposed in [2]. The plasma channel produced by the hydrogen-filled capillary discharge waveguide is modified by a ns-scale laser pulse, which heats the electrons near the capillary axis. Laser-heated capillary discharge waveguides are low plasma density guiding structures able to guide intense laser pulses over many diffraction lengths and have enabled the acceleration of electrons to 7.8 GeV by using a laser-plasma accelerator (LPA) [3]. These devices represent an improvement over conventional capillary discharge waveguides, as the channel matched spot size and plasma density can be tuned independently of the capillary radius. Capillary discharges in the high repetition rate regime are of interest for a broad range of applications. We studied the capillary discharge in such regime in connection with the ultrashort laser pulse guiding for laser electron acceleration [4].

The magnetic field generated inside the capillary has high gradients thus providing the conditions for compact, tunable, focusing of electrons which are critical to laser-plasma accelerator applications [5,6].

Active plasma lenses have the potential to enable various applications of plasma-based accelerators owing to their compact design and radially symmetric focusing fields, facilitating beam-quality preservation and compact beam transport. The theoretical results gave a basis for optimizing the laser electron acceleration and active lensing.

We performed computer modelling of a fast electrical discharge in a nitrogen-filled alumina capillary in order to discover discharge system parameters that may lead to efficient recombination pumping of soft X-ray laser with active medium created by H-like nitrogen ions [7, 8].

References

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