Evolution of plasma conditions within capillary discharges, with application to plasma accelerators

G.J. Boyle[1], M. Mewes[2], J. Beinortaite[2], J. Chappell[3], R. D'Arcy[2], S. Diederichs[2], J.M. Garland[2], C.A. Lindstrøm[2], G. Loisch[2], J. Osterhoff[2], A. Scaachi[4], S. Schroeder[2], R.J. Shalloo[2], M. Wing[4] and M. Thévenet[2]

[1] *James Cook University, Townsville, Australia*

[2] *Deutches Elektronen-Synchrotron DESY, Hamburg, Germany*

[3] *John Adams Institute, Oxford, United Kingdom*

[4] *University College London, London, United Kingdom*

The ability to characterize and manipulate the plasma conditions within capillary discharge devices, such as plasma accelerator modules, laser waveguides (LWs), and active plasma lenses (APLs), is paramount to the development and optimization of next generation compact particle accelerator technology.

The FLASHForward [1] experiment at DESY aspires to use beam-driven plasma wakes to accelerate GeV electron beams of sufficient quality to generate free-electron laser gain. Experimental parameters, such as the discharge current pulse shape, alter the plasma properties, and the relaxation time of these properties places a limit on the repetition rate [2]. In LWs, the radially non-uniform current heating from the discharge forms a plasma channel that can be used for guiding ultrashort, high-intensity lasers [3]. In APLs, the current is utilized to provide strong axi-symmetric focusing of charged-particle beams [4]. Unlike LWs, the formation of radially non-uniform plasma conditions is detrimental to APL quality. In both cases, the evolution of the radially-varying plasma properties is critically important.

In this study, we simulate the evolution of the electron temperature and density in plasma capillaries after the initiation of a current discharge, to comment on the operation of high-repetition-rate plasma-wakefield accelerators, development of LWs, and operation of aberration-free APLs.

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