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Time-dependent behavior of capillary discharge devices for plasma-wakefield acceleration

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The future (and potential limitations) of compact particle accelerator technology depends on the ability to characterize and manipulate the conditions in plasma discharge devices, such as plasma targets and active plasma lenses (APLs).

For many high energy physics applications and novel radiation sources, high repetition rates are required. For example, the FLASHForward [1] experiment at DESY aims to use beam-driven plasma-wakefield acceleration (PWFA) to produce GeV electron beams of sufficient quality to allow for free-electron laser gain, and plans to investigate the efficacy of PWFA at repetition rates up to the MHz level. The plasma-forming discharge causes an increase in temperature and pressure and an expansion of the plasma, and the time required for the plasma conditions to relax to a state that does not affect the formation of subsequent wakefields places a limit on the repetition rate [2].

APLs are gas-filled capillary discharge devices that can provide strong radially-symmetric focusing fields in an extremely compact size. Within the capillary an electron temperature profile develops via competition between the current heating and heat lost to capillary wall. A non-uniform radial temperature profile results in a non-linear radial magnetic field profile contributing to emittance growth, and the temporal development of this phenomena is critical to the operation of aberration-free APLs [3,4].

In this study, we investigate the heating and subsequent cooling phases of plasma capillaries after the initiation of a current discharge, to comment on the operation of high-repetition rate PWFA and aberration-free APLs.

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