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Dense Plasma Focus Z-Pinch Fully Kinetic Modeling and Ion Probe-Beam Experiments

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The Z-pinch phase of a dense plasma focus (DPF) emits multiple-MeV ions on a cm-scale length, even for kJ-scale devices. The mechanisms through which these physically simple devices generate such high energy beams in a relatively short distance are not fully understood. We are exploring the mechanisms behind these large gradients using the first fully kinetic simulations of a DPF Z-pinch as well as an ion probe beam experiment in which a 4 MeV deuteron beam is injected along the z-axis of a DPF Z-pinch plasma and accelerated. Our table-top DPF has demonstrated > 50 MV/m acceleration gradients during 800 J operation using a fast capacitive driver [1]. We have now directly measured the DPF gradients and demonstrated acceleration of an injected ion beam for the first time. Our particle-in-cell simulations have successfully predicted observed DPF ion beams and neutron yield, which past fluid simulations have not reproduced [2]. We have now experimentally measured and observed in the simulations for the first time, electric field oscillations near the lower hybrid frequency. This is suggestive that the lower hybrid drift instability, long speculated to be the cause of the anomalous plasma resistivity that produces large DPF gradients, is playing an important role. Direct comparisons between the experiment and simulations enhance our understanding of these plasmas and provide predictive design capability for accelerator and neutron source applications. This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and supported by the Laboratory Directed Research and Development Program (11-ERD-063) at LLNL.

[1] J. Ellsworth et al., "Design and Initial Results from a Kilojoule Level Dense Plasma Focus with Hollow Anode and Cylindrically Symmetric Gas Puff," RSI, 2012 (submitted).

[2] A. Schmidt et al., "Fully Kinetic Simulations of Dense Plasma Focus Z-Pinch Devices," PRL, 109(20), 205003, 2012.