Abstract

Configuring the dense plasma focus to maximize ion beams and neutron yield

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Intense neutron sources are needed for survivability testing of electronics, flash neutron imaging, and other applications. One candidate source is the dense plasma focus (DPF). The DPF is a co-axial plasma rail gun that serves to couple the slow rise time of a capacitor bank (microseconds) with a fast Z-pinch event that accelerates ions into a gas target and produces neutrons in the presence of deuterium or deuterium/tritium gas. The DPF's discharge ends in a 10-100 ns neutron pulse, with total demonstrated yield of up to 10^{12} for deuterium fill gas (10^{19} n/s peak) into 4π, with ~1 MegaJoule of stored energy. It is one of the brightest neutron sources in existence and can be made compact. A MJ DPF could be designed to fit on a pick-up truck. Although DPFs have been around for 50 years, until recently these devices have been optimized empirically due to lack of a predictive model. While the device itself is physically simple, the physics behind the ion beam acceleration is complex and not well understood. Our group in conjunction with Voss Scientific has developed the first fully kinetic model of these devices, in the particle-in-cell (PIC) code, LSP. It has been benchmarked to both kJ-scale and MJ-scale DPFs. Our model includes the electrode geometry and pulsed power circuit at the anode-cathode boundary. I will discuss how the model can be used in conjunction with experiments to optimize the DPF design for desired yield and pulse shape through varying electrode shape, insulator properties, and driver properties, and through the use of solid targets. Prepared by LLNL under Contract DE-AC52-07NA27344 and supported by US DOE/NA-22 Office of Non-proliferation Research and Development and the Laboratory Directed Research and Development Program (15-ERD-034) at LLNL. Computing support for this work came from the LLNL Institutional Computing Grand Challenge program.

Biographical Summary

Dr. Schmidt is a member of the scientific staff at Lawrence Livermore National Laboratory, working in the area of plasma physics. Additionally, she is the Accelerator Group Leader within the Engineering directorate and APL of Pulsed Power Fusion Plasmas within the Physics Division. She is leading a team of 20 scientists working on several projects to engineer dense plasma focus (DPF) Z-pinch devices for multiple applications. The group is using both experiments and particle-in-cell (PIC) simulations to better understand and optimize these devices. One of their key capabilities is fully kinetic modeling of these devices using a particle-in-cell code which can predict neutron yield from first principles. They also have 100-J and 1 kJ scale table-top DPF experiments which can be used for code validation, rapid prototyping, and diagnostic development. They are in the process of designing and building a MJ scale DPF experiment. The team is also helping develop flow z-pinches for fusion energy, developing compact neutron sources with field ionizer ion sources, and modeling high power magnetron sputtering plasmas.