Ultra-strong magnetic fields for high energy density science

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The addition of a controlled external magnetic field (B-field) at major high power laser facilities is pushing the frontiers of laser-driven high energy-density (HED) magnetized plasma science. In inertial confinement fusion the B-field compressed with the target acts in addition to inertia to confine the hot spot, resulting in a hotter fuel and enhanced fusion yields. Using a cylindrical (rather than spherical) implosion facilitates investigations of the magnetized transport of heat and magnetic flux [1]. We performed Ar-doped D2-filled cylinder implosion experiments with 15 kJ laser drive, with and without an imposed B-field. The observed systematic changes in Ar K-shell spectra reveal a 50% core temperature increase at peak compression when an external pulsed power 30 T seed B-field is applied. The experimental data is in line with extended-MHD simulations, evidencing the impact of a 10 kT compressed B-field [2]. This platform has been scaled to 20 times higher laser drive in expectation of spatially-resolved core temperature [3] and B-field compressibility measurements.

In settings where external pulsed power coils are not available, laser-driven coil (LDC) targets are an all-optical alternative for delivering strong B-fields as seeds to laser-plasma experiments, over open volumes with minimal excess hardware and debris. Recent characterization data consolidates the LDC performance and deepens our understanding of the underlying physics behind the laser-triggered current-driving that ultimately induces the B-field.

[1] C.A. Walsh *et al.*, Plasma Physics and Controlled Fusion **64**, 025007 (2022).

[2] M. Bailly-Grandvaux *et al.*, Physical Review Research **6**, L012018 (2024).

[3] G. Pérez-Callejo *et al.*, Physical Review E **106**, 035206 (2022).