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Axial Proton Radiography of Electric and Magnetic Fields Inside Laser-Driven Coils[1]

JONATHAN PEEBLES, Laboratory for Laser Energetics

In a laser-driven coil (LDC) a laser ejects electrons from a plate, which then draws a current through an advantageously shaped loop to generate a magnetic field. B-dot probes, Faraday rotation, and transverse (perpendicular to the coil axis) proton radiography have been used in previous LDC experiments, where fields of 600 T or more are commonly cited, but cannot directly probe inside the coils and are subject to confounding factors, often delivering conflicting measurements on the same experiment. Here we report the first detailed measurements of both magnetic and electric fields inside an LDC using axial proton radiography with a grid fiducial. Protons traveling down the axis of a coil are rotated by the radial magnetic field due to coil current and are displaced radially by the radial electric field due to coil charging. In conjunction with probing at multiple proton energies, axial radiography can unambiguously break the degeneracy between magnetic and electric fields. OMEGA EP experiments were carried out using axial radiography of double- and single-plate LDC's. Detailed reconstructions of radiographs over several proton energies were performed using current and charge distributions to reproduce the proton grid distortions. In single-plate coils axial magnetic fields at the center of up to 65 +/- 15 T were inferred, but with nonuniform currents around the coils. In double-plate coils magnetic fields were below the detection threshold of 15 T. Significant radial electric fields due to electron ejection from the coils were present in both configurations. Laser probe measurements of plasma expansion on the plates indicate that x-ray drive of the second plate led to the lack of a detectable current in double-plate coils.

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