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Magnetic-field evolution in Z-pinch implosion with preembedded axial magnetic field

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We investigate the effects of an axial magnetic field (B_z) on the current distribution in imploding plasma and the efficiency of the B_z-field compression by the imploding plasma. In the experiment, a cylindrical argon gas puff, in which is initially embedded quasi-static magnetic flux (up to 0.4 T), prefills the volume between two electrodes. Subsequently, a pulsed-current (rising to 300 kA, in 1.6 µs) driven through the gas, ionizes it, and generates an azimuthal magnetic field that compresses the plasma and the embedded B_z-field. Here, for the first time, we directly and simultaneously measure the evolution of the axial and azimuthal magnetic fields during the implosion and stagnation. This measurement was achieved by employing a spectroscopic technique based on the polarization properties of Zeeman split emission, combined with laser-doping technique that provided mm-scale spatial resolution. The measurements show that for implosions with B_z(t=0) = 0.4 T, the azimuthal magnetic field (B) in the imploding argon plasma shell is much smaller than expected from the measured current and plasma radius, demonstrating that B_z dramatically affects the current distribution. It is found that in the presence of a low B_z, a significant part of the current flows at large radii through a non-imploding dilute plasma ($n_e \leq 10^{17}$ cm^{-3}). In addition, simultaneous B_z and B measurements at stagnation for B_z(t=0) = 0.4 T show that B_z is compressed about 12 × relative to its initial value, giving at stagnation a B_z-magnitude ~ 4 × larger than B. The pressure in the stagnated plasma (including the thermal pressure) becomes 16 × higher than the pressure of B. This demonstrates the large role of the ram pressure of the imploding plasma on the compression of Bz in this experiment.
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