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Direct observation of the current evolution in a small-scale self-compressing plasma column

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We report on the direct measurement of the evolution of the azimuthal magnetic field (B_θ) in a small-scale, self-compressing plasma column using spectroscopic methods. This measurement allows for calculating the radial distribution of the axial current density which is crucial for understanding the dynamics of the plasma compression, and for improving predictions of detailed MHD simulations. The direct measurement of the magnetic field in self-compressing plasma systems is challenging, since the plasma density rises to few $10^{19}\ cm^{-3}$, resulting in strong spectral line broadening that fully obscures the Zeeman-split pattern.
In our experiment, a 27-kA current pulse with a rise time of 170 ns drives the implosion of an oxygen column with an initial radius of ˜3 mm. The main diagnostics is a high-resolution, polarization-based spectroscopic setup. Simultaneous measurement of the σ+ and σ- components of the Zeeman pattern enables the determination of the magnetic field from the separation of these two components. Additionally, we obtain the electron temperature and the electron density simultaneously with the magnetic field.

The detailed time and space resolved characterization of the magnetic field and plasma parameters results in a comprehensive picture of the plasma compression dynamics. During the compression stage, we observe that the entire discharge current is located in the imploding plasma. At stagnation, however, the current flowing in the stagnating plasma decreases significantly and the 'missing'current resides at much higher radii.

The data presented here can be used to build a detailed model of the current evolution that includes the plasma resistivity and inductance. This may explain the mechanism of the current re-distribution, which is relevant for numerous similar experiments in the pulsed power community.

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