Spectroscopic characterization of compressed core conditions in directly-driven magnetized cylindrical implosions

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The application of external magnetic fields in inertial confinement fusion (ICF) implosions has been identified as a method to enhance hot-spot performance, reducing thermal losses and enabling higher fusion yields. To facilitate the investigation of the magnetic-field compression mechanism, a cylindrical geometry is particularly appropriate. This works discusses the use of Ar K-shell spectroscopy to characterize the core conditions in magnetized cylindrical implosion experiments conducted at the OMEGA laser facility. The targets, filled with Ar-doped deuterium, were symmetrically imploded using a 40-beam, 14.5 kJ, 1.5 ns laser drive. Recorded space- and time-integrated Ar K-shell spectra exhibit highly reproducible, distinctive features both with and without an imposed magnetic field. A uniform spectroscopic model was insufficient to replicate the observations; however, a multizone spectroscopic model, combined with a random-search χ^2 minimization procedure, successfully fitted the experimental spectra. The analysis allows to extract intensity-weighted average conditions of the cylindrical imploded core, namely revealing a 50% core temperature rise at half mass density when a 30 T seed B-field was applied. Additionally, the methodology shows potential for deriving a coarse-grained radial profile of core conditions at stagnation, supporting the formation of a hotter central spot in the magnetized scenario. Concurrently, the experimental spectra align well with synthetic spectra obtained by post-processing extended-magnetohydrodynamics simulations, incorporating detailed atomic-kinetics and Stark-broadened line shapes. This provides strong evidence that the attained core conditions at peak compression are consistent with the impact of a 10-kT compressed field.

References

[1] M. Bailly-Grandvaux *et al.*, Phys. Rev. Research **6**, L012018 (2024).

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