Characterizing strongly magnetized hot dense plasmas in cylindrical implosion experiments

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Magnetization of inertial confinement implosions is key to improve their performance. By applying a sufficiently large B-field to the imploding plasma, one can magnetize the electron conduction, thereby reducing the energy losses due to electronic collisions, and increasing the temperature of the compressed core. Additionally, the growth of hydrodynamic instabilities detrimental to implosion performance can be suppressed by the effect of magnetic tension. Lastly, a magnetic field strong enough can confine the alpha particles generated in the fusion reactions, enhancing alpha-induced heating. This approach is particularly interesting in cylindrical implosions, as the B-field can be applied along the axis of the cylinders, facilitating the confinement of particles in the radial direction while being parallel to longitudinal modulations that can be smoothed out by magnetic tension.

In this talk we present the design, numerical simulations, and first results of a series of experiments performed at the OMEGA 60 laser facility, which aim to magnetize and characterize laser-driven cylindrical implosions. Targets were cylindrical plastic (CH) shells filled with Ar-doped deuterium at 11 atm. Targets were imploded in the standard configuration for cylindrical implosions at OMEGA [1], using a 36-beam, 15 kJ, 1.5 ns laser drive. Some of these shots were magnetized by applying a 24 T seed B-field along the cylindrical axis using an external pulsed power system.

Two-dimensional extended-MHD simulations using the code Gorgon were run to model the implosions [2]. These simulations predict that the B-field is compressed to values above 10 kT. Under these conditions, the plasma becomes heavily magnetized, and the effects of electron magnetization and magnetic pressure modify the temperature and density of the compressed core.

The implosion velocity and uniformity were studied using orthogonal X-ray Imaging Framing Cameras [3]. We found that the compression ratio was slightly lower than predicted by the hydrodynamic simulations. To characterize the changes in the temperature and density of the core, we recorded the K-shell emission spectra from the Ar dopant using both time-integrated and time-resolved X-ray spectrometers.

The Ar K-shell spectra were highly reproducible and show clear differences in the line ratios between magnetized and non-magnetized implosions. These differences are consistent with the temperature of the core being higher in the magnetized case than when no B-field is applied. Furthermore, the data show good agreement with synthetic spectra produced by postprocessing the 2D hydrodynamic simulations with atomic kinetics and lineshape codes. The comparison between experiment and simulations has allowed us to test several techniques for extracting the plasma parameters from both synthetic and experimental spectra.

Building on the results at OMEGA, we plan to extend this platform to the LMJ facility, with a laser-drive ~20x more energetic [4]. By using larger targets and driving them with more energy, a higher compression ratio can be achieved, thus increasing the compressed B-field and the plasma magnetization. For LMJ we will implement a double-dopant in the core (Ar and Kr). Since Ar becomes completely ionized at temperatures above ~2.5keV, whereas Kr K-shell emission is negligible at temperatures below that value, this double-dopant will effectively introduce a *spatial resolution*, as each element will be mapping regions with different temperatures.

References

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