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Production of keV-Temperature Plasma Core with Magnetized Fast Isochoric Heating

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The quest for the inertial confinement fusion (ICF) ignition is a grand challenge, as exemplified by extraordinary large laser facilities like National Ignition Facility (NIF) [J. Lindl et al., Phys. Plasmas 11, 339 (2004), J. Lindl et al., Phys. Plasmas 21, 020501 (2014)]. Although scientific break-even, the energy released by fusion reaction exceeds the energy contains in the compressed fusion fuel, was achieved on NIF [O. A. Hurricane et al., Nature 506, 343 (2014)], the pathway to the ignition is still unclear.
Fast isochoric heating, also known as fast ignition, of a pre-compressed fuel core with a high-intensity laser is an attractive and alternative approach to the ICF ignition [M. Tabak et al., Phys. Plasmas 1, 1637 (1994)] that avoids the ignition quench caused by the hot spark mixing with the cold fuel, which is the crucial problem of the currently pursued ignition scheme.
High-intensity laser-plasma interactions efficiently produce relativistic electron beams (REB). However, only a small portion of the REB collides with the core because of its large divergence. Here we have demonstrated enhanced laser-to-core coupling with a magnetized method to confine the REB in a narrow transport region resulting in efficient isochoric heating. The method employs a laser-produced kilo-tesla-level magnetic field [S. Fujioka et al., Sci. Rep., 3, 1170 (2013)] that is applied to the transport region from the REB generation point to the core which results in guiding the REB along the magnetic field lines. We have created successfully a 1.6 ± 0.2 keV-temperature plasma core having 1 Gbar of energy density by using the MFI scheme with 7.7 ± 1.3% of an efficient laser-to-core energy coupling [S. Sakata et al., ArXiv 172.06029 (2017)]. We should emphasize that our result can be explained by a simple model coupled with the comprehensive plasma diagnostics, while several ICF experiments relay heavily on computer simulations due to difficulties of diagnosing micro-scale phenomena occurred in the small and complex plasma. The simplicity may secure scalability of this scheme to the ignition. 15% of the laser-to-core coupling is achievable for an ignition-scale high area density core (0.3 - 0.5 g/cm2) according to the model. The ignition target based on the MFI scheme is being designed by using multi-scale and multi-dimensional simulations.

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