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Enhanced energy coupling for indirect-drive fast-ignition fusion targets

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One of the most promising approaches to reach a high gain in inertial confinement fusion is the fast ignition scheme. In this scheme, a relativistic electron beam is generated; this passes through the imploded plasma and deposits parts of its energy in the core. However, the large angular spread of the relativistic electron beam and the poorly controlled compression of the target affect realization of the fast ignition technique. Here, we demonstrate that indirectly driven (that is, driven by X-rays generated inside a gold hohlraum) implosions with a 'high-foot' and a short-coast time of less than 200 ps allow us to tightly compress the shell. Furthermore, we show the ability to optimize the symmetry of the imploding shell by changing the hohlraum length, successfully tuning a suitable tube-shaped shell to compensate for the large angular spread of the relativistic electron beam and to enhance the electron-to-core coupling efficiency via resistive magnetic fields. Benefiting from those experimental techniques, a significant enhancement in neutron yield was achieved in our indirectly driven fast ignition experiments. These results pave the way towards high-coupling fast ignition experiments with indirectly driven targets similar to those at the National Ignition Facility.

References

[1] Zhang, F., Cai, H.B., Zhou, W.M. et al. Enhanced energy coupling for indirect-drive fast-ignition fusion targets. Nat. Phys.(2020). https://doi.org/10.1038/s41567-020-0878-9

[2] Zhang, F. et al. Measurement of the injecting time of picosecond laser in indirect-drive integrated fast ignition experiments using an X-ray streak camera.Rev. Sci. Instrum.90, 033504 (2019).

[3] Shan, L. Q. et al. Experimental evidence of kinetic effects in indirect-drive inertial confinement fusion hohlraum. Phys. Rev. Lett.120, 195001 (2018)

[4] Cai, H. B. et al. Enhancing the number of high-energy electrons deposited to a compressed pellet via double cones in fast ignition. Phys. Rev. Lett. 102, 245001 (2009).

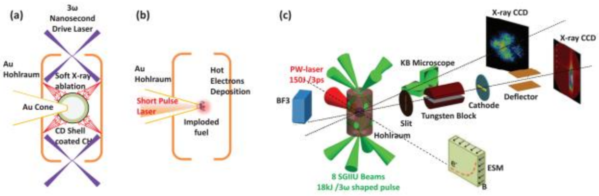

Figure 1 Schematic of an indirect-drive fast ignition experiment. (a) A cone-in-shell target is imploded by soft x-ray radiation produced inside laser-irradiated cylindrical hohlraum at SGIIU laser facility. (b) The short pulse laser irradiates the inner tip of the hollow gold cone to generate REB which serves to heat the compressed fuel. (c) Schematic view of the experimental setup. Two BF3 detectors are used to measure the neutron yield of implosion, and a Kirkpatrick-Baez microscope is coupled with XFC to record time-resolved x-ray radiographic images of compressed plasma. An especially shielded XSC is used to measure the injection time of the short pulse laser and a 0:2 Telsa ESM was used to record the escaping electrons out of the compressed core.

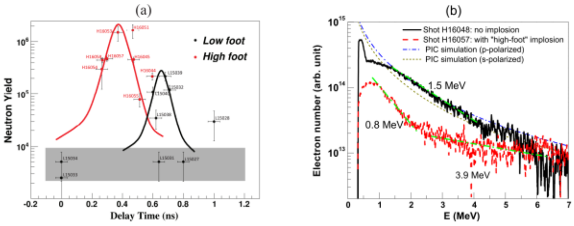

Figure 2 Fusion yield and REB spectrum. (a) Measured neutron yield as a function of the timing of short pulse laser. Time zero was defined as the end of nanosecond laser. The delay time was measured by XSC. Black dots show results for the "low-foot" cases and red dots for the "high-foot" cases. The grey shadow represents the neutron yield without the short pulse laser injection. (b)Comparison of measured spectra of escaping REBs between the cases with "high-foot" implosion and without implosion. The blue dash-dotted line and dark-yellow short-dashed line show the PIC simulated REB source for p-polarized and s-polarized laser pulse, respectively. The green dash-dotted lines represent the fit lines of the slope temperature.