Fast Heating of Imploded Plasma By Abnormal Penetration of Ultra-Intense Laser Light

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We're investigating the Fast Ignition with direct irradiation of imploded core plasma without reentrant cone, so called, "Super-penetration". This scheme is the relativistic laser penetration into the overdense plasma beyond the classical critical density, and is therefore one of the attractive options of fast ignition [1]. When the laser power exceeds the critical power of relativistic self-focusing, the laser beam is focused during the propagation in coronal, underdense plasma. The enhancement of focused laser intensity allows further penetration of overdense plasma due to relativistic induced transparency effect. Once the pulse front successfully propagates into the region, following part of the laser pulse can easily propagate its energy into the dense region via laser hole boring. In the series of experiments, we have demonstrated a stable single plasma channel in mm-size coronal plasma and penetration of UIL into overdense plasma [2,3].

In this presentation, we present the energy transport inside the imploded plasma using Gekko XII and LFEX laser system in Institute of Laser Engineering, Osaka University. By adding the optimum thickness of pure plastic coating on Cu-doped plastic ball target, we successfully eliminate Cu Kα emissions during the implosion process by superthermal electrons, and successfully observed the emission only by the fast electrons. In the results, the size of emission is nearly equivalent with the core (~50μm) at the maximum compression timing. Based on theoretical estimation [4], the energy coupling on the core is estimated as around 0.3% of LFEX energy in our experimental conditions, with too low (0.05g/cm^2) areal density of the plasma and too high (10 MeV) average kinetic energy of fast electrons compared with the ideal heating conditions [5].

In order to improve the coupling efficiency, we demonstrated the magnetic collimation of fast electrons by utilizing the self-generated magnetic field via the resistive gradient between embed metal cylinder in the imploded plasma. The results indicate almost 3 times enhancement of Cu Kα emission, corresponding to about 1% of coupling efficiency. If we can use the ignition scale plasma (nearly 10 times higher than the current experiment) and reduce the electron slope temperature, one can expect the practical coupling efficiency (>10%). From these observations, this scheme could be fruitful in the application to full-scale fast ignition.

References

[1] M. Tabak, *et al.*, Phys. Plasmas **1** (1994) 1626.
[2] L. Ceurvorst, *et al.*, Phys. Rev. E **97** (2018) 043208.
[3] H. Habara, *et al.*, Plasma Physics and Controlled Fusion **57** (2015) 064005.
[4] L.C. Jarrott, *et al.*, Physics of Plasmas **24** (2017) 102710.
[5] T. Gong, H. Habara, *et al.*, Nature Communications **10** (2019) 5614.

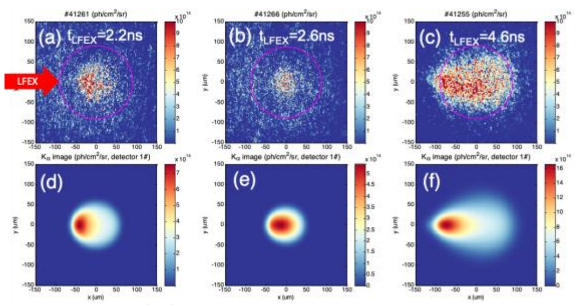

Figure 1 (a)-(c) Cu-Kα image measured in the experiment for different LFEX injection timing. (d)-(f) Reproduced image from MHD calculations