§45. Effects of Long Rarefied Plasma Inside Cone on Fast Electron Generation

Sakagami, H.,
Sunahara, A. (Inst. for Laser Technology),
Johzaki, T., Nagatomo, H. (Inst. of Laser Engineering, Osaka Univ.)

First series of fast ignition experiments have been performed in 2009, and only 30-fold enhancement in neutron yield, which was ~ 1/30 smaller than that in 2002 experiments,[1)] was achieved and lower energy coupling from the heating laser to the imploded core was expected.[2)] According to two-dimensional core heating simulations where uniform core heating rate was assumed, an energy coupling rate of the heating laser to the compressed core could be estimated around 20 % in 2002 experiments, but less than 5 % in 2009 experiments.[3)] An unavoidable pre-pulse of the heating laser generates long-scale low-density plasmas (preformed plasmas) inside the cone. A main pulse of the heating laser has to interact with these long-scale preformed plasmas and it results in increasing the distance from the generation point of fast electrons to the core and generating too energetic fast electrons.[4)] In turn, low energy fast electrons especially suitable for core heating decease and it leads to low energy coupling. To mitigate the preformed plasma effects, an entrance of the cone is suggested to be covered with an extremely thin film. The pre-pulse could be interrupted and absorbed by this film, and cannot irradiate the cone wall to produce the preformed plasma. But inside of the cone is filled up with rarefied plasmas, which are the residue of expanding thin film plasmas. Thus the main pulse of the heating laser must propagate through very long (>500μm) rarefied ($<<n_{cr}$) plasmas. However there has been few research using such long rarefied plasmas, and we have investigated effects of long rarefied plasmas on core heating with the use of FI^3, which consists of PINOCO (radiation-hydro code), FISCOF (Particle-in-Cell code), and FIBMET (Fokker Planck-hydro code).

To investigate effects of the long rarefied plasma inside the cone on fast electron characteristics, laser-plasma interactions are computed by FISCOF-1D. The heating laser is set to $I_L=10^{20}$W/cm^2, λ_L=1.06μm, τ_{FWHM}=1ps Gaussian, and the Au (A=197, Z=30) cone tip is introduced as a 10μm, 500n_{cr} flat profile, which is followed by 20μm long CD (500n_{cr}, A=7, Z=3.5) plasma. We put the CH foam plasma (10n_{cr}, A=6.5, Z=3.5) with 50μm thickness in front of the Au cone tip plasma to efficiently generate fast electrons. We also put the H uniform plasma (A=1, Z=1, L_{rare}=150 or 300μm thickness) with different densities (n_{rare}=0.01n_{cr} ~ n_{cr}) in front of the CH foam plasma as the long rarefied plasma. As the core heating is greatly affected by not only the beam intensity but also the energy distribution of fast electrons, we have performed FI^3 integrated simulations to estimate core temperatures. Observed fast electron profiles from FISCOF-1D are used as the time-dependent momentum distributions of fast electrons for FIBMET-1D. Background plasma profiles from PINOCO are also used. Core electron temperatures are computed by FIBMET-1D and averaged over the dense region (ρ>10g/cm^3). Time evolutions of them are shown in Fig.7 without rarefied plasmas and with rarefied plasmas of different densities (0.01, 0.05, 0.1, 0.5 and 1n_{cr}) for (a) L_{rare}=150 and (b) 300μm. Maximum averaged core electron temperatures are measured from Fig.1, and they are interpreted to reduction rate of a rise of the electron temperature. Degradations of electron temperature increment against the case without rarefied plasmas are shown in Fig.2 as a function of ρL n_{cr}· μm for both L_{rare}=150 and 300μm. In the case of 150μm thickness rarefied plasma, fast electrons that are suitable for core heating (< 2MeV) are not affected so much by the rarefied plasma. Thus time evolutions are almost similar to the case without rarefied plasmas, and the maximum core electron temperature is only reduced by 15% even for the $n_{rare}=n_{cr}$ case. The electron temperature increment of the $n_{rare}=n_{cr}$ and 300μm thickness case is, however, strongly reduced and the degradation reaches more than 50% because of much less appropriate fast electrons for core heating. If the degradation of less than 10% is acceptable for the fast ignition, ρL of the rarefied plasma must be smaller than 50 n_{cr}· μm. On the other hand, too small ρL plasma cannot absorb the pre-pulse and it hits the cone wall to generate long-scale preformed plasmas. Therefore, we must optimize the film thickness against the pre-pulse intensity and more research is needed.

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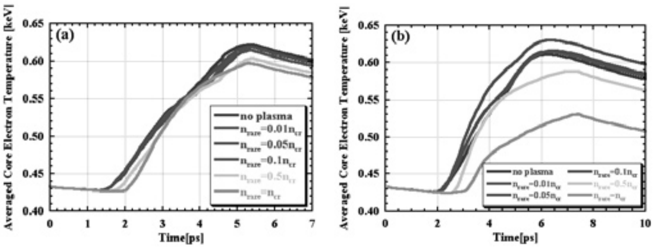

Fig.1. Time evolutions of averaged core electron temperature for (a) L_{rare}=150 and (b) 300μm.

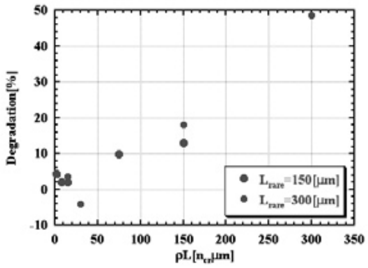

Fig.2. Degradations of electron temperature increment against the case without rarefied plasmas as a function of ρL n_{cr}· μm for both L_{rare}=150 and 300μm.

1) Kodama, R., et al.:Nature **418** (2002) 933.
2) Mima, K. et al.:Plasma Phys. Control Fusion **52** (2010) 124047.
3) Johzaki, T., et al.:Nucl. Fusion **51** (2011) 073022.
4) Kemp, A., et al.:Phys. Rev. E **79** (2009) 066406.