§20. Generation Control of Fast Electron Beam by Low-Density Foam for FIREX-I

Sakagami, H.,
Johzaki, T., Nagatomo, H., Mima, K. (Institute of Laser Engineering, Osaka Univ.)

The FIREX-I project is elaborated in response to a success of the previous experiments and it aims at demonstrating that the imploded core can be heated up to the ignition temperature, 5 keV. The heating laser in FIREX-I, which is called as LFEX, is designed to have the total energy of 10 kJ but to retain the same intensity in the previous experiments because a higher intensity laser generates faster electrons that cannot heat the core efficiently. So the pulse duration is set up to be 10 ps instead of 750 fs. The 10 ps pulse length is long enough even for heavy Au preformed plasma of the cone to be pushed and compressed by the ponderomotive force and the laser-plasma interaction is much affected by deformation of the preformed plasma. There have been, however, few researches using such a long pulse laser. Thus we have investigated fast ignition for 10 ps heating laser with the use of FI^3.[1)]

The core heating properties in the fast ignition are affected by the characteristics of the preformed plasma, which is generated by a pre-pulse of the heating laser. The pre-pulse is, however, nature of the laser device itself and is not easily controllable. To control the plasma density at the interaction region, we propose to coat an inner surface of the cone tip with low-density foam materials, such as aerogel. The plasma density of the low-density foam can be kept much lower than the solid density even it is fully ionized. Thus we can prevent the foam plasma from being snowplowed to extremely high density at the laser front, and expect that the fast electron beam intensity is kept at the high level during laser irradiation. We set up the LFEX laser to λ_L=1.06 μm, τ_{rise}=375 fs, τ_{flat}=10 ps, τ_{fall}=375 fs, $I_L=10^{20}$ W/cm^2, and the Au-cone tip to 500n_{cr}, real mass, Z=30 and 10 μm flattop plasma. We introduce the foam plasma (SiO_2 aerogel, A=20, Z=10, 40 μm thickness) with different densities (n_{foam}) in front of the Au cone tip plasma and the CD plasma (500n_{cr}, A=7, Z=3.5, 50 μm thickness) behind it. The fast electron beam is observed at the 10 μm rear point of the Au-CD boundary. Time evolutions of fast electron beam intensities for n_{foam}=2, 5, 10, 20, 30 and 50n_{cr} are shown in Fig.1. If the density of the foam plasma is below the relativistic critical density, namely 8.6n_{cr} for $I_L=10^{20}$ W/cm^2 (n_{foam}=2n_{cr} case), the heating laser can penetrate into the foam plasma, and it starts to directly interact with the extreme overdense Au plasma at 2 ps. After that, the fast electron beam intensity is quickly reduced and fast electrons cannot be generated so much. In the case of n_{foam}=5n_{cr}, the foam density is still relativistic underdense. The leading part of the heating laser is, however, relatively low intensity, with which the relativistic critical density is lower than 5n_{cr}, and the rising time of the heating laser is long enough to compress the foam plasma higher than 8.6n_{cr} before the laser reaches the peak intensity. So the laser cannot penetrate into the foam plasma. The fast electron beam intensity is sustained at the nearly peak level until 4, 5 and 7 ps with the cases of n_{foam} =5, 10 and 20n_{cr} because the electron density at the interaction region does not increase so much. After that time, the foam plasma is completely plunged into the Au plasma. Therefore the heating laser has to directly interact with the extreme overdense Au plasma as in n_{foam}=2n_{cr} case, and it results in reduction of the fast electron beam intensity. On the other hand, when the foam density is high enough (the case of n_{foam}=50n_{cr}), electrons in the foam plasma are snowplowed at the laser front to such density that the fast electron beam intensity can be substantially repressed at a low level. The beam intensity is dropping after 12 ps when the laser irradiation is turned off.[2)]

As the core heating is greatly affected by not only the beam intensity but also the energy spectrum of fast electrons, hence the foam density, we have performed FI^3 integrated simulations to estimate core temperatures, assuming the same core parameters as in Ref.3. Maximum core electron temperatures as a function of the foam density for different thicknesses are shown in Fig.2. Under these parameters, the averaged core electron temperature can reach 2.6 keV with 20n_{cr}, 60 μm thickness foam.

This work was supported by MEXT, Grant-in-Aid for Scientific Research (C)(19540528).

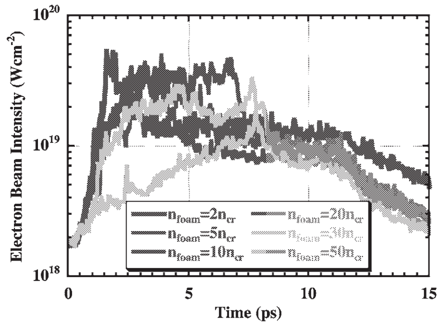

Fig.1. Time evolutions of fast electron beam intensity with the low-density foam.

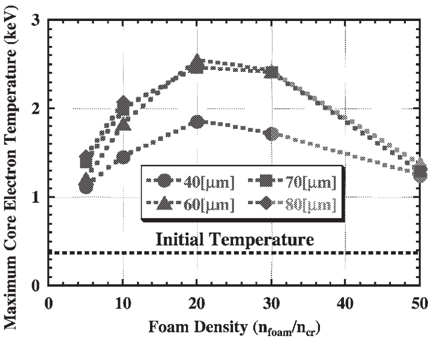

Fig.2. Maximum averaged core electron temperatures as a function of foam density.

1) Sakagami, H. et al., Laser Part. Beams **24** (2006) 191.
2) Sakagami, H. et al., to be published in Nuclear Fusion (2009).
3) Johzaki, T. et al., Laser Part. Beams **25** (2006) 621.