4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

Fast Isochoric Heating of Dense Plasma Core through multi-picosecond relativisitc laser-plasma interaction

S. Fujioka and FIREX Project
[1] Institute of Laser Engineering, Osaka University
sfujioka@ile.osaka-u.ac.jp

Fast isochoric heating of a pre-compressed fusion fuel core with a relativistic intensity short-pulse laser is an alternative path to create the inertial confinement fusion (ICF) ignition spark. This scheme avoids the ignition quench caused by the hot spark mixing with the surrounding cold fuel, which is the crucial problem of the currently pursued ignition scheme, namely the central ignition scheme. In the fast isochoric heating scheme, laser-produced relativistic electron beam (REB) deposits a part of REB kinetic energy in the core, and then the heated region becomes the hot spark to trigger the ignition.

However, there are two critical concerns in the scalability of this scheme to the fusion ignition [1]. One is that a small portion of the REB can collide with the fuel core after long travel of the REB from the generation zone to the core because of the inherent large angular spread of the REB. The other is inhabitation of production of relatively low energy REB (< 3 MeV) due to a hydrodynamic expansion of a bulk plasma during multi-pico-second laser-plasma interaction.

Recently, we have demonstrated significant enhancement of laser-to-core energy coupling with the magnetized fast isochoric heating [2]. The pressure of the heated plasma is close to 2.2 PPa [3] with The method employs several hundreds Tesla magnetic field that is applied to the transport region from the REB generation zone to the core. This results in guiding the REB along the magnetic field lines to the core [4]. The magnetic field was generated by using the laser-driven capacitor-coil scheme [5].

In addition to this, we found that the bulk electron density profile around the relativistic critical density surface expands by the pressure of the heated plasma and the lower temperature REs are produced in the steepened interaction zone [6]. This density steepening remains for multi-pico-second time scale, therefore, efficient production of the relatively low temperature REB can be sustained even with multi-pico-second heating laser. Further progress of the project based on these results will secure scalability of this scheme to the ignition.

[1] S. Fujioka, Y. Arikawa, S. Kojima, T. Johzaki, H. Nagatomo, H. Sawada, S. H. Lee, T. Shiroto, N. Ohnishi, A. Morace, X. Vaisseau, S. Sakata, Y. Abe, K. Matsuo, K. F. Farley Law, S. Tosaki, A. Yogo, K. Shigemori, Y. Hironaka, Z. Zhang, A. Sunahara, T. Ozaki, H. Sakagami, K. Mima, Y. Fujimoto, K. Yamanoi, T. Norimatsu, S. Tokita, Y. Nakata, J. Kawanaka, T. Jitsuno, N. Miyanaga, M. Nakai, H. Nishimura, H. Shiraga, K. Kondo, M. Bailly-Grandvaux, C. Bellei, J. J. Santos, and H. Azechi, Phys. Plasmas **23**, 056308 (2016).

[2] S. Sakata, S. Lee, T. Johzaki, H. Sawada, Y. Iwasa, H. Morita, K. Matsuo, K. F. F. Law, A. Yao, M. Hata, A. Sunahara, S. Kojima, Y. Abe, H. Kishimoto, A. Syuhada, T. Shiroto, A. Morace, A. Yogo, N. Iwata, M. Nakai, H. Sakagami, T. Ozaki, K. Yamanoi, T. Norimatsu, Y. Nakata, S. Tokita, N. Miyanaga, J. Kawanaka, H. Shiraga, K. Mima, H. Nishimura, M. Bailly-Grandvaux, J. J. J. J. Santos, H. Nagatomo, H. Azechi, R. Kodama, Y. Arikawa, Y. Sentoku, S. Fujioka, T. Johzaki, H. Sawada, Y. Iwasa, K. Matsuo, K. F. F. Law, A. Yao, M. Hata, A. Sunahara, S. Kojima, Y. Abe, H. Kishimoto, A. Syuhada, T. Shiroto, A. Morace, A. Yogo, N. Iwata, M. Nakai, H. Sakagami, T. Ozaki, K. Yamanoi, T. Norimatsu, Y. Nakata, S. Tokita, N. Miyanaga, J. Kawanaka, H. Shiraga, K. Mima, H. Nishimura, M. Bailly-Grandvaux, J. J. J. J. Santos, H. Nagatomo, H. Azechi, R. Kodama, Y. Arikawa, Y. Sentoku, and S. Fujioka, Nat. Commun. **9**, 1 (2018).

[3] K. Matsuo, N. Higashi, N. Iwata, S. Sakata, S. Lee, T. Johzaki, H. Sawada, Y. Iwasa, K. F. F. Law, H. Morita, Y. Ochiai, S. Kojima, Y. Abe, M. Hata, T. Sano, H. Nagatomo, A. Sunahara, A. Morace, A. Yogo, M. Nakai, H. Sakagami, T. Ozaki, K. Yamanoi, T. Norimatsu, Y. Nakata, S. Tokita, J. Kawanaka, H. Shiraga, K. Mima, H. Azechi, R. Kodama, Y. Arikawa, Y. Sentoku, and S. Fujioka, Phys. Rev. Lett. **124**, 035001 (2020).

[4] M. Bailly-Grandvaux, J. J. Santos, C. Bellei, P. Forestier-Colleoni, S. Fujioka, L. Giuffrida, J. J. Honrubia, D. Batani, R. Bouillaud, M. Chevrot, J. E. Cross, R. Crowston, S. Dorard, J.-L. Dubois, M. Ehret, G. Gregori, S. Hulin, S. Kojima, E. Loyez, J.-R. Marques, A. Morace, P. Nicolai, M. Roth, S. Sakata, G. Schaumann, F. Serres, J. Servel, V. T. Tikhonchuk, N. Woolsey, and Z. Zhang, ArXiv **35**, 1 (2016).

[5] S. Fujioka, Z. Zhang, K. Ishihara, K. Shigemori, Y. Hironaka, T. Johzaki, A. Sunahara, N. Yamamoto, H. Nakashima, T. Watanabe, H. Shiraga, H. Nishimura, and H. Azechi, Sci. Rep. **3**, 1170 (2013).

[6] S. Kojima, M. Hata, N. Iwata, Y. Arikawa, A. Morace, S. Sakata, S. Lee, K. Matsuo, K. F. F. Law, H. Morita, Y. Ochiai, A. Yogo, H. Nagatomo, T. Ozaki, T. Johzaki, A. Sunahara, H. Sakagami, Z. Zhang, S. Tosaki, Y. Abe, J. Kawanaka, S. Tokita, M. Nakai, H. Nishimura, H. Shiraga, H. Azechi, Y. Sentoku, and S. Fujioka, Commun. Phys. **2**, 99 (2019).