Novel Schemes of Laser-Ion Acceleration with Multi-Picosecond Pulses

A. Yogo, A. Morace, M. Hata, N. Iwata, Y Sentoku, S. Fujioka, Y. Arikawa, T. Johzaki[1], K. Mima[2], H. Nagatomo, H. Sakagami[3], T. Ozaki[3], S. Tokita, Y. Nakata, J. Kawanaka, N. Miyanaga, K. Yamanoi, T. Norimatsu, M. Murakami, M. Nakai, H. Shiraga, A. Sagisaka[4], K. Kondo[4], H. Azechi, R. Kodama, and H. Nishimura

Institute of Laser Engineering, Osaka University, Osaka, Japan

E-mail: yogo-a@ile.osaka-u.ac.jp

1) Graduate School of Engineering, Hiroshima University, Hiroshima, Japan

2) The Graduate School for the Creation of New Photon Industries, Shizuoka, Japan

3) National Institute for Fusion Science, National Institutes of Natural Sciences, Gifu, Japan

4) National Institutes for Quantum and Radiological Science and Technology, Kyoto, Japan

The laser-plasma interaction of multi-picosecond (ps) pulse [1-4] in the relativistic regime (>10^{18} Wcm^{-2} in the intensity) is an unexplored field, where the scaling of acceleration of both electrons and ions is completely different from the one studied a lot in sub-picosecond regime. Recently, utilizing multiple beams of ps pulses from LFEX laser [1], we find various new schemes of laser-driven ion acceleration. In this talk, we present the schemes, especially of (i) stochastic growth of electron temperature [5,6], (ii) enhanced absorption due to interference between multiple laser beams [7,8], and (iii) two-stage (accelerated at both front and rear surfaces) acceleration [9].

In the scheme (i), by extending the pulse duration from 1.5 to 3 ps with fixed laser intensity of 10^{18} Wcm^{-2}, the maximum proton energy was improved more than twice (from 13 to 29 MeV). This achievement is attributed to the nonlinear evolution of electron energy through the recirculation around the target plasma. In the scheme (ii), 50-MeV protons were achieved from a typical micron-thick aluminum target with 1×10^{19} Wcm^{-2} as total laser intensity of four bundled beams. This result is ascribed to the interference effects, which appear in multiple laser beams focused on the target with small angle each other. The modulated laser fields induce localized electric and magnetic fields also on the rear side, which make a beneficial effect for enhancing the ion energy owning to the high absorption efficiency due to the modulation. In the scheme (iii), a foil of deuterium substituted plastic was irradiated with the bundled 10^{19}-Wcm^{-2} beams, resulting in successful acceleration of deuterons with high conversion efficiency. Our simulation indicates that the deuterons kicked by the laser photon pressure [10] at the front side move to the rear side, and subsequently, they are promptly boosted by the sheath electric field sustained over picoseconds due to the pico-second laser irradiation.

The facts common to these three schemes are that the plasma expansion during the ps time scale can be assumed to be *one dimensional* in our experiments, where the laser focal spot is set to be large enough to make the beneficial effects on ion acceleration. Details will be discussed in the talk.

References

[1] Miyanaga N et al 2006 J. Phys. IV **133** 81.

[2] Crane J et al 2004 J. Phys. Conf. Ser. **244** 032003.

[3] Batani D et al 2014 Phys. Scr. **T161** 014016.

[4] Maywar D N et al 2008 J. Phys. Conf. Ser. **112** 032007

[5] Yogo A et al 2017 Sci. Rep.**7** 42451

[6] Iwata N et al 2017 *submitted to* Phys. Plasmas.

[7] Morace A et al *submitted to* IFSA2017.

[8] Yogo A et al *submitted to* NWP-2017, Russia.

[9] Yogo A et al OPIC2017, Yokohama.

[10] Sentoku Y et al 2003 Phys. Plasmas **10** 2009