Development of Micron-size Hydrogen Cluster Targets for Laser-Plasma Interactions

S. Jinno,[1] M. Kanasaki,[2] M. Uno,[2] R. Matsui,[3] M. Uesaka,[1] Y. Kishimoto,[3] and Y. Fukuda[4]

[1]*Nuclear Professional School, The University of Tokyo, 2-22 Shirakata Shirane, Tokai, Naka, Ibaraki 319-1188, Japan*
[2]*Graduate School of Maritime Sciences, Kobe University, 5-1-1 Fukaeminamimachi, Higashinada, Kobe, Hyogo 658-0022, Japan*
[3]*Graduate School of Energy Science, Kyoto University, Gokasho, Uji, Kyoto 611-0011, Japan*
[4]*Kansai Photon Science Institute (KPSI), National Institutes for Quantum and Radiological Science and Technology (QST), 8-1-7 Umemidai, Kizugawa, Kyoto 619-0215, Japan*
**jinno@nuclear.jp*

The recent advancements in laser-driven ion acceleration techniques using thin foil targets allow the maximum proton energies close to 100 MeV [1,2]. From a view point of practical applications, high-purity proton beams with high reproducibility are quite advantageous. In experiments using thin foil targets, however, protons from surface contaminants along with the high-z component materials are accelerated together, making the production of impurity-free proton beams unrealistic. Here we propose another way to produce impurity free, highly reproducible, and robust proton beams exceeding 100 MeV using Coulomb explosion of micron-size hydrogen clusters. For example, 100 MeV protons could be produced via the Coulomb explosion of the 1.2 m diameter hydrogen cluster when irradiated by a laser pulse with a peak intensity of 1.6×10^{21} W/cm^2.

In this study, the micron-size hydrogen clusters were generated by expanding the supercooled high-pressure hydrogen gas into a vacuum via a conical nozzle connected to a solenoid valve cooled by a cryogenic refrigerator. The size distribution of the hydrogen clusters is evaluated by measuring the angular distribution of laser light scattered from the cluster [3,4]. The data were analyzed based on Mie scattering theory combined with Tikhonov regularization method. The size distribution of the hydrogen clusters was found distributed from 0.3-2.0 m. The background gas density profile of the targets is also evaluated using a Nomarski interferometer assuming the cylindrical symmetry of the target.

The 3D Particles-in-Cell (PIC) simulations concerning interaction processes of micron-size hydrogen clusters with high power laser pulses predict the generation of protons exceeding 100 MeV, accelerated in a laser propagation direction via an anisotropic Coulomb explosion mechanism, demonstrating a future candidate in laser-driven proton sources with the upcoming multi-PW lasers [5].

References

[1] F. Wagner *et al*., Phys. Rev. Lett. **116**, 205002 (2016).
[2] I. J. Kim *et al*., Phys. Plasmas **23**, 070701 (2016).
[3] S. Jinno *et al*., Appl. Phys. Lett. **102**, 164103 (2013).
[4] S. Jinno, *et al*., Optics Express **21**, 20656 (2013).
[5] C. Danson *et al*., High Power Laser Science and Engineering **3**, e3 (2015).