Muti-MeV proton beams accelerated by Coulomb explosion of micron-size hydrogen clusters

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Laser-driven ion acceleration has been one of the most active areas of research over approximately the past decade, because accelerated multi-MeV ion beams have unique properties that can be employed in a broad range of applications. 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 introduce a micron-size hydrogen cluster (composed of $10^{8\text{-}10}$ hydrogen molecules) as a target to generate impurity-free, highly-reproducible, and robust multi-MeV proton beams [1]. Because of the recent progress in intense laser technology, the advanced PW class lasers can now achieve intense laser fields around 10^{22} W/cm^2; with such fields, all the electrons inside the micron-size hydrogen cluster can be fully stripped off, resulting in a pure Coulomb explosion with a pronounced increase in accelerated maximum proton energies

By using the micron-size hydrogen cluster target, we have conducted ion acceleration experiments with the 0.1 Hz PW class J-KAREN laser at QST-KPSI [3]. In order to characterize the accelerated ions, we used nuclear track detector plates (CR-39), nuclear emulsion plates, and a real-time Thomson parabola equipped with a micro-channel plate (MCP), a phosphor screen, and a CCD camera. We found that only protons having the maximum energy of ~12 MeV, consistent with the theoretical prediction, were accelerated at a laser focused intensity of 1×10^{20} W/cm^2. Based on the experimental results, the detailed ion acceleration mechanism by Coulomb explosion of clusters is discussed with the help from numerical simulations using a particle-in-cell (PIC) method.

[1] S. Jinno, Y. Fukuda *et al.*, Opt. Exp. **25**, 18774 (2017).