Laser-driven high-purity quasi-monoenergetic proton acceleration utilizing micron-scale hydrogen cluster targets

Yuji Fukuda - Kansai Photon Science Institute (Japan)

The recent advancements in both laser and target fabrication techniques have led to the enhancement of the accelerated proton cutoff energies close to 100 MeV/u.

The unique characteristics of ultrashort pulses and point sources possessed by laser-accelerated ions have potential applications for various research fields, such as proton radiography, fast ignition, nuclear science, heavy particle radiotherapy and radiation-induced processes in matter.

In laser-driven ion acceleration experiments, thin films with thicknesses from nanometers to micrometers have been widely utilized as targets for laser irradiation.

However, in such experiments, regardless of the target material, not only protons, but also other ion species, such as carbon and oxygen, all of which originate from surface contaminants of thin films, are accelerated together, making the production of high-purity proton beams unrealistic.

From the viewpoint of practical applications, impurity-free multi-MeV proton beams have a great advantage. Therefore, laser acceleration of protons with various types of hydrogen targets (high density hydrogen gases, solid hydrogen slabs, liquid hydrogen microjets etc.) has recently attracted much attention.

Here, we present a different approach using micron-scale hydrogen clusters with a spherical shape [12,3], which is an alternative to other types of hydrogen targets that allows very efficient coupling with laser pulses compared to planar-shaped targets, thus exhibiting prominent linear and nonlinear dynamics and associated optical properties.

Recently, we have presented a new scheme using prominent characteristics of cluster targets for achieving sub-GeV quasi-monoenergetic proton bunch acceleration with a low angular divergence by utilizing the internal degree of freedom (d.o.f.) [4]. In this scheme, the collisionless shock dynamics inside the micron-size cluster subsequently coupled with relativistically induced transparency (RIT) effect of high-intensity laser plays an important role. The external d.o.f. associated with the cluster expansion due to the sheath field is also incorporated. These multiple processes can be synchronized in a self-consistent manner once conditions for the laser and cluster are satisfied, leading to the quasi-monoenergetic proton bunch acceleration. Here the result of a proof-of-principle experiment for the quasi-monoenergetic proton bunch acceleration, via interaction of micron-scale hydrogen cluster targets with PW-class laser pulses conducted using the J-KAREN-P laser facility at KPSI-QST [5, 6], will be reported.

References: