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Enhancing Quasi-Monoenergetic Deuteron Acceleration via Boosted Coulomb Explosion by Reflected Picosecond Laser Pulse

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Laser-driven ion acceleration has attracted significant research interest due to its ability to generate high-flux pulsed ions. Applications such as compact neutron sources [1] have already been demonstrated. However, for further applications such as cancer therapy and nuclear physics studies, quasi-monoenergetic ions with controllable energy are highly desirable.

In this presentation, we report our recent works on producing quasi-monoenergetic deuterons using the petawatt LFEX laser. We developed a method to fabricate D_2O-deposited targets [2] inside the laser focal chamber using heavy water capsules. This method enables the deposition of a D_2O layer with a thickness of several tens of nanometers on a metal target. Using these targets, we achieved quasi-monoenergetic deuteron pulse ($\Delta E/E = 4.6\%$) via the Target Normal Sheath Acceleration (TNSA) mechanism, though the peak energy was limited to ~11 MeV. This limitation arises because protons play a significant role in shaping the quasi-monoenergetic component of the deuterons. To overcome this limitation, we have proposed an acceleration mechanism, boosted Coulomb explosion, initiated by a standing wave [3]. This standing wave is formed in a pre-expanded plasma by the interference of the incident main laser pulse and the pulse reflected from a solid target. The pre-expanded plasma is generated from a thin surface layer by a relatively strong pre-pulse. This mechanism creates a persistent Coulomb field on the front surface of the target with field strengths on the order of TV/m lasting several picoseconds. Using the D_2O-deposited targets [2], we successfully generated quasi-monoenergetic deuteron pulse with an energy of up to 50 MeV at the target front side. Furthermore, our results indicate that the deuteron peak energy can be tuned by adjusting the laser pulse duration.

A relatively long pulse duration and a relatively strong pre-pulse have important roles for generation of the standing wave in the present scheme. The boosted Coulomb explosion mechanism thus provides a tunable and efficient approach for generating quasi-monoenergetic ion beams using high-power laser systems. Additionally, ion species selection is feasible by depositing specific surface layers, e.g., T_2O layers for quasi-monoenergetic triton generation.

Ref.

[1] Zechen Lan, et al, Nat. Commun. 15, 5365 (2024)
[2] Tianyun Wei, et al, Phys. Plasmas 31, 073903 (2024)
[3] Tianyun Wei, et al, arXiv preprint arXiv:2504.19789 (2025).

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