7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

A multi-channel scintillation counter for GeV-scale multi-species ion spectroscopy in laser-driven particle acceleration experiments

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High-power lasers have shown their unique capability of producing ultrashort-pulsed beams of energetic ions with extremely high current densities, providing unprecedented opportunities for research in high energy density physics, nuclear astrophysics, and fusion science. The growing attention to laser-driven ion sources is also based on the rapid progress in attainable ion energy and repetition rate: from multi-MeV to GeV per nucleon and from mHz to the order of 10 Hz. Such improved beam performance makes lasers an interesting alternative to conventional large accelerators, but requires appropriate modifications to current diagnostic techniques.

Laser-driven ion beams are known to produce multiple ion species (H^+, C^{n+}, O^{n+} *etc.*) in picosecond bunch durations with broad spectra and energy-dependent divergence angles. Such complex ion properties cannot be fully characterized by conventional diagnostic techniques such as Thomson parabola spectrometer because of their poor spectral resolution and particle identification accuracy in the energy range above 100 MeV/nucleon. Therefore, we have developed a new diagnostic concept based on Particle Counting Analysis (PCA). The diagnosis uses scintillation detectors to provide a mass-dependent ion energy spectrum based on time-of-flight and pulse-height analysis of detected single particle events. With a novel arrangement of multiple scintillators with different ions stopping powers, PCA offers potential advantages over commonly used diagnostic instruments (CR-39, radiochromic films, Thomson parabola, etc.) in terms of spectral resolution in sub-GeV range, coverage solid angle, detection efficiency, and real-time analysis during the experiment. The basic detector unit was tested using 230-MeV proton beam from a synchrotron facility, where we demonstrated its potential ability to discriminate major ion species accelerated in laser–plasma experiments (i.e., protons, deuterons, carbon, and oxygen ions) with excellent energy and mass resolution. The proposed diagnostic concept would be essential for a better understanding of laser-driven near-relativistic ion acceleration [2–4], which paves the way toward all-optical compact accelerators for a range of applications.

References

[1] Y. Abe *et al*., Rev. Sci. Instrum. **93**. 063502 (2022)
[2] Y. Kurmaitsu *et al*., Sci. Rep. **12**, 2346 (2022)
[3] R. Matsui *et al*., Phys. Rev. Lett. **122**, 014804 (2019)
[4] S. Isayama *et al*., Phys. Plasmas **28**, 073101 (2021)