Mono-charge super-heavy ion beams accelerated by a multi-PW laser

J. Domański and J. Badziak

Institute of Plasma Physics and Laser Microfusion, Warsaw, Poland

Recent developments in short-pulse laser technology made it possible to generate femtosecond pulses with multi-PW power and the intensity of a focused laser beam of 10^{23} W/cm^2. Laser beams with such high powers and intensities can potentially accelerate ions to multi-GeV energies, including super-heavy ions with mass numbers $A \geq 200$ [1,2]. However, the laser-driven heavy ion beams demonstrated in both numerical simulations [1-3] and experiments [4,5] are multi-charge beams and contain a large number of ion species with different charge states and energy spectra. Such multi-charge ion beams suffer from a number of disadvantages that make their practical use difficult.

In this contribution, the acceleration of super-heavy ions from a 100-nm lead target irradiated by a femtosecond laser pulse with an intensity in the range of ~ 10^{22} - 10^{23} W/cm^2 was investigated using an advanced 2D3V particle-in-cell code. It was found that by properly selecting the laser pulse parameters, it is possible to produce a practically mono-charge Pb ion beam with multi-GeV ion energies and the laser-to-ions energy conversion efficiency approaching 30%. At the laser intensity of 10^{23} W/cm^2, Pb ions with the charge state Z = 72 carry over 90% of the total energy of all ions, while the peak intensity and peak fluence of the Pb^{+72} ion beam are at least two orders of magnitude higher than for other types of ions. Moreover, the Pb^{+72} ion beam is more compact and has a smaller angular divergence than those for other types of ions. The intensity of the beam is much higher and its duration is much shorter than that achieved in conventional accelerators.

The unique properties of mono-charge super-heavy ion beams demonstrated in our work, create a prospect for the application of these beams in high energy-density physics and in new areas of nuclear physics as well as in accelerator technology as an intense ion source for large RF-driven heavy ion accelerators.

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