Laser-Driven MeV Argon Ion Beam Generation with Narrow Energy Spread

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Abstract: Here we report a highly collimated, narrow-energy-spread argon(Ar^{16+}) ion beam with minimum absolute energy spread of 0.19 MeV/u, is experimentally produced by a 45fs ultra-intense laser pulse interacting with clustering argon gas target. A novel mechanism proposed based on PIC simulation well explains the experimental observation and gives an energy scaling to GeV for argon ion beam.

Laser driven particle acceleration shows a remarkable progress in generating multi-GeV electron bunches and 10's of MeV ion beams based on ultra-short super-intense laser facility. High-energy laser pulse offers acceleration field of TV/m, several orders of magnitude higher than that in conventional accelerators, enabling compact devices. Here we report on an experimental result that a highly collimated argon ion beam (Ar^{16+}) with narrow energy spread has been produced by a 45fs ultra-intense laser pulse interacting with a clustering argon gas target. The observed argon ion beams have a minimum absolute energy spread of 0.19 MeV per nucleon [1]. The generated ion beam offers a high-quality injector for conventional ion accelerators.

We identify a novel scheme of the high-quality ion beam generation, based on two-dimensional particle-in-cell (PIC) simulations. High-energy argon ion beam with narrow energy spread was also observed. It is found that there are two distinct stages for in the argon ion acceleration process, i.e. Coulomb explosion and ion spectrum modulation. In the first stage, the intense laser field induces Coulomb explosion of the argon clusters in its focus volume, and the ions get energy gain mainly from the cluster explosion and have a flat continuous spectrum. In the second stage, the laser wakefield modulates the ion spectrum and significantly reduces the energy spread. The proposed mechanism well explains our experimental observation and gives an energy scaling up to GeV for high- quality argon ions.

Based on this novel regime, laser-cluster interaction has an ability to provide ions of more species including Xe, Kr, C, O, N, and so on, from noble-gas cluster as well as molecules cluster. Moreover, the cluster-gas target is able to work on a high repetition rate. Since the 10Hz PW laser facility is in progress, the reproducible high-quality ion source will become more feasible for many applications in near future, including medical therapy, fusion targets diagnostics, nuclear physics, and injector of ion accelerators.

References

[1] Jiancai Xu et al., Laser-driven MeV argon ion beam generation with narrow energy spread.