CD-P1 AAPPS-DPP2019

3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Modulation of ion beams in two-component plasmas: Three-dimensional particle-in-cell simulation

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Ion beam pulses are commonly used in a variety of research fields, such as ion-driven inertial fusion and warm-dense matter research. Usually, the ion beam needs to be focused before it is delivered to the target. Plasmas can be provided as an effective medium for the transport and focusing of intense charged particle beams, due to the effective neutralization of beam space charge by plasma electrons. At the same time, beam-plasma instabilities have important impacts on the beam transport. For non-relativistic low energy ion beams, longitudinal modulation effect driven by the two-stream instability[1,2] is the main aspect.

We have developed a three-dimensional electrostatic particle-in-cell code BPVLAB (Beam and Plasmas Physics Virtual Lab) to investigate the wakefield induced by low energy proton beam in two-component plasmas.

Before entering the plasma, the energy spectrum of cold beam ions can be described as δ-function. Under the effect of self-modulation, energy spectrum evolved into two peaks. It is found that after the well known self-modulation effect, a secondary self-modulation occurs, leading to a trimodal energy spectrum of the ion beam (Figure 1). This evolution can also be clearly observed in the phase space distributions shown in Figure 2. At the initial stage of the two-stream instability, the narrow banded phase space distribution of the ion beam splits into two branches---a higher energy branch and a lower one. As the travel distance increases, the lower branch similarly splits into two branches with different energies. At the same time, the higher one does not split and the spectrum pattern thus evolves into trimodal distribution. We call this the “secondary self-modulation” of the ion beam. The branch with the lowest energy continue to split in the phase space, which we call the “multiple self-modulation” of the ion beam.

The form of the wakefield induced by two counter-propagation ion beams is verified. It is observed that the wakefield in the form of standing wave would grow up.

This work was supported by the National Natural Science Foundation of China (Project Nos. 11775042 and U1532263) and the Fundamental Research Funds for the Central Universities No. DUT17LK12.

References

[1]R. N. Sudan, Phys. Rev. Lett. 37, 1613 (1976).
[2]T. C. Genoni, D. V. Rose, D. R. Welch, and E. P. Lee, Physics of Plasmas 11, L73 (2004)

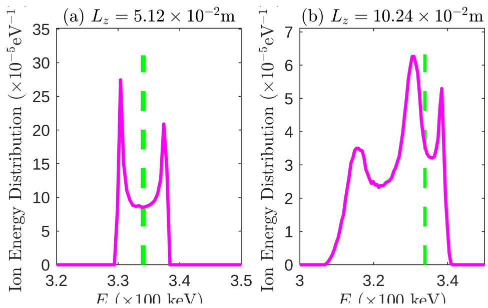

Figure 1: Energy spectrum of beam ions absorbed by the right boundary. Time period is 13.80 to 18.82×2πω_{pe} after their heads reach the right boundaries, and boxes size are (a) 64×64×512, (b) 64×64×1024 cells. Green dashed line marks the initial energy of beam ions.

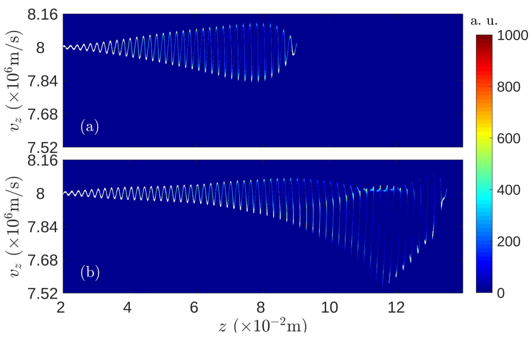

Figure 2: Secondary self-modulation. (z,v_z) phase space distributions of beam ions at the time (a) $\omega_{pe}t/2\pi \approx 45.17$ and (b) $\omega_{pe}t/2\pi \approx 67.76$. The lower energy branch splits into two branches as indicated in Figure (b).