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1D PIC Simulation of Cold Plasma Electrostatic Waves beyond Wave-Breaking Limit

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Abstract : Electrostatic Waves in plasma have emerged as a new source for the acceleration of charged particles. The accelerated particles have a wide range of applications, for example in cancer therapy to cutting and melting of hard materials. The maximum acceleration can only be achieved when the amplitude of the plasma wave stays below a critical limit known as wave-breaking amplitude. Beyond this limit amplitude of the wave diminishes dramatically as the coherent energy of the wave starts to convert into random kinetic energy. In this work, spatiotemporal evolution of non-relativistic electrostatic waves in a cold plasma has been studied in the wave-breaking regime using a 1D particle-in-cell simulation (PIC). It is found that plasma gets heated after the wave-breaking but a fraction of initial energy always remains with the remnant wave in the form of Bernstein-Greene-Kruskal (BGK) mode in warm plasma. Another interesting finding of this work is that the frequency of the resultant BGK wave is found be below electron plasma frequency which decreases with increasing initial amplitude and the acceleration mechanism after the wave-breaking is also found to be different from the previous work. In order to explain the results observed in the numerical experiments, a simplified theoretical model is constructed which exhibits a good agreement with the simulation. In conclusion, it is shown in this work that electrostatic waves get shower after the wave-breaking and a fraction of initial coherent energy always remains with remnant wave. These investigations have direct relevance in wakefield acceleration experiments.

Keywords : nonlinear plasma waves, longitudinal, wave-breaking, wake-field acceleration
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