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Effect of transverse beam size on the wakefields and driver beam dynamics in plasma wakefield acceleration scheme

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Plasma wakefield acceleration (PWFA) is a technique of accelerating charge particles to high energy using a relativistic electron beam in a plasma. The charge particles get accelerated using the electric field (wakefield) associated with the plasma waves excited by the electron beam propagating inside the plasma. The efficiency of the acceleration highly depends on the nature of the wakefields and beam-plasma parameters.

To elucidate the effect of transverse beam size and driver beam dynamics on the excitation of wakefields, we present here an extensive study on the relativistic electron beam driven wakefield in a cold plasma over a wide range of beam-plasma parameters using 2D fluid simulation techniques. It has been shown that in the limit when the transverse size of a rigid beam is greater than the longitudinal extension, the wake wave acquires a purely electrostatic form, and the simulation results show a good agreement with the 1D results given by Bera *et al.* [Phys. Plasmas **22**, 073109 (2015)]. In the other limit when the transverse dimensions are equal to or smaller than the longitudinal extension, the wake waves are electromagnetic in nature, and 2D effects play a crucial role. Furthermore, a linear theoretical analysis of 2D wakefields for a rigid bi-parabolic beam has also been carried out and compared with the simulations. It has also been shown that the transformer ratio, which is a key parameter that measures the efficiency in the process of acceleration, becomes higher for a 2D system (i.e., for a beam having a smaller transverse extension compared to the longitudinal length) than the 1D system (i.e., for a beam having a larger transverse extension compared to the longitudinal length). Furthermore, including the self-consistent evolution of the driver beam in the simulation, we have seen that the beam propagating inside the plasma undergoes transverse pinching, which occurs much earlier than the longitudinal modification. Due to the presence of transverse dimensions in the system, the 1D rigidity limit given by Tsiklauri [Phys. Plasmas **25**, 032114 (2018)] gets modified. We have also demonstrated the modified rigidity limit for the driver beam in a 2D beam–plasma system. The simulations results obtained from fluid simulation have also been verified using particle-in-cell (PIC) simulation results.

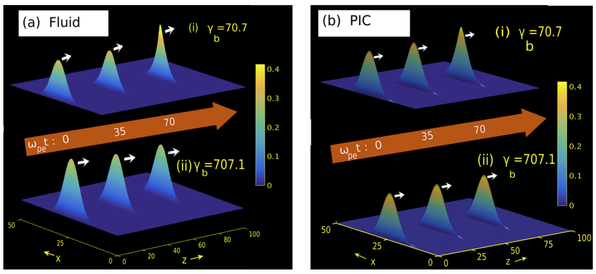

Fig.1: Plot of driver beam density profile inside a plasma for different beam energy at different times using (a) Fluid simulation (b) PIC simulation.

References

1. Bera et al., Physics of Plasmas, 22 073109 (2015)
2. Bera et al., Physics of Plasmas, 23, 083113 (2016)
3. Tsiklauri et al., Phys. Plasmas **25**, 032114 (2018)