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Editorial: Wakefield generation and particle acceleration in high-intensity laser plasma and beam-plasma interactions

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Editorial on the Research Topic
Wakefield generation and particle acceleration in high-intensity laser plasma and beam-plasma interactions

Introduction

The plasma based particle acceleration mechanism has been recognized as one of the most promising alternative acceleration schemes in recent years. In particular, hot topics have included the laser wakefield acceleration scheme, which uses a wave electric field whose strength is associated with the plasma density, and the direct laser acceleration scheme, which relies on the laser field intensity for energy transfer inside the plasma, as well as particle acceleration by beam plasma interactions, owing to their potential applications in laboratory and astrophysical plasmas. Furthermore, depending on the laser pulse size compared to the typical plasma skin depth, both the wakefield generation and soliton formation are possible in plasmas. This Research Topic presents recent developments on the particle acceleration mechanism as well as the propagation characteristics of solitons and their interactions in laser-and-beam-driven multi-component plasmas. The Research Topic includes four research articles, two examining particle accelerations in plasmas using twisted laser beams and the formation of electromagnetic solitons and their stability in high-density degenerate plasmas and their applications. Two research articles present studies on the propagation characteristics of electron-acoustic waves in unmagnetized plasmas and the dusty-plasma response in the presence of the polarization force.

Particle acceleration using twisted laser beams

After the advent of high-power lasers, the laser-plasma-based acceleration of electrons and ions has received widespread research attention around the globe. The laser-wakefield acceleration scheme has been instrumental for the acceleration of electrons. Several Petawatt (PW) laser schemes are operational worldwide with more to come in the near future [1]. New optical schemes have been concomitantly developed, e.g., circularly polarized helical laser beams [2]. The key advantage of using the helical or twisted or Laguerre–Gaussian (LG) laser beam is that it can be generated using a conventional Gaussian laser pulse in reflection from a spiral-shaped foil plasma or light fan carrying significant orbital angular momentum [3].

The article by [4] proposes three different wakefield configurations using twisted LG laser modes, which are shown to be described by similar expressions for the density perturbations and the wave electric field. In the weakly relativistic case of using a single LG laser mode, an explicit solution of the donut wakefield is obtained. In this study, they use two LG laser modes to obtain helical wakes associated with light-spring laser beams, which can be seen as a beat-wave acceleration scheme. Furthermore, a new configuration is proposed with the superposition of two distinct LG laser modes to exhibit a transition from donut shaped to moon-shaped wakefield (self-torque wake). The latter is shown to produce azimuthal acceleration and hence represents an alternative mechanism for producing helical electron beams. The detailed particle-in-cell (PIC) simulations confirm the findings of the self-torque laser wakefield acceleration and the generation of a quasi-helical electron beam.

Soliton formation

It has been investigated that besides laser-driven plasma wakefield accelerations, where electrons get excited when providing strong longitudinal coherent electric fields (i.e., wakes) with relativistic phase speed, the formation of solitons may become more prominent when the laser pulse size is larger than the typical plasma skin depth. In this context, the plasma number density may play a key role in the transition from wakefield generation to soliton formation [5]. This theory has been recently advanced in relativistic non-degenerate [5] and degenerate [6] plasmas. Such electromagnetic (EM) envelope solitons are typically high-frequency modulated (by low-frequency plasma density perturbations) laser pulses that propagate without diffraction. They have potential applications in laser fusion and particle accelerations. [7] studied the evolution of EM solitons in the non-linear interaction of circularly polarized intense EM waves with low-frequency electron-acoustic perturbations that are driven by the EM wave ponderomotive force in relativistic degenerate dense plasmas. They also studied the existence domains of EM solitons and their stability in the parameter space of soliton velocity and eigenfrequency. It has been shown that solitons in the instability domain may collapse due to the dominant effects of the non-local nonlinearity over the cubic non-linearity. The results were predicted to be useful for compact astrophysical objects like white dwarfs and neutron stars as they emanate EM radiation spectra in a wide frequency range (ranging from radio to γ-rays) and their interactions with high-density degenerate plasmas may initiate the formation of EM solitons as localized bursts of x-rays and γ-rays.

Author contributions

AM summarized the investigations and wrote the original draft. AH edited the manuscript and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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