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Study of laser plasma instabilities on their suppression and simulation methods

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Laser plasma instabilities (LPIs) are one of the most critical and fundamental problems to be mitigated to achieve inertial confinement fusion ignition. LPIs not only scatter away a considerable proportion of the laser energy out of the fusion pellet, but also produce harmful hot electrons that affect its compression and implosion efficiency. In this study, we propose a new strategy to suppress LPIs by sunlight-like lasers[1], which can be generated by coupling two broadband laser beams with different random phase-frequency spectra and orthogonal polarizations, as shown in Fig. (1). Particle-in-cell (PIC) simulations are carried out to verify the suppression of LPIs by sunlight-like lasers. It is found the sunlight-like lasers have much stronger suppression effects on LPIs than the broadband lasers under same bandwidths. Namely, the application of sunlight-like lasers in the ICF experiments may greatly reduce the requirement of bandwidth of broadband lasers for the suppression of LPIs.

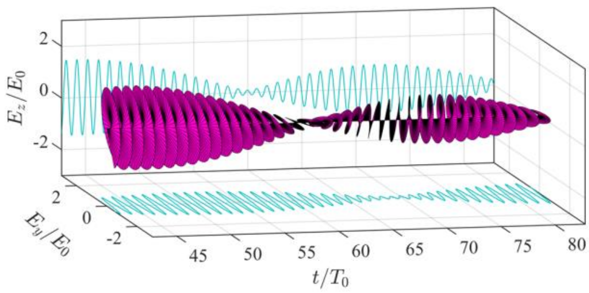

Figure 1: A sunlight-like laser can be obtained by combining two broadband laser beams with different phase spectra or amplitude frequency spectrum vertically. Here two green lines show the electric fields of two independent broadband lasers for constructing a sunlight-like laser, and the purple surface is the electric field of sunlight-like laser.

Besides of the suppression of LPIs, numerical simulation of LPIs also poses a big challenge. Generally, the simulation of LPIs may be carried out either by kinetic codes or fluid codes. The kinetic codes, i.e., PIC codes or Vlasov codes, can give a detailed description of LPIs at the expense of huge simulation costs, which makes it hard to simulate the LPIs under large scale and long-time conditions. The fluid codes, either based on the enveloped three wave coupled equations or Zakharov equations have much lower simulation costs and faster calculation speeds. However, the fluid codes ignore a series of nonlinear effects of LPIs and are unable to describe the kinetic effects self-consistently. In this study, we firstly establish a set of full-wave fluid equations including both SRS and SBS instabilities. The physical model is then solved by particle-mesh method and a one-dimensional PM1D code is finally developed [2,3]. The benchmark of the PM1D code can be found in Fig. (2). Compared with the PIC codes, our PM1D code has a much faster calculation speed while keep the kinetic effects as well. Comparing with the fluid codes, our PM1D code can give a more detailed description of LPIs.

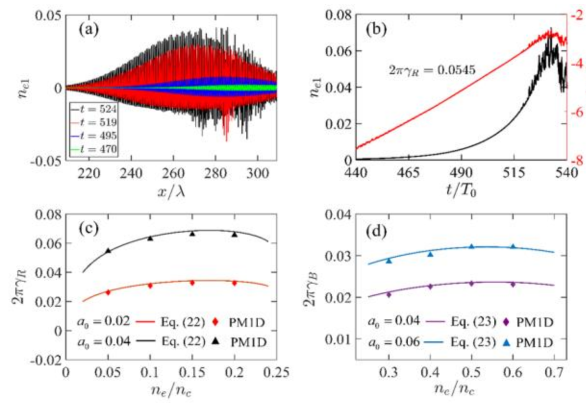

Figure 2: The benchmark of the PM1D code, where the growth-rate of SRS and SBS between the numerical results (shown in solid lines) and theoretical results (shown in discrete points) are compared, a good agreement can be found.

References

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