5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

Control of parametric instabilities in plasma with broadband lasers

Z. M. Sheng[1,2], S. M. Weng[1], Y. Zhao[3], H. H. Ma[1], X. F. Li[1], S. H. Yew[1], M. Chen[1], J. Zhang[1,4]
[1] Laboratory for Laser Plasmas and School of Physics and Astronomy, Shanghai Jiao Tong University, [2] Department of Physics, University of Strathclyde, [3] Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, [4] Institute of Physics, Chinese Academy of Sciences
e-mail (Z. M. Sheng): zmsheng@sjtu.edu.cn

The development of parametric instabilities such as stimulated Raman scattering (SRS), stimulated Brillouin scattering (SBS), and two-plasmon decay (TPD) is a great concern for the realization of inertial confined fusion ignition [1,2]. Many ideas and techniques to mitigate these instabilities have been proposed in the last decades via spatial and temporal smoothing techniques [3-6], such as random phase plates, induced spatial incoherence, and smoothing by spectral dispersion, etc. Even though these smoothing techniques can considerably reduce the level of the parametric instabilities, but they are not sufficient for applications in ICF. The spectral widths for these techniques studied so far are limited to less than 0.1%. In this talk, we present our recent studies on the control of parametric instabilities by use of broadband lasers with spectral width over 1%.

Early studies suggest that finite laser bandwidths can reduce the linear growth rate of SRS as long as the bandwidth is larger than the growth rate [7]. Particle-in-cell simulations show that the laser bandwidths cannot reduce the saturation level of SRS even though the linear growth rate is reduced [8,9]. We re-investigate the physical mechanism of SRS suppression with broadband lasers and propose the concept of decoupled broadband lasers (DBLs), which can effectively reduce the saturation level of SRS and SBS [10]. A DBL is composed of many laser beamlets, where the frequency difference between two neighboring beamlets is large enough so that their coupling disappears. It is shown that SRS can be almost completely suppressed with DBLs at the laser intensity of 10^{15} W/cm^2 with the total bandwidth of a few percentage. With DBLs, the suppression of parametric instabilities is also achieved in inhomogeneous plasma and in the multi-beam interaction geometry [11,12]. In addition to the suppression of SRS and SBS, TPD can also be effectively suppressed with DBLs.

We further propose the concept of sunlight-like lasers, which have a continuous broad frequency spectrum, random phase spectrum, and random polarization. With a sunlight-like laser beam consisting of a sequence of temporal speckles, the resonant three-wave coupling that underlies parametric instabilities in laser-plasma interactions can be greatly degraded due to the limited duration of each speckle and the frequency shift between two adjacent speckles. The wave coupling can be further weakened by the random polarization of such beams [13,14].

References

[1] P. K. Kaw, Rev. Mod. Plasma Phys. 1, 2 (2017)
[2] D. S. Montgomery, Phys. Plasmas 23, 055601 (2016).
[3] Y. Kato et al., Phys. Rev. Lett. 53, 1057 (1984).
[4] S. P. Obenschain et al., Phys. Rev. Lett. 62, 768 (1989).
[5] S. Skupsky et al., J. Appl. Phys. 66, 3456 (1989).
[6] W. Seka et al., Phys. Fluids B 4, 2232 (1992).
[7] J. J. Thomson and J. I. Karush, Phys. Fluids 17, 1608 (1974)
[8] Y. Zhao et al., Phys. Plasmas 22, 052119 (2015).
[9] Y. Zhao et al., Matter Radiat. Extrem. 2, 190 (2017).
[10] Y. Zhao et al., Phys. Plasmas 24, 112102 (2017).
[11] Y. Zhao et al., Plasma Phys. Control. Fusion 61, 115008 (2019)
[12] Y. Zhao et al., Plasma Phys. Control. Fusion 63, 055006 (2021).
[13] H. H. Ma et al., submitted to Matter Radiat. Extrem. (2021).
[14] H. H. Ma et al., Plasma Phys. Control. Fusion 63, 095005 (2021).

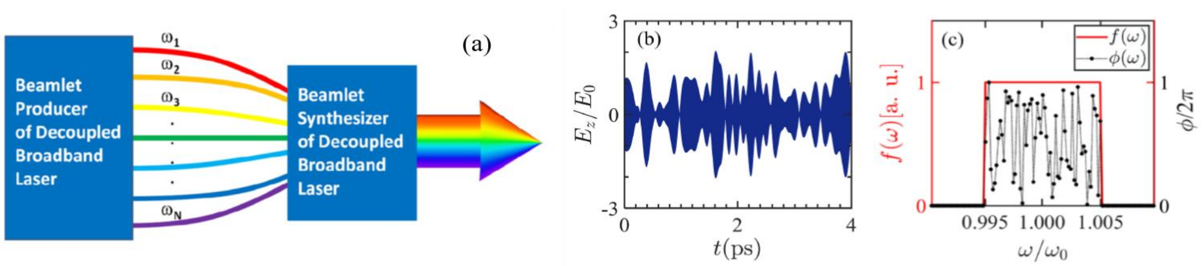

Figure 1. (a) The concept of decoupled broadband lasers, which are composed of many beamlets with slightly different frequencies. (b) Typical temporal file and (c) frequency and phase spectra of a sunlight-like laser.