Broadband mitigation of laser-plasma instabilities for inertial confinement fusion

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Laser-plasma instabilities, such as cross beam energy transfer (CBET), stimulated Raman scattering (SRS), and two-plasmon decay (TPD), present a major challenge for laser-driven inertial confinement fusion (ICF). The plasma waves driven in these instabilities inhibit the compression of the fusion capsule, and ultimately the gain, by scattering light into unwanted directions and accelerating hot electrons that preheat the fuel. Attempts at mitigating these instabilities have primarily focused on modifying the implosion design to limit the instability growth rate [1]. This approach, however, severely restricts the ICF design space. The introduction of temporal incoherence in the drive lasers offers a path towards mitigation without sacrificing hydrodynamic efficiency in the implosion design. Through the use of three-dimensional laser-plasma interactions simulations, we show that two forms of temporal incoherence—frequency detuning and laser bandwidth—can suppress SRS and TPD. The simulations were conducted with LPSE (Laser Plasma Simulation Environment), which provides a unique capability to model the dynamic evolution of parametric instabilities at the long scale lengths and with the complex, multiple beam geometries characteristic of ICF facilities. The viability of each form of temporal incoherence, both in terms of instability suppression and practical implementation, is considered. For instance, a three-wavelength scheme, with the detuning available on current laser architectures, has been found to nearly eliminate TPD and the associated hot electrons [2]. Similarly, continuous laser bandwidths have been shown to suppress CBET and greatly increase the laser intensity threshold for the absolute TPD and SRS instabilities [3]. A next generation ICF driver capable of suppressing CBET, SRS, and TPD with temporal incoherence will allow for higher laser intensities and ablation pressures, greatly expanding the ICF design space.

[1] "Two-plasmon Decay Mitigation in Direct-Drive Inertial Confinement Fusion Experiments Using Mid-Z Layer Targets," R. K. Follett, J. A. Delettrez, D. H. Edgell, V. N. Goncharov, R. J. Henchen, J. Katz, J. F. Myatt, J. Shaw, and D. H. Froula, Phys. Rev. Lett. **116**, 15502 (2016).

[2] "Suppressing Two-Plasmon Decay with Laser Frequency Detuning," R. K. Follett, J. G. Shaw, J. F. Myatt, J. P. Palastro, R. W. Short, D. H. Froula, Phys. Rev. Lett. **120**, 135005 (2018).

[3] "Thresholds of absolute instabilities driven by a broadband laser," R.K. Follett, J.G. Shaw, J.F. Myatt, C. Dorrer, D.H. Froula, and J.P. Palastro, Phys. Plasmas **26**, 062111 (2019).