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Recent developments in laser plasma interactions

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Parametric instabilities play a major role in laser fusion and in plasma amplification and energy transfer of laser beams. In laser fusion parametric instabilities can scatter considerable amounts of laser energy reducing the coupling efficiency [1-4]. The standard approach to study parametric instabilities is based on a coherent wave description which is limited because, in most cases the waves are only partially coherent, with incoherence either inherently induced by fluctuations or induced by external passive systems such as phase plates in inertial confinement fusion. A generalised Wigner-Moyal theory of radiation is used to obtain general dispersion relations for parametric instabilities such as Stimulated Raman and Brillouin scattering. The use of the Wigner-Moyal statistical theory has proven to be quite powerful in studying these kind of instabilities, with some of the most important developments using this technique carried out in nonlinear optics. With the derivation of a statistical description of a partially incoherent electromagnetic wave propagating in a nonlinear medium [5], it became clear that a stabilization of the modulational instability is possible as a result of an effect similar to Landau damping, and caused by random phase fluctuations of the propagating wave, which is equivalent to the broadening of the Wigner spectrum. The statistical description of light achieved through the Wigner-Moyal formalism of quantum mechanics, provides, in its original formulation, a one-mode description of systems ruled by Schrödinger-like equations. In order to address other processes apart from the direct forward scattering, a generalization of Photon Kinetics theory (GPK) was recently developed [6,7]. This new formulation is completely equivalent to the full Klein Gordon equation for propagation of light in plasmas, and was readily employed to derive a general dispersion relation for stimulated Raman scattering driven by white light [6]. These results leveraged on previous developments that have considered the Wigner-Moyal description in plasma physics [8] as a way to represent laser propagation. We focus on white light parametric instabilities that are critical in ICF both direct and indirect, and several applications in laser-plasma and astrophysical scenarios demand a detailed analysis of the backscattered radiation. We show that the monochromatic limit is recovered from the general results, reproducing the classic monochromatic dispersion relation. The results show that the effect of incoherent waves reduces the growth rates on the three wave parametric instabilities for typical NIF parameters but is less effective in controlling filamentation and modulational instabilities. Cross beam energy transfer or CBET [9] is also described and shown to have interesting consequences in the non-linear regime.

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