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Stimulated scattering in relativistic plasmas

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The nonlinear self-interactions of finite amplitude intense electromagnetic waves (EMWs) and relativistic plasmas have received significant research attention in recent years [1-6], because of their relevance in plasma heating, e.g., in inertial fusion plasmas, as well as for plasma diagnostics, e.g., in solid density plasmas that are created by intense laser and charged particle beams. Furthermore, laser-plasma interaction provides a rich source of nonlinear phenomena including the formation of coherent structures [3] as localized bursts of x rays and gamma rays from compact astrophysical objects, fast ignition, particle acceleration, generation of different kinds of waves and instabilities [1,2,4]. So, under certain conditions, the collective parametric effects such as stimulated Raman and Brillouin scattering instabilities and localization of high-frequency (hf) EMWs could have a definite signature on the radiation spectra (ranging from radio to gamma rays) of astrophysical objects [2].

On the other hand, for high-density plasmas, such as those in the interior of white dwarfs, neutron stars, and also at the source of gamma-ray bursts, the relevant plasmas are relativistically degenerate and thus obey the Fermi-Dirac statistics [7].

In this talk, we present a theoretical study on the stimulated scattering instabilities of intense linearly polarized EMWs in a relativistic plasma with degenerate electrons and adiabatic thermal ions. Starting from a set of relativistic hydrodynamic equations and the Maxwell's equations, we derive a coupled nonlinear equations for the EMW field and low-frequency electron and ion plasma oscillations that are driven by the EMW's ponderomotive force. The nonlinear dispersion relations are then obtained from these coupled equations that reveal stimulated Raman scattering (SRS), stimulated Brillouin scattering (SBS), and modulational instabilities (MIs) of EMWs. It is shown that the thermal pressure of ions and the relativistic degenerate pressure of electrons significantly modify the characteristics of SRS, SBS, and MIs.

The results of stimulated scattering instabilities as well as the modulational instability of intense EMWs in a relativistic degenerate plasma are highly pertinent for understanding the salient features of enhanced density fluctuations and the dynamics of X-ray pulses that may emanate from compact astrophysical objects. The results can also be useful in the next-generation highly intense laser produced solid density compressed plasma experiments.

References

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