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Nonlinear backward Raman scattering in the short laser pulse interaction with a cold underdense transversely magnetized plasma

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Abstract

Raman backward scattering is investigated in the interaction of linearly polarized ultra short laser pulse with a homogenous cold underdense magnetized plasma by taking into account the relativistic effect and the effect of nonlinearity up to third order. The plasma is embedded in a uniform magnetic field perpendicular to both of propagation direction and electric vector of the radiation field. Nonlinear wave equation is set up and differential equations, which model the instability, are derived. Using of the Fourier transformation, analytical solutions are obtained for a set of physically relevant initial conditions and the temporal growth rate of instability is calculated. Results are significantly different in comparison with lower order computations. The growth rate of backward Raman scattering shows an increase due to the presence of external magnetic field as well as nonlinear effects.

Keywords: Growth rat; Magnetized plasma; Nonlinear effect; Ponderomotive force; Raman backward scattering; Relativistic effect; Underdense plasma; Wakefield

1. INTRODUCTION

The nonlinear interaction of short-pulse high-intensity lasers with plasmas has been a subject of experimental and theoretical study due to its relevance to laser driven fusion and laser wakefield accelerators (Esarey *et al.*, 1996). There are many different kinds of studies about the use of intense laser pulse or electron beam to excite large amplitude plasma wakes (Matlis *et al.*, 2006). Large amplitude waves is a great source of energy in a multi-mode media such as plasma. The energy of these wakes can be used for different purposes as an example of inertial confinement fusion (ICF), particle acceleration or radiation (Sawan *et al.*, 2008; Barbiellini *et al.*, 2008; Dorranian *et al.*, 2005, 2004, 2003). An interesting physical phenomena in laser plasma experiments is stimulated Raman scattering (SRS), where the incident laser light resonantly couples with an electron plasma wave, and a scattered light wave (Kline *et al.*, 2009). From one point of view, SRS is a physical process that decreases the efficiency in ICF or particle acceleration experiments. From another point of view, Raman scattering such as harmonic generation or photon acceleration is a kind of coherent radiation mechanism of plasma, which can be used as a diagnostic tool in the laser and plasma interaction experiments (Kim *et al.*, 2003; Purohit *et al.*, 2010). This possibility rise from the multi-mode nature of plasma and shows that plasma is a capable medium for converting the different initial energies into coherent radiation. Traditionally, the first view about the SRS has attracted more attention since in this case SRS can waste a large part of input energy and stop the experiment as an instability.

SRS is usually described as the decay of an incident electromagnetic pump wave into a longitudinal electrostatic plasma wave plus another scattered light wave with a downshifted/upshifted frequency (Stokes/Anti-Stokes). Scattered wave may propagate in the forward direction as same as the pump wave direction or backward direction that is in the opposite direction of propagation of the pump wave, which are known as Raman forward scattering (RFS) and Raman backward scattering (RBS), respectively. The conservation of energy and momentum in this decay is signified by the frequency and wave vector matching conditions $\omega_0 = \omega_1 \pm \omega_p$ and $\mathbf{k}_0 = \mathbf{k}_1 \pm \mathbf{k}_p$, in which $(\omega_0, \mathbf{k}_0)$, $(\omega_1, \mathbf{k}_1)$, and $(\omega_p, \mathbf{k}_p)$ describe the frequency and wave vector of pump beam,

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