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Brillouin-shifted third-harmonic backscattering of laser in a magnetized plasma

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Abstract

Third-harmonic Brillouin backscattering (3HBBS) instability is investigated in the interaction of a picosecond extraordinary laser pulse with a homogeneous transversely magnetized underdense plasma. Nonlinear coupled equations that describe the instability are derived and solved for a weakly coupled regime to find the maximum growth rate. The nonlinearity arises through the combined effect of relativistic mass increase, static magnetic field, and ponderomotive acceleration of plasma electrons. The growth rate is found to decrease as the static magnetic field increases. It also increases by increasing both plasma density and laser intensity. It is also established that the growth rate of 3HBBS instability in a magnetized plasma is lower than that of fundamental Brillouin backscattering instability.

Keywords: Growth rate; Magnetized underdense plasma; Third-harmonic Brillouin backscattering

1. INTRODUCTION

The interaction of an intense, picosecond laser pulse propagating in an underdense plasma is of fundamental interest in plasma physics, with applications to fast-ignition fusion, harmonic generation, and laser–plasma accelerator concepts (Nakajima, 2000; Hora *et al.*, 2011; 2013; Foldes *et al.*, 2013). Stimulated Raman scattering and stimulated Brillouin scattering are two important instabilities that occur in an underdense plasma, which are still a major issues in the realization and understanding of inertial confinement fusion (ICF) because the driving energy for the implosion is provided by the incident laser and the occurrence of backscattered light could greatly reduce the laser energy absorption efficiency (Bawaaneh, 2006; Paknezhad & Dorranian, 2011, Paknezhad, 2013*a*, *b*). Hence, the control of this instability is therefore of a fundamental concern for ICF. Brillouin scattering occurs in the interaction of a picosecond laser pulse with a plasma, which involves coupling of a large-amplitude light wave to a scattered light wave and an ion acoustic wave (Baton *et al.*, 1994; Froula *et al.*, 2003). Stimulated Brillouin scattering in a transversely magnetized plasma involves decaying of a pump laser wave (ω_0, k_0) into an ion acoustic upper-hybrid wave (ω, k) and two scattered upshifted (anti-Stokes) and downshifted (Stokes) light waves ($\omega_s = \omega_0 \pm \omega$, $k_s = k \pm k_0$) (Paknezhad, 2012; 2013*a*; Sharma *et al.*, 2012). Brillouin instability has been extensively studied in magnetized and unmagnetized plasmas for many years both theoretically and experimentally (Wang *et al.*, 2009; Bernhardt *et al.*, 2010; Paknezhad, 2012; 2013*a*). In an important earlier research, Salimullah and Hassan (1990) investigated the relativistic effects on the stimulated scattering of large-amplitude laser radiation in the presence of the self-generated magnetic field in a laser-produced plasma. They show that the extreme relativistic effects increase the growth rate of the stimulated scattering. Recently, Sharma and Singh (2013) have studied stimulated Brillouin backscattering of filamented hollow Gaussian beams in a collisionless plasma. They have shown that self-focusing and Brillouin backscattering decrease for higher order of a hollow Gaussian beam.

In addition to this topic, generation of harmonic radiation is also an important issue in the study of laser–plasma instabilities (Gibbon, 1997; Gupta *et al.*, 2007; Jha *et al.*, 2007). In a study in connection with this subject related to the Brillouin instability, Singh and Tripathi (2010) have carried out a numerical analysis of resonant Brillouin-shifted third-harmonic generation of a Gaussian laser pulse in a plasma. They demonstrated that the ion acoustic wave, generated in the stimulated Brillouin backscattering process, provides an uncompensated momentum between the harmonic photon and the combining fundamental photons, leading to the resonant enhancement of the harmonic power through the coupling of the laser with the ion acoustic wave.

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