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Third harmonic Brillouin scattering of laser in weakly and strongly coupled plasmas

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ABSTRACT

In this theoretical research, the mechanism of third harmonic stimulated Brillouin scattering (SBS) of laser in the interaction with a homogeneous unmagnetized plasma is investigated. Using the fluid model, we set up two coupled equations describing the third harmonic SBS and solve them to find the maximum temporal growth rate of the instability in both weakly and strongly coupling regimes. Electron-ion collision and Landau damping effects are also examined in this research. Results show that the growth rate in the strongly coupled regime is higher than that in the weakly coupled regime. It has also a reduction on enhancing the laser frequency. Moreover, in the weakly coupled regime, the growth rate strongly depends on the electron thermal velocity.

1. Introduction

The interaction of high intensity laser pulses with plasma has been a subject of much theoretical and experimental interest [1–4]. At these high intensities, electrons quiver velocity is close to the velocity of light and the motion of plasma electrons becomes nonlinear. SBS is one of the most important phenomenons that happens in the interaction of high intensity lasers with plasmas. In SBS, the incident electromagnetic wave (EM) resonantly decays into scattered EM wave and an ion-acoustic wave (IAW). The pump wave beats with the scattered EM wave to fortify the low-frequency ion acoustic wave [5–8]. Beside this, many laser plasma experiments have shown the generation of higher harmonics during the laser plasma interaction [9–15]. Higher harmonic generation in laser plasma interaction affects the laser plasma instabilities. In the case of SBS, beating the pump wave and scattered EM wave produces a ponderomotive force which acts on plasma electrons to generate second harmonic current density oscillation and gives the Brillouin shifted third harmonic scattered radiation field [15].

Ganeev et al., studied third and fourth harmonic generation of picosecond laser radiation in the perforated plasma plumes [14]. They obtained the 8 fold enhancement of third harmonic yield from the set of 0.15 mm long plasma jets compared with the plain aluminium plasma. Singh and Tripathi, studied the resonant Brillouin shifted third harmonic generation of laser in a plasma and demonstrated that the ion acoustic wave, generated in the stimulated Brillouin backscattering process, provides the 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 [15]. Recently, Humphrey and et al., have reported particle in cell simulations of energy transfer between a laser pump beam and a counter-propagating seed beam using the Brillouin scattering process in uniform plasma including collisions [16]. They have found that collisions, including the effects of Landau damping, allow for a more efficient transfer of energy between the laser beams, and a significant reduction in the amount of seed pre-pulse produced. In our previous study, we investigated the Brillouin-shifted third-harmonic backscattering of X-mode laser in a magnetized plasma [17]. It was revealed that the growth rate has a reduction in magnetized plasma in comparison with the unmagnetized plasma.

In the present research, we have carried out a theoretical analysis to develop the generation of third harmonic SBS instability in a homogeneous unmagnetized plasma. Using fluid model, we set up nonlinear wave equation and nonlinear Lorentz equation then solve them to find the maximum temporal growth rate of the instability. We perform this analysis in both the weak and strong coupling regimes at which the growth rate is small or large compared to the ion acoustic frequency, respectively. The present work neglects the laser self focusing and filamentation of laser. This paper is organized as follows. In Section 2, we introduce the theoretical model describing the third harmonic Brillouin scattering process. In Section 3, we determine the nonlinear growth rate of the 3rd harmonic

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