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Influence of density ripple on pulse slippage of third harmonic generation in plasma

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ABSTRACT

Influence of density ripple on pulse slippage of third harmonic generation has been investigated. When highly intense short range laser pulse incident on plasma, it imparts oscillatory velocity to electrons and exert a ponderomotive force at twice the frequency of incident laser beam. It induces oscillatory velocity at second harmonic frequency 2ω which further couples with density ripple resulting in density oscillations at 2ω. Density oscillations at 2ω, couple with the oscillatory velocity at ω, to produce non-linear current density at 3ω which drives the third harmonic generation. In order to provide phase matching condition between fundamental and third harmonic pulses, density ripple in plasma is introduced which offers the required momentum to the third harmonic photon to make the process resonant. At resonance, amplitude of the third harmonic pulse is found to be maximum for optimized values of density ripple factor. It is observed that the peak value of third harmonic pulse shifted towards higher value of normalized distance z' for higher values of normalized time t'. It is also seen that on account of the group velocity mismatch between pump and third harmonic pulses, the third harmonic pulse slips out of the domain of pump pulse.

1. Introduction

Harmonic generation during laser plasma interaction has been a fascinating field of research for last few years. When intense short range laser pulse interacts with plasma, interesting non linear phenomena arises i.e. X-ray generation [1], neutron production [2], laser plasma accelerators [3], harmonic generation [4–8] and self-focusing [9–12] etc. Harmonic generation is one of the most important non linear phenomena as it has wide range applications and third harmonic has its important place in the research related to laser plasma interaction due to its wide range of applications. It converts infrared lasers to shorter wavelengths in the visible and ultraviolet region and widely used in microscopy imaging. Saytashev et al. [13] reported on multimodal imaging of blood using sub-50 fs pulses centred at 1060 nm wavelength. They found that red blood cells seems dark on Second harmonic images while on third harmonic images of blood provide bright signal and good contrast. Graham et al. [14] studied the three- dimensional imaging of direct- written photonic structures where third harmonic generation microscopy is employed to analyse the morphology of photonic structures created using the femto-second laser direct- write technique. Due to homogenous nature of the medium odd harmonics can only be generated and third harmonic is dominant.

When large amplitude electromagnetic wave of frequency ω_1 and wave vector $\vec{k}_1$ propagates through the nonlinear medium it produces electromagnetic waves at harmonic frequencies say third harmonic, 3 ω_1. The efficiency is not very high due to a phase

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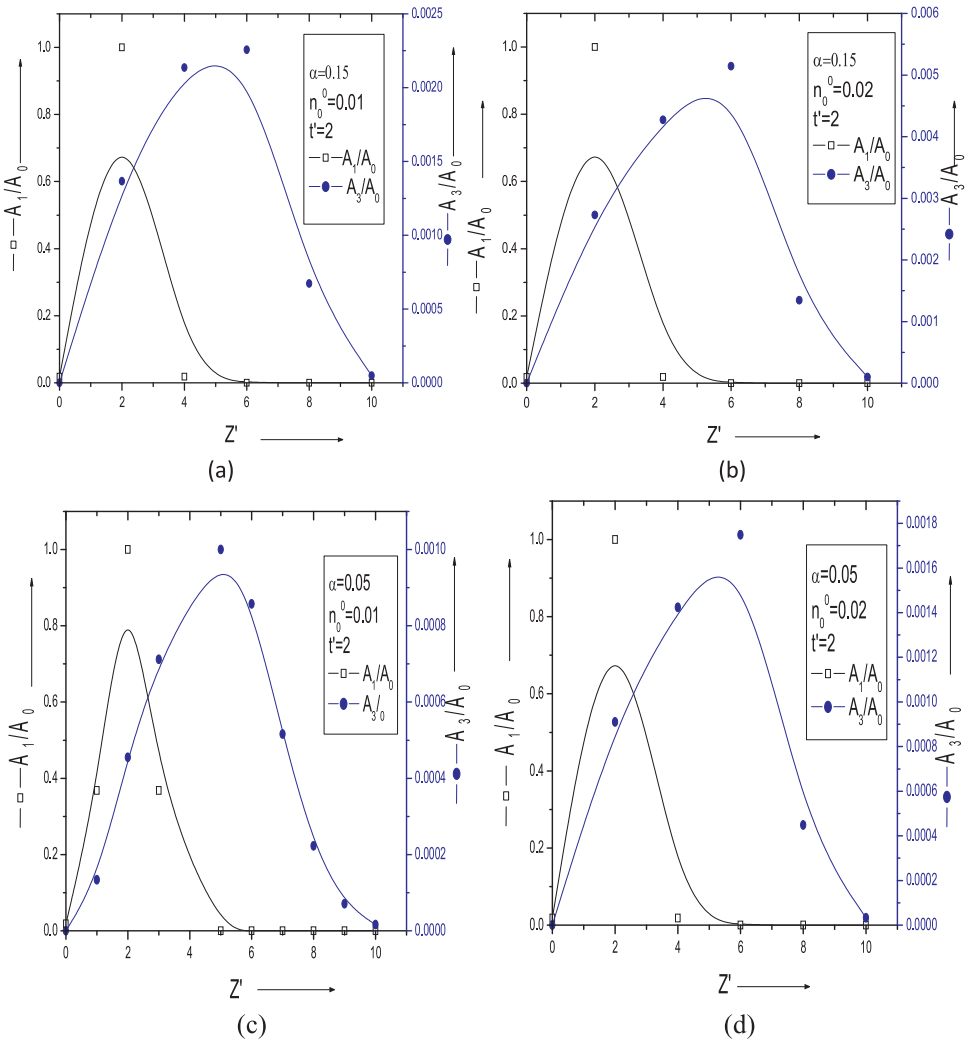

Fig. 1. Variation of normalized amplitude of fundamental and third harmonic pulses with normalized propagation distance at $\alpha = 0.15$ for $n_0^0 = 0.01\,\&\,0.02$ and at $\alpha = 0.05$ for $n_0^0 = 0.01\,\&\,0.02$ at $t' = 2$.

mismatch ($\vec{k_3} > 3\vec{k_1}$) between the third harmonic and pump pulses. For high efficiency phase matching is need to be satisfied and various researchers proposed different schemes to satisfy phase matching condition and to overcome the phase mismatch problem [15–18]. Milchberg et al. [15] have proposed the idea of using extra degree of freedom available in plasma fibre for phase matching of nonlinear conversion processes. Further, Chen et al. [19] have first time experimentally reported the phase-matched relativistic third-harmonic generation in forward direction with the variation of temporal delay and the energy of the laser pulse. Prashar and Pandey [20] suggested density ripple present in plasma and applied Wiggler magnetic field to satisfy the phase matching condition required for second harmonic. They studied the process of second harmonic generation in a plasma having a density ripple that could offer additional momentum required for generating resonant harmonic photons. Verma and Sharma [21] studied second harmonic generation which is increased by applying magnetic field and density ripple provide the phase matching between the fundamental and second harmonic pulses. Shim et al. [22] Reported controlled enhancement of optical third harmonic generation (THG) from

Table 1
Peak value of A_3/A_0 at different values of t' for a given values of α and n_0^0.

α	$t' = 2$		$t' = 6$		$t' = 10$	
	A_3/A_0 at $n_0^0 = 0.01$	A_3/A_0 at $n_0^0 = 0.02$	A_3/A_0 at $n_0^0 = 0.01$	A_3/A_0 at $n_0^0 = 0.02$	A_3/A_0 at $n_0^0 = 0.01$	A_3/A_0 at $n_0^0 = 0.02$
0.05	0.0011	0.0018	0.0048	0.0088	0.0087	0.0158
0.15	0.0023	0.0052	0.0142	0.029	0.027	0.058