SHG of self-focused cosh-Gaussian laser in magnetized plasma

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Abstract

In this study, we analyze the second harmonic generation (SHG) in a magnetized plasma by considering the self-focused cosh-Gaussian (chG) laser beam. Due to ponderomotive force electrons acquire the oscillatory velocity that result density perturbation. This perturbed density beats with the oscillatory velocity of electrons, induces second harmonic current. Wiggler magnetic field adds the momentum to the photons of second harmonic and this result increase in the efficiency of SHG. Self-focusing with linear propagation distance has been analyzed, the derived expression for normalized amplitude of SHG is solved mathematically and analyzed graphically, with linear propagation distance, at optimum values of intensity parameter of incident laser.

Key words: - SHG, cosh-Gaussian laser beam, wiggler magnetic field.

Introduction:

Short pulse laser propagating through plasma results harmonic generation and due to their wide range of applications has created great interest amongst the different workers. Amongst different harmonic generations the second harmonic generation (SHG) have specific importance due to its application, such as microscopic resonance imaging [1], in medical science [2], to probe different surface [3], in optoelectronics [4], to probe molecular structure[5] etc. Due to their significance in different fields, the SHG is investigated by various researchers using different laser profiles. Sharma et al. [6] had seen the self-focusing with the effect of linear absorption. Kaur et al. [7] studied the self-focusing and THG in a plasma having density ripple, under the condition of resonance. They had seen the dependence of THG on self-focusing which leads to enhance the third harmonic power. The density ripple’s effect on the pulse slippage and the efficiency of THG for Gaussian laser was given by Sharma et al. [8]

Here, we have undertaken the study the self-focused chG laser beam which impacting the efficiency of SHG in magnetized plasma. Expressions for normalized amplitude has been given in section II and results have been discussed graphically in section III and section IV comprises the conclusion of the study.

Theory:

Electric field of cosh-Gaussian laser incident on plasma region under wiggler magnetic field $\vec{B}_w$, is given as

$$\vec{E_i} = \hat{z}A(z)\exp[-i(\omega_i t - k_i z)]$$ and $\vec{B_i} = \frac{ck_i}{\omega_i} \times \vec{E_i}$,

$$\vec{B}_w = \hat{y}B_0 \exp(ik_0 z),$$

(1a)

(1b)
where, for incident laser, $\vec{k}_i$ is the wave vector, $\omega_i$ is the frequency, $\vec{B}_i$ is the laser’s magnetic field, $c$ gives the velocity of light and the wiggler wave vector is given by $\vec{k}_0$. The amplitude, $A$, of Gaussian wave is

$$A(z) = A_0(z, r) \exp[-ikS(r, z)],$$

where $A_0$ and $S$ are functions of $r$ and $z$. $A_0$ gives the amplitude of laser pulse as

$$A_0^2 = \frac{E_0^2}{f^2(z)} \left[ \frac{b^2}{2} + 2 \exp\left[-2\left(\frac{r}{r_0 f(z)} - \frac{b}{2}\right)^2\right] + 2 \exp\left[-\left(\frac{r}{r_0 f(z)} - \frac{b}{2}\right)^2\right] \right].$$

Expression of the beam width parameter [22] is given by

$$\frac{\partial^2 f(z)}{\partial \xi^2} = \left[ 4 - 4b^2 - \frac{6\alpha E_0^2 m_0}{M} \left( \frac{\omega_i^2 r_0^2}{c^2} \right) \left( \frac{\omega_p^2}{\omega_i^2} \right) \exp\left[\frac{b^2}{2}\right] \right] \frac{1}{f^3(z)}.$$

Wave equation is given as,

$$\nabla^2 \vec{E}_2 = \left[ \frac{\varepsilon_0 + \phi(E, E_1)}{c^2} \right] \frac{\partial^2 E_1}{\partial t^2} + \frac{4\pi \alpha \vec{J}_3^L}{c^2 \partial t} + \frac{4\pi \alpha \vec{J}_3^{NL}}{c^2 \partial t},$$

where $\vec{J}_3^L$ and $\vec{J}_3^{NL}$ are the linear and non-linear current densities.

Using simple mathematic we obtain normalized amplitude of second harmonic pulse

$$\begin{align*}
-4i \left[ \frac{\partial A_{20}}{\partial \xi} \{1 - b^2\} \right] + & \left[ \frac{8r_0^2 \omega_i^2}{c^2} \left( 1 - \frac{\omega_p^2}{4\omega_i^2} \right) \{1 - b^2\} \right] \\
+ & \left\{ \left( \frac{16}{f^2(z)} \right) \{1 - b^2\} \right\} + \left\{ \left( \frac{24b^2}{f^2(z)} \right) \{1 - b^2\} - \left( \frac{2b^2}{f^2(z)} \right) \exp(-2) \right\} A_{20}^2 \\
= & \left( \frac{\omega_i^2 r_0^2}{c^2} \right) \left( eB_w/m\omega_0 c \right) \left( eA_{20}/m\omega_0 c \right) + 2 \left( 1 - \frac{\omega_p^2}{4\omega_i^2} \right)^{1/2} - \frac{1}{4} \left( 1 - \frac{\omega_p^2}{\omega_i^2} \right)^{1/2} \{1 - b^2\}.
\end{align*}$$

**Results and discussions:-**

Eqs. (4) and (13) are the coupled equations for $f$ and normalized amplitude $A_{20}/A_{10}$ of second harmonic pulse. We have solved these equations numerically at optimum values of different laser parameters $eA_{10}/m\omega_0 c = 5$, $\omega_i r_0 / c = 18$, $e\varepsilon z^2 A_{10}^2 / \varepsilon_0 = 1$, $eB_w/m\omega_0 c = 3$ and $\omega_p / \omega_i = 0.8$ and results have been interpreted graphically. The graphical representation for beam width parameter, with $\xi$, is given in Fig. 1 and it is found that $f$ attains its minimum value of 0.13 at $\xi = 0.02$ and continue to show oscillatory behavior showing self-focusing and defocusing and due to oscillation of electrons, transverse to axis, results oscillatory variation in plasma density and refractive index. Rawat and Purohit [10] had given the model for self-focusing of chG laser beam in magnetized
plasma and analyzed the behaviour of $f$ at different laser parameters. In Fig 2, the variation of $A_{20}/A_{10}$ with $\xi$ for separate values of $eA_{10}/m\omega_1c = 1, 3$ and $5$ is depicted. It is revealed that the efficiency of SHG rises appreciably with increasing values of intensity of incident laser. It is due to the fact that the ponderomotive force becomes stronger and this result the motion of electrons away from the axial region, therefore increasing the refractive index and stronger self-focusing is induced. Due to stronger self-focusing the gain in efficiency of SHG is appreciable. We observed that even at lower value of $eA_{10}/m\omega_1c = 1, 3$ and $5$ our result shows appreciable gain in $A_{20}/A_{10}$ up to $0.32$.

**Conclusion:**

From given study we have realized that the chG laser shows the oscillatory behaviour with propagation distance due to regular self-focusing and defocusing of incident laser. The efficiency of SHG is found to be increased due to stronger self-focusing of incident laser under resonance condition.

Variation of $f$ with $\xi$. The other parameters are $eA_{10}/m\omega_1c = 5, \ \varepsilon_2A_{10}^2/\varepsilon_0 = 1, \ x_1r_0/c = 18, \ x_0/m\omega_1c = 3$ and $\omega_p/\omega_1 = 0.8$.

Variation of $A_{20}/A_{10}$ with $\xi$ for separate values of $eA_{10}/m\omega_1c$. Other parameters are taken from Fig. 1.
References:


