Enhancement in the THz-radiation Generation by fs Laser Pulse

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Abstract

In this theoretical work, we develop a comperehensive scheme for the generation of THz-radiation with the help of two fs laser pulses under the action of applied d.c. electric field and transeversly applied magnetic field on a collisional plasma. The Action of Filamentation between fs pulses on a collisional plasma plays an important role under the action of applied d.c. electric field and transeverse magnetic field, resulting in non Linear coupling . In this way, non linear electro magnetic force comes in to action known as ponderomotive forece and causes non Linear transverse oscillatory current that produces excitations at resonance to generate THz-radiation. The amplitude of THz-radiation can be enhanced by varying magnitude of magnetic field and electric field.

Key words: collisional plasma, THz-radiation, non-linear coupling. fs laser pulse

I. Introduction

In the present world of technology, THz-radiation has lot of potential due to its number of applications in scientific, technical, industrial and commercial fields such as THz-radiation can be used in THz-spectroscopy, THz-sensors, THz-scanners, THz-explosive detectors.The researchers has provided number of mechanisms for the generation and detection of THz-radiationin , but THz-radiation pulse energy generation is said to be achieved its maximum value during filamentation action of fs laser pulses because of its extraordinary property to produce weak plasmas in the presence of propagating fs pulses, Also it can rectify narrow wave band pulse in to a broad wave band pulse [1,2], it results in production of THz-radiation in a very effcient way [3]. Consider two fs laser pulses propagating along Z-axis and magnetic field, d.c.electric field are applied in mutually perpendicular directions i.e. along Y-axis and X-axis to provide drift to plasma. Plasma is a very suitable non linear medium for the generation of THz-radiation with effective fs pulse laser [4,5,6]. With an advantage that it can sustain very high powers and shows stronger non Linear effects [7,8], The laser exerts a non linear electro magnetic force

F_{qw} and Ponderomotive static force F_{pq} on electrons [9]. The static Ponderomotive force is well cancels out by pressure gradient force effect and results in the null frequency density ripple . The non linear electro magnetic force which is responsible for electron velocity and density oscillations at beat wave frequency, further results in d.c. drift of electrons in the plasma so that transverse current $J_{w,k}$ can be produced and it further helps in the generation of THz-radiation [10].

In the second section (II) of this paper we perform the calculations for the expressions of non linear velocity perturbation and non linear density perturbation at THz-radiation frequency. In the third section (III) of this paper we discuss enhancement in generation of THz-radiation by fs laser pulse under the combined action of d.c.electric field and magnetic field on a collisional plasma by using model wave propagation equation with the help of the phase matching condition.In the section (IV) this paper we provide discussion and conclusion.

II.Calculation for non linear velocity and density perturbation Under the action of d.c. electric field applied along X-axis on collisional plasma [11],the plasma electrons will show d.c. drift

$$\vec{V}_{d.c} = \frac{-e\,\vec{E}_{st.}}{m_e\, \upsilon_e} \qquad (1)$$

where -e is the charge of single electron, m_e is the mass of single electron and υ_e is the collisional frequency of electrons. When we incident two fs pulse lasers on the collisional plasma, under the combined action of d.c. electric field and magnetic field ,plasma start oscillating . The electric field of lasers are,

$$\vec{E}_j = \hat{y}\, D_{j0}\, [\, 1+ \mu_j \cos qx]\, e^{-i(\omega_j t - k_j z)} \quad \text{where } j=1\text{and}2 \qquad (2)$$

Here μj is the modulation depth and frequency difference between two fs pulse lasers results in the THz-radiation frequency that is $\omega = (\omega_1 - \omega_2)$.These fs laser pulses are responsible in providing oscillatory velocities to electrons in plasma.

$$\vec{V}_j = \frac{e\,\vec{E}_j}{m_e\,(i\omega_j - \upsilon)} \qquad (3)$$

These fs laser pulses are also responsible to provide static electro magnetic force $F_{pq} = e\,\vec{V}\,\varphi_{pq}$ and non linear electro magnetic force $Fp\omega = e\,\vec{V}p\omega$ at beat frequency.

$$\Phi p\omega = \frac{e}{4\, m_e T_0}\left(\frac{D_{10}^2\ \mu_1}{(i\omega_1 - \upsilon_e)^2} + \frac{D_{20}^2\ \mu_2}{(i\omega_2 + \upsilon_e)^2}\right)(e^{iqx}) \tag{4}$$

Where, T_0 is equilibrium temperature of plasma electrons. By using model equations of motion, we have calculated the velocity components along X and Z axis

$$\vec{V}_x^{NL} = \frac{(\upsilon - i\omega)(F_x)}{m_e\, \omega_\alpha^2} + \frac{\omega_c}{m_e\, \omega_\alpha^2}(F_z) \tag{5}$$

$$\vec{V}_Z^{NL} = \frac{(\upsilon - i\omega)(F_z)}{m_e\, \omega_\alpha^2} - \frac{\omega_c}{m_e\, \omega_\alpha^2}(F_x) \tag{6}$$

Here, $[(\upsilon - i\omega)^2 + \omega_c^2] = \omega_\alpha^2$ and ω_c represent cyclotron frequency. With the help of above velocity components we can calculate density perturbation along X and Z axis that is $\vec{n}_{w,k}^{NL}$. With the help of density perturbation the non linear current density along X and Z axis is given by

$$\vec{J}_{X\ \omega,k}^{NL} = \frac{-\, n_0^0\, e^4\ D_{10}\, D_{20}\,[i]}{2\, m_e^3\ \omega_\alpha^2\,(i\omega_1 - \upsilon_e)\,(i\omega_2 + \upsilon_e)}\left[\left(\frac{k_B^2\, \vec{E}_{dc.}}{\omega\, \upsilon_e} - \frac{eq(\mu_1+\mu_2)}{8\, T_0}\right)^{[(\upsilon-i\omega)+\omega c)]}\left(\frac{D_{10}^2\ \mu_1}{(i\omega_1 - \upsilon_e)^2} + \frac{D_{20}^2\ \mu_2}{(i\omega_2 + \upsilon_e)^2}\right)(\upsilon-i\omega-\omega_c)\right]$$

$$.(e^{-i(\omega t - kx)}) \tag{7}$$

$$\vec{J}_{z\ \omega,k}^{NL} = \frac{-\, n_0^0\, e^4\ D_{10}\, D_{20}\,[i]}{(i\omega_1 - \upsilon_e)\,(i\omega_2 + \upsilon_e)}\left[\frac{e\, k_B\,(\mu_1+\mu_2)}{8\, T_0}\left(\frac{D_{10}^2\ \mu_1}{(i\omega_1 - \upsilon_e)^2} + \frac{D_{20}^2\ \mu_2}{(i\omega_2 + \upsilon_e)^2}\right)\frac{(\upsilon-i\omega+\omega_c)}{e} + \frac{mk_B[(\upsilon-i\omega)+\omega_c]}{2\, m_e^3\ \omega_\alpha^2}\right]$$

$$.(e^{-i(\omega t - kz)}) \tag{8}$$

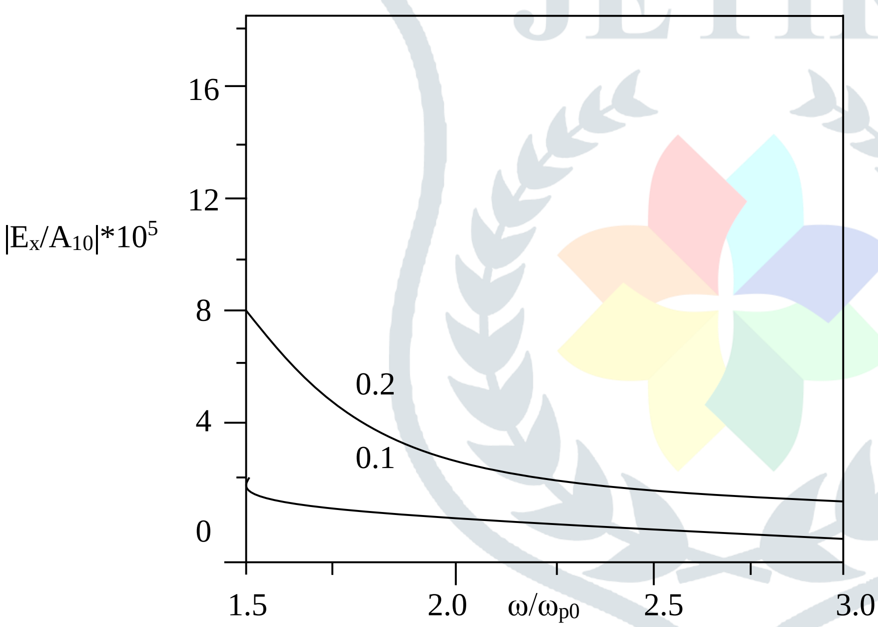
III. Enhancement in the Production of THz radiations

By using standard Maxwell's equation of wave propagation and by using Phase Matching Condition we get

$$E_x = \frac{-2\pi\omega}{k_B' C^2}\left[\vec{J}^{NL}_{X\,\omega,k} + \frac{\varepsilon_{ZX}}{\varepsilon_{ZZ}}\vec{J}^{NL}_{Z\,\omega,k}\right] Z \quad (9)$$

By using the particular values of $\omega_c/\omega_p = 0.1$ and 0.2, The plot between ($|E_x/A_{10}|*10^5$) and (ω/ω_{p0}) shows enhancement in the amplitude of normalized THz radiation

$\omega_1 = 2.4 \times 10^{14}$ rad/s, $\omega_2 = 2.1 \times 10^{14}$ rad/s, $E'_{dc.} = 0.053$, $\omega_p = 2.0 \times 10^{13}$ rad/s, $\mu_1 = \mu_2 = 0.3$, $q' = 0.3$ and $\omega' = 2.0$ to 5.0.



IV.Discussion and Conclusion

When there is a non Linear interaction of fs laser pulses with collisional plasma under the combined effect of applied d.c. electric field and magnetic field, interaction results in the production of perturbation in the velocity of electrons in plasma, which is further responsible for perturbation in the density of electrons. Due to both, under the action of electric field and magnetic field, non Linear current is produced (because of non-linear coupling with d.c electric field) and this non linear oscillatory current further generates the THz-radiation at beat frequency after satisfying phase matching conditions. In this way the amplitude of THz-radiation can be enhanced and controlled by fs laser pulse factors and magnitude of d.c.electric field and magnetic field.

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