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Strong terahertz radiation generation by beating of two laser beams in magnetized overdense plasma

A. HEMATIZADEH, F. BAKHTIARI, S. M. JAZAYERI, AND B. GHAFARY
Department of Physics, Iran University of Science & Technology, Narmak, Tehran, Iran

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Abstract

Terahertz (THz) radiation generation by nonlinear mixing of two laser beams, obliquely incident on an overdense plasma is investigated. In an overdense plasma, the laser beams penetrate to only thin layer of a plasma surface and reflected. At this thin layer, the laser beams exert a ponderomotive force on the electrons of plasma and impart them oscillatory velocity at the different frequency of lasers. THz waves appear in the reflected component from the plasma surface. The amplitude of THz waves can be augmented by applying the magnetic field perpendicular to the direction of propagation of lasers. It is found that the field strength of the emitted THz radiations is sensitive to the angle of incident of the laser beams, beat frequency, and magnetic field strength. In this scheme, the magnetic field strength plays an important role for strong THz wave generation.

Keywords: Overdense plasma; Magnetic field; Beat frequency; Terahertz generation

1. INTRODUCTION

The problem of efficient generation of terahertz (THz) radiation, frequency range 0.1–10 THz, has attracted considerable interest over the past 10 years due to a lot of important promising applications. Numerous applications can be found in a wide range of fields such as physics, chemistry, biology, information, and security (Cooke & Jespen, 2009; Bartman *et al.*, 2011; Tao *et al.*, 2011; Kim *et al.*, 2012). Various techniques have been employed for THz generation using high-power lasers. Many laser-based THz emitters have been proposed to generate THz wave, using electro-optic crystals (ZnTe, GaAs, LiNbo3, etc.), semiconductors and photoconductive antennas (Jepsen *et al.*, 1996; Hashimshony *et al.*, 1999; Lee *et al.*, 2000; Faure *et al.*, 2004; Vodopyanov, 2008; Chen *et al.*, 2011). When the energy or focusing intensity of the pump laser is high, the materials may be damaged (Li *et al.*, 2012*b*). In contrast, plasmas can overcome the damage problem of neutral materials. Recent studies have shown that plasmas are promising media to generate strong THz radiation (Sheng *et al.*, 2005). In principle, the laser intensity can be arbitrarily high for plasmas. The typical intensity of a multi-terawatt (TW) laser system is higher than 10^{18} w/cm^2 (up to 10^{21} w/cm^2 with a Petawatt laser) (Li *et al.*, 2012*b*). Hamster *et al.* (1993) observed a high-power THz radiation from a plasma short pulse produced by laser, employing 1 TW, 100 fs laser beam focused on gas and solid targets. They also observed THz radiation in a laser-induced plasma channel where ponderomotive force drives radiation. Antonsen *et al.* (2007) examined the ponderomotive force-driven THz radiation generation in a plasma with space periodic axial density variation. Wu *et al.* (2007) have studied the effect of transverse magnetic field on the wakefield process and found a significant enhancement in the efficiency of THz generation. Fedele *et al.* (1986) have reported radial electric field components generated by the propagation of two electromagnetic waves resonantly beating in a plasma. Malik *et al.* (2010) investigated the THz generation by tunnel ionization of a gas jet with the help of superposed femtosecond laser pulses and by laser beating in periodically modulated plasma. They also reported the generation of tunable THz radiation under the application of 2 fs laser pulses with an external magnetic field (Malik & Malik, 2011). The resonant excitation of THz radiation by beating of two spatial-Gaussian laser beams has been proposed by Malik *et al.* (2012). Bakhtiari *et al.* (2015*a*) have studied the THz generation by beating of two dark hollow laser beams and two circular flat-topped laser beams. Bakhtiari *et al.* (2015*b*) have showed strongly THz radiation generation through shape control of emitted THz radiation in collisional plasmas. Chauhan and Parashar (2014) have

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Address correspondence and reprint requests to: A. Hematizadeh, Department of Physics, Iran University of Science & Technology, Narmak, Tehran, Iran. E-mail: hematizade@physics.iust.ac.ir

considered two laser beams, which obliquely incident on a plasma slab for two different electron density profiles. Parashar (2014) has reported THz radiation by beating of two laser beams, which obliquely incident on the plasma. Kumar *et al.* (2015) investigated THz generation in hot plasma with step density profile by two obliquely incident of lasers on the plasma. Compared with low-density gases, overdense plasmas of solids have higher electron density thus holding the promise of producing higher-power THz pulses (Li *et al.* 2012*b*). Interaction of laser with an overdense plasma also results in generation of electromagnetic radiation at harmonics of incident wave in the reflected component. Gopal *et al.* (2012) have reported experimental observation of THz radiation from the rear surface of a solid target with an intense laser pulse and showed THz radiation is mostly emitted at large angles to the target normal. Adak *et al.* (2015) have observed experimentally THz radiation by a pump pulse at an angle of 45° and a probe pulse at near normal incident, which are focused on a polished BK-7 glass target. Weiss *et al.* (2000) have showed experimentally by applying an external magnetic field, the power of the generated THz radiation is increased for all examined semiconductor materials. Hangyo *et al.* (2001) have studied experimentally THz radiation from indium arsenide (InAs) surfaces in the presence of the magnetic field, which excited by femtosecond laser pulses. McLaughlin *et al.* (2000) have demonstrated experimentally enhancement of THz emission from InAs in the presence of magnetic fields up to 8 T. Migita and Hangyo (2001) have reported experimentally enhancement of THz radiation from InAs surfaces under magnetic fields excited by ultrashort laser pulses for low and high pump power densities. Li *et al.* (2012*a*) have reported a plasma-based strong THz source generated in intense laser–solid interactions at relativistic intensities when the laser pulses are incident onto a copper foil at 67.5° Li *et al.* (2011) have studied interactions of 100 fs laser pulses with solid targets. Shvartsburg and Stenflo (1994) have formulated a new method to study reflection of wideband electromagnetic pulses at a plasma boundary. Aliev *et al.* (1993) have studied total backward reflection of electromagnetic radiation due to resonant excitation of surface wave over plasma. Parashar *et al.* (2013) have studied THz radiation in the overdense plasma. Chen *et al.* (2013) have studied THz radiation by interaction of a relativistic circularly polarized laser pulse with an overdense plasma and have showed remarkably intense THz pulses.

In this work, we study THz radiation generation via nonlinear mixing of two obliquely incident laser beams over an overdense plasma in the presence of magnetic field. Overdense plasmas have been considered since it can be easily realized by employing a metallic sheet or a semiconductor. Also contrary to neutral materials and plasma filaments, almost arbitrarily high laser energies and intensities can be used in laser–solid interactions (Li *et al.*, 2012*b*).

This paper is organized as follows: In Section 2, we study nonlinear oscillatory current density due to the ponderomotive force developed during photo mixing of two laser beams in the presence of static magnetic field. In Sections 3 and 4, we evaluate the THz radiation field and efficiency. In Section 5, we present the results of analytical investigations. Conclusions are presented in Section 6.

2. CALCULATION OF NONLINEAR CURRENT DENSITY

We consider two p-polarized lasers with frequencies ω_1, ω_2 and wave vector $\vec{k}_1$, $\vec{k}_2$, propagating and polarized in the xy-plane that obliquely incident on an overdense plasma in the presence of a static magnetic field B_0 along the z-direction (Fig. 1).

We consider the electric field of incident lasers as

$$\vec{E}_j = \vec{E}_{j0}\exp\left(-i\left(\omega_j t - \frac{\omega_j}{c}\cos\theta_i x - \frac{\omega_j}{c}\sin\theta_i y\right)\right), \tag{1}$$

where $\vec{E}_{j0} = A_{j0}(-\tan\theta_i\hat{x} + \hat{y})$, $j = 1{,}2$.

In an overdense plasma, where the frequency of incident laser beam smaller than plasma frequency, the electromagnetic radiation cannot penetrate deeply into the plasma. It penetrates into the plasma as far as the evanescence length, which is of the order of $\sim c/\omega_p$ (Bulanov *et al.*, 2001), where, c is the speed of light in the vacuum and ω_p is the plasma frequency. Therefore the transmitted fields of laser in the plasma, can be written as (Parashar *et al.*, 2013).

$$\begin{aligned}\vec{E}_{jT} = {} & \left(\hat{y} - \frac{\omega_j}{c}\frac{\sin\theta_i}{i\alpha_j}\hat{x}\right)T_j A_{j0} \\ & \times\exp\left(-i\left(\omega_j t - \frac{\omega_j}{c}\sin\theta_i y - \frac{\omega_j}{c}\cos\theta_i x\right)\right) \\ & \times\exp(-\alpha_j x),\end{aligned} \tag{2}$$

where $\alpha_j = (\omega_p^2/c^2 - \omega_j^2\cos^2\theta_i/c^2)^{1/2}$, $\omega_p = (4\pi n_0 e^2/m)^{1/2}$, $T_j = 2/(1 + (i\omega_j/\alpha_j c)\cos\theta_i)$, n_0 is equilibrium electron density, m and e are the electron mass and charge. Since the plasma is overdense, the plasma frequency ω_p must be larger than ω_1 and ω_2. It is supposed that $\omega_1 > \omega_2$, therefore $n_0 > n_c$. n_c is the critical density and given by $n_c = m\omega_1^2/4\pi e^2$. Lasers impart

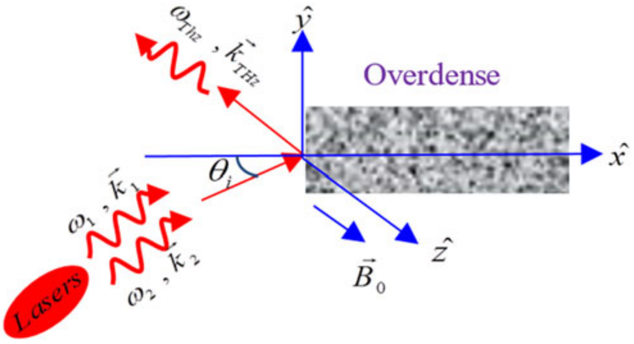

Fig. 1. Schematic diagram of THz radiation generation from overdense plasma.

oscillatory velocity to the electrons of plasma $\vec{v}_j = e\vec{E}_j / mi\omega_j$ and exert beat frequency ponderomotive force on them.

$$\vec{F}_{\mathrm{p}}^{\mathrm{NL}} = -\frac{m}{2}\vec{\nabla}(\vec{v}_1 \bullet \vec{v}_2^{*}). \tag{3}$$

The nonlinear perturbations in the electron density $n_{\mathrm{e}}^{\mathrm{NL}}$ due to nonlinear ponderomotive force $\vec{F}_{\mathrm{p}}^{\mathrm{NL}}$ are obtained by solving of continuity equation

$$n_{\mathrm{e}}^{\mathrm{NL}} = \frac{n_0}{m(\omega^2 - \omega_{\mathrm{c}}^2)}\vec{\nabla}.\left(\vec{F}_{\mathrm{p}}^{\mathrm{NL}} + \vec{F}_{\mathrm{p}}^{\mathrm{NL}} \times \frac{\omega_{\mathrm{c}}\hat{z}}{i\omega}\right), \tag{4}$$

where $\omega_{\mathrm{c}} = e\mathrm{B}_0/mc$, $\omega = \omega_1 - \omega_2$ are the electron cyclotron frequency and beating frequency. The density perturbation produces a self-consistent space charge field $\vec{E} = -\vec{\nabla}\phi$ that also produces a density perturbation $n_{\mathrm{e}}^{\mathrm{L}} = -(\chi_{\mathrm{e}}/4\pi e)\vec{\nabla}.(\vec{\nabla}\phi)$, where $\chi_{\mathrm{e}} = -\omega_{\mathrm{p}}^2/(\omega^2 - \omega_{\mathrm{c}}^2)$. Linear ponderomotive force is given by $\vec{F}^{\mathrm{L}} = e\vec{\nabla}\phi$. Using Poisson's equation $\vec{\nabla}.(\vec{\nabla}\phi) = 4\pi e(n_{\mathrm{e}}^{\mathrm{L}} + n_{\mathrm{e}}^{\mathrm{NL}})$ and equation of motion $m(d\vec{v}_{\omega}^{\mathrm{NL}}/dt) = \vec{F}^{\mathrm{L}} + \vec{F}^{\mathrm{NL}} - \vec{v}_{\omega}^{\mathrm{NL}} \times (e\mathrm{B}_0/c)\hat{z}$ the nonlinear electron velocity obtained as follows:

$$\begin{aligned}\vec{v}_{\omega}^{\mathrm{NL}} = {}& \left[f_x\hat{x} + f_y\hat{y}\right]\exp(-(\alpha_1 + \alpha_2)x) \\ & \times \exp\left(-i\left[\omega t - k_x x - k_y y\right]\right),\end{aligned} \tag{5}$$

where f_x, f_y, f_0, k_y, and k_x are defined as

$$f_x = \frac{f_0}{mi\omega(1 + (\omega_{\mathrm{c}}/i\omega)^2)} \times \left[\begin{array}{l}\left(\left(\frac{-\chi_{\mathrm{e}}}{(1+\chi_{\mathrm{e}})} + 1\right) + \frac{-\omega_{\mathrm{c}}^2\chi_{\mathrm{e}}}{\omega^2(1+\chi_{\mathrm{e}})}\right)(ik_x - (\alpha_1 + \alpha_2)) \\ + \left(\frac{-\chi_{\mathrm{e}}\omega_{\mathrm{c}}}{i\omega(1+\chi_{\mathrm{e}})} + \frac{\omega_{\mathrm{c}}}{i\omega}\left(\frac{-\chi_{\mathrm{e}}}{(1+\chi_{\mathrm{e}})} + 1\right)\right)ik_y\end{array}\right],$$

$$f_y = \frac{f_0}{mi\omega(1 + (\omega_{\mathrm{c}}/i\omega)^2)} \times \left[\begin{array}{l}-\left(\frac{-\chi_{\mathrm{e}}\omega_{\mathrm{c}}}{i\omega(1+\chi_{\mathrm{e}})} + \frac{\omega_{\mathrm{c}}}{i\omega}\left(\frac{-\chi_{\mathrm{e}}}{(1+\chi_{\mathrm{e}})} + 1\right)\right) \\ (ik_x - (\alpha_1 + \alpha_2)) \\ + \left(\left(\frac{-\chi_{\mathrm{e}}}{(1+\chi_{\mathrm{e}})} + 1\right) + \frac{-\omega_{\mathrm{c}}^2\chi_{\mathrm{e}}}{\omega^2(1+\chi_{\mathrm{e}})}\right)ik_y\end{array}\right],$$

$$f_0 = \frac{e^2 T_1 T_2^{*} A_{10} A_{20}}{2m\omega_1\omega_2}\left(1 + \frac{\omega_1\omega_2\sin^2\theta_i}{c^2\alpha_1\alpha_2}\right),$$

$$k_y = \frac{\omega\sin\theta_i}{c}, \quad k_x = \frac{\omega\cos\theta_i}{c}.$$

From Eq. (5) we can calculate the nonlinear current density $\vec{J}_{\omega}^{\mathrm{NL}}$ as

$$\vec{J}_{\omega}^{\mathrm{NL}} = -n_0 e\vec{v}_{\omega}^{\mathrm{NL}},$$

$$\begin{aligned}\vec{J}_{\omega}^{\mathrm{NL}} = {}& -n_0 e\left[f_x\hat{x} + f_y\hat{y}\right]\exp(-(\alpha_1 + \alpha_2)x) \\ & \times \exp\left(-i\left[\omega t - k_x x - k_y y\right]\right).\end{aligned} \tag{6}$$

3. THZ RADIATION GENERATION

The wave equation governing the THz wave is derived from the third and fourth Maxwell's equations

$$\nabla^2\vec{E}_{\omega} - \vec{\nabla}(\vec{\nabla}.\vec{E}_{\omega}) + \frac{\omega^2}{c^2}\bar{\bar{\varepsilon}}\vec{E}_{\omega} = \frac{-4\pi i\omega}{c^2}\vec{J}_{\omega}^{\mathrm{NL}}, \tag{7}$$

where $\bar{\bar{\varepsilon}}$ is the electric permittivity tensor with components $\varepsilon_{xx} = \varepsilon_{yy} = 1 - (\omega_{\mathrm{p}}^2/(\omega^2 - \omega_{\mathrm{c}}^2))$, $\varepsilon_{xy} = -\varepsilon_{yx} = (i\omega_{\mathrm{p}}^2\omega_{\mathrm{c}}/\omega(\omega^2 - \omega_{\mathrm{c}}^2))$, $\varepsilon_{zz} = 1 - (\omega_{\mathrm{p}}^2/\omega^2)$, and $\varepsilon_{xz} = \varepsilon_{yz} = \varepsilon_{zx} = \varepsilon_{zy} = 0$ (Bittencourt, 2004). The solution of wave equation in the vacuum $x < 0$ is given by plane wave as

$$\begin{aligned}\vec{E}_{\mathrm{I}} = \vec{E}_{\mathrm{THz}} = {}& A_{\mathrm{R}}\left[\frac{k_y}{k_x}\hat{x} + \hat{y}\right] \\ & \times \exp\left(-i\left[\omega t + k_x x + k_y y\right]\right).\end{aligned} \tag{8}$$

Equation (7) is nonhomogeneous second-order partial differential equation. The general solution of this equation comprises from its particular solution and solution of homogeneous part. Homogeneous part of Eq. (7) is $\nabla^2\vec{E}_{\omega} - \vec{\nabla}(\vec{\nabla}.\vec{E}_{\omega}) + (\omega^2/c^2)\bar{\bar{\varepsilon}}\vec{E}_{\omega} = 0$, which its solution is as

$$A_{\mathrm{T}}[\delta\hat{x} + \hat{y}]\exp(-i[\omega t - k_x x - k_y y]),$$

where

$$\delta = \frac{(-k_y\beta + (\omega^2/c^2)\varepsilon_{yx})}{(-k_y^2 + (\omega^2/c^2)\varepsilon_{xx})}, \quad \beta = \sqrt{\frac{\omega^2}{c^2}\left(\varepsilon_{xx} + \frac{\varepsilon_{yx}^2}{\varepsilon_{xx}}\right) - k_y^2}.$$

Particular solution of Eq. (7) is given by

$$\begin{aligned}& \left[E'_{0x}\hat{x} + E'_{0y}\hat{y}\right]\exp(-(\alpha_1 + \alpha_2)x) \\ & \times \exp\left(-i\left[\omega t - k_x x - k_y y\right]\right),\end{aligned}$$

where

$$E'_{0x} = \frac{\left(4\pi i\omega n_0 e/c^2\right)}{\begin{array}{c}(-k_y^2 + (ik_x - (\alpha_1 + \alpha_2))^2)(\omega^2/c^2)\varepsilon_{xx} \\ + ((\omega^2/c^2)\varepsilon_{xx})^2 + ((\omega^2/c^2)\varepsilon_{yx})^2\end{array}} \times \left(\begin{array}{l}f_y((ik_x - (\alpha_1 + \alpha_2))ik_y + \frac{\omega^2}{c^2}\varepsilon_{yx}) \\ + f_x((ik_x - (\alpha_1 + \alpha_2))^2 + \frac{\omega^2}{c^2}\varepsilon_{xx})\end{array}\right),$$

$$E'_{0y}=\frac{\left(4\pi i\omega n_0 e/c^2\right)}{(-k_y^2+(ik_x-(\alpha_1+\alpha_2))^2)(\omega^2/c^2)\varepsilon_{xx}+((\omega^2/c^2)\varepsilon_{xx})^2+((\omega^2/c^2)\varepsilon_{yx})^2}\times\begin{pmatrix} f_x((ik_x-(\alpha_1+\alpha_2))ik_y-\frac{\omega^2}{c^2}\varepsilon_{yx}) \\ +f_y(-k_y^2+\frac{\omega^2}{c^2}\varepsilon_{xx}) \end{pmatrix}.$$

Therefore, general solution of Eq. (7) in the plasma $x \geq 0$ is

$$\vec{E}_{\mathrm{II}}=\begin{pmatrix} A_{\mathrm{T}}[\delta\hat{x}+\hat{y}] \\ +\left[E'_{0x}\hat{x}+E'_{0y}\hat{y}\right]\exp(-(\alpha_1+\alpha_2)x) \end{pmatrix}\times\exp\left(-i\left[\omega t-k_x x-k_y y\right]\right). \tag{9}$$

A_{R} and A_{T} are the constant coefficients. On applying the boundary conditions at $x=0$, $(E_{\mathrm{I}})_y=(E_{\mathrm{II}})_y$ and $(\varepsilon_{\mathrm{IE\_I}})_{\mathrm{x}}=(\varepsilon_{\mathrm{II}}E_{\mathrm{II}})_x$. We obtain from Eqs (8) and (9)

$$A_{\mathrm{R}}=A_{\mathrm{T}}+E'_{0y} \tag{10}$$

and

$$A_{\mathrm{R}}\frac{k_y}{k_x}=\varepsilon_{xx}\left[A_{\mathrm{T}}\delta+E'_{0x}\right]-\varepsilon_{yx}\left[A_{\mathrm{T}}+E'_{0y}\right]. \tag{11}$$

From Eqs (10) and (11), the amplitude of generated THz wave in the reflected component is obtained as follows:

$$|A_{\mathrm{R}}|=\left|\frac{-\varepsilon_{xx}\delta E'_{0y}+\varepsilon_{xx}E'_{0x}}{k_y/k_x-\varepsilon_{xx}\delta+\varepsilon_{yx}}\right|. \tag{12}$$

4. THZ RADIATION EFFICIENCY

The efficiency of the emitted radiation is the ratio of the energy of THz radiation and the energy of the incident lasers. According to Rothwell and Cloud (2009) in general, the average electromagnetic energy stored per unit volume is given by the formula:

$$w_{\mathrm{E}i}=\frac{\varepsilon}{8\pi}\frac{\partial}{\partial\omega_i}\left[\omega_i\left(1-\frac{\omega_{\mathrm{p}}^2}{\omega_i^2}\right)\right]\langle|E_i|^2\rangle. \tag{13}$$

The energy densities of the incident lasers and THz radiation are evaluated as

$$w_{\mathrm{pump}}=\frac{\varepsilon}{8\pi}\frac{\partial}{\partial\omega_i}\left[\omega_i\left(1-\frac{\omega_{\mathrm{p}}^2}{\omega_i^2}\right)\right]\langle|E_{\mathrm{pump}}|^2\rangle \quad \text{and}$$

$$w_{\mathrm{THz}}=\frac{\varepsilon}{8\pi}\frac{\partial}{\partial\omega}\left[\omega\left(1-\frac{\omega_{\mathrm{p}}^2}{\omega^2}\right)\right]\langle|E_{\mathrm{THz}}|^2\rangle,$$

respectively. Based on this and following the method used by Malik *et al.* (2014), the efficiency of the THz radiation (η) is calculated as

$$\eta=\frac{w_{\mathrm{THz}}}{w_{\mathrm{pump}}}=\frac{\langle|E_{\mathrm{THz}}|^2\rangle}{\langle|E_{\mathrm{pump}}|^2\rangle}=\frac{1}{A_{10}^2}\left|\frac{-\varepsilon_{xx}\delta E'_{0y}+\varepsilon_{xx}E'_{0x}}{(k_y/k_x)-\varepsilon_{xx}\delta+\varepsilon_{yx}}\right|^2. \tag{14}$$

5. RESULTS AND DISCUSSION

We have used the following set of parameters $\lambda_1=9.6$, $\lambda_2=9.75$ µm, and $eA_{20}/\omega_1 mc=0.003$. The typical parameters can be belonged to a CO2 laser. Plasma frequency supposed as $\omega_{\mathrm{p}}=2.25\times10^{14}$ rad/s, which is corresponding to the electron density $n_0=1.6\times10^{19}$ cm^{-3}. Critical density supposed as $n_{\mathrm{c}}=1.2\times10^{19}$ cm^{-3}. In Figure 2, the normalized THz wave amplitude $|A_{\mathrm{R}}/A_{10}|$ versus angle of incident lasers θ_i is plotted. As the figure shows, in the absence of magnetic field the normalized THz amplitude has a minimum about $\theta_i=20°$ and a maximum about $\theta_i=70°$. In the presence of a magnetic field, the form of curve roughly does not change, but the magnetic field increases generated THz amplitude for all angles of incident.

Figure 3 shows the variation of efficiency of THz radiation with normalized beating frequency for different values of magnetic field strength. From this figure it is clear that the effect of magnetic field gradually disappears in large beating frequency. Also by increasing of beating frequency the efficiency is decreasing, the similar behavior occurs in the underdense plasma (Malik *et al.*, 2014). This figure and Figure 4 illustrate that the present scheme of frequency-mixing of two laser beams in an overdense magnetized plasma is very effective. High efficiency can be obtained if

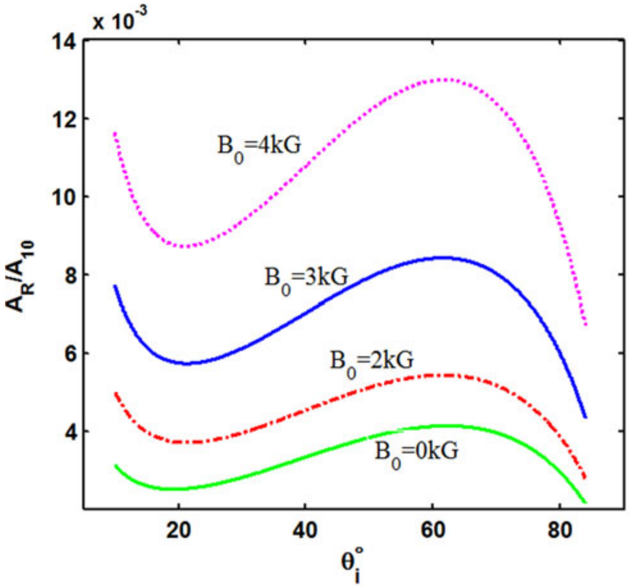

Fig. 2. Normalized THz amplitude $|A_{\mathrm{R}}/A_{10}|$ versus angle of incident θ_i for different values of magnetic field strength.

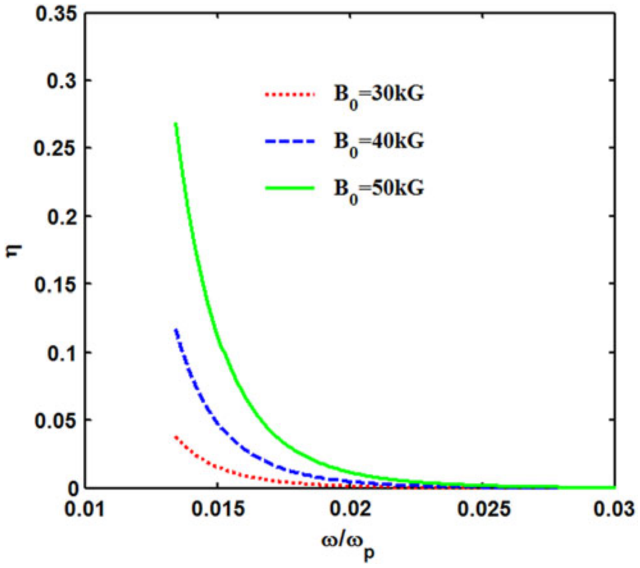

Fig. 3. Variation of efficiency of THz radiation versus normalized beating frequency for different values of strength of magnetic field.

large angle of incident lasers and strong magnetic field are used. Figure 3 also shows that the efficiency of THz radiation from an overdense magnetized plasma is greater than the underdense plasma (Malik *et al*. 2010, 2012, 2014; Malik & Malik, 2011; Bakhtiari *et al.* 2015*a*, *b*). Malik and Singh (2015) have proposed THz radiation generation by beating of two super-Gaussian lasers in rippled density plasma and realized the efficiency about 0.25 for an applied magnetic field about 60 kG, where the present scheme can be realized efficiency about 0.27 for the applied magnetic field about 50 kG.

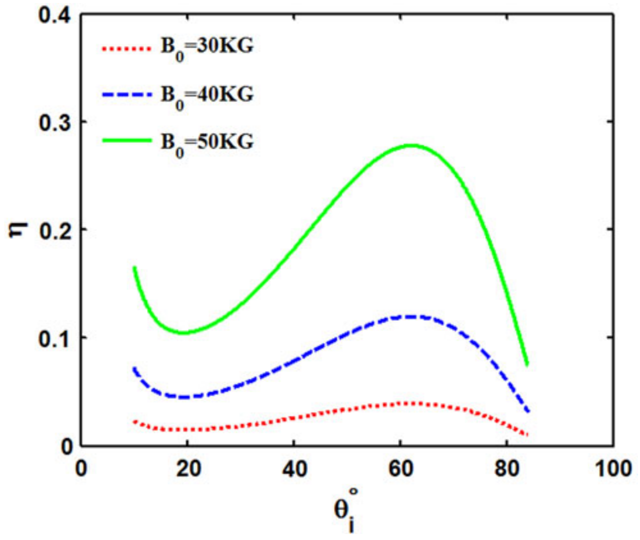

Fig. 4. Efficiency of THz radiation versus angle of incident θ_i for different values of strength of magnetic field, when $\omega/\omega_p = 0.01338$.

6. CONCLUSION

We have presented a scheme for THz generation based on nonlinear mixing of two obliquely incident laser beams on an overdense magnetized plasma. It is investigated that the amplitude and efficiency of the THz wave increases with increasing of magnetic field also THz wave amplitude can be optimized at a particular angle which occurred in large incident angle of lasers. Our analytical investigations show that this scheme is quite effective for getting the strong THz radiation and the efficiency of THz radiation from an overdense magnetized plasma is greater than the underdense plasma. A natural extension for future works is to include collision into this scheme.

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