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RESEARCH ARTICLE

Enhance the Terahertz Wave by Varying the Laser Beam Intensity via Relativistic Plasma

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Abstract

In this work, the use of CO_2 laser and high intensity at the wavelength 10.6 μm with Gaussian beam shape. This research focuses on the derivation of the equation which represents interaction between laser and plasma parameters in to states paraxial and nonparaxial in the case of self-focusing .The interaction of the laser with longitudinal magneto plasma occurs. The relation between the laser beam width and normalized distance parameters for three types intensities (0.9, 0.8, 0.7) self-focusing were studied. Then the best result self-focusing obtained at high intensity and at the lowest intensity, the self-focusing become weak .In nonparaxial beam the self-focusing been very weak and the best state at in high intensity and then at least intensity there no self-focusing exist .The THz radiation in case of paraxial beam is appear clearly with clean peaks (high resolution) so that the best at the power full self-focusing, either case nonparaxial beam obtained on the semi-stability phenomena. These results were studied and discussion.

Keywords: *Relativistic nonlinearity, Magneto plasma, Non paraxial, Terahertz radiation*, *Laser density, Self-focusing.*

Introduction

Producing strong electromagnetic radiation and monochromatic that is powerful enough for all spectrums that are required is considered as one of the biggest encounters [1, 4]. Currently the terahertz physics, abbreviated (THz), has been of much interest to researchers for its vast dominance of applications in fields such as security identification [7, 8], medical imaging [5, 6] and spectroscopy of time domain [9, 11].

Detecting appropriate methods for the production of THz emission characterized with prominent conversion efficiencies has been a featuring concern in plasma. Previous attempts for THz radiation production relied mainly on electron beams acceleration by means of synchrotron accelerators [12], or by impacting short laser pulses characterized with solid targets (nonlinear crystals or semiconductors) [13, 14]. However, these conventional techniques generate energy that could not be higher than a few µJ per pulse. Laser with ultra-short pulse was employed by Leemans ET. al. [15].To generate beams of accelerated electron, by which THz radiation ranging 10-100 µJ per pulse is achieved via medium of plasma. Hamster et al [16].Initiated the direct monitoring of a Wakefield induced by laser. As high as 10^{12}W laser pulses focused on solid targets and gas. The THz frequencies processes of radiation detected from the resulting plasmas are focused by space charge fields that are ponderomotively induced. A ridged plasma channels have been promoted by Antonson et al [17]. This scheme can be attained by a range of (500 mJ, 100 ps) primary pulse of laser to generate an ionized region and then employing a second pulse range of (100 mJ, 50 ps) after 2 ns for the nonlinear currents to be driven consequently producing THz radiation. Sharma et al [18].

Have examined the THz radiation production interacting high-power laser beam with plasma wave ripple density. However, lasers used were at ultra relativistic level of power for the THz sources to be generated. The ponderomotive nonlinearity is less essential than the relativistic nonlinearity; therefore, the generation of THz theory set by Sharma

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et al. [18], is inapplicable with a maximized flux of laser power as such. The current study examines the electron mass increment relativistic impacts to produce radiation of THz when transmitting highly intensified beam of laser with a propagation vector parallel in magnetic plasma to static magnetic field. By frequency of density ripple as (ω_1) and of pump wave as (ω_0) differentiation, (ω_t) frequency occurs in THz frequency range. Therefore, with satisfied matching conditions, the THz radiation is excited resonantly. The influence of propagation of laser beam in a self-focusing relativistic manner is investigated in this study since the generation of THz radiation is related to power flux of laser beam regarding the approximation of paraxial ray.

Self-focusing of Laser Beam in a Relativistic Manner

Consider an unchanging electron density n_o of plasma magnetic equilibrium in magnetic static field B_o in line with z-direction. The vector of electric field $\vec{E}_{0+}$ of circular right electromagnetic polarized wave propagating in line with z-direction by means of magneto plasma can be formulated as [19]:

$$\vec{E}_{0+} = \vec{A}_{0+} \exp i(\omega_0 t - k_{0+} z) \qquad (1)$$

The electric field amplitude is $\vec{A}_{0+} = \vec{E}_x + i\vec{E}_y$, k_{0+} wave vector and ω_0 angular frequency, dielectric constant k_{0+} is $k_{0+}^2 = \frac{\varepsilon_{0+}\omega_0^2}{c^2}$ where a velocity of vacuum light symbolized c. The equation of highly intensified laser electron in relativistic motion is:

$$m\frac{\partial}{\partial t}[\gamma\, \vec{v}(x,y)] = -e\vec{E} - \frac{e}{c}[\vec{v}(x,y) \times \vec{B}_0] \qquad (2)$$

Where the relativistic factors γ, $\vec{v}$, and $\vec{B}_0$, are the laser beam transmitted oscillation velocity, and the external magnetic field .

If the pulse width τ_L is short, viz .$\tau_L \ll \frac{1}{(\omega_{pe})}$, just relativistic nonlinearity occurs.

By (2) to calculate velocity of oscillation electron (v_{0+}) to the polarized right circular mode of laser beam:

$$\vec{v}_{0+} = \vec{v}_x + i\vec{v}_y = \frac{ie\vec{E}_{0+}}{m_e\gamma\omega_0\left(1 - \frac{\omega_{ce}}{\gamma\omega_0}\right)} \qquad (3)$$

Where m_0 , e, and $\omega_{ce} = \frac{eB_0}{m_0 c}$ are the rest mass electron, the electronic charge, and the frequency of electron–cyclotron, and $\gamma = (1 - \frac{v_{0+}^2}{c^2})^{-\frac{1}{2}}$ setting $(\gamma - 1 < 1)$ [20], γ (relativistic factor) is,

$$\gamma \approx 1 + \frac{e^2}{8m_e^2\, c^2\, \omega_0^2}\frac{\vec{A}_{0+}\, \vec{A}_{0+}^*}{\left(1 - \frac{\omega_{ce}}{\omega_0}\right)^2} + \cdots = 1 + \alpha_+\, \vec{A}_{0+}\, \vec{A}_{0+}^* + \cdots \qquad (4)$$

The factor of relativistic nonlinearity, $\alpha_+ = \frac{e^2}{8m_e^2\, c^2\, \omega_0^2}\left(1 - \frac{\omega_{ce}}{\omega_0}\right)^{-2}$ in non-relativistic regime (i.e. γ =1) is equal to zero.

The equation of general electromagnetic wave transmitted via magnetized plasma is formulated as:

$$\nabla^2\vec{E} - \vec{\nabla}(\vec{\nabla}\cdot\vec{E}) + \frac{\omega_0}{c^2}\varepsilon\, \vec{E} = 0 \qquad (5)$$

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The dielectric constant tensor ε component in relativistic system is formulated as:

$$\varepsilon_{xx} = \varepsilon_{yy} = 1 - \frac{\omega_{pe}^2}{\omega_0^2\, \gamma \left(1 - \frac{\omega_{Ce}^2}{\omega_0^2\, \gamma^2}\right)} \quad (6)$$

$$\varepsilon_{xy} = \varepsilon_{xy} = \frac{-i \left(\frac{\omega_{pe}^2}{\omega_0^2\, \gamma}\right)\left(\frac{\omega_{Ce}}{\omega_0\, \gamma}\right)}{\left(1 - \frac{\omega_{Ce}^2}{\omega_0^2\, \gamma^2}\right)} \quad (7)$$

$$\varepsilon_{xz} = \varepsilon_{yz} = \varepsilon_{zx} = \varepsilon_{zy} = 0 \quad (8)$$

$$\varepsilon_{zz} = 1 - \frac{\omega_{pe}^2}{\omega_0^2 \gamma} \quad (9)$$

The circular right electromagnetic polarized wave (pump) ε_+ as corresponded by dielectric effective constant is:

$$\varepsilon_+ = \varepsilon_{xx} - i\varepsilon_{xy} = 1 - \frac{\frac{\omega_{pe}^2}{\omega_0^2\, \gamma}}{\left(1 - \frac{\omega_{Ce}}{\omega_0\, \gamma}\right)} \quad (10)$$

$\omega_{pe} = \sqrt{\left(\frac{4\,\pi n_0 e^2}{m_0}\right)}$ is the frequency of electron plasma.

Using equation (4) the effective dielectric constant ε_+ is formulated as:

$$\varepsilon_+ = 1 - \frac{\left(\frac{\omega_{pe}}{\omega_0}\right)^2}{\left(1 - \frac{\omega_{Ce}}{\omega_0}\right)} + \frac{\left(\frac{\omega_{pe}}{\omega_0}\right)^2}{\left(1 - \frac{\omega_{Ce}}{\omega_0}\right)} \alpha_+\, \vec{A}_{0+}\, \vec{A}_{0+}^* \quad (11)$$

It is obvious that effective dielectric constant ε_+ contains a nonlinear part $\varphi_+(A_{0+}A*_{0+})$ and a linear part which is ε_{0+}. The first is appears as a consequence of relativistic electron mass increment. We can write both parts of the dielectric effective constant ε_+ in the following way:

$$\varepsilon_{0+} = 1 - \frac{\left(\frac{\omega_{pe}}{\omega_0}\right)^2}{\left(1 - \frac{\omega_{ce}}{\omega_0}\right)} \quad (12)$$

$$\phi_+ = \varepsilon_{2+}\, \vec{A}_{0+}\, \vec{A}_{0+}^* \quad (13)$$

$$\varepsilon_{2+} = \frac{1}{2}\left(\frac{e}{m_0\, c\, \omega_0}\right)^2 \frac{\left(\frac{\omega_{pe}}{\omega_0}\right)^2}{\left(1 - \frac{\omega_{Ce}}{\omega_0}\right)^4} \quad (14)$$

The electromagnetic magneto plasma wave can be considered a transverse wave. This is due to the fact that its field change consistently with magnetic external field; namely the z-direction in a larger capacity than its change through the plane of wave front; or x–y plane [21]; therefore, there is no space charge, hence:

$$\vec{\nabla} \cdot \vec{D} = \vec{\nabla} \cdot (\varepsilon \vec{E}\,) = 0 \quad (15)$$

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By equation (10) with dielectric tensor components we get:

$$\frac{\partial E_z}{\partial z} \approx -\frac{1}{\varepsilon_{zz}}\left[\varepsilon_{xx}\left(\frac{\partial E_x}{\partial x}+\frac{\partial E_y}{\partial y}\right)+\varepsilon_{xy}\left(\frac{\partial E_y}{\partial x}-\frac{\partial E_x}{\partial y}\right)\right]$$

Using approximation of zero-order after compensating (11) in (5), the following differential equation is obtained to reach polarized circular electric field amplitude A_{0+} as

$$\frac{\partial^2 A_{0+}}{\partial z^2}+\frac{1}{2}\left(1+\frac{\varepsilon_{0+}}{\varepsilon_{0zz}}\right)\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)A_{0+}+\frac{\omega_0^2}{c^2}(\varepsilon_{0+}+\varepsilon_{2+}\,A_{0+}\,A_{0+}^*)A_{0+}=0 \quad (16)$$

Nonlinear part product of $\frac{\partial^2 A_{0+}}{\partial x^2}$ or $\frac{\partial^2 A_{0+}}{\partial y^2}$ is neglected [22]. We assume $A_{0+}=A'_{0+}\exp i(\omega_0 t-k_{0+}z)$, $A_{0+}=A'_{0+}$ and its value is substituted on (2), to get:

$$-2ik_{0+}\frac{\partial A'_{0+}}{\partial z}+\frac{1}{2}\left(1+\frac{\varepsilon_{0+}}{\varepsilon_{0zz}}\right)\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)A'_{0+}+\frac{\omega_0^2}{c^2}(\varepsilon_{2+}\,A'_{0+}\,A'^*_{0+})A_{0+}=0 \quad (17)$$

Where $A`_{0+}$ it's the complex amplitude.

Suggesting a Gaussian beam of two dimensions ($\frac{\partial}{\partial y}=0$), and presenting an eikonal $A`_{0+}=A_{0+}^0\exp(i\,k_{0+}S_+)$, A_{0+}^0 represents a real function and S_+ is laser beam phase in magnetoplasma, (13) after the parting up the real and imaginary parts the equation becomes [21]:

$$2\frac{\partial S_+}{\partial z}+\frac{1}{2}\left(1+\frac{\varepsilon_{0+}}{\varepsilon_{0zz}}\right)\left(\frac{\partial S_+}{\partial z}\right)^2+\frac{1}{2\,k_{0+}^2\,A_{0+}^0}\left(1+\frac{\varepsilon_{0+}}{\varepsilon_{0zz}}\right)\frac{\partial^2 A_{0+}^0}{\partial x^2}=\frac{\varepsilon_{2+}}{\varepsilon_{0+}}(A_{0+}^0)^2 \quad (18)$$

$$\frac{\partial (A_{0+}^0)^2}{\partial z}+\frac{1}{2}(A_{0+}^0)^2\left(1+\frac{\varepsilon_{0+}}{\varepsilon_{0zz}}\right)\frac{\partial^2 S_+}{\partial x^2}+\frac{1}{2}\left(1+\frac{\varepsilon_{0+}}{\varepsilon_{0zz}}\right)\frac{\partial S_+}{\partial x}\frac{\partial (A_{0+}^0)^2}{\partial x}=0 \quad (19)$$

In the approximation of non-paraxial ray, S_+ could be extended to $S_+=\frac{1}{2}x^2\beta_+(z)+\varphi_+(z)$ the β_+^{-1} is a symbol of the laser beam curvature radius and φ_+ is a constant which does not depend on x.

$$A_0^2=\frac{E_{00}^2}{f_{0+}^2}\left(1+\alpha_0\frac{r^2}{r_0^2 f_{0+}^2}+\alpha_2\frac{r^4}{r_0^4 f_{0+}^4}\right)e^{-\frac{r^2}{r_0^2 f_{0+}^2}} \quad (20)$$

$$S_+=\left[\frac{1}{\left(1+\frac{\epsilon_{0+}}{\epsilon_{zz}}\right)}\frac{1}{f_{0+}}\frac{df_{0+}}{dz}\right]r^2+\left[\frac{S_{2+}}{r_0^4}\right]r^4+\cdots \quad (21)$$

$$\frac{d^2 f_{0+}}{dz^2}=\frac{\left(1+\frac{\epsilon_{0+}}{\epsilon_{zz}}\right)^2}{4k_{0+}^2\,r_0^4}\frac{1}{f_{0+}^3}(8\alpha_2-3\alpha_0^2-2\alpha_0+1)$$

$$-\frac{\left(1+\frac{\epsilon_{0+}}{\epsilon_{zz}}\right)}{2\epsilon_{0+}}\frac{\epsilon_{r+}(1-\alpha_0)E_{00}^2}{r_0^2 f_{0+}^2} \quad (22)$$

This equation show self-focusing in case nonparaxial, we note composed of two mini , the first term of this equation referred to the neutral defection term .The second term from right side equation (22) referred to the nonlinear self-focusing associated with intensity of laser. This equation will become to paraxial when the $\alpha_2=\alpha_0=0$ so will rewrite equation (22) as:

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$$\frac{d^2 f_{0+}}{dz^2} = \frac{\left(1+\frac{\epsilon_{0+}}{\epsilon_{zz}}\right)^2}{4k_{0+}^2\, r_0^4}\frac{1}{f_{0+}^3} - \frac{\left(1+\frac{\epsilon_{0+}}{\epsilon_{zz}}\right)}{2\epsilon_{0+}}\frac{\epsilon_{r+}E_{00}^2}{r_0^2 f_{0+}^2} \qquad (23)$$

Technique of Terahertz (THz) Generation

The technique of generation THz radiation ($\vec{E}_{t+}, \omega_t, \vec{k}_{t+}$) depends upon nonlinear coupling between rippled density plasma $(\vec{E}_1, \omega_1, \vec{k}_1)$ and high intense laser beam $(\vec{E}_{0+}, \omega_0, \vec{k}_{0+})$. The phase-matching conditions are $\omega_0 = \omega_1 + \omega_t$ and $\vec{k}_{0+} = \vec{k}_1 + \vec{k}_{t+}$, where E1, k1 are the electric fields and wave vectors of plasma wave and _Et+, _kt+ are the electric fields and wave vectors of THz wave

The wave's electric fields are:

$$\vec{E}_1 = \hat{z}E_1 \exp i(\omega_1 t - k_1 z) \qquad (24)$$

$$\vec{E}_{t+} = \vec{A}_{t+} \exp i(\omega_t t - k_{t+} z) \qquad (25)$$

Where$\vec{A}_{t+} = \vec{E}_{tx} + i\vec{E}_{ty}$; which is the amplitude of the right polarized circular field of THz. $\vec{v}_1 = -\frac{ie\vec{E}_1}{m_e \gamma \omega_1}$ Plasma wave field in z-direction produces the relativistic oscillating velocity associated with ripple plasma of density which is $v_1 = \frac{\omega_1}{k_1}\mu$ where $\mu = \frac{\tilde{n}_p}{n_0}$ the normalized amplitude of ripple density symbolizing the ratio between density perturbed $\tilde{n}_p$ with density of background plasma n_0, and $n_p = n_0 + \tilde{n}_p \exp i(\omega_1 t - K_1 z)$.

By using the equations, the nonlinear interaction between plasma wave field and electromagnetic field can be formulated: The momentum equation $m_j\gamma = \frac{\partial \vec{v}_j}{\partial t} + m_j(\vec{v}_j .\nabla)\vec{v}_j = -e\vec{E} - \frac{e}{c}\overrightarrow{(v_j} \times (\vec{B} + \vec{B}_0))$ and The continuity equation $\frac{\partial n_j}{\partial t} = -\vec{\nabla}.(n_j\vec{v}_j)$, where m_j, n_j ,$and\ v_j$ are the mass, the particle density, and the species velocity$j = i$, e respectively; $\vec{E}$, $\vec{B}$ they are electric fields with self-consistency related to the wave.

At the magneto plasma atmosphere the electric vector wave equation $\vec{E}_{t+}$with magneto plasma is formulated as [25],

$$\nabla^2 \vec{E}_{t+} - \frac{1}{c^2}\frac{\partial^2 \vec{E}_{t+}}{\partial t^2} = \frac{4\pi}{c^2}\frac{\partial \vec{J}_{t+}}{\partial t} \qquad (26)$$

When $\vec{J}_{t+}$ is the total vector of current density with lower electric field of frequency, $\vec{E}_{t+}$ and is formulated as:

$$\vec{J}_{t+} = \vec{J}_{1+} + \vec{J}_{2+} \qquad (27)$$

The current linear density $\vec{J}_{1+}$ is produced by

$$\vec{J}_{1+} = -en_0\vec{v}_{1+}^e + en_0\vec{v}_{1+}^i \qquad (28)$$

Also the current nonlinear density $\vec{J}_{2+}$ is produced by

$$\vec{J}_{2+} = -e\tilde{n}_p^*\vec{v}_{0+} - en_0\vec{v}_{2+}^e \qquad (29)$$

Where the ion and the electron linear velocities are symbolized by $\vec{v}_{1+}^i$ and $\vec{v}_{1+}^e$ respectively, and can be found, regarding the wave of right circular polarization of less

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frequency, by solving the momentum equation:

$$\vec{v}_{1+}^{e} = \frac{ie\vec{E}_{t+}}{m_0(\gamma\omega_t - \omega_{ce})} \qquad (30)$$

$$\vec{v}_{1+}^{i} = \frac{-ie\vec{E}_{t+}}{m_0(\gamma\omega_t + \omega_{ci})} \qquad (31)$$

Where the ion–cyclotron frequency is $\omega_{ci} = \frac{eB_0}{m_i c}$. Introducing $\vec{B} = \left(\frac{c\vec{K}_{0+}}{\omega_0}\right) \times \vec{E}_{0+}$ of the equation of momentum, $\vec{v}_{2+}^{e}$ which is the nonlinear velocity interacting to the ripple density and electric field of the magneto plasma laser beam:

$$\vec{v}_{2+}^{e} = \frac{-ie\vec{E}_{0+}\omega_{ce}k_{0+}v_1^*}{2m_0\,\omega_0(\omega_0\gamma - \omega_{ce})(\omega_t\gamma - \omega_{ce})} \qquad (32)$$

$$\vec{J}_{1+} = \frac{-i\omega_p^2}{4\pi}\frac{\gamma\omega_t\vec{E}_{t+}}{(\gamma\omega_t - \omega_{ce})(\gamma\omega_t + \omega_{ci})} \qquad (32)$$

Finally, $\vec{v}_{0+}$ or quiver electron velocity in laser field (see figure 3) is

$$\vec{v}_{0+}^{e} = \frac{ie\vec{E}_{0+}}{m_0(\gamma\omega_0 - \omega_{ce})} \qquad (33)$$

Substituting (30) and (31) in (28) and (32), (33) in (29), the expressions of densities of nonlinear and linear current are:

$$\vec{J}_{2+} = -\frac{i\omega_p^2}{4\pi}\frac{\mu^*}{(\gamma\omega_0 - \omega_{ce})}\left[1 - \frac{\omega_1\,k_{0+}\,\omega_{ce}}{2\omega_0\,k_{1+}\,(\gamma\omega_t - \omega_{ce})}\right]\vec{E}_{0+} \qquad (34)$$

The contribution in nonlinear interaction has been ignored for its immobility. Placing (32) and (34) in (35) the following equation is formulated:

$$\frac{\partial^2\vec{E}_{t+}}{\partial z^2} + \frac{\omega_t^2}{c^2}\left[1 - \frac{\gamma\omega_p^2}{(\gamma\omega_t - \omega_{ce})(\gamma\omega_t + \omega_{ci})}\right]\vec{E}_{t+} =$$

$$\frac{\omega_p^2}{c^2}\frac{\mu^*\omega_0}{(\gamma\omega_0 - \omega_{ce})}\left[1 - \frac{\omega_1\,k_{0+}\,\omega_{ce}}{2\omega_0\,k_{1+}\,(\gamma\omega_t - \omega_{ce})}\right]\vec{E}_{0+} \qquad (35)$$

By a similar technique we can calculate relativistic factor γ as in Sec. 2 [25], (35) by the following equation:

$$\frac{\partial^2\vec{E}_{t+}}{\partial z^2} + \left\{\frac{\omega_t^2}{c^2}\left[1 - \frac{\omega_{pe}^2}{(\omega_t - \omega_{ce})(\omega_t + \omega_{ci})}\right] + \alpha_{t+}\right\}\vec{E}_{t+} =$$

$$\left\{\frac{\omega_p^2}{c^2}\frac{\mu^*\omega_0}{(\omega_0 - \omega_{ce})}\left[1 - \frac{\omega_1\,k_{0+}\,\omega_{ce}}{2\omega_0\,k_{1+}\,(\omega_t - \omega_{ce})}\right] + \alpha_{tt+}\right\}\vec{E}_{0+} \qquad (36)$$

Where relativistic growing mass contribution terms are symbolized by α_{t+} *and* α_{tt+} , and the following equation is produced:

$$\alpha_{t+} = \frac{\omega_0\,\omega_{pe}^2}{c^2(\omega_0 - \omega_{ce})^2}\,\alpha_+\,E_{0+}\,E_{0+}^* \qquad (37)$$

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$$\alpha_{tt+} = \frac{\omega_t\,\mu^*}{c^2}\left[\frac{\omega_{pe}^2(2\omega_{ce}-\omega_0)}{\omega_0(\omega_0-\omega_{ce})^2} - \frac{\omega_0\,k_{1+}\,\omega_{Ce}\,\omega_{pe}^2}{\omega_1 k_0(\omega_{ce}-\omega_t)(\omega_0-\omega_{ce})} \times\left(\frac{\omega_{Ce}}{(\omega_{ce}-\omega_t)}+\frac{\omega_{Ce}}{(\omega_0-\omega_{ce})}-2\right)\right]\alpha_+\,E_{0+}\,E_{0+}^* \quad (38)$$

It is evident that the non-relativistic issue can be satisfied when α_{t+} and α_{tt+} have disappeared, and for THz generation intensity, (36) was numerically solved. The function of z is f_+ and is governed by (22). The field of THz produced by this technique can numerically be found also straightforward by equation (36) with appropriate limited conditions when the parameter width of laser beam alters with propagation distance given by (22).

Results and Discussion

The results show that the increasing of initial laser beam intensity leads to increase the self-focusing laser beam in both paraxial and nonparaxial cases (see Fig. (1) and Fig. (2) respectively).Fig. (1) And Fig (2) also demonstrate the oscillating medal to the competition between diffraction effect and nonlinear self-focusing effect (i.e. first and second term of right hand side of equation (23) and equation (22) respectively Figure (3) and figure (4) explain the terahertz field generation in the paraxial and nonparaxial regions respectively .In both region, the terahertz wave amplitude is increasing as long as the initial laser beam intensity is increased. High terahertz wave amplitude is observed for nonparaxial region comparing with paraxial region. Using the Rung Kutta program and laser frequency angular (1.777×10^{14}rad.sec^{-1}),programmed in the language of Matlab, was used to solve the paraxial equation and nonparaxieal equation of self-focusing and the terahertz in numerical analysis terms .

Figure 1 shows that the laser beam self-focusing in paraxial region will be related with the initially laser beam intensity which corresponding to laser streak parameter here gets self-focusing for laser beam inside plasma magnetic which indicates that the self-focusing beam width parameter gets a change because of change the initially laser beam intensity. Now note increase of initially laser beam intensity will lead to more self-focusing, red dash curve$r_R=0.9$, solid black curve $r_R=0.8$ and blue dotted curve $r_R=0.7$ Red dash curve $r_R=0.9$ gets self-focusing the more powerful and the largest .That is clear from equation (23).

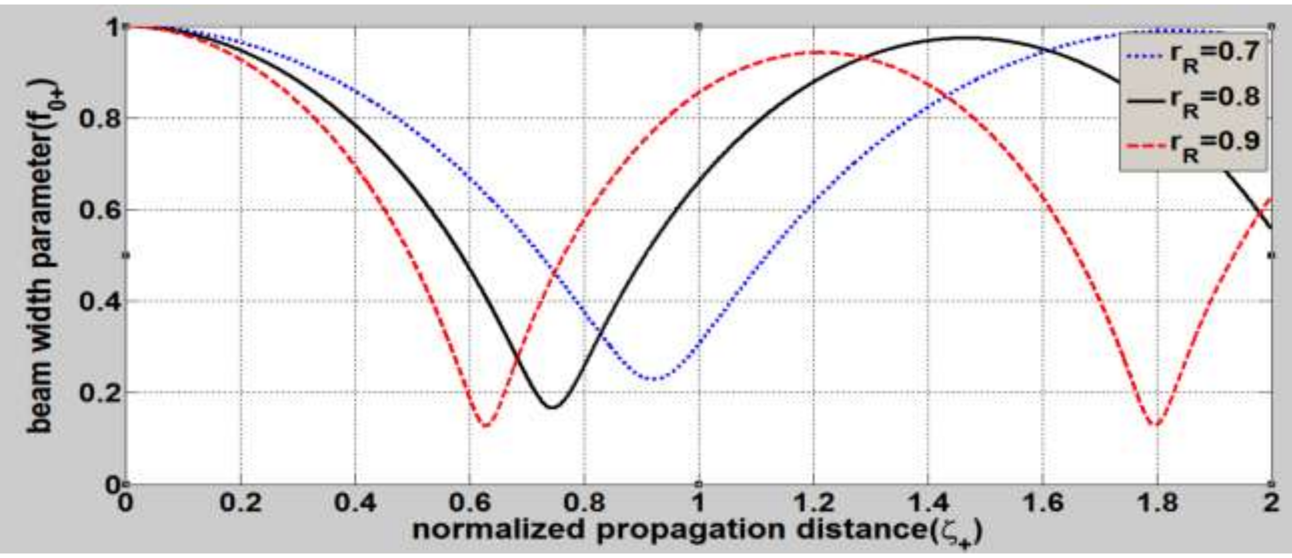

Figure 1: Variation of paraxial laser beam self-focusing inside magnetized plasma due to relativistic laser strength parameters ($r_R=0.7$,$r_R=0.8$,$r_R=0.9$)

Figure (2) The behavior it was nonparaxil case we note when the intensities increase obtained more self-focusing with we observed when ($r_R=0.7$) because of the intensity is not enough for the situation self-focusing in nonparaxial would suffers of simple self-focusing, that is causes a defocusing, that is means in this case overcome neutral

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diffraction phenomena over come on nonlinear self-focusing as in equation (22).

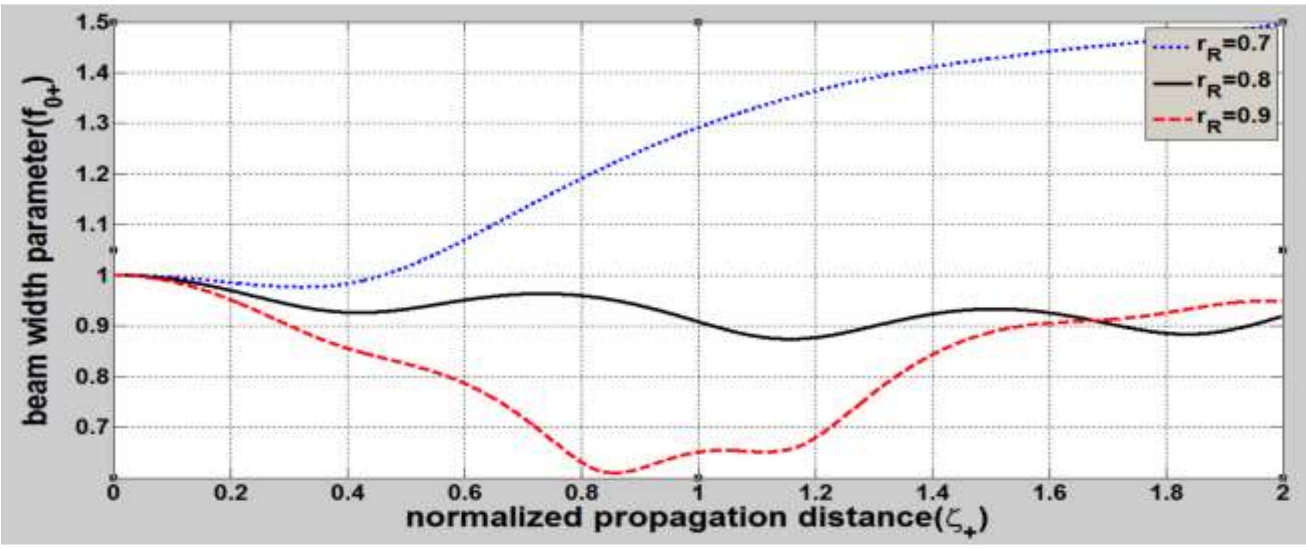

Figure 2: Variation of nonparaxial laser beam self-focusing inside magnetized plasma due to relativistic laser strength parameters ($r_R = 0.7$, $r_R = 0.8$, $r_R = 0.9$).

Figure 3 Shows production terahertz in paraxial region and observed the terahertz associated with intensity when the intensity is higher the terahertz is also higher peak, from the compared Figure 1 with Figure 3. we found when the self-focusing is stronger and higher will be accompanied by the same area inside plasma severe height in intensity terahertz and the other intensities take low peak THz intensities respectively due to self-focusing as in Figure 1.

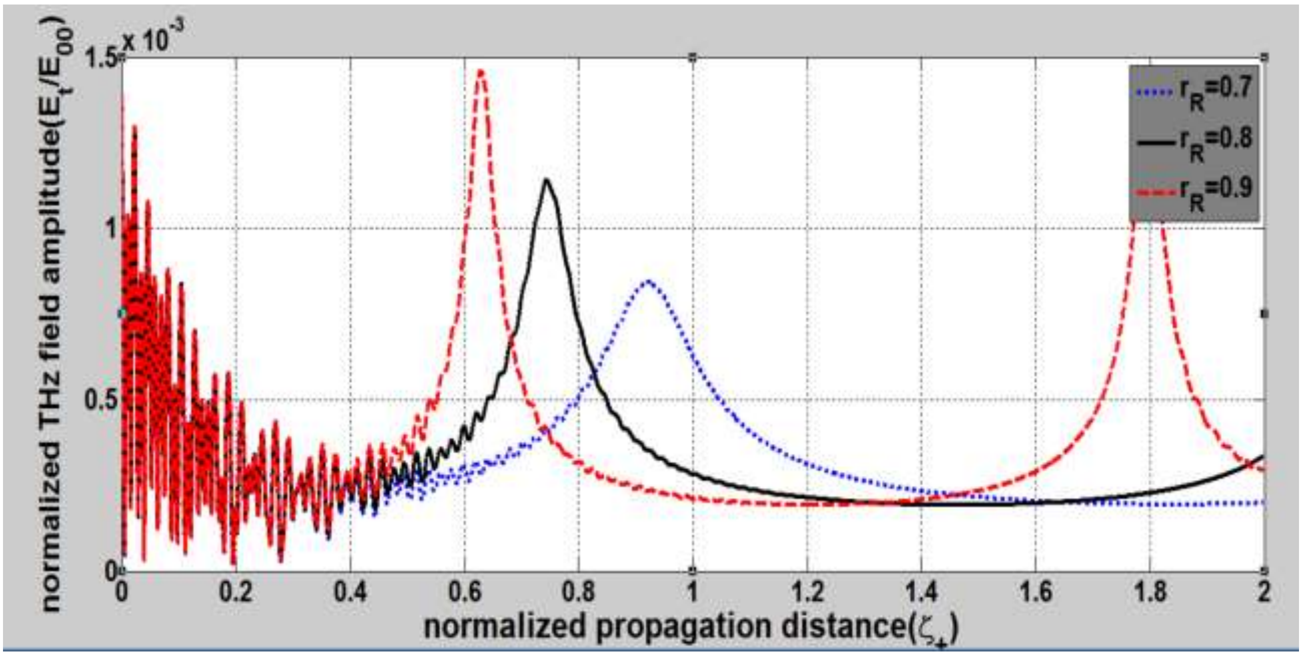

Figure 3: Variation of paraxial terahertz intensity inside magnetized plasma due to relativistic laser strength parameters ($r_R = 0.7$, $r_R = 0.8$, $r_R = 0.9$)

Figure 4 Shows production terahertz in nonparaxial region, now was observed the terahertz associated with intensity whenever y the intensity is higher the terahertz is also higher, but when the compared Figure 2 with Figure 4 we noted when the self-focusing is stronger and high will be accompanied by the same area inside plasma severe height in terahertz intensity, but the terahertz in nonparaxial gets semi stability comparison with paraxial region due to the balanced between the self-focusing and defocusing this may be belonging to soliton wave phenomena [26, 27].

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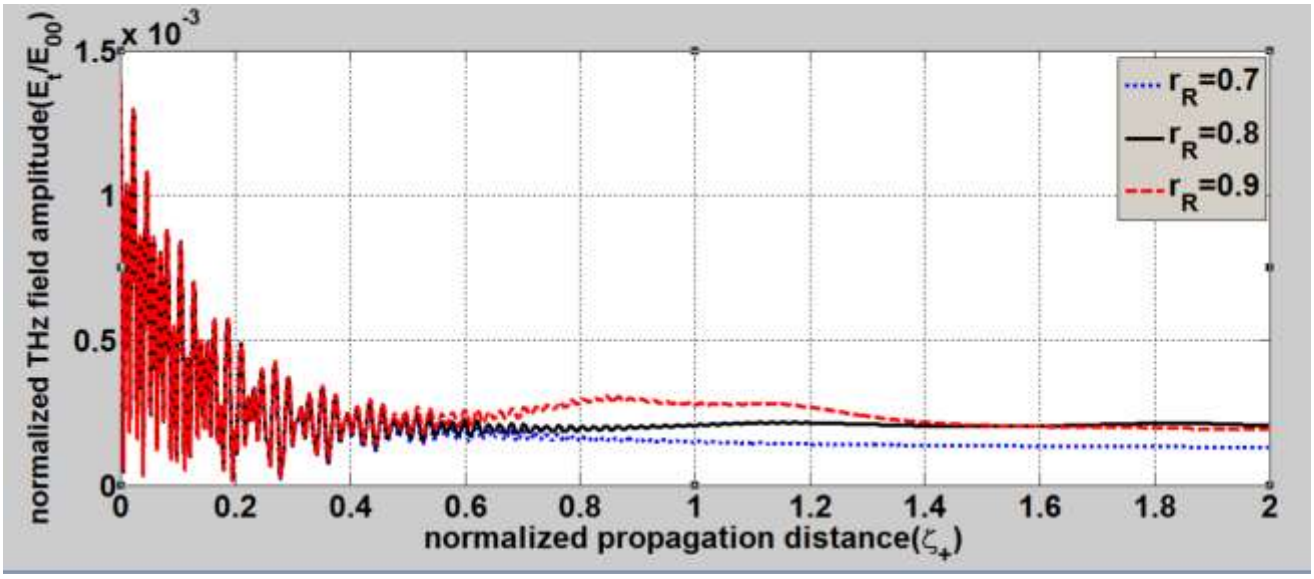

Figure 4: variation of nonparaxial terahertz intensity inside magnetized plasma due to relativistic laser strength parameters ($r_R = 0.7$, $r_R = 0.8$, $r_R = 0.9$).

Conclusion

In this paper have been presented the best self-focusing at high intensities the self-focusing become weak, this relative to paraxial beam .Here when the nonparaxial the self-focusing is very weak at all intensities.

The THz radiation with high peak, clear, and corresponding with power full self-focusing at high intensity. This results show that the THz was better at the paraxial beam .Semi stability phenomena is appear in the nonparaxial without self-focusing may be depend up on the equilibrium between the two forces ,self-focusing and defocusing.

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