On the exploration of graphical and analytical investigation of effect of critical beam power on self-focusing of cosh-Gaussian laser beams in collisionless magnetized plasma

Article *in* Laser and Particle Beams · August 2018

DOI: 10.1017/S0263034618000253

T. U. Urunkar
Shivaji University, Kolhapur

Supriya dilip Patil
Lewis University

Amol Tanaji Valkunde
Shivaji University, Kolhapur

B. D. Vhanmore
D.Y.Patil College of Engineering and Technology

Laser and Particle Beams

cambridge.org/lpb

On the exploration of graphical and analytical investigation of effect of critical beam power on self-focusing of cosh-Gaussian laser beams in collisionless magnetized plasma

T. U. Urunkar[1], S. D. Patil[2], A. T. Valkunde[1], B. D. Vhanmore[1], K. M. Gavade[1] and M. V. Takale[1]

[1]Department of Physics, Shivaji University, Kolhapur 416 004, India and [2]Department of Physics, Devchand College, Arjunnagar, Kolhapur 591 237, India

Research Article

Cite this article: Urunkar TU, Patil SD, Valkunde AT, Vhanmore BD, Gavade KM, Takale MV (2018). On the exploration of graphical and analytical investigation of effect of critical beam power on self-focusing of cosh-Gaussian laser beams in collisionless magnetized plasma. *Laser and Particle Beams* 1–7. https://doi.org/10.1017/S0263034618000253

Received: 12 April 2018
Revised: 13 June 2018
Accepted: 27 June 2018

Key words:
Cosh-Gaussian beam; critical beam power; decentered parameter; magnetized plasma; self-focusing

Author for correspondence:
M. V. Takale, Department of Physics, Shivaji University, Kolhapur 416 004, India.
E-mail: mvtphyunishivaji@gmail.com

Abstract

The paper gives graphical and analytical investigation of the effect of critical beam power on self-focusing of cosh-Gaussian laser beams in collisionless magnetized plasma under ponderomotive non-linearity. The standard Akhmanov's parabolic equation approach under Wentzel–Kramers–Brillouin (WKB) and paraxial approximations is employed to investigate the propagation of cosh-Gaussian laser beams in collisionless magnetized plasma. Especially, the concept of numerical intervals and turning points of critical beam power has evolved through graphical analysis of beam-width parameter differential equation of cosh-Gaussian laser beams. The results are discussed in the light of numerical intervals and turning points.

Introduction

Self-focusing of laser beams in plasmas (Chiao *et al*., 1964; Tabak *et al*., 1994; Gill *et al*., 2004) is one of the most interesting phenomena in the field of research for several decades due to its various applications, like high harmonic generation (Ganeev *et al*., 2015; Vij *et al*., 2016*a*, 2016*b*), laser-driven inertial confinement fusion (Hora, 2007; Winterberg, 2008), laser-based plasma acceleration (Sari *et al*., 2005; Niu *et al*., 2008; Jha *et al*., 2011, 2013; Rajeev *et al*., 2013), and generation of x-rays (Arora *et al*., 2014).

The main thrust of the theoretical and experimental investigations on self-focusing of a laser beam has been directed toward the study of the propagation characteristics of a Gaussian beam (Akhmanov *et al*., 1968; Sodha *et al*., 1974, 1976; Sharma *et al*., 2003, 2004; Singh *et al*., 2009; Aggarwal *et al*., 2016). Subsequently, a few studies have been made on self-focusing of super Gaussian beams (Gill *et al*., 2012), cosh-Gaussian beams (Patil *et al*., 2008, 2012; Gill *et al*., 2011*a*, 2011*b*; Aggarwal *et al*., 2014; Vhanmore *et al*., 2017), Hermite cosh-Gaussian beams (Patil *et al*., 2007, 2010; Ghotra and Kant, 2016; Kaur *et al*., 2017; Valkunde *et.al*., 2018*a*, 2018*b*), dark-hollow Gaussian beams (Sodha *et al*., 2009; Gill *et al*., 2010), quadruple Gaussian beams (Aggarwal *et al*., 2015*a*, 2015*b*; Vij *et al*., 2016*a*, 2016*b*), elliptic Gaussian beams (Saini and Gill, 2006; Singh *et al*., 2008), *q*-Gaussian beams (Valkunde *et.al*., 2018*a*, 2018*b*; Vhanmore *et al*., 2018). Recently, the propagation of Gaussian laser beam in three distinct regimes has been studied by Sharma *et al*. (2003, 2008). Such propagation regimes include steady divergence, oscillatory divergence, and self-focusing of laser beams.

In recent years, considerable interest has been evinced toward the production and propagation of decentered Gaussian beams, usually known as cosh-Gaussian beams on account of their wide and attractive applications in complex optical systems (Lu *et al*., 1999; Lu and Luo, 2000) and turbulent atmosphere (Chu 2007; Chu *et al*., 2007). The propagation properties of cosh-Gaussian laser beams have important technological issues, since these beams possesses high power in comparison to that of a Gaussian beam (Konar *et al*., 2007). The self-focusing of cosh-Gaussian laser beam passing through different plasma media have been studied (Sodha *et al*., 2007; Patil *et al*., 2008, 2012; Gill *et al*., 2011*a*, 2011*b*; Aggarwal *et al*., 2014; Nanda and Kant, 2014; Vhanmore *et al*., 2017). Moreover, all the above references discuss the effect of decentered parameter on self-focusing. However, in the present attempt, authors have carried out an exploratory study of critical beam power by employing a parabolic equation approach under Wentzel–Kramers–Brillouin (WKB) and paraxial approximations.

The organization of the paper is as follows: "Basic formulation" section gives the evolution of beam-width parameter equation. Discussion of results in the context of self-focusing of cosh-Gaussian laser beams is elaborated in "Results and discussion" section. Finally, "Conclusion" section involves overall conclusions drawn from the present study.

Basic formulation

Let us consider the propagation of cosh-Gaussian laser beams through collisionless magnetized plasma along the z direction, which is the direction of static magnetic field B_0. The electric field of the laser beam propagating in either of the two modes, that is, extraordinary and ordinary can be written as,

$$E_{\pm} = \hat{x} E_{0\pm}(r, z, t) \exp[-i(\omega t - k_{\pm} z)], \quad (1)$$

where $k_{\pm} = \omega/c\sqrt{\varepsilon_{0\pm}}$ is the propagation constant of the wave. Here $\epsilon_{0\pm}$ is the linear part of plasma dielectric constant and c is the speed of light in vacuum. The effective dielectric constant of magnetized plasma can be written as,

$$\varepsilon_{\pm} = \varepsilon_{0\pm} + \Phi_{\pm}(EE^{*}), \quad (2)$$

where $\varepsilon_{0\pm} = 1 - \omega_p^2/\omega(\omega \mp \omega_c)$ is the linear part of dielectric constant with $\omega_p = (4\pi N_0 e^2/m)^{1/2}$ as a plasma oscillation frequency and $\omega_c = eB_0/mc$ as a cyclotron frequency. Here, e and m are the electronic charge and rest mass, respectively.

The second term in [Eq. (2)], the intensity-dependent part of dielectric constant for a collisionless magnetized plasma, is given by

$$\Phi_{\pm}(E_{\pm}E_{\pm}^{*}) = \frac{\omega_p^2}{2\omega(\omega \mp \omega_c)}[1 - \exp(-\alpha E_{\pm}E_{\pm}^{*})]. \quad (3)$$

In the light of Maxwell's equations, the general form of wave equation governing the propagation of laser beam is given as,

$$\frac{\partial^2 E_{\pm}}{\partial z^2} + \delta_{\pm}\left(\frac{\partial^2 E_{\pm}}{\partial r^2} + \frac{1}{r}\frac{\partial E_{\pm}}{\partial r}\right) + \frac{\omega^2}{c^2}(\varepsilon_{\pm} E_{\pm}) = 0, \quad (4)$$

where $\delta_{\pm} = 1/2(1 \mp \varepsilon_{0\pm}/\varepsilon_{0zz})$ and $\varepsilon_{0zz} = 1 - \omega_p^2/\omega^2$. The amplitude of electric field $E_{\pm}$ in laser beam is given by [Eq. (1)] which satisfies [Eq. (4)]. Under slowly varying envelope approximation, the evolution of electric field envelope in collisionless magnetized plasma can be written as,

$$-2ik_{\pm}\frac{\partial E_{0\pm}}{\partial z} + \delta_{\pm}\left(\frac{\partial^2 E_{0\pm}}{\partial r^2} + \frac{1}{r}\frac{\partial E_{0\pm}}{\partial r}\right) + \frac{\omega^2}{c^2}\Phi_{\pm}(E_{\pm}E_{\pm}^{*})E_{0\pm} = 0. \quad (5)$$

In WKB approximation, one can neglect $\partial^2 E_{\pm}/\partial z^2$ from [Eq. (4)]. The complex amplitude of electric vector may be expressed as,

$$E_{0\pm}(r, z) = A_{\pm}(r, z)\exp[-ik_{\pm}S_{\pm}(r, z)], \quad (6)$$

where $A_{\pm}(r, z)$ and $S_{\pm}(r, z)$ are the real functions of r and z, $S_{\pm}$ is eikonal. Substituting [Eq. (6)] in [Eq. (5)] and separating into real and imaginary parts,

$$2\frac{\partial S_{\pm}}{\partial z} + \delta_{\pm}\left(\frac{\partial S_{\pm}}{\partial r}\right)^2 + \frac{2S_{\pm}}{k_{\pm}}\frac{\partial k_{\pm}}{\partial z} = \frac{\delta_{\pm}}{k_{\pm}^2 A_{\pm}} \left(\frac{\partial^2 E_{0\pm}}{\partial r^2} + \frac{1}{r}\frac{\partial E_{0\pm}}{\partial r}\right)A_{\pm} + \frac{\omega^2}{c^2}\Phi_{\pm}(A_{\pm}A_{\pm}^{*}) \quad (7)$$

and

$$\frac{\partial A_{\pm}^2}{\partial z} + \delta_{\pm}\frac{\partial S}{\partial r}\frac{\partial A_{\pm}^2}{\partial r} + \delta_{\pm}A_{\pm}^2\left(\frac{\partial^2 S_{0\pm}}{\partial r^2} + \frac{1}{r}\frac{\partial S_{0\pm}}{\partial r}\right) + \frac{A_{\pm}^2}{k_{\pm}}\frac{\partial k_{\pm}}{\partial z} = 0. \quad (8)$$

The solution of [Eqs. (7) and (8)] for cosh-Gaussian laser beam can be written as

$$A_{0\pm}^2 = \frac{E_{0\pm}^2}{f_{\pm}^2}\exp\left(\frac{b^2}{2}\right)\left\{\exp\left[-2\left(\frac{r}{f_{\pm}r_0} + \frac{b}{2}\right)^2\right] + \exp\left[-2\left(\frac{r}{f_{\pm}r_0} - \frac{b}{2}\right)^2\right] + 2\exp\left[\left(\frac{2r}{f_{\pm}r_0} + \frac{b}{2}\right)^2\right]\right\} \quad (9a)$$

$$S_{\pm} = \frac{r^2}{2}\beta_{\pm}(z) + \varphi_{\pm}(z), \quad (9b)$$

$$\beta_{\pm}(z) = \frac{1}{\delta_{\pm}}\frac{1}{f_{\pm}}\frac{df_{\pm}}{dz}, \quad (9c)$$

where $E_{0\pm}^2$ is an initial laser intensity and $f_{\pm}$ is the dimensionless beam-width parameter for extraordinary and ordinary modes, respectively. The $\beta_{\pm}^{-1}$ is the radius of the curvature of wave front, $\varphi_{\pm}(z)$ is the phase shift, and $f_{\pm}$ is the beam-width parameter, which is the measure of both axial intensity and width of the beam. Substituting [Eqs. (9a)–(9c)] in [Eq. (7)] and equating coefficients of r^2 on both sides we get

$$\frac{\partial^2 f_{\pm}}{\partial \xi_{\pm}^2} = \frac{1}{\varepsilon_{0\pm}}\frac{1}{f_{\pm}^3}\left(\frac{(12 - 12b^2 - b^4)\delta_{\pm}^2}{3} - \frac{(2 - b^2)\exp[-p_{\pm}]p_{\pm}\rho_{\pm}^2\gamma_{\pm}\delta_{\pm}}{2}\right), \quad (10)$$

where

$$\gamma_{\pm} = \frac{\Omega_p^2}{1 \mp \Omega_c},$$

$$\Omega_p = \frac{\omega_p}{\omega},$$

$$\Omega_c = \frac{\omega_c}{\omega},$$

$$p_{\pm} = \frac{\alpha E_{0\pm}^2}{f_{\pm}^2},$$

https://doi.org/10.1017/S0263034618000253

$$\rho_{\pm} = \frac{r_0 \omega}{c}.$$

The quantity $p_{\pm}$ which is proportional to $E_{0\pm}^2$ represents the beam power. The beam-width parameters $f_{\pm}$ are the functions of $\xi_{\pm}$, with $\xi_{\pm} = z/k_{\pm} r_0^2$ as the normalized propagation distance.

Results and discussion

Equation (10) is a second-order, non-linear differential equation which represents variation of beam-width parameter $f_{\pm}$ with normalized distance of propagation $\xi_{\pm}$. The first term on the right-hand side of [Eq. (10)] corresponds to the diffraction divergence of the beam and the second term corresponds to the convergence resulting from the ponderomotive non-linearity.

By subjecting [Eq. (10)] under critical condition ($f_{\pm} = 1$, $\xi_{\pm} = 0$), the general power of laser beam $p_{\pm}$ and beam radius $\rho_{\pm}$ are replaced by critical power $p_{0\pm}$ and critical beam radius $\rho_{0\pm}$. Therefore, right-hand side of [Eq. (10)] takes the form

$$F(p_{0\pm}) = \frac{(12 - 12b^2 - b^4)\delta_{\pm}^2}{3} - \frac{(2 - b^2)\exp[-p_{0\pm}]p_{0\pm}\rho_{0\pm}^2\gamma_{\pm}\delta_{\pm}}{2}. \tag{11}$$

Henceforth following investigation is restricted only for extraordinary mode.

$$F(p_{0+}) = \frac{(12 - 12b^2 - b^4)\delta_{+}^2}{3} - \frac{(2 - b^2)\exp[-p_{0+}]p_{0+}\rho_{0+}^2\gamma_{+}\delta_{+}}{2}. \tag{12}$$

The condition that the critical beam power should be always finite and positive leads to the numerical interval of decentered parameter as $0 \le b \le 0.9634$. By reducing defining equations for δ_+, γ_+ and ρ_{0+} numerically with the help of values $N_0 = 1 \times 10^{18} \text{cm}^{-3}$, $\omega = 1.776 \times 10^{15}$ rad/s, $B_0 = 10^6$ gauss, $r = 20 \times 10^{-4}$ cm and by defining the values of decentered parameter $b = 0.00,\ 0.45,\ 0.90$. [Eq. (12)] depends upon critical beam power.

To explore the effect of critical beam power right at the beginning one has to pay little attention to the plot shown in Figure 1. From the plot, it is clear that at the beginning, two values of critical beam powers $p_{0+\text{lower}}$ and $p_{0+\text{upper}}$ are possible.

The function $F(p_{0+})$ has minimum value at $p_{0+} = 0.98$, which is a common value for all decentered parameters ranging from 0.00 to 0.90. Hence, the value of $p_{0+} < 0.98$ and $p_{0+} > 0.98$ can be considered as $p_{0+\text{lower}}$ and $p_{0+\text{upper}}$, respectively.

The plot shown in Figure 1 can be studied for three distinct conditions stated below and the simple analytical approach leads to the following limits for critical beam power.

For self-trapping:

$$F(p_{0+}) = 0 \text{ for : } p_{0+\text{lower}} = 0.00333927 \text{ and } p_{0+\text{upper}} = 7.75349 (b = 0.00)$$
$$\text{and for : } p_{0+\text{lower}} = 0.00294922 \text{ and } p_{0+\text{upper}} = 7.89545 (b = 0.45)$$
$$\text{and for : } p_{0+\text{lower}} = 0.000757512 \text{ and } p_{0+\text{upper}} = 9.43014 (b = 0.90).$$

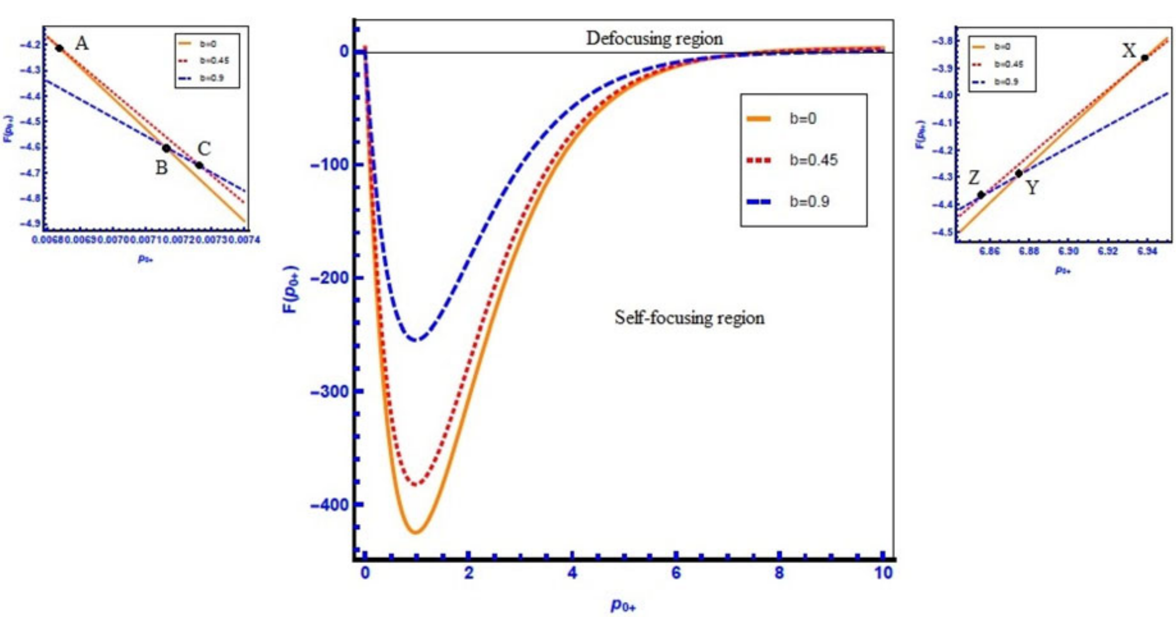

Fig. 1. Variation of $F(p_{0+})$ with p_{0+}.

https://doi.org/10.1017/S0263034618000253

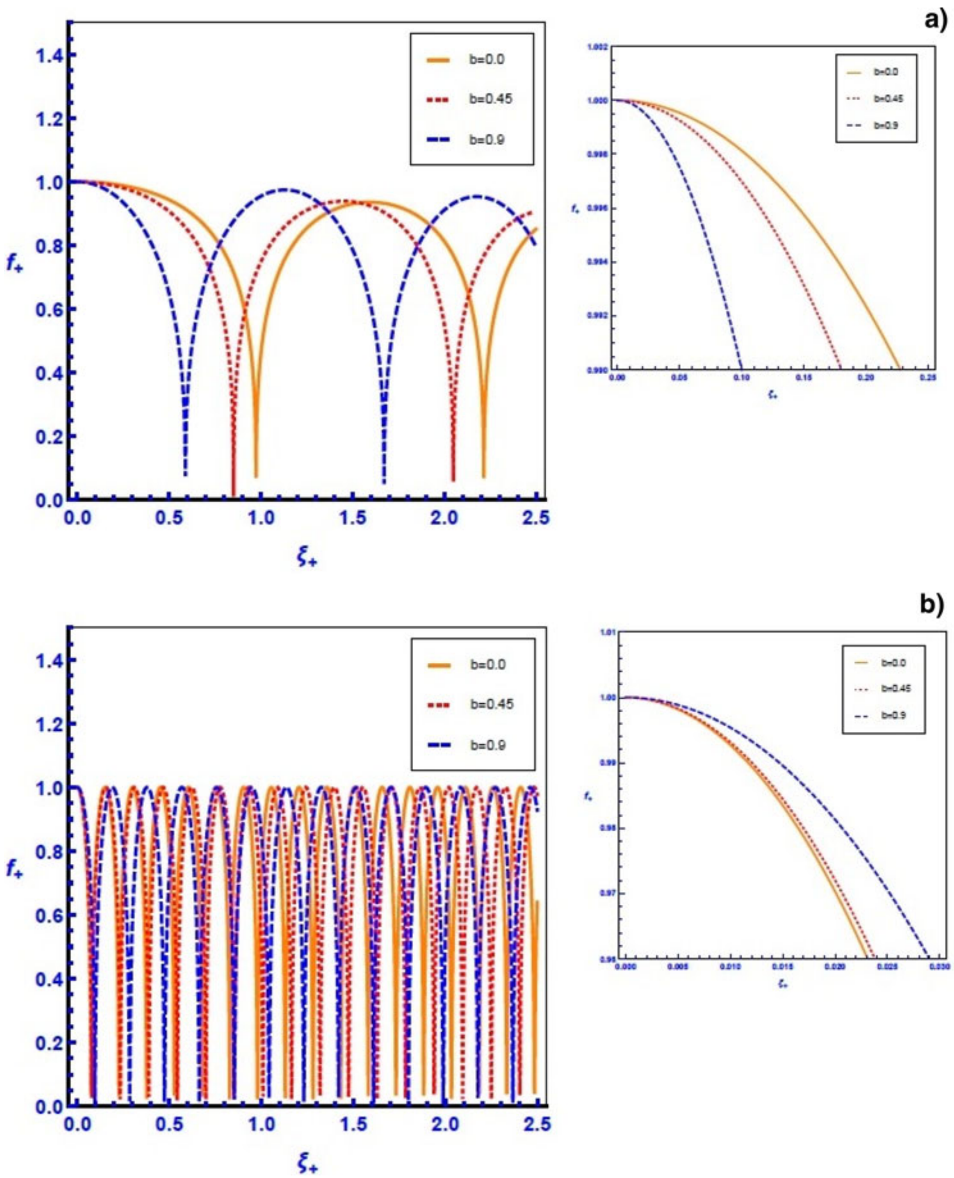

Fig. 2. (a) Variation of beam-width parameter f_+ with dimensionless propagation distance ξ_+ before turning point for $p_{0+lower} = 0.0035$. (b) Variation of beam-width parameter f_+ with dimensionless propagation distance ξ_+ after turning point for $p_{0+lower} = 0.15$.

For defocusing:

$$F(p_{0+}) > 0 \text{ for} : p_{0+\text{lower}} < 0.000757512 \text{ and } p_{0+\text{upper}} > 9.43014.$$

For self-focusing:

$$F(p_{0+}) < 0 \text{ for} : (p_{0+\text{lower}})0.00333927 < p_{0+} < 7.75349\,(p_{0+\text{upper}}).$$

In the present analysis, authors are interested only in the self-focusing region in Figure 1.

From Figure 1, it is also seen that for above limits of critical beam powers for the condition of self-focusing of laser beams, three curves for three distinct values of decentered parameters intersect each other at three distinct points close to $p_{0+\text{lower}}$ and $p_{0+\text{upper}}$ as shown in insets of Figure 1.

In the analytical investigation, the intersecting points are called as turning points, which affect the propagation of laser beams through collisionless magnetized plasma. The turning points are as follow:

The above study shows that preconditioning of a critical beam power in the beginning of propagation of laser beam can determine propagation dynamics effectively.

In the lower region, (p_{0+} <0.98) of Figure 2a, 2b, which is the present region of interest, gives variation of beam-width

$$p_{0+\text{lower}} = 0.00681507\ (A) \text{ and } p_{0+\text{upper}} = 6.93151\ (X) \text{ for } b = 0.00 \text{ and } b = 0.45$$
$$p_{0+\text{lower}} = 0.00715664\ (B) \text{ and } p_{0+\text{upper}} = 6.87472\ (Y) \text{ for } b = 0.00 \text{ and } b = 0.90$$
$$p_{0+\text{lower}} = 0.00727055\ (C) \text{ and } p_{0+\text{upper}} = 6.85637\ (Z) \text{ for } b = 0.45 \text{ and } b = 0.90.$$

https://doi.org/10.1017/S0263034618000253

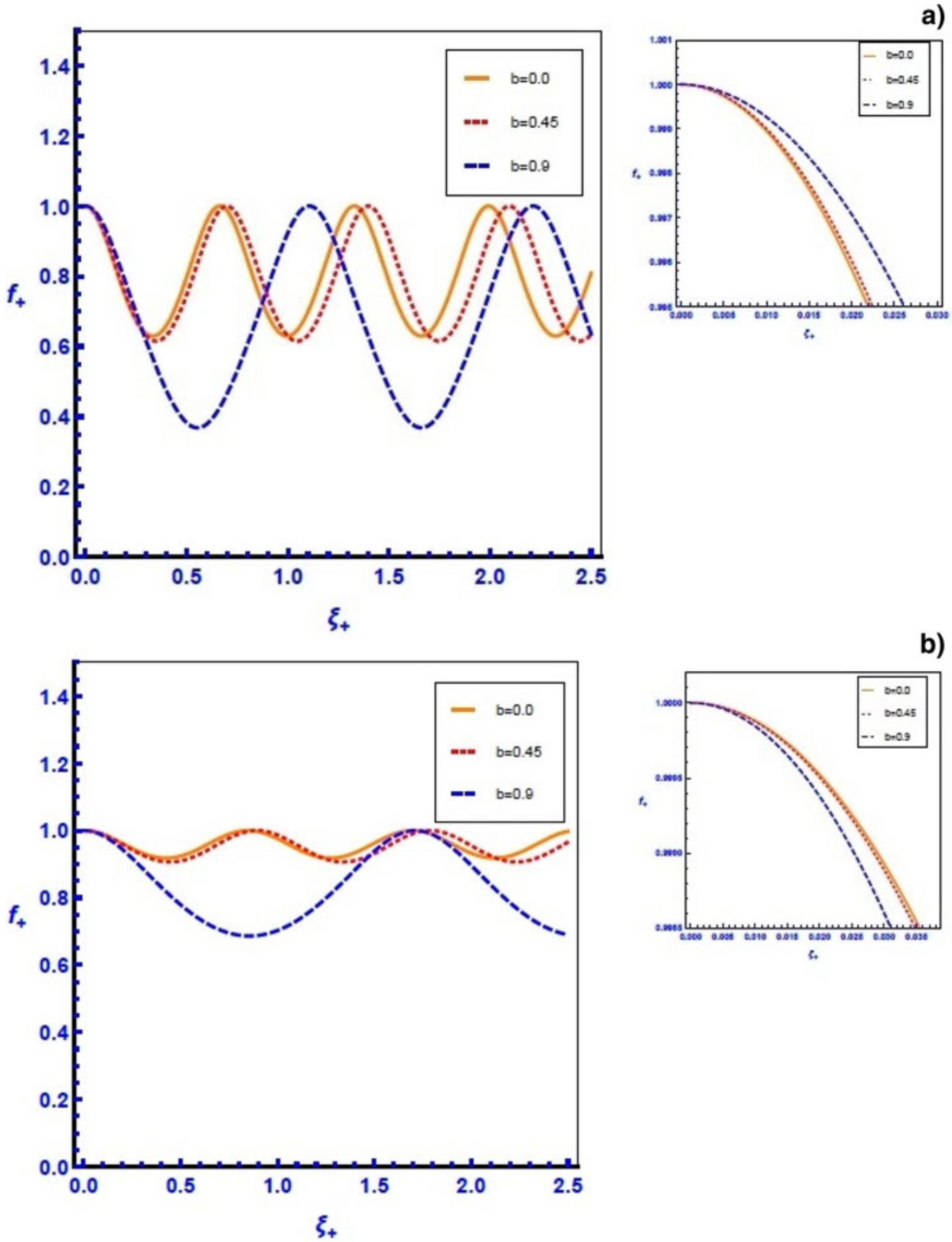

Fig. 3. (a) Variation of beam-width parameter f_+ with dimensionless propagation distance ξ_+ before turning points for $p_{0+\mathrm{upper}} = 5.5$. (b) Variation of beam-width parameter f_+ with dimensionless propagation distance ξ_+ after turning point for $p_{0+\mathrm{upper}} = 7.2$.

parameter f_+ against normalized propagation distance ξ_+. In Figure 2a, 2b, strong self-focusing is observed. However, in Figure 2a, periodicity in self-focusing length is observed over larger interval of ξ_+ as compared with periodicity in self-focusing length observed in Figure 2b over a given range of ξ_+. Additionally, with increase in the values of decentered parameter, the effect of decentered parameter b on self-focusing length in Figure 2a is exactly opposite to that in Figure 2b. From the insets of Figure 2a, 2b, it is evident that the rate of self-focusing is exactly opposite with increase in the values of decentered parameter b.

In the upper region, (p_{0+} >0.98) of Figure 3a, 3b, which is the subsequent region of interest, gives variation of beam-width parameter f_+ against normalized propagation distance ξ_+. In Figure 3a, 3b, weak self-focusing is observed and the effect of decentered parameter b on self-focusing length is same, that is, with increase in the values of decentered parameter self-focusing, the length increases. Moreover, from Figure 3a, it is observed that with increase in the values of decentered parameter b, the rate of self-focusing is exactly opposite to that observed in Figure 3b, which is also evident from the insets of Figure 3a, 3b.

Conclusion

In conclusion, the numerical intervals of critical beam power for the non-linear phenomena such as self-trapping, self-focusing, and defocusing of cosh-Gaussian laser beams are studied. Following, important conclusions are obtained for collisionless magnetized plasma from the present investigation.

https://doi.org/10.1017/S0263034618000253

- Two values of critical beam power ($p_{0+\text{lower}}$, $p_{0+\text{upper}}$) are possible for each specified value of decentered parameter under self-trapping condition of cosh-Gaussian laser beams.
- In the lower region, exactly opposite trends of self-focusing before and after turning points are observed with increase in the values of decentered parameter. It is to be noted that in the lower region, self-focusing length before turning points and after turning points shows exactly opposite trends.
- In the lower and upper regions, rate of self-focusing is exactly opposite with increase in the values of decentered parameter before and after turning points.

References

Aggarwal M, Kumar H and Kant N (2016) Propagation of Gaussian laser beam through magnetized cold plasma with increasing density ramp. *Optik* **127**, 2212–2216.

Aggarwal M, Vij S and Kant N (2014) Propagation of cosh-Gaussian laser beam in plasma with density ripple in relativistic ponderomotive regime. *Optik* **125**, 5081–5084.

Aggarwal M, Vij S and Kant N (2015*a*) Propagation of circularly polarized quadruple Gaussian laser beam in magnetoplasma. *Optik* **126**, 5710–5714.

Aggarwal M, Vij S and Kant N (2015*b*) Self-focusing of quadruple Gaussian laser beam in an inhomogeneous magnetized plasma with ponderomotive non-linearity: effect of linear absorption. *Communications in Theoretical Physics* **64**, 565–570.

Akhmanov SA, Sukhorov AP and Khokhlov RV (1968) Self-focusing and diffraction of light in a nonlinear medium. *Soviet Physics Uspekhi* **93**, 609–636.

Arora V, Naik PA, Chakera JA, Bagchi S, Tayyab M and Gupta PD (2014) Study of 1–8 keV K-α x-ray emission from high intensity femtosecond laser produced plasma. *AIP Advances* **4**, 047106.

Chiao RY, Garmire E and Townes CH (1964) Self-trapping of optical beams. *Physical Review Letters* **13**, 479–482.

Chu X (2007) Propagation of a cosh-Gaussian beam through an optical system in turbulent atmosphere. *Optics Express* **15**, 17613–17618.

Chu X, Ni Y and Zhou G (2007) Propagation of cosh-Gaussian beams diffracted by a circular aperture in turbulent atmosphere. *Applied Physics B: Photophysics and Laser Chemistry* **87**, 547–552.

Ganeev RA, Toşa V, Kovács K, Suzuki M, Yoneya S and Kuroda H (2015) Influence of ablated and tunnelled electrons on quasi-phase-matched high-order harmonic generation in laser-produced plasma. *Physical Review A* **91**, 043823.

Ghotra HS and Kant N (2016) TEM modes influenced electron acceleration by Hermite–Gaussian laser beam in plasma. *Laser and Particle Beams* **34**, 385–393.

Gill TS, Kaur R and Mahajan R (2011*a*) Relativistic self-focusing and self-phase modulation of cosh-Gaussian laser beam in magnetoplasma. *Laser and Particle Beams* **29**, 183–191.

Gill TS, Mahajan R and Kaur R (2010) Relativistic and ponderomotive effects on evolution of dark hollow Gaussian electro-magnetic beams in a plasma. *Laser and Particle Beams* **28**, 521–529.

Gill TS, Mahajan R and Kaur R (2011*b*) Self-focusing of cosh-Gaussian laser beam in a plasma with weakly relativistic and ponderomotive regime. *Physics of Plasmas* **18**, 033110.

Gill TS, Mahajan R, Kaur R and Gupta S (2012) Relativistic self-focusing of super-Gaussian laser beam in plasma with transverse magnetic field. *Laser and Particle Beams* **30**, 509–516.

Gill TS, Saini NS, Kaul SS and Singh A (2004) Propagation of elliptic Gaussian laser beam in a higher order non-linear medium. *Optik* **11**, 493–498.

Hora H (2007) New aspects for fusion energy using inertial confinement. *Laser and Particle Beams* **25**, 37–45.

Jha P, Saroch A and Mishra RK (2011) Generation of wake-fields and terahertz radiation in laser magnetized plasma interaction. *Europhysics Letters* **91**, 15001.

Jha P, Saroch A and Mishra RK (2013) Wakefield generation and electron acceleration by intense super-Gaussian laser pulses propagating in plasma. *Laser and Particle Beams* **31**, 583–588.

Kaur S, Kaur M, Kaur R and Gill TS (2017) Propagation characteristics of Hermite-cosh-Gaussian laser beam in a rippled density plasmas. *Laser and Particle Beams* **35**, 1–8.

Konar S, Mishra M and Jana S (2007) Nonlinear evolution of cosh-Gaussian laser beams and generation of flat top spatial solitons in cubic quintic nonlinear media. *Physics Letters A* **362**, 505–510.

Lu B and Luo S (2000) Beam propagation factor of hard-edge diffracted cosh-Gaussian beams. *Optics Communications* **178**, 275–281.

Lu B, Ma H and Zhang B (1999) Propagation properties of cosh-Gaussian beams. *Optics Communications* **164**, 165–170.

Nanda V and Kant N (2014) Strong self-focusing of a cosh-Gaussian laser beam in collisionless magneto-plasma under plasma density ramp. *Physics of Plasmas* **21**, 072111.

Niu HY, He XT, Qiao B and Zhou CT (2008) Resonant acceleration of electrons by intense circularly polarized Gaussian laser pulses. *Laser and Particle Beams* **26**, 51–59.

Patil SD, Takale MV, Navare ST and Dongare MB (2008) Cross focusing of two coaxial cosh-Gaussian laser beams in a parabolic medium. *Optik* **122**, 1869–1871.

Patil SD, Takale MV, Navare ST and Dongare MB (2010) Focusing of Hermite-cosh-Gaussian laser beams in collisionless magneto plasma. *Laser and Particle Beams* **28**, 343–349.

Patil SD, Takale MV, Navare ST, Fulari VJ and Dongare MB (2007) Analytical study of HChG-laser beam propagation in collisional and collisionless plasmas. *Journal of Optics* **36**, 136–144.

Patil SD, Takale MV, Navare ST, Fulari VJ and Dongare MB (2012) Relativistic self-focusing of cosh-Gaussian laser beams in a plasma. *Optics & Laser Technology* **44**, 314–317.

Rajeev R, Madhu Trivikram T, Rishad KPM, Narayanan V, Krishnakumar E and Krishnamurthy M (2013) A compact laser driven plasma accelerator for megaelectronvolt energy neutral atoms. *Nature Physics* **9**, 185–190.

Saini NS and Gill TS (2006) Self-focusing and self-phase modulation of an elliptic Gaussian laser beam in collisionless magneto-plasma. *Laser and Particle Beams* **24**, 447–453.

Sari AH, Osman F, Doolan KR, Ghoranneviss M, Hora H, Hopfl R, Benstetter G and Hantehzadehi MH (2005) Application of laser driven fast high density plasma blocks for ion implantation. *Laser and Particle Beams* **23**, 467–473.

Sharma A, Kourakis I and Sodha MS (2008) Propagation regimes for an electromagnetic beam in magnetized plasma propagation regimes for an electromagnetic beam in magnetized plasma. *Physics of Plasmas* **15**, 103103.

Sharma A, Prakash G, Verma MP and Sodha MS (2003) Three regimes of intense laser beam propagation in plasmas. *Physics of Plasmas* **10**, 4079–4084.

Sharma A, Verma MP and Sodha MS (2004) Self focusing of electromagnetic beams in collisional plasmas with nonlinear absorption. *Physics of Plasmas* **11**, 4275–4279.

Singh A, Aggarwal M and Gill TS (2008) Optical guiding of elliptical laser beam in nonuniform plasma. *Optik* **119**, 559–564.

Singh A, Aggarwal M and Gill TS (2009) Dynamics of filament formation in magnetized laser produced plasma. *Physica Scripta* **80**, 015502.

Sodha MS, Ghatak AK and Tripathi VK (1974) *Self-Focusing of Laser Beams in Dielectrics, Plasmas and Semiconductors*. Delhi: Tata-McGraw-Hill.

Sodha MS, Ghatak AK and Tripathi VK (1976) Self-focusing of laser beams in plasmas and semiconductors. *Progress in Optics* **13**, 169–265.

Sodha MS, Mishra SK and Agarwal SK (2007) Self-focusing and cross-focusing of Gaussian electromagnetic beams in fully ionized collisional magnetoplasmas. *Physics of Plasmas* **14**, 112302.

Sodha MS, Mishra SK and Misra S (2009) Focusing of dark hollow Gaussian electromagnetic beams in plasma. *Laser and Particle Beams* **27**, 57–68.

Tabak M, Hammer J, Glinsky ME, Kruer WL, Wilks SC, Woodworth J, Campbell EM, Perry MD and Mason RJ (1994) Ignition and high gain with ultrapowerful lasers. *Physics of Plasmas* **1**, 1626–1634.

Valkunde AT, Patil SD, Vhanmore BD, Urunkar TU, Gavade KM and Takale MV (2018*a*) Effect of exponential density transition on self-focusing of q-Gaussian laser beam in collisionless plasma. *AIP Conference Proceedings* **1953**, 140088.

Valkunde AT, Patil SD, Vhanmore BD, Urunkar TU, Gavade KM, Takale MV and Fulari VJ (2018*b*) Analytical investigation on domain of decentered parameter for self-focusing of Hermite-cosh-Gaussian laser beam in collisional plasma. *Physics of Plasmas* **25**, 033103.

Vhanmore BD, Patil SD, Valkunde AT, Urunkar TU, Gavade KM and Takale MV (2017) Self-focusing of asymmetric cosh-Gaussian laser beams propagating through collisionless magnetized plasma. *Laser and Particle Beams* **35**, 670–676.

Vhanmore BD, Patil SD, Valkunde AT, Urunkar TU, Gavade KM, Takale MV and Gupta DN (2018) Effect of q-parameter on relativistic self-focusing of q-Gaussian laser beam in plasma. *Optik* **158**, 574–579.

Vij S, Gill TS and Aggarwal M (2016*a*) Effect of the transverse magnetic field on spatiotemporal dynamics of quadruple Gaussian laser beam in plasma in weakly relativistic and ponderomotive regime. *Physics of Plasmas* **23**, 123111.

Vij S, Kant N and Aggarwal M (2016*b*) Resonant third harmonic generation in clusters with density ripple: effect of pulse slippage. *Laser and Particle Beams* **34**, 171–177.

Winterberg F (2008) Laser for inertial confinement fusion driven by high explosives. *Laser and Particle Beams* **26**, 127–135.