Ponderomotive self-focusing of q-Gaussian laser in plasma

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Abstract

The laser of non-uniform intensity exerts a transverse ponderomotive force, which ejects the electrons away from the longitudinal axis towards the region of low intensity. The ponderomotive force alters the local effective permittivity of plasma. The laser will focus / defocus consequently to the modified plasma parameters. Therefore, the space-time evolution of the electromagnetic wave in plasma is sensitive to the magnitude and profile of intensity (Misra et al. 2014). The examination of Vulcan Petawatt laser (Patel et al. 2005) and other studies (Malik and Escarguel 2019) advocates the unconventionality of intensity distribution from the Gaussian distribution. Further, exploration by Nakatsutsumi et al. (2008) suggests that the beam intensity is in general q-Gaussian which can be defined by the function $I(r) = I(0)(1 + r^2/qr_0^2)^{-q}$, where q and r_0 are real parameter and can be obtained by fitting the experimental data. The parameter q represents the deviation from the Gaussian profile. Long tails are the features of the q-Gaussian beams in the case of small q, as shown in the Fig.1

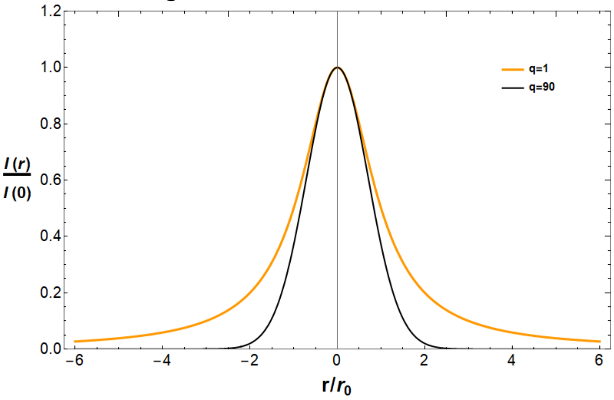

Fig. The intensity distribution of $q = 1$ and 90 valued q-Gaussian laser.

We have done comparative study of the ponderomotive self-focusing of q-Gaussian laser with two values of q as 1 and 90. Such study is useful for understanding the effects of the characteristic tail of q-Gaussian laser. We employed Maxwell's equation and used paraxial approximation to obtain the differential equation governing the propagation of laser in plasma. By using WKB approximation, we derived the parabolic differential equation of dimensional less beam width parameter $f(z)$ for the ponderomotive non-linearity. The numerical solution is obtained for the experimentally feasible parameters of the laser and plasma. It is inferred from our investigation that there is a critical density below which self-focusing does not occur. The density gradient, below the critical density, is not enough to cause the self-focusing. We also observed the oscillator nature of the beam width parameter, which is different for the cases of $q = 1$ and 90. We concluded based on our examination that in the non-relativistic case, the self-focusing power of the $q = 1$ valued laser is higher than that of $q = 90$ valued laser.

References

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