A comparative behavior of nonlinear current generated by graphite nanoparticles on laser interaction under two different approximations

Tamanna Punia* and Hitendra K. Malik
Plasma Science and Technology Laboratory, Department of Physics, Indian Institute of Technology Delhi, New Delhi – 110 016, India
Email: - *tamannapunia01@gmail.com

Due to unique size and shape dependent properties of particles in nanoscale regime, nanostructures such as nanorods, nanowires, nanoparticles etc. have found a variety of applications in interdisciplinary research areas [1, 2]. The study of interaction of metallic nanoparticles (NPs) with electromagnetic waves is quite interesting due to nonlinear phenomena in nano-optics and plasmonics. The biological applications of THz technology of nanostructures and nanomaterials [3] also opened up the medical aspects related to nano-area.

In the present work, a comparative study in two different approximations of a medium containing spherical graphite nanoparticles (SNPs) is done by beating of two skew coshyperbolic Gaussian beams (SCGBs). The graphite NPs are assumed to have their basal planes parallel to the electric field of the incoming laser beam. Since the basal planes oriented parallel to the electric field have a higher value of plasma frequency due to the anisotropy in the medium, the corresponding plasma frequency is considered. The response of the nanoparticle with respect to the electric field can be studied within dipole approximation if the size of the nanoparticle is much smaller than the wavelength [4]. In the present study, two different approximations are considered – i) when the NPs are treated exactly as dipoles and ii) when the NPs behave like a dipole but in reality they are not. When the medium containing NPs is irradiated by the laser, there is a displacement of electron cloud of NPs with respect to the positive ions and hence, the conduction electrons of NPs acquire an oscillatory velocity by the electric field of the laser beams. Due to the nonlinear interaction of laser beams at beating frequency the conduction electrons of NPs experience a nonlinear ponderomotive force, which can be evaluated from ponderomotive potential [5]. Our study shows that the force experienced by the electrons is higher when the NPs are treated exactly as dipoles because the oscillatory velocity of the electrons couples with the magnetic field of the laser. The coupling between the magnetic field of the laser and oscillatory velocity of the electrons results into higher generation of nonlinear current density as compared to the current density generated in the case when the behavior of the NPs is approximated to the dipole. SCGBs are taken because they are non-diffracting and switchable (unifocal to bifocal and vice-versa) and their peaks can be controlled by varying the values of the skewness parameter and index of the laser beam [6].

The findings of our work shall play an important role in strong generation of nonlinear current so that the emitted THz radiation can take place efficiently which will further prove to be useful in medical applications such as treatment and diagnosis of cancer cells.

References

[1] Cao, G., & Wang, Y. (2004). Nanostructures and nanomaterials: synthesis. *Properties and Applications*, *2*.
[2] Fendler, J. H. (Ed.). (2008). *Nanoparticles and nanostructured films: preparation, characterization, and applications*. John Wiley & Sons.
[3] Zhou, R., Wang, C., Xu, W., & Xie, L. (2019). Biological applications of terahertz technology based on nanomaterials and nanostructures. *Nanoscale*, *11*(8), 3445-3457.
[4] Amendola, V., Bakr, O. M., & Stellacci, F. (2010). A study of the surface plasmon resonance of silver nanoparticles by the discrete dipole approximation method: effect of shape, size, structure, and assembly. *Plasmonics*, *5*(1), 85-97.
[5] Sepehri Javan, N., & Rouhi Erdi, F. (2017). Theoretical study of the generation of terahertz radiation by the interaction of two laser beams with graphite nanoparticles. *Journal of Applied Physics*, *122*(22), 223103.
[6] Malik, H. K. (2020). Generalized treatment of skew-cosh-Gaussian lasers for bifocal terahertz radiation. *Physics Letters A*, 126304.