High-energy radiation generation in collisional underdense plasma

Sheetal Punia[1], Hitendra. K. Malik[2]
[1,2] Department of physics, Indian Institute of Technology Delhi, New Delhi, India
e-mail: sheetalpunia.iitd@gmail.com

Abstract: We present an analytical treatment for the generation of high-energy gamma radiation by laser-plasma interaction. The peculiar property of plasma to tackle high accelerating gradients makes it suitable to operate under ultra-intense laser fields.[1] When laser impinges into plasma, the pondermotive force associated with the laser expels the electrons towards the low-intensity region and induces an electrostatic field. This space-charge field further produces a plasma channel that focuses the laser beam due to the modified refractive index. In the quasi-static regime, the generation of a spontaneous magnetic field [2] in both the axial and azimuthal direction takes place, which confines the motion of electrons. The trapped electrons execute the betatron oscillations inside the channel and radiate synchrotron gamma radiation.[3]

Under the extreme intense laser field, the quiver velocity of electrons enters into the relativistic regime. We opt long laser pulse with time duration less than the characteristic response time of ions but higher than that of the electrons. In this regime, the direct acceleration [4] of electrons dominates the laser wakefield acceleration, and the ions make a stationary background. The incident Laguerre-Gaussian (LG) [5] laser beam (shown in Fig. 1) belongs to the dark hollow family possessing the intrinsic angular momentum. On the one hand, the circular polarization incident beam produces the spin angular momentum to the electrons, and on the other hand, the LG beam transfers its orbital angular momentum to them.

In the present work, we have studied how to regulate the angular momentum of the electrons by using laser and plasma parameters. The control over this additional degree of freedom also makes us able to understand the dynamics behind the generation of emitted gamma radiation. The momentum and energy losses associated with the collisions among the particles alters the dynamics of the electrons in a significant way that needs to be studied. It encourages us to analyze the effects of collisions on the generation of gamma radiation along with other laser and plasma parameters.

Keywords: Laguerre-Gaussian, relativistic regime, angular momentum, spontaneous magnetic field, gamma radiation.

References

[1] Malik, Hitendra K. "Energy gain by an electron in the fundamental mode of a rectangular waveguide by microwave radiation." Journal of Plasma Physics 69.1 (2003): 59-67.
[2] Stamper, J. A., et al. "Spontaneous magnetic fields in laser-produced plasmas." Physical Review Letters 26.17 (1971): 1012.
[3] Phuoc, Kim Ta, et al. "Laser based synchrotron radiation." Physics of Plasmas 12.2 (2005): 023101.
[4] Huang, Sujuan, et al. "Composite vortex beams by coaxial superposition of Laguerre–Gaussian beams." Optics and Lasers in Engineering 78 (2016): 132-139.
[5] Jiang, S., et al. "Microengineering laser plasma interactions at relativistic intensities." Physical review letters 116.8 (2016): 085002.

Figure 1: Graphical representation of Laguerre-Gaussian laser pulse (a) side view and (b) top view.