Photon Vortex Generation from Synchrotron Radiation of Electron in Relativistic Quantum Approach

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Photon vortices caring orbital angular momentum (OAM) [1] with a wave function of Laguerre Gaussian (LG) wave or Bessel wave are one of the most interesting topics in various fields of physics. These wave-functions are the eigen-state of z-component of the total angular momentum of the photon when the photon fly along z-axis. The interaction between a photon vortex and a material such as a nucleus may be different from that with a standard photon because the photon vortex has non-zero orbital angular momentum parallel to the z-direction.

In quantum theory, electron orbitals in a magnetic field are under Landau states. In the present work we have calculated the photon vortex production from a spiral moving electron under a uniform magnetic field with a strength of $10^7 - 10^8$ T taking into account Landau quantization. Such strong magnetic fields are considered to be realized in the
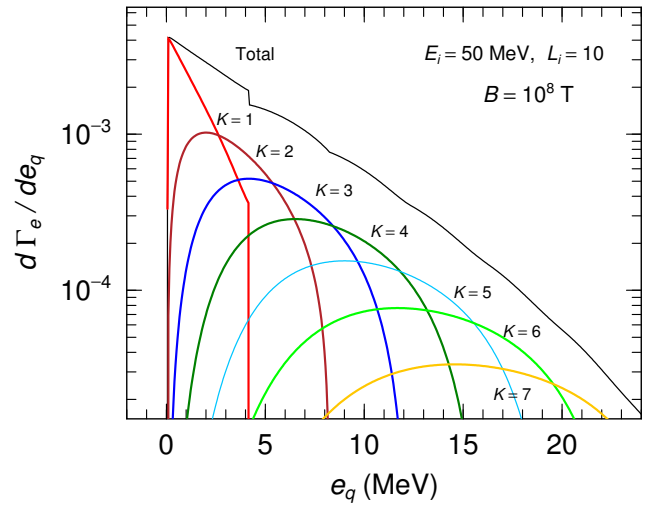

Figure 1: Differential decay width of electron with the energy of 50 MeV and the orbital angular momentum of $10\hbar$ at the magnetic field strength of 10^8 T

universe. We have theoretically presented that photon vortices are predominantly generated in astrophysical environments with strong magnetic fields such as magnetars or magnetized accretion disks around black holes [2]. This suggests that nucleosynthesis with photons should be changed from that with standard photons. A photon vortex is generated through a transition of an electron between two Landau levels and has a Bessel wave-function. We also calculate the decay widths from an electron in Landau levels and the energy spectra. In Figure we present the energy spectra of K-the harmonic radiations of photon vortices in synchrotron radiations from electrons with an energy of 50 MeV. The present result suggests a possibility that the photon vortices may be dominant in high energy region although there is no coherent structure at the macro level.

By the way, this subject can be confirmed by experiments in the laboratory. However, the strength of the magnetic field that can be realized in the laboratory is as week as approximately 10 T, and when the Larmor radius is 10 mm the number of Landau levels of an incident electron is huge, approximately 10^5. Recently, we have developed a calculation method to obtain photon vortex production from such a huge Landau level number in the laboratory. This will be presented in the paper.

References

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