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Photon Vortex Generation by Synchrotron Radiation

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Abstract

Optical vortices caring orbital angular momentum (OAM) [1] are one of the most interesting topics in various fields of physics. It was shown that optical vortices can be created in astronomical systems such as black holes [2]. While they have been actively studied in applied fields using laser, Allen et al. [1] have predicted that the existence of photon vortex with a wave function such as Laguerre Gaussian (LG) wave or Bessel wave in quantum level. Optical vortices and photon vortices are completely different concepts. When photon vortices are used for interactions with materials, it is possible to control quantum phenomena. However, even if an optical vortex is generated, it does not necessary mean that photon vortex is generated in quantum level. Therefore, a method to generate photon vortices in quantum level has been required, and we have theoretically shown that photon vortices can be generated even in strong magnetic fields such as those of neutron stars whose magnetic fields have $10^6 - 10^{10}$ T strengths [3]. In such strong fields, electrons are in an eigenstate of angular momentum due to Landau quantization, and a photon produced by a transition of an electron between two Landau states is also an eigenstate of the angular momentum.

The magnetic field strength that can be realized in actual experiments is only about 10^5 T at maximum, where the Landau level number becomes about 10^6. Because of the huge level number, it was thought to be very difficult to theoretically calculate the generation rate of the photon vortex in the quantum approach. However, we recently found a reasonable method to solve this problem.

In this seminar we explain the formulation to describe the photon vortex generation in strong magnetic field and show calculation results in the astronomical system and the laboratory.

Referencesthe

[1] L. Allen, et al. Phys. Rev. A 45, 8185 (1992).
[2] F. Tamburini, et al. Nature Phys. 7, 195 (2011).
[3] T. Maruyama, et al. Phys. Lett. B826. 136779 (2022).