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Distortion of photon HBT image by the vacuum birefringence in strong magnetic field

The experiment by the ultrarelativistic heavy ion collisions has opened a novel insight into the extreme state of matter. Besides, it provides an opportunity to study the dynamics of strong Abelian and non-Abelian gauge fields. In peripheral collisions, an extremely strong Abelian magnetic field is created by two colliding heavy ions having large electric charges. The magnetic field has a much greater order of magnitude than those of ever observed astronomical objects.

Such a strong magnetic field becomes not only the source of an exotic phenomenon called the chiral magnetic effect but also a background field which allows for nonlinear QED phenomena, where the strong magnetic field interacts with photons emitted in the early stages of time evolution of the created matter. Even though photon self-interaction is diagrammatically a higher order process with a number of external photon legs intermediated by an electron loop, extraordinarily strong magnitude of the background magnetic field compensates the smallness of the coupling constant, and leads to intriguing nonperturbative effects. The interaction causes a modification of production and propagation of photon, which results in significant effects on the observable photon spectrum. It was discussed recently that the presence of magnetic fields also allows for the decay of a real photon into a particle-antiparticle (lepton, or quark) pair, yielding an elliptic flow of observed photons [1]. The study of such nonlinear QED phenomena provides a prevision of planned photon detection in the LHC experiment.

In this contribution, we examine the effect of the interaction, between an emitted photon and the background magnetic field, on Hanbury Brown and Twiss (HBT) interferometry. Recently, one of the authors investigated effects of the hadronic final state mean field interaction on the pion interferometry in the central collisions [2,3]. We have found therein that the HBT images are distorted due to the phase shift of the pion amplitude propagating through the one-body mean field interaction region, which is computed by using the semi-classical approximation. The analysis was done on the basis of an analogue of eikonal approximation in the geometrical optics. In the present work, we incorporate the interaction of photon with the background magnetic field as a deviation of the refraction index from the unity, wherein the analogue is more evident. While the HBT interferometry by a photon pair is more promisingly accessible to the primordial image of the created matter than that by a pion pair, we have to take into account the distortion of image by the strong magnetic field.

The refraction index of the vacuum in the presence of the magnetic field is obtained by incorporating the self-energy of photon, resummed with respect to the number of external photon legs, into the equation of motion for the Abelian gauge field. Depending on the two physical propagating modes of photon, two distinct refraction indices, called the vacuum birefringence, are obtained. Calculating the optical-path-length of the photon specified by the refraction indices, we have the images distorted depending on the helicity of photons. In addition to the conventionally discussed three HBT parameters, e.g. outward, sideward and longitudinal radii, we investigate the distortion of the outward-sideward cross parameter, which indicates the azimuthal-angle dependence of the image in the non-central collisions [4]. The magnitude of the distortion also depends on the azimuthal angle because the presence of the magnetic field provides a preferred orientation. We show how and to what extent the elliptic shape of the original image is distorted depending on the magnitude of momentum, helicity and azimuthal angle.

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