Photon propagation in a charged Bose-Einstein condensate model

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We consider the propagation of photons in a model of charged scalar Bose-Einstein (BE) condensate. We determine the dispersion relations of the collective modes, as well as the photon polarization tensor and the dielectric constant in the model. Two modes correspond to the transverse photon polarizations, with dispersion relations of the usual form for transverse photons in a plasma. The other two modes, denoted as the ±modes, are combinations of the longitudinal photon and the massive scalar field. Their dispersion relations behave very differently as functions of momentum. The +mode dispersion relation increases steadily and remains greater than the momentum as the momentum increases. The dispersion relation of the -mode decreases in a given momentum range, with the group velocity being negative in that range, while in another range it increases steadily but remains smaller than the momentum, akin to the situation in a medium with an index of refraction greater than 1. We consider the non-relativistic limit of the (±) dispersion relations and discuss some aspects of the results. We also determine the wavefunctions of the ± modes, which are useful to obtain the corrections to the dispersion relations, e.g., imaginary parts due to the damping effects and/or the effects of scattering, due to the interactions with the excitations of the system. The results can be useful in various physical contexts that have been considered in the literature involving the electrodynamics of a charged scalar BE condensate.

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