The refractive index of a single three-level atom experienced by a quantum field

Trever Harborth, Jacob Emerick, and Yuri Rostovtsev

Department of Physics, University of North Texas, 1155 Union Circle, #311427, Denton, USA

The refractive index of a system is often considered as the collective response of a medium to an electromagnetic field. However, even when light targets a single atom, it undergoes dispersion. By studying the propagation of a single photon interacting with a two-level atom, we can examine the dispersion behavior of the photon wave packet and further analyze the dispersion experienced by the single photon [1,2]. These findings are critical for advancing long-distance quantum communications.

Moreover, the question of the refractive index of a single atom arises when the atom interacts with a quantum field consisting of multi-photon states of radiation. Surprisingly, there is no difference when the quantum field interacts with a single two-level atom. However, when the atom has more levels (e.g., three levels in Lambda or Ladder configurations), the dispersion for the quantum field differs compared to a two-level atom. In our poster, we will present the applications arising from the new findings on the dispersion of three-level atoms, which are important for advancing quantum information manipulation and improving quantum communications.

[1] Yuri Rostovtsev, Jacob Emerick, Anil Patnaik, "The refractive index of a single atom experienced by a single photon", Results in Optics, 2023. DOI: 10.1016/j.rio.2023.100568

[2] https://sciencefeatured.com/2024/01/24/light-particle-meets-atom-revolutionizes-communication/