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Highly nonlocal optical nonlinearities

Nonlinear optical phenomena are typically local. We predict the possibility of highly nonlocal optical nonlinearities for light propagating in atomic media trapped near a nano-waveguide, where long-range interactions between the atoms can be tailored. When the atoms are in an electromagnetically-induced transparency configuration, the atomic interactions are translated to long-range interactions between photons and thus to highly nonlocal optical nonlinearities. We derive and analyze the governing nonlinear propagation equation, finding a roton-like excitation spectrum for light and the emergence of order in its output intensity. For atoms coupled to a waveguide with a bandgap spectrum illuminated by an off-resonant laser, the resulting dynamics of the atoms is predominantly affected by an extremely long-range conservative force that can enhance their interaction. Even more dramatic, giant, enhancement of the interaction is achievable via the control of the geometry, for dipolar forces induced by the electromagnetic vacuum, namely, the Casimir and van der Waals (vdW) forces. The idea is to consider atoms coupled to an electric transmission line (TL), such as a coaxial cable or coplanar waveguide, which support the propagation of quasi-1d transverse electromagnetic (TEM) modes. Then, virtual excitations (photons) of these extended modes can mediate much stronger and longer-range Casimir and vdW forces than in free-space. These predictions open the door to studies of unexplored wave dynamics and many-body physics with highly-nonlocal interactions of optical fields in one dimension.
References E. Shahmoon et al , Optica 3, 725 (2016); PRA 89, 043419 (2014); PRA 87, 03383 (2013); PNAS 111, 10485 (2014)

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