Physics of electromagnetically induced chirality and its applications

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Abstract

Chiral media have some unusual properties which are not possessed by naturally found materials. The reflection and transmission of a light ray passing through a boundary between two linear isotropic media is governed by Snell’s law. However, we show that this law takes a modified form in case of chiral media. There are different techniques to make a linear isotropic medium as chiral. One such is the application of external electromagnetic fields which couple to different atomic transitions of its molecules and atoms resulting in quantum coherence and quantum interference. These coupled modes induce magnetoelectric cross coupling which introduces chirality in the atomic ensemble. We consider a four-level double Λ-type atomic configuration of Rubidium D1 line and demonstrate the chirality under such a coherent treatment. We show that the system splits a linearly polarized light pulse into left-(LCP) and right-circularly polarized (RCP) beams which can be directly related to the optical activity of a medium. An important property of these schemes is their sensitivity to the phases of the driving fields due to their closed loop nature. Therefore, the medium’s responses can be efficiently tuned by varying the Rabi frequencies as well as phases of the applied fields. This enhanced tunability can be used to detect the exact position of the transmitted beams and images.

Next, the strong chirality of such electromagnetically induced chiral media can be of particular interest in plasmonics. We show that surface plasmons (SPs) at the interface between such atomic medium and a dielectric can still exist even both the permittivity and permeability of the medium are positive. This is in contrast to the conventional case where the sign of permittivities of the two media along the interface must be opposite. Moreover, we show that the SPs at the interface are not purely transverse magnetic or transverse electric but are hybrid modes. As stated above, the medium responses are highly dependent on intensity and phases of the driving fields, therefore the properties of the SPs can be manipulated conveniently.

Surface plasmons have always greater momentum than that of the incident radiation of the same frequency. To overcome this mismatch between the two momentums, different coupling schemes have been proposed. We demonstrate, further, that chiral media can be used as a prism-like coupler for the excitation of SPs both in Otto- or Kretschmann-type configurations. We find that there is a proper angle of incidence for the RCP light beam beyond which SPs are excited along an interface between gold and air. This angle can be related to the critical angle of a totally internally reflecting surface, i.e., a prism. Moreover, the direction and polarization control of the SPs can be achieved by making the gold film to have two columns of orthogonal slits which couple the two components of a circularly polarized light beam independently. We only consider the RCP beam from the chiral medium for excitation of SPs and show that their properties can be highly controlled by tuning a number of variables.