Chiral Three-Dimensional Photonic Crystals for Controlling Light-Matter Interactions

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In photonic crystal (PhC) structures, the electromagnetic vacuum fields are largely modified compared with those in uniform media. This allows to engineer light propagation and light-matter interactions in the structures. Various demonstrations, such as efficient lasing at the photonic bandedge in defect-less PhCs, slow light enhancement of nonlinear optics in PhC waveguides, have been reported. In addition, cavity quantum electrodynamics in PhC nanocavities coupled with semiconductor quantum dots (QDs) has also been explored intensively. However, in most of them, 2D PhC slabs have been used. On the other hand, in 3D PhCs, the third dimension will add new degrees of freedom for controlling photons and light-matter interaction.

In this presentation, we discuss semiconductor-based chiral 3D PhC and its application to controlling the light emission properties of InAs QDs. Our chiral 3D PhC structure is composed of rotationally-stacked 1D gratings and can be fabricated by layer-by-layer techniques. Because of the chiral nature of the structure, we can control the electromagnetic vacuum field for circularly polarized photons in chiral 3D PhCs. As a consequence, the structures exhibit artificial optical activity although they are fabricated by non-chiral materials. We have fabricated GaAs chiral 3D PhCs by using micro-manipulation method and have demonstrated giant optical rotation [1] and broadband circular dichroism [2]. The modified circularly polarized vacuum field also influences the light emission properties of materials located in the environment. We experimentally observed highly-circularly polarized light emission from QDs embedded in a chiral 3D PhC [3]. At the bandedge of a circularly-polarized photonic band, the degree of polarization of emitted photons is enhanced, which reflects the increase of photonic density of stats of circularly polarized photons at the bandedge.

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