Control of angular momentum of photons by photonic nanostructures

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Photonic nanostructures such as photonic crystals (PhCs), plasmonic structures, and optical metamaterials can provide a wide variety of possibilities for engineering the light propagation and localization as well as light-matter interactions. One of applications of these structures are efficient control of optical polarization, "spin" angular momentum of light. We have developed semiconductor chiral 3D PhCs for controlling circularly polarized state of light [1,2] and the interaction between quantum dots (QDs) and circularly polarized photons[3]. Recently, photonic nanostructures has started to be applied to manipulate other degrees of freedom of light such as orbital angular momentum and topological properties.

In this presentation, we will discuss a possible scheme to generate single photon vortex from a single QD embedded in a PhC nanocavity [4]. Emission from a spin-polarized QD embedded at an appropriate position within a H1-type PhC nanocavity can excite degenerate quadrupole cavity modes with $\pi/2$ phase difference. Consequently, the excited electromagnetic field in the cavity rotates accordingly and radiates light with twisted wavefront. Our numerical simulation demonstrates that the radiated light possesses optical orbital angular momentum with opposite sign depending on the QD spin state. This approach can be also applicable to realize a novel spin-photon interfaces [5] as well as to generate single photon vortices.

As another related topic, we will briefly discuss our recent research on valley photonic crystals, in which vortex structures in phase distribution of electromagnetic eigenmodes play important roles [6].

Acknowledgements:

This work was partly supported by JSPS KAKENHI Grant-in-Aid for Specially promoted Research (15H05700), Grant-in-Aid for Scientific Research (B) (17H02796) and Grant-in-Aid for Scientific Research on Innovative Area (15H05868) and JST-CREST.

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