PD Research Report for the 2015 year

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Research Theme Theoretical Research on Electronic Properties and Quantum Phenomena in Atomically Thin Materials

Research Period October 1, 2015 ~ March 31, 2016

Research Results

In the half year period of research, I focus on the topological properties of two-dimensional (2D) photonic crystal composed of conventional dielectrics like silicon, which is a kind of mimicking for atomically thin materials by photonic medium. Compared with 2D electronic materials, 2D photonic crystals composed of conventional dielectrics offer us a highly controllable environment both for theoretical and experimental investigations, due to their macroscopic sizes of unit cells. The results summarized below based on 2D photonic crystals composed of conventional dielectrics like silicon can also shed a light on 2D electronic materials because the similarities among photons and electrons.

(1) **Two Dimensional Topological Dielectric Photonic Crystal Characterized by Vectored Zak Phases**: We propose an experimentally readily available design of 2-dimensional photonic crystal composed of conventional dielectric cylinders arranged in a square lattice, which holds non-trivial topological photonic gaps for harmonic transverse magnetic modes. These topological photonic gaps are uniquely characterized by a quantized vectored Zak phase when $C_{4v}$ point group symmetry presents. Through the band engineering among p, d, and f electromagnetic modes without breaking any symmetries, we observe robust edge states within these topological photonic gaps in realistic finite-elements-based numerical simulation. These robust edges may have potentials to improve the transportations of electromagnetic waves, and our result may provide a new angle for designing topological materials.

(2) **Quadratic degeneracies induced edge states in two dimensional photonic crystal composed conventional dielectrics**: We study a photonic crystal arrayed in a 2D square lattice that respects $C_{4v}$ point group symmetry, which lacks corresponded counterparts among 2D electric materials. In this work we show that the protected quadratic degeneracies in the photonic crystal composed conventional dielectrics with $C_{4v}$ point group symmetry can induce edge states when the photonic crystal is joining with a perfect metal or a trivial insulator for photons.

**Planed publications:**

(1) F. Liu, H. Y. Deng, K. Wakabayashi, X. Yong, Z. Li, F. Nori, “Two Dimensional Topological Dielectric Photonic Crystal Characterized by Vectored Zak Phases”, under preparation

(2) F. Liu, K. Wakabayashi, “Quadratic degeneracies induced edge states in two dimensional

photonic crystal composed conventional dielectrics", under preparation

(3) H. Y. Deng, F. Liu, K. Wakabayashi, "Optical excitation of surface plasma waves without grating structures", submitted to Nano Lett.

Poster Presentation:

F. Liu, "A Novel Topological Insulating Phase in Crystalline Photonic Crystals Composed of Conventional dielectrics", 17th International Conference on Physics of Light-Matter Coupling in Nanostructures (PLMCN17) in Nara, Japan.