The Exploration of Topological Photonic States in Photonic Crystals

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The topology of electronic systems has recently attracted much attention in condensed matter physics research because of its unique properties including robust one-way edge (helix surface) states and fermionic time-reversal symmetry protected spin dependent edge (surface) states in quantum spin Hall (topological insulator) system. In this talk, the speaker proposes some quasi-particle counterparts of the quantum spin Hall effect (topological insulator) in two-dimensional photonic or phononic crystals. For photonic analogy, two linear electromagnetic polarizations (transverse electric and transverse magnetic waves) can unidirectional propagate with opposite directions at the edge of photonic crystal composed of a gyrotropic medium exhibiting both gyroelectric and gyromagnetic properties simultaneously. Two circular polarizations (left-circular and right-circular waves) can be also used to realize photonic topological insulator consisting of artificial electric-magnetic coupling materials with piezo-electric and piezo-magnetic superlattices. Such photonic topological systems show unidirectional polarization-dependent transportation of photonic topological edged states, which is robust against certain disorders and impurities. Analyzing the symmetry in these systems, the speaker and his research team find that some bosonic time-reversal invariant chiral impurities would invalidate such topological states, indicating that the conventional bosonic time-reversal symmetry is not valid to protect their robustness. Instead, the robustness is rather protected by a new anti-unitary symmetry, which might be the general requirement for topological photonic crystals. Thus, the speaker and his research team disclose that the robustness and non-trivial edged states of photonic topological insulators are not protected by conventional time-reversal symmetry of photons obeying the bosonic statistics with T2=1 but rather by the same symmetry, T2=-1, as electron’s time-reversal symmetry. Based on the tight-binding approximation approach, the speaker and his research team construct an effective Hamiltonian for these photonic structures, which have a similar form to that of an electronic system. Furthermore, the Z2 invariant of such models is calculated in order to unify their topological non-trivial character. The finding provides a viable way to exploit the topological property of quasi-particles, and also can be used to develop a platform of photonic quantum simulation.

Biologsist:

Ming-Hui Lu got his PhD in Nanjing University, Nanjing, China, in 2007. He was a visiting scholar in the SIMES and Department of Materials Science and Engineering, Stanford University, 2011-2012. Now, he is a Professor at Nanjing University in Department of Materials Science and Engineering in Nanjing University.