Weyl Points and Topological Notions in Classical Waves

Wen-Jie Chen*, Meng Xiao, Wen-Yu He, C. T. Chan

Department of Physics and the Institute for Advanced Study,

The Hong Kong University of Science and Technology, Hong Kong

***Email of Presenting Author:** wjchen@ust.hk

Stimulated by the concepts of the quantum Hall effect and topological insulators, the analogues of 2D quantum Hall effect and quantum spin Hall effect have been proposed and realized in various kinds of classical wave systems. Topologically non-trivial bands characterized by non-zero Chern numbers are realized through either the breaking of time reversal symmetry using an external magnetic field or dynamic modulation. Due to the absence of a Faraday-like effect, the breaking of time reversal symmetry in an acoustic system is commonly realized with moving background fluids, which drastically increases the engineering complexity. Here we show that we can create an effective gauge flux in a reduced two-dimensional system by engineering interlayer couplings, achieving an acoustic analogue of the topological Haldane model. We show that the synthetic gauge flux is closely related to Weyl points in the three-dimensional band structure and the system supports chiral edge states for fixed values of kz.

In addition, our idea can be extended to electromagnetic wave systems. We designed and fabricated a Weyl photonic crystal by introducing chiral interlayer coupling in microwave regime. Nontrivial 2D bulk band gap for fixed kz and Weyl point were confirmed by angle-resolved transmission spectra. The robustness of the associated surface states against kz-preserved scattering was experimentally observed.

Topological insulators, as a new phase of matter, have been extensively studied for their exotic properties due to the topology of the bulk bands. A signature of the 2D topological insulator (quantum spin Hall insulator) is the presence of spin-filtered edge states whose spin is locked to the momentum. And the edge transport is robust against backscattering from nonmagnetic impurities as they do not induce spin flip. Quantum spin Hall insulator has been mapped to photonic systems using two schemes, namely coupled resonator optical waveguides and bianisotropic metacrystals. Spin-filtered edge states at the boundary of these systems are protected by the nontrivial topology of bulk states. They are robust against backscattering provided that scatterers preserve the pseudospin. These pseudospin states and spin-polarized transport can be achieved in carefully designed photonic crystals or bulk metamaterials which are usually difficult to fabricate. The natural question is whether “pseudospin” transport is possible with light guided in air without using any bulk material. Here, we propose a new paradigm in which symmetry-protected pseudospin states are guided in air inside a channel, and the pseudospin is enforced simply by imposing perfect electric and perfect magnetic conductor boundary conditions. Wave propagation in the waveguide is robust against deformations that do not induce spin flip. To achieve a broad bandwidth, one can also employ an "all perfect electric conductor" configuration where additional symmetries mimic an effective perfect magnetic conductor boundary. We generate several conceptual designs and symmetry-protected pseudospin transport in the microwave regime is experimentally demonstrated.