Valley photonic crystals for control of spin and topology

Subject Code: A04

With the support by the National Natural Science Foundation of China, the research team led by Prof. Dong Jianwen (董建文) at the State Key Laboratory of Optoelectronic Materials and Technologies & School of Physics, Sun Yat-sen University, discovered the control of spin and topology in valley photonic crystals, which was published in *Nature Materials* (2017, DOI: 10.1038/NMAT4087).

In 2016, Nobel Physics Prize was awarded to David Thouless, Michael Kosterlitz and Duncan Haldane for their marvelous contributions to topological phase transitions and topological phases of matter. In the past few years, the application of topology has created unprecedented opportunities in photonics. Some fancy phenomena such as unidirectional transport, spin-directional locking propagation, optical delay line, and quantum simulation have been proposed or demonstrated at the boundary of topological photonic systems. By contrast, without the assist of any boundary, Dong's group has studied the control of spin and topology in valley photonic crystals. This work was done in cooperation with the group led by Prof. Zhang Xiang at the University of California, Berkeley.

The key problem is how to realize another kind of interaction in photonic systems. To solve this problem, they employed valley photonic crystals. Due to lattice symmetry, the photonic band structure always has extrema at the corner of Brillouin zone, K′ and K. These two *k*-points are time-reversal partners, and the intrinsic binary degree of freedom, the so-called valley, is well defined. By exploiting the valley degree of freedom, the valley spin coupled physics in valley photonic crystals is clearly illustrated and confirmed through both theoretical Hamiltonian analysis and numerical simulation. It leads to the valley-dependent spin-split bands and the resultant spin band gap. Photonic spin-momentum locking propagation, i.e., photonic valley Hall effect, was demonstrated inside the bulk crystals, not at the boundary of photonic systems. In addition, unidirectional spin flow can also be designed in such a topologically trivial photonic system.

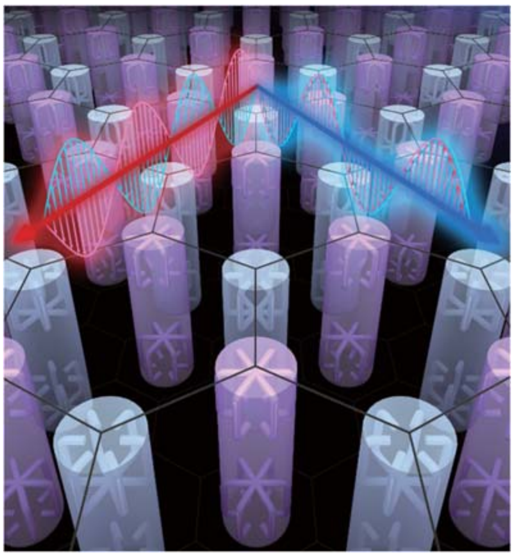

Figure Valley Optics: Photonic valley Hall effect in bulk photonic crystal.

What's more amazing is that the independent control of valley and topology can be achieved in one single valley photonic crystal with the configuration of bianisotropy-nonbianisotropy. It brings a new opportunity to realize valley-related flat edge states due to the balance between the non-zero valley-spin coupling and non-zero spin-orbit coupling,

Valley photonic crystals not only offer a route towards the experimental observation of fundamental physics, such as topological photonics, but also open a way for device applications in the next generation of integrated photonics and information propagation and processing, in particular for the use of spin and orbital angular momentum.