Parity-Time-Symmetric Optics, extraordinary momentum and spin in evanescent waves, and the quantum spin Hall effect of light

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Abstract: This talk provides a brief and pedagogical overview to parity-time-symmetric optics, extraordinary momentum and spin in evanescent waves, and the quantum spin Hall effect of light.

1. Parity-Time-Symmetric Optics

Optical systems combining balanced loss and gain provide a unique platform to implement classical analogues of quantum systems described by non-Hermitian parity–time (PT)-symmetric Hamiltonians [1]. Such systems can be used to create synthetic materials with properties that cannot be attained in materials having only loss or only gain. We report PT-symmetry breaking in coupled optical resonators. We observed non-reciprocity in the PT-symmetry-breaking phase due to strong field localization, which significantly enhances nonlinearity. In the linear regime, light transmission is reciprocal regardless of whether the symmetry is broken or unbroken. We show that in one direction there is a complete absence of resonance peaks whereas in the other direction the transmission is resonantly enhanced, which is associated with the use of resonant structures. Our results could lead to a new generation of synthetic optical systems enabling on-chip manipulation and control of light propagation.

2. The quantum spin Hall effect of light: photonic analog of 3D topological insulators.

Maxwell's equations, formulated 150 years ago, ultimately describe properties of light, from classical electromagnetism to quantum and relativistic aspects. The latter ones result in remarkable geometric and topological phenomena related to the spin-1 massless nature of photons. By analyzing fundamental spin properties of Maxwell waves, we show [2] that free-space light exhibits an intrinsic quantum spin Hall effect—surface modes with strong spin-momentum locking. These modes are evanescent waves that form, for example, surface plasmon-polaritons at vacuum-metal interfaces. Our findings illuminate the unusual transverse spin in evanescent waves and explain recent experiments that have demonstrated the transverse spin-direction locking in the excitation of surface optical modes. This deepens our understanding of Maxwell's theory, reveals analogies with topological insulators for electrons, and offers applications for robust spin-directional optical interfaces. Related work can be found in [3].

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