Synthetic hamiltonians and spin-orbit engineering in tunable birefringent microcavities

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Spin-orbit optical interactions in photonic systems exploit the analogy between the quantum mechanical description of electronic spin-orbit system and synthetic Hamiltonians derived for propagation of electromagnetic waves in dedicated spatial structures. We realize an artificial Rashba-Dresselhaus spin-orbit interaction (SOI) and synthetic magnetic field (Zeeman term) using a birefringent photonic microcavity.

A nematic liquid crystalline (LC) optical medium was enclosed in a typical Fabry-Perot resonator. The long-range order of elongated liquid crystals molecules results in a strong anisotropy in particular in optical properties. The liquid nature of these materials, thus freedom of molecular reorientation, allow for convenient control of these properties by relatively weak external electric fields. Significant changes in the optical properties of LC can be obtained after applying merely several volts. With the ability to manipulate the permittivity tensor and, therefore, effective refractive indices for different polarizations of light it is possible to tune the energy splitting between cavity modes which strongly influences the reflectivity and transmission of the microcavity (Fig. 1).

When two linearly polarized modes of different parity are brought into resonance theoretical analysis of birefringent electromagnetic waveguide results in SOI effects of light which stem directly from the solutions of Maxwell equations, in the form of $\hat{H}_{RD} = -2\alpha\hat{\sigma}_z k_y$, where $\hat{\sigma}_z$ is the Pauli matrix describing polarization ("spin") of light and k_y is light's direction of propagation. The Rashba parameter α depends on the properties of LC and cavity dimension. We performed three-dimensional tomography in energy-momentum space to directly observe the spin-split photon dispersion relation in the presence artificial spin-orbit coupling. Engineering of spin-orbit synthetic Hamiltonians in cavities opens the way to photonic emulators of quantum Hamiltonians with internal degrees of freedom.

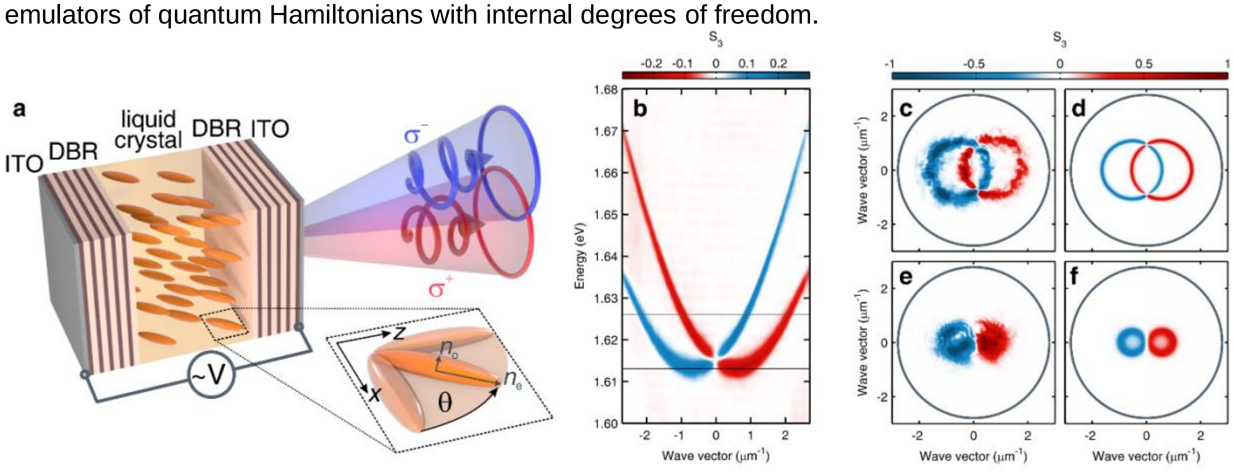

Fig 1. a Scheme of the birefringent microcavity and degree of circular polarization (S3 Stokes parameter) of **b** reflected and **c-f** transmitted light in momentum space. **b,c,e** experiment **d,f** modeling for different energies marked in **b**.

[1] K. Lekenta *et al.*, Tunable optical spin Hall effect in a liquid crystal microcavity. *Light Sci. Appl.* **7**, 74 (2018).

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