Quantized Hall drift in a frequency-encoded photonic Chern insulator

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Over the last decade, considerable efforts have been devoted to extending topological band theory to photonic systems in order to enable transformative applications across a broad range of applications, ranging from optical isolation and light emission (lasers, frequency combs, quantum light sources…) to signal processing and quantum computing [1].

So far, most of the experimental realizations in the field of topological photonics rely on time-reversal symmetric (T) models, notably inspired by the spin- and valley-Hall effect, because these can be easily implemented in passive platforms, e.g. photonic crystals, and arrays of waveguides or resonators. However, photon transport in these architectures is critically prone to back-scattering, because Kramers' degeneracy theorem which precludes the hybridization of counter-propagating electrons in T-invariant topological matter doesn't apply to bosonic fields.

I will present a recent work [2] in which we directly overcome this fundamental challenge by realizing a photonic Chern insulator – a topological insulator with broken T – by implementing the Haldane model [3] in the synthetic frequency dimension of an optical fibre loop platform. The breaking of time-reversal and the complete control of inter-site connectivity is ensured through electro-optic modulation. Thanks to the versatility and driven-dissipative nature of our platform, we realize a full characterization of the bands' topological properties, including the band structure (Fig. 1a), and Berry curvature with the corresponding Chern numbers. We finally extract a drive-dissipative analogue of the quantum anomalous Hall drift in frequency space (Fig. 1b) upon implementing an effective electric field.

These results pave the way to robustly engineering the flow of light in frequency-multiplexed photonic devices, including frequency combs, quantum sensors, optical neural networks and photonic quantum processors.

References

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[3] F. D. M. Haldane, Phys. Rev. Lett., 61 (1988) 2015

Figures

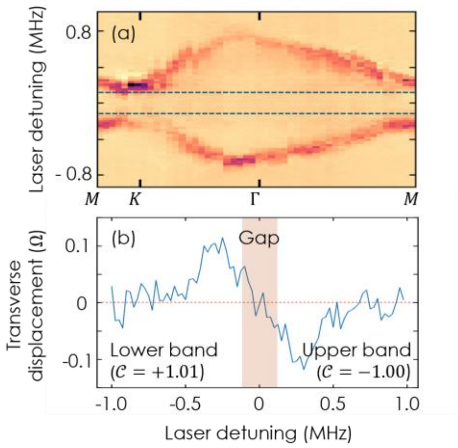

Figure 1: (a) Band structure in the Haldane phase. (b) Transvers Hall drift (and associated Chern number) as a function of laser detuning.