# How fast does the edge spin current flow?

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Topologically nontrivial band structure of a two-dimensional electronic material may give rise to edge states at its boundaries that are robust with respect to disorder and scattering. These edge states are at the origin of quantum Hall effects (QHE), including the quantum spin Hall (QSHE) and quantum anomalous Hall (QAHE) effects, manifesting themselves in quantized values of electrical conductance [1]. Recent technologies allow for visualizing current flows inside a two-dimensional material with spatial resolution and provide elements of the answer to a long-standing question of "*where* does the current flow" [2].

In the present work, we use a microwave platform that mimics QSHE to explore the time-domain, QSHE-specific counterpart of this question: "*how fast* does the edge spin current flow"? Our experiment exploits the idea of Wu and Hu [3] allowing for simulating QSHE with electromagnetic waves by making the orbital angular momentum of light in hexagonal clusters of dielectric cylinders to play the role of electron spin. We construct a sample made of two topologically distinct parts by arranging clusters of two different sizes in a triangular lattice, see Fig. 1. Electromagnetic waves are excited along the interface between the two parts of the sample and transport of angular momentum (or pseudospin) along the interface is measured with both spatial and temporal resolution [4]. Our measurements allow for determining the velocity of pseudospin transport and comparing it to the group velocity of microwaves. Both velocities turn out to be equal and 2 to 3 orders of magnitude slower than the speed of light in the free space, which may limit performance of photonic devices that use topologically protected edge states for transmission, storage or processing of information.

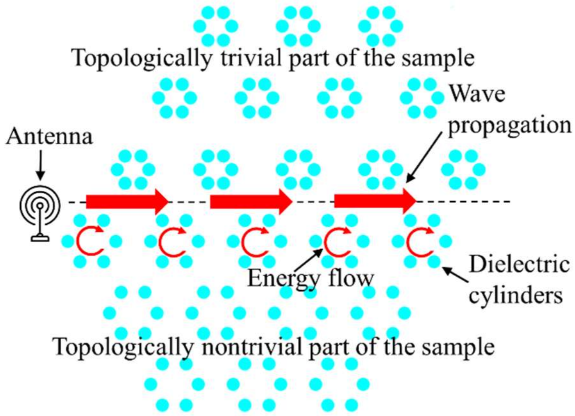


*Fig. 1. Schematic representation of our experiment. The sample is a triangular lattice of clusters made of six dielectric cylinders (cyan circles) each. Cluster size is smaller (larger) than one third on the lattice spacing in the upper (lower) half of the sample, making the two halves topologically distinct. An antenna excites an electromagnetic wave propagating along the interface between the two halves of the sample (bold red arrows). The wave is spin-polarized, with the orbital angular momentum of light in clusters (see red circular arrows showing the direction of energy flow within individual clusters) playing the role of spin.*

Note that the breakdown of lattice symmetry near an edge spoils the analogy between the optical angular momentum and electron spin, preventing the spectral gap from closing. This flaw can be exploited to realize a unidirectional wave propagation despite the preserved time-reversal symmetry of our experimental setup. In Fig. 1, for example, an isotropic antenna excites an electromagnetic wave along the horizontal interface between the two topologically distinct parts of the sample (bold red arrows) but not along the interface between the sample and the air surrounding it. "Switching" propagation from one interface to another can be achieved by tuning the frequency of the signal, allowing for new opportunities in routing of electromagnetic waves in photonic circuits.

## References

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