Nanoimaging of Topologically Protected Waveguide Mode at Telecommunication Frequency

A. M. Dubrovkin[1,2], U. Chattopadhyay[2], B. Qiang[1,3], Q. J. Wang[1,2,3], Y. Chong[1,2], N. I. Zheludev[1,2,4]

1. *Centre for Disruptive Photonic Technologies, TPI, Nanyang Technological University, 637371 Singapore*
2. *School of Physical and Mathematical Sciences, Nanyang Technological University, 637371 Singapore*
3. *OPTIMUS, Centre for OptoElectronics and Biophotonics, School of Electrical and Electronic Engineering, Nanyang Technological University, 639798 Singapore*
4. *Optoelectronics Research Centre and Centre for Photonic Metamaterials, University of Southampton, SO17 1BJ, UK*

Abstract: We demonstrate near-field mapping of a valley-Hall photonic waveguide at telecommunication frequency. Launching and guiding of an optical mode along the boundary between opposite valley-Chern-index domains is experimentally observed in real space, in agreement with theoretical calculations.

Topologically protected states of light allow for robust wave-guiding in appropriately-designed photonic systems. This has attracted tremendous attention in the past decade and stimulated a number of practical applications. In microwave experiments, topological states of light have been demonstrated and accurately mapped in real space. At visible and infrared frequencies, however, nanoimaging of topologically protected states remains a significant challenge. In this work, we use scattering-type scanning near-field optical microscopy (s-SNOM), at telecommunication frequency, to directly map the mode of a valley-Hall topological photonic waveguide (Fig. 1a).

The topological waveguide is based on a triangular air-hole motif with broken inversion symmetry, realized on a high-index semiconductor slab (Fig. 1b). This photonic crystal device supports a topological gap in the transverse magnetic (TM) spectrum. We perform s-SNOM using single-line laser radiation ($\lambda = 1.55$ μm), which provides amplitude- and phase-resolved nanoimaging of the sample with 10-20 nm spatial resolution. Fig. 1c shows an example of mode launching from the unpatterned slab medium to the topological waveguide. Fig. 1d shows the detailed near-field distribution along the boundary between topologically distinct opposite valley-Chern-index domains (top and bottom parts of the photonic crystal). The observed decay of the optical field away from the boundary is a typical feature of a wave-guide mode, and agrees with theoretical calculations. Our results provide insight into the design and use of topological protection for optical-to-infrared regime waveguiding applications.

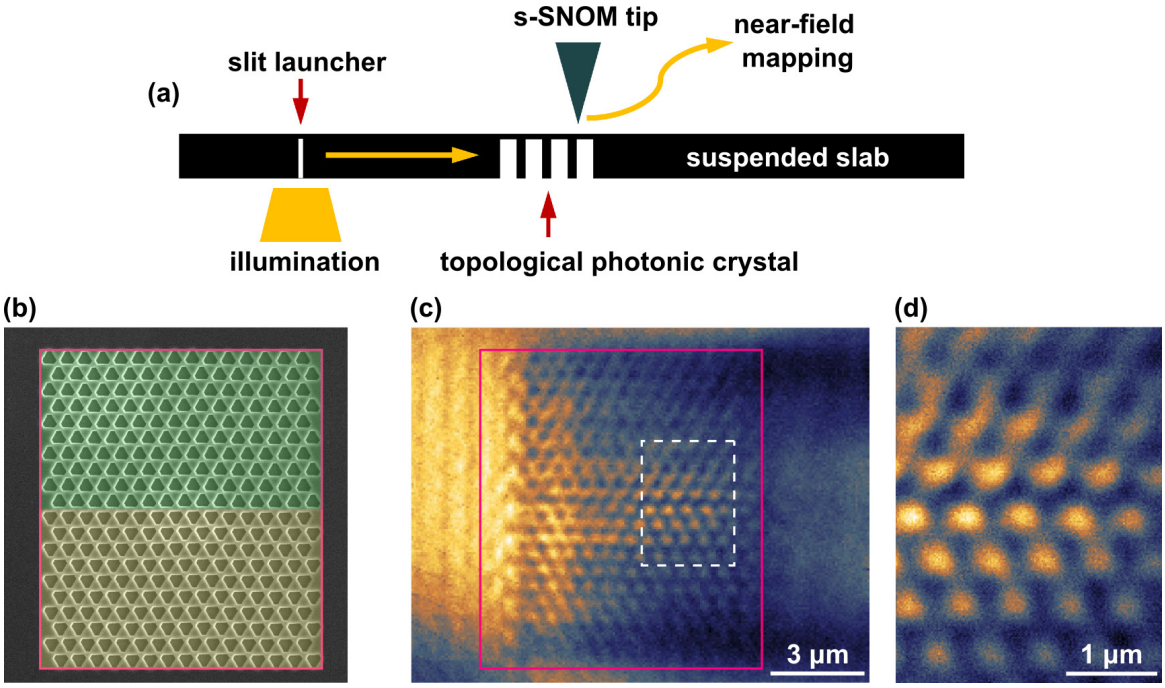

Fig. 1 (a) Schematics of the experiment. (b) SEM image of fabricated valley-Hall photonic crystal waveguide recorded from the bottom side of the experimental sample; green and yellow artificial colours highlight regions with distinct valley-Chern indexes. (c) Near-field optical image of the topological waveguide recorded at $\lambda = 1.55$ μm; light travels from the left to the right. (d) Zoomed image of the area on the panel (c) marked with white dotted frame. Pink frames in images (b,c) highlight the location of the topological waveguide.