Realization of Z_2 Topological Photonic Insulators Based on Bulk Transition Metal Dichalcogenides

T. Isoniemi[1], P. Bouteyre[1], X. Hu[1], F. Benimetskiy[1], Y. Wang[2], M. S. Skolnick[1], D. N. Krizhanovskii[1] and A. I. Tartakovskii[1]

[1]*Department of Physics and Astronomy, University of Sheffield, UK*
[2]*School of Physics, Engineering and Technology, University of York, UK*

t.isoniemi@sheffield.ac.uk

Recently a new field of nanophotonics based on bulk transition metal dichalcogenides, two-dimensional materials with weak van der Waals bonding between layers, has emerged. These materials can be integrated with a variety of substrates, possess high-oscillator-strength excitons and can be incorporated in various tunable heterostructures, which is very promising for development of novel optical devices. Their high refractive indices (up to n=5) and a variety of transmission windows with low losses enable the fabrication of nanophotonic structures with a tightly localised electromagnetic field and hence strong nonlinear effects.[1]

We demonstrate topologically distinct photonic crystals with interface modes on slab waveguides of thin (70 nm) exfoliated films of WS_2. The spin-Hall hole lattice structures are fabricated via electron beam lithography and reactive ion etching (Fig. 1a). Topological photonic devices are essential for various nonlinear and quantum applications, since they have unidirectional photonic edge states at their interface, which have inherently low scattering losses and backscattering-immune transport protected by topological invariant.

With a symmetric lattice ($R=R_0$) the photonic band structure has a Dirac cone at Γ point. A photonic gap opens, blocking propagation, in perturbed configurations (R_s, R_e) with the bands flipped. At the interface of the domains the gap closes and a topological interface state appears, confirmed with angle-dependent reflectance measurements and band structure simulations (Fig. 1b,c). Unidirectional propagation confined in the slab waveguide controlled with the handedness of circular polarization in plane is observed in emission, and confirmed with simulations of the same structure (Fig. 1d,e).

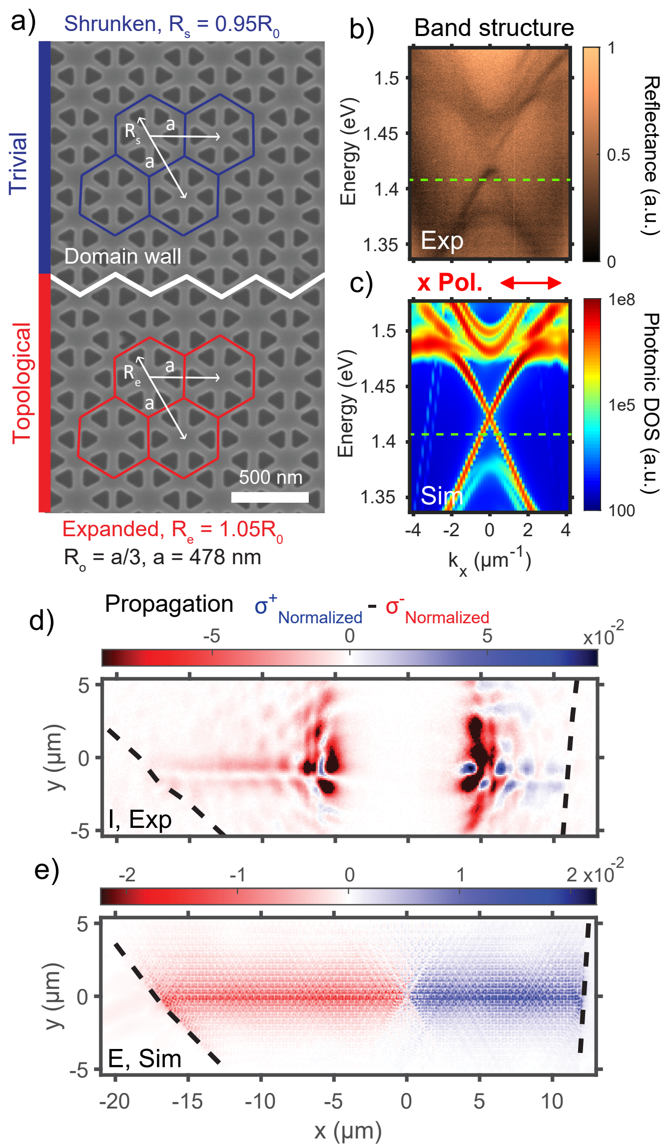

Fig. 1. a) Schematic on a SEM image of photonic lattices fabricated in a WS_2 flake on 1 μm SiO_2 on Si. b) Measured angle-dependent reflectance of the interface in a), with c) corresponding simulated density of states at the domain wall near Γ (k_y = 0), linear polarization. d) Real-space propagation at the domain interface plotted as a subtraction of emitted light with right (σ^+) and left circular (σ^-) polarizations in the plane. Excitation at 881 nm wavelength (marked on b,c) to spot at 0 μm, flake edges at dashed lines. e) Corresponding simulation with electric field in the plane of the WS_2 flake integrated over 700 fs.

References

[1] P.G. Zotev, Y. Wang, D. Andres-Penares, et al. Laser Photonics Rev. 2200957 (2023).

[2] M. Li, I. Sinev, F. Benimetskiy, et al. Nat. Commun. **12**(1), 1-10 (2021).