Valley-Hall Topological Plasmons in Graphene Crystal Waveguides

Jian Wei You(1), Yupei Wang(1), Zhihao Lan(1), and Nicolae C. Panoiu(1),*
(1) Department of Electronic and Electrical Engineering, University College London, Torrington Place, London, WC1E 7JE, e-mail: n.panoiu@ucl.ac.uk

Topological photonics has recently attracted rapidly increasing interest, due to the unique opportunities it provides to manipulate light in a robust way [1,2]. In this talk, we present two types of valley-Hall topological graphene plasmonic crystal waveguides, namely single- and bi-layer graphene plasmonic crystal waveguides.

The single-layer graphene plasmonic crystal waveguide is illustrated in Fig. 1a. It consists of a domain-wall interface highlighted by a transparent green strip, and it is constructed by joining together two graphene nanohole crystals referred to as domains D_1 and D_2. The domain D_1 is the mirror-symmetric counterpart of the domain D_2. The unit cells of the D_1 and D_2 domains are marked by blue and red hexagons, respectively. The projected band diagram of this single-layer graphene crystal waveguide is depicted in Fig. 1b, where a valley-Hall topological edge-mode band is formed inside the topological bandgap [3]. To confirm the topologically-protected unidirectional propagation feature of the waveguide modes, a straight graphene plasmonic crystal waveguide is studied and the results are presented in Fig. 1c. Thus, a source located at the middle of the graphene plasmonic crystal waveguide generates right-circularly polarized (RCP) monochromatic light with frequency ω_0. As a result of the valley-chirality-locking feature, unidirectional propagation of plasmonic waves is achieved.

Similar physics are observed in a bi-layer graphene plasmonic crystal waveguide consisting of two coupled graphene plasmonic crystals with the same unit cell, as per Fig. 1e (see also [4]). However, the left- and right-hand side domains of the top graphene layer are horizontally shifted, in opposite directions, by a certain distance. The projected band diagram of a finite bilayer graphene plasmonic crystal waveguide is evaluated, and the results are given in Fig. 1f, where the green regions represent the bulk states and the topological interface modes are marked by red lines. The blue lines indicate edge modes confined at the metasurface boundaries rather than the domain-wall interface. We also show the field distribution of the interface mode "1" in Fig. 1f is given in Fig. 1g, where the electric field is strongly confined at the domain-wall interface. The field distribution of the edge mode "2" in Fig. 1f is given in Fig. 1h, where the electric field is now confined at the boundary of the graphene metasurface.

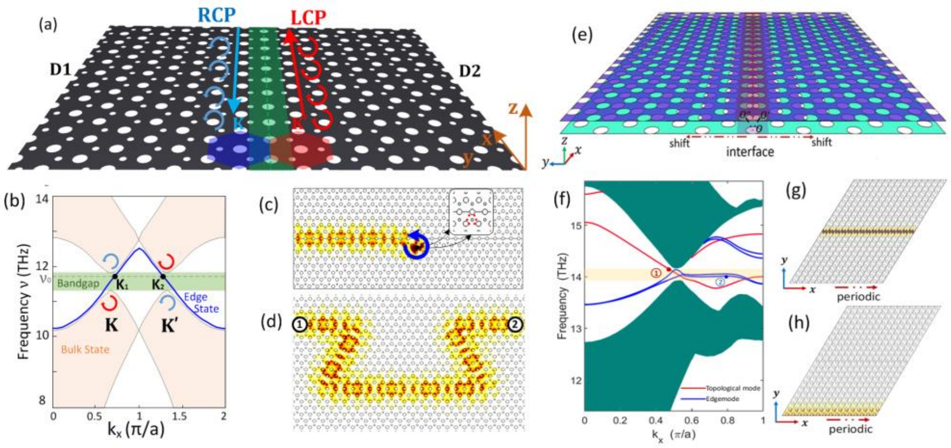

Figure 1. Two types of graphene crystal waveguides possessing plasmonic topological valley-Hall interface modes. (a)-(d) Band diagram and topological propagation features of a single-layer graphene plasmonic crystal waveguide. (e)-(d) Same as in (a)-(d), but for a bi-layer graphene plasmonic crystal waveguide.

1. T. Ozawa, *et al.*, "Topological photonics", *Rev. Mod. Phys*., vol. 91, no. 1, 2019, pp. 015006.
2. J. W. You, Z. Lan, and N. C. Panoiu, "Four-wave mixing of topological edge plasmons in graphene metasurfaces", *Sci. Adv.*, vol. 6, no. 13, 2020, art. no. eaaz3910.
3. J. W. You, Z. Lan, Q. Bao, and N. C. Panoiu, "Valley-Hall topological plasmons in a graphene nanohole plasmonic crystal waveguide", *IEEE J. Sel. Top. Quantum Electron*. (to be published).
4. Y. Wang, J. W. You, Z. Lan, and N. C. Panoiu, "Topological valley plasmon transport in bilayer graphene metasurfaces for sensing applications", *Appl. Phys. Lett.* (submitted).