Topological darkness in van der Waals materials

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For decade, researchers face numerous challenges trying to embed two-dimensional (2D) van der Waals (vdWs) materials into optoelectronic devices[1]. One such key problem is the small phase accumulation ($\Delta\varphi \sim 0.01\pi$) inside 2D material due to its atomic thickness ($t \sim 0.7$ nm),[2] while the majority of optoelectronic devices require $\Delta\varphi \sim \pi$. As a result, current efficiency of 2D photonic devices limited by about 1%. Here, we provide a solution to this task through topological darkness in vdW materials[3].In this work, we utilize the concept of topological phase singularity points in reflection[4] to acquire the desired optical phase change $\Delta\varphi \sim \pi$ in atomically thin materials. These points arise at zero-reflection since at zero amplitude the phase is undefined and thanks to excitonic resonances obtain topological charge in contrast to classical Brewster zero-reflection phenomena[5]. As a consequence of topology, optical phase exhibit rapid optical phase change $\Delta\varphi \sim \pi$, which we experimentally observed by spectroscopic ellipsometry for 2D $PdSe_2$, MoS_2, WS_2, and graphene. Hence, the proposed topological approach provide an indispensable route to manipulate optical phase in vdW-based devices. For demonstration, we created a label-free biological sensor with the record phase sensitivity of $7.5 \cdot 10^4$ degrees per refractive index change using topological phase singularity of atomically thin $PdSe_2$. Additionally, we describe topological phenomena of phase singularities in reflection: annihilation of topological charges and high-order topological charges.

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