Optical activity in monolayer black phosphorus

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Abstract

We show that strong optical activity can be obtained in unpatterned monolayer black phosphorus (BP). The optical activity can be attributed to the extrinsic chirality from the mutual orientation of the BP film with in-plane anisotropy and the incident light. This phenomenon may have potential applications in spectroscopy, polarization optics and precision metrology.

The interaction of circularly polarized light with two-dimensional atomic crystals has attracted significants attentions in the past few years. It can lead to interesting phenomena which, by incorporating the quantum weak measurement techniques [1, 2], may be exploited for precision metrology or characterization of the structure parameters.

Black phosphorus (BP) is two-dimensional material known for its intrinsic anisotropy. This property has been explored for novel effects and potential applications including photonic spin Hall effect (SHE) [3] and polarization convertors [4]. In this talk, we show theoretically and numerically that strong optical activity responses can be realized in unpatterned monolayer BP. The unpatterned black phosphorus is simply put on the top of a homogeneous and isotropic semi-infinite substrate with the oblique incidence of circularly polarized waves (RCP or LCP). The projection of incident plane in in-plane should not coincide with the crystal axis to avoid mirror line in the plane of incidence. Simulation results show that the maximum circular dichroism can be higher than 10% in the THz range when the incident angle β and the azimuth α are fixed as 79° and 40°, respectively. The optical activity, including both circular dichroism and circular birefringence, is caused by extrinsic 3D chirality which relies on the mutual orientation of incident beam with the BP film. The obtained circular dichroism in this atomically thick material is comparable to that in previously reported chiral metamaterials and the optical activity is inherently tunable by controlling the Fermi level of monolayer BP. This phenomena may promote the research on polarization-dependent quantum optical effects in atomically thick materials and find applications in spectroscopy, polarization optics and precision metrology.

[1] O. Hosten, and P. Kwait, Observation of the Spin Hall Effect of Light via Weak Measurements, Science **319**, 787–790(2008).

[2] L. Cai, M. Liu, S. Chen, Y. Liu, W. Shu, H. Luo, and S. Wen, Quantized photonic spin Hall effect in graphene, Physical Review A **95**, 013809 (2017).

[3] W. Zhang, W. Wu, S. Chen, J. Zhang, X. Ling, W. Shu, H. Luo, and S. Wen, Photonic spin hall effect on the surface of anisotropic two-dimensional atomic crystals, Photonics Research **6**, 511–516 (2018).

[4] Q. Hong, F. Xiong, W. Xu, Z. Zhu, K. Liu, X. Yuan, J. Zhang, and S. Qin, Towards high performance hybrid two-dimensional material plasmonic devices: strong and highly anisotropic plasmonic resonances in nanostructured graphene-black phosphorus bilayer, Optics Express **26**, 22528–22535 (2018).