

Anisotropic van der Waals Metasurfaces: High-Q Resonances via High-Order Multipole Coupling

Alexei V. Prokhorov^{1,2}, A.V. Shesterikov², M.Yu. Gubin², S.M. Novikov², R.V. Kirtaev¹, E.I. Titova², A.N. Toksumakov¹, D.I. Yakubovsky², A.V. Arsenin¹, V.S. Volkov¹

¹Emerging Technologies Research Center, XPANCEO, Emmay Tower, Internet City, Dubai 00000, United Arab Emirates;

²Center for Photonics and 2D Materials, Moscow Institute of Physics and Technology, Institutskiy per. 9, Dolgoprudny 141701, Russia

alprokhorov33@gmail.com

Harnessing the giant intrinsic anisotropy of van der Waals (vdW) materials provides a transformative platform for engineering light-matter interactions at the nanoscale. Here, we introduce a new physical mechanism—high-order multipole coupling (HOC)—that enables the excitation of high-Q quasi-trapped modes (QTM) in metasurfaces without requiring conventional structural symmetry breaking. This principle emerges from the unique interplay between material anisotropy and the geometry of individual nanoresonators, offering a novel degree of freedom for controlling near-field energy. We first experimentally validate this remarkable effect in MoS₂-based metasurfaces, demonstrating a new pathway to achieve sharp spectral features for sensing and nonlinear optics.

Leveraging this principle, we demonstrate a portfolio of flat-optic components, including a polarizing metamirror (Fig.1a) and a near-field energy concentrator (Fig.1b), culminating in a prototype vdW-metalaser. This device integrates a Si-based QTM metasurface, precisely tuned to the photoluminescence peak of a MoTe₂ monolayer, to achieve laser generation (Fig.1e). Our work establishes HOC in anisotropic vdW systems as a powerful new tool for designing next-generation flat optics, with future applications ranging from optomechanics (Fig.1f) to integrated quantum photonics.

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References

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Figures

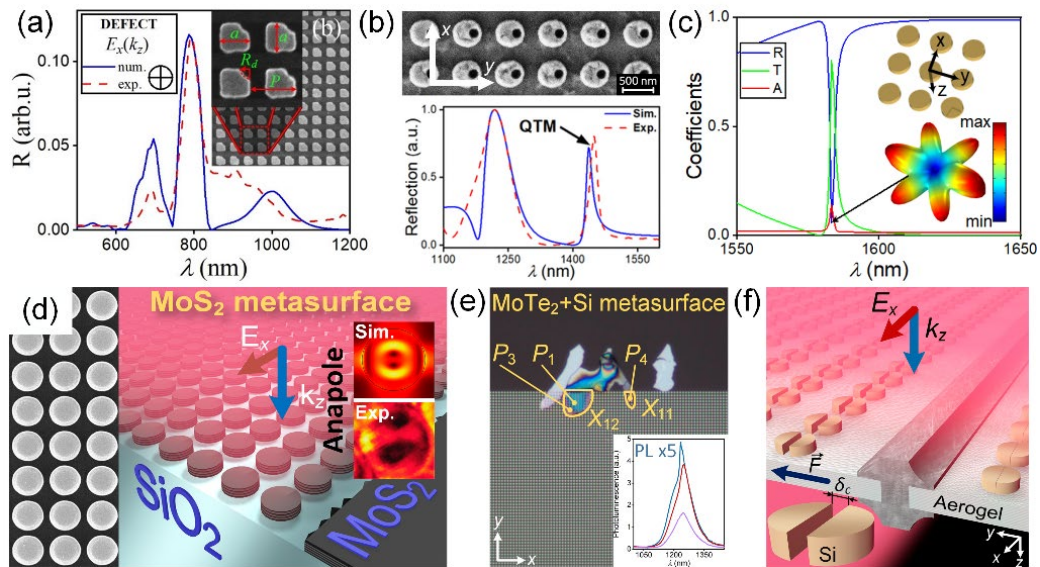


Figure 1: Metasurface-assisted near-field and far-field light manipulation.