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Two-Dimensional Materials based Integrated Photonic Devices

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Publication date:
2022

Document Version
Publisher's PDF, also known as Version of record

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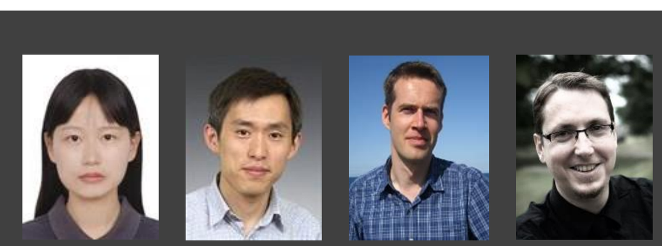

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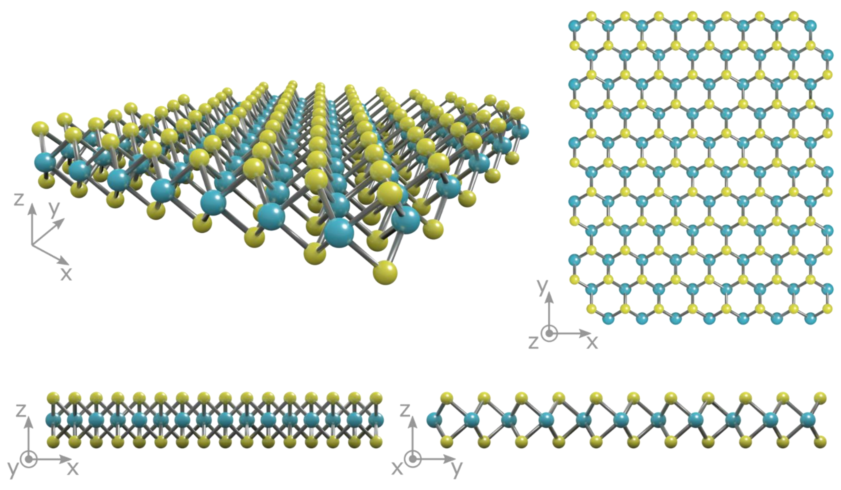
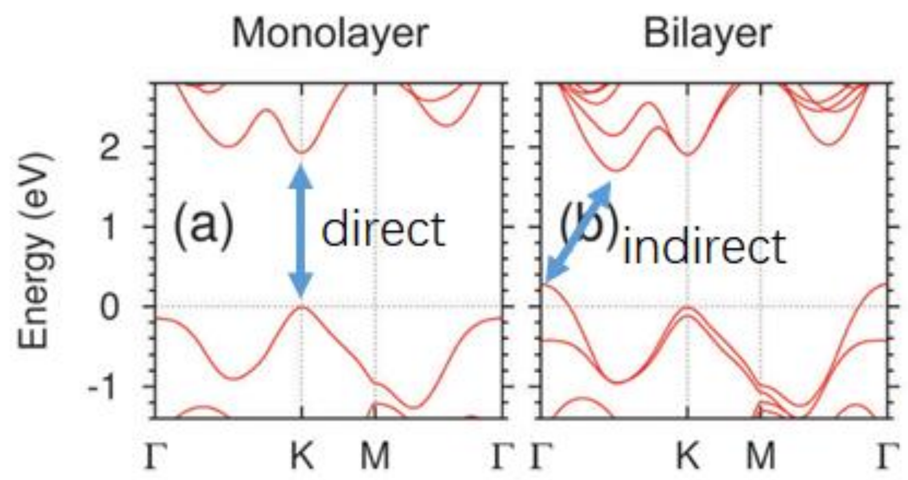
Two-dimensional (2D) transition-metal dichalcogenides (TMDs) MX2 (with M=Mo,W; X=S,Se,Te) are emerging platforms for fundamental research and optoelectronic application, due to its novel electric and photonic properties. For example, these materials have a direct bandgap in monolayer, large exciton binding energy, and are easy to integrate with other materials.
With TMDs and photonic cavities combined, our vision is to explore the physics of light-matter interaction and develop a novel class of TMDC-based optoelectronic devices, such as nanolasers.



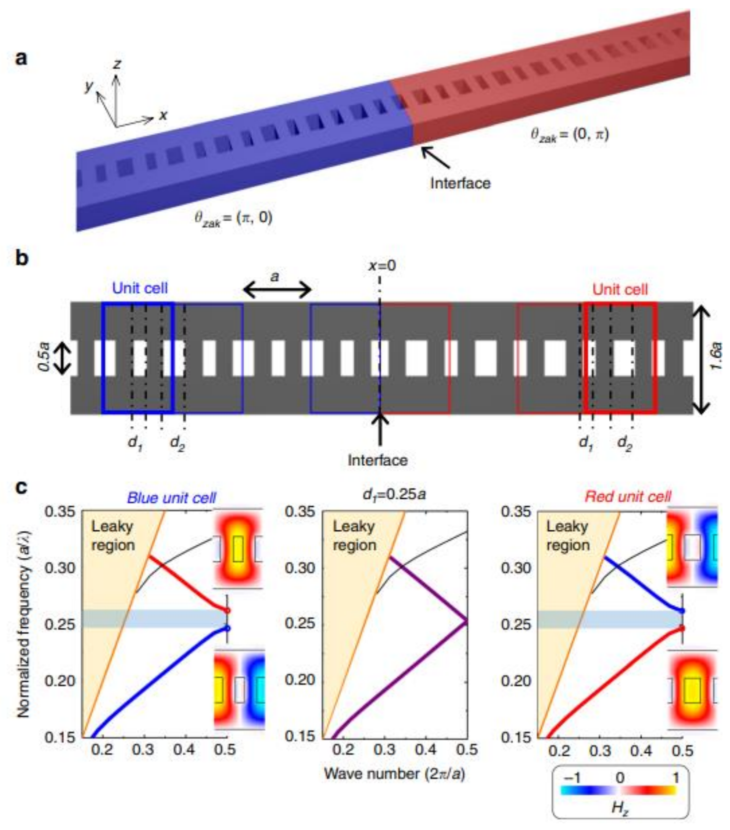
The crystal structure of monolayer TMD. M atoms (blue) and X atoms (yellow).
https://www.ossila.com/



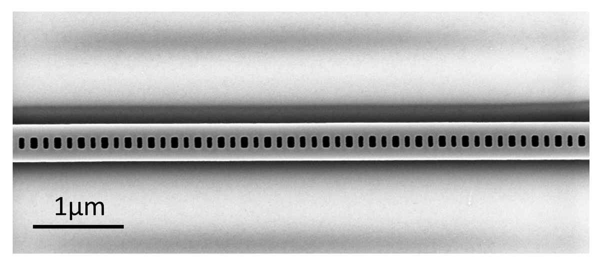
The electronic bandstructures monolayer and bilayer TMD.
Liu, Gui-Bin, et al. Chemical Society Reviews 44.9 (2015): 2643-2663.

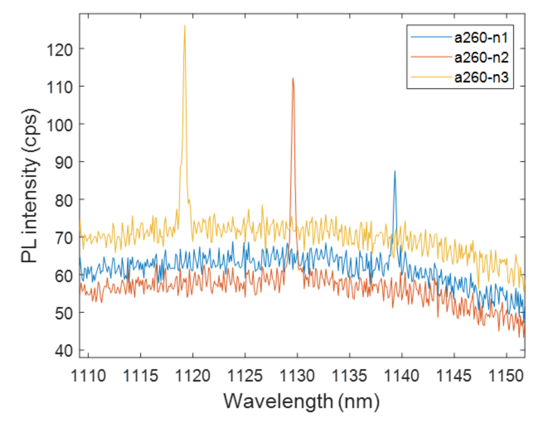
Topological PhC nanocavity

Photonic crystal cavity (PhC) can confine electromagnetic filed in a small volume, that strongly enhance the interaction between light and matter. In 2018, Yasutomo Ota et al, reported a topological PhC nanobeam[1]. The single 0D edge mode is formed at the inversion-symmetric interface with near-diffraction-limited mode volumes and high Q factor. Here, we fabricated and characterized the nanocavity. The measured Q factor is ~4000 , which reaches the resolution limit of our setup. The simulation work is done by our collaborator in Chalmers to the wavelengths that we are interested.



Topological nanocavity design concept[1]

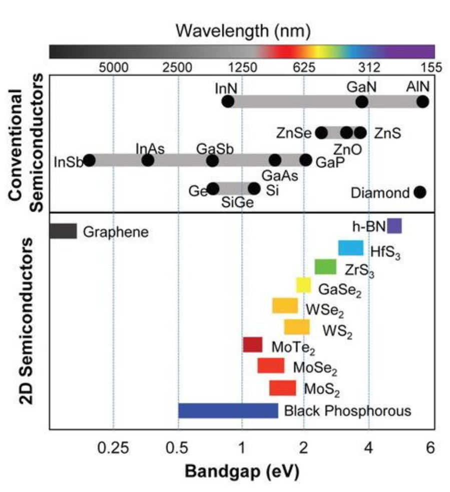




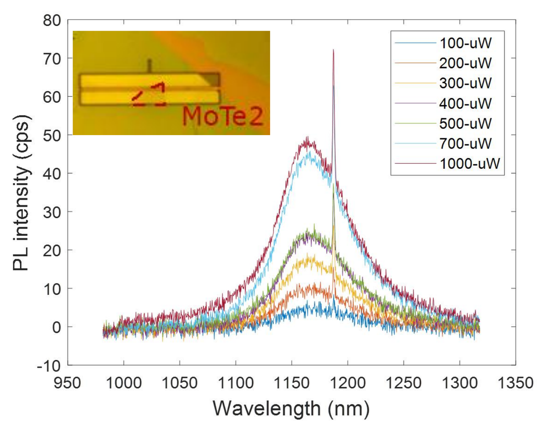
(top) SEM image of nanocavity; (bottom) PL spectra with different parameters

Cavity-enhanced Photoluminenscences (PL)

Molybdenum ditelluride (MoTe2) is a member of TMDs with PL in near-infrared range, making it a potential candidate for on-chip integrated silicon photonics. Silicon nanocavity MoTe2-based nanolasers have been demonstrated[2-4]. Here, we transferred MoTe2 onto the topological PhC nanobeam, and observed cavity-enhanced PL.

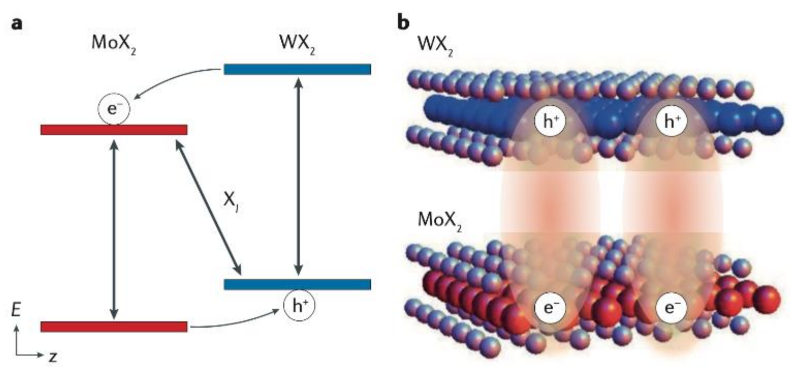


Bandgap and absorption wavelengths
Seo, Jung-Hun, et al. Materials Research Letters 8.4 (2020): 123-144.

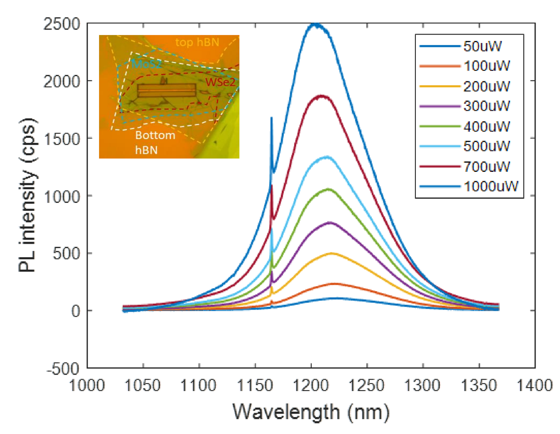


Pump power-dependent PL spectra of MoTe2, (insert) optical image of the sample

The staking of two different monolayers together (heterostructures) may forms interlayer exciton (IX), which electrons and holes are separated in different layers. Its novel properties make it an efficient gain medium for lasing[6-7]. Here, we used MoS2 and WSe2 to form IX in near-infrared range, and achieved cavity-enhanced PL.



Interlayer excitons in 2D heterostructures
Schaibley, John R., et al. Nature Reviews Materials 1.11 (2016): 1-15.



Pump power-dependent PL spectra of IX, insert: optical image of the sample

Collaborators:
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Kresten Yvind: Technical University of Denmark
Zhipei Sun: Aalto University

[1]Ota, Y. et al, Communications Physics 1.1 (2018): 1-8
[2] Li, Yongzhuo, et al. Nature nanotechnology 12.10 (2017): 987-992.
[3] Fang, Hanlin, et al. Laser & Photonics Reviews 12.6 (2018): 1800015.
[4] Fang, Hanlin, et al. Advanced Optical Materials 7.20 (2019): 1900538.
[6]Liu, Yuanda, et al. Science Advances 5.4 (2019): eaav4506.
[7] Paik, Eunice Y., et al. Nature 576.7785 (2019): 80-84.