Polaritonic Recycling in Self-Hybridized Transition Metal Dichalcogenides

Kayla Pham[1], Paul Brown[1], Milan Delor[1]

[1] Department of Chemistry, Columbia University, USA

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Background

- Energy, in its many forms, is central to life on Earth.
- The sun is an enormous energy source providing nearly 173,000 TW of solar energy striking the Earth — in comparison, the United States uses 4 TW annually. Learning how to extract this energy is of utmost importance to meet increased demands for energy.
- In modern devices, such as solar panels, energy must reach specific targets to be extracted for useful interfaces.
- Energy transport occurs randomly due to scattering — a key limitation in improving efficient energy extraction. This could theoretically lead to nearly doubling the efficiency of single-junction solar cells.

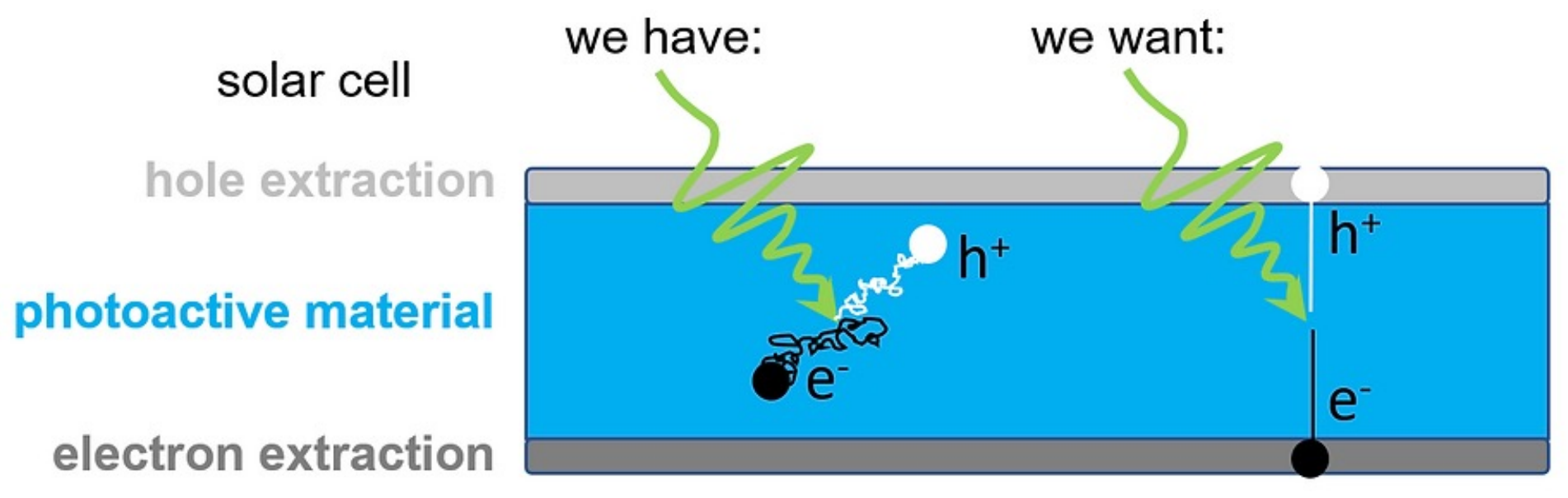


Figure 1. *To be extracted for useful interfaces, energy carriers must move to our designated targets.*

- Combining the practical extractability of matter with the speeds of light, polaritons (quasiparticles that part-light and part-matter) provide an ideal middle ground for a long-lived existence with fast speeds — addressing current limitations in today's slow and inefficient energy regimes.
- By harnessing the potential of the strong light-matter interactions that form polaritons, we can move towards transport that has greater extractability, less dissipation, and more usability in semiconductors.
- Transition metal dichalcogenides (TMDs) are a class of 2D semiconductors that are widely available and have unique electronic properties.
- TMDs exhibit "polaritonic self-hybridization" — a phenomenon wherein exciton-polaritons can be intrinsically formed without the need for an external cavity.
- At certain TMD thicknesses, we hypothesize that our polaritons inherit enough light-like properties to overcome transport barriers caused by material defects

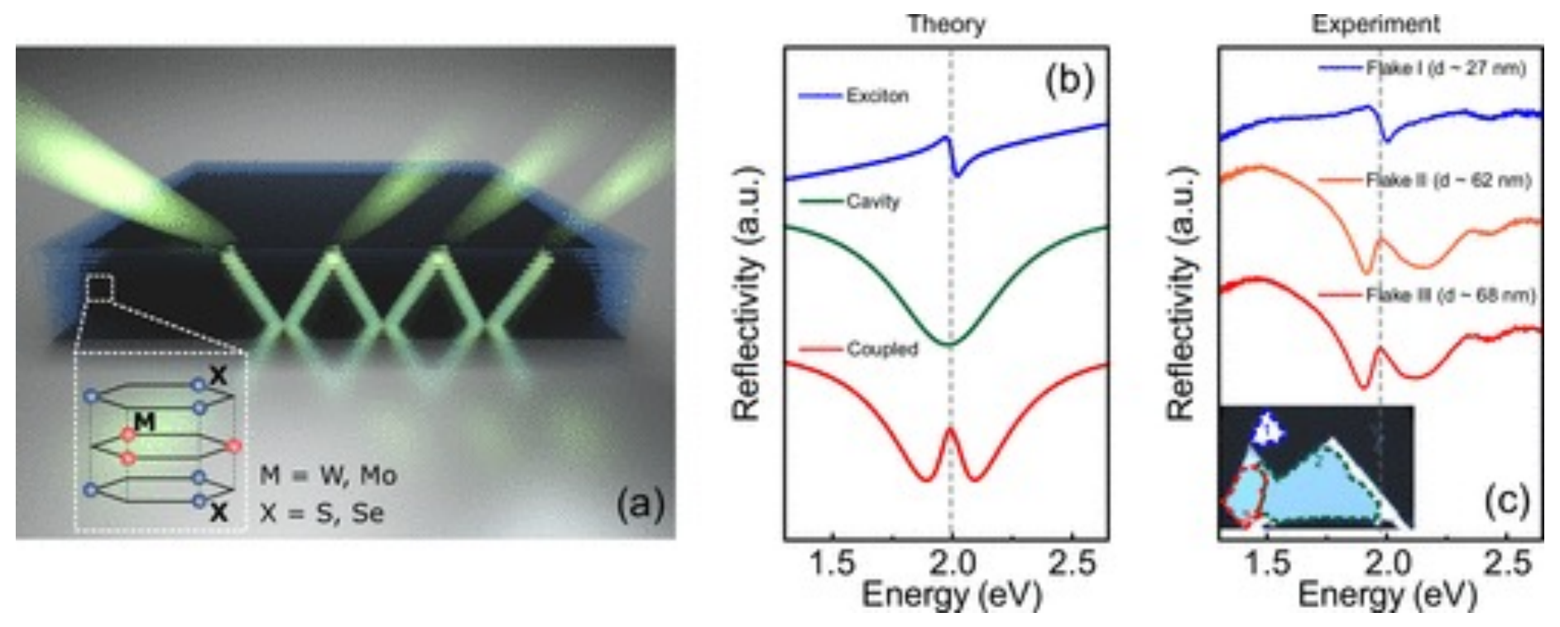
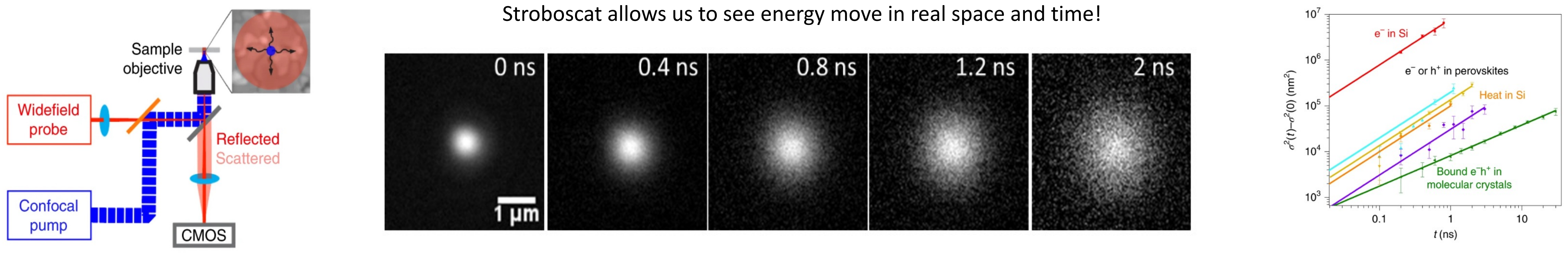


Figure 2. *TMDs uniquely exhibit self-hybridization (the ability to form intrinsic polaritons). Munkbhat et al, ACS Photonics, 2019, 6, 139-147*

Results and Methods

a)

Stroboscat allows us to see energy move in real space and time!

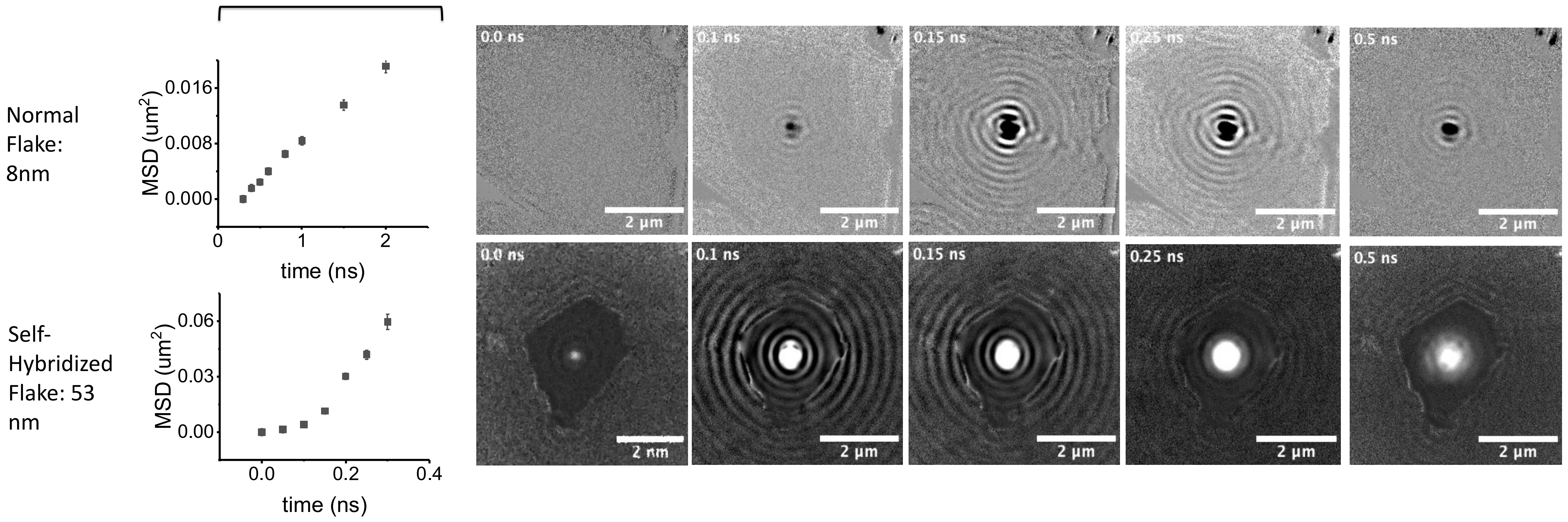


Stroboscat also reveals function trends in a range of materials

b)

Self-hybridized MoS_2 transport is much faster than unhybridized MoS_2!

Scan to see "movies" of energy transport



c)

Exciton bands in unhybridized MoS_2

Self-hybridized MoS_2 forming intrinsic polaritons

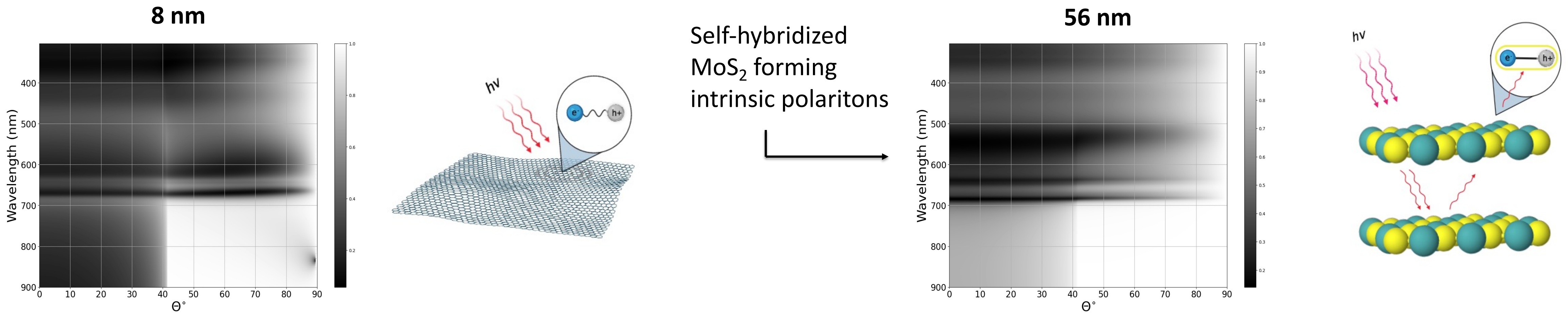


Figure 3. ***a)*** *Stroboscat allows us to perform spatiotemporal characterizations of energy transport.* ***b)*** *Intermediate thickness MoS_2 flakes show enhanced transport compared to monolayer MoS_2.* ***c)*** *Transfer matrix method (TMM) provides angle-resolved wavelength spectra for theoretical fits of exciton-polariton states.*

Conclusions

- Our key result is the observation of enhanced exciton transport in TMDs at intermediate thicknesses that exhibit self-hybridization.
- Our results prompt the question of the roles that defects in materials play in energy transport and whether this phenomena will be be present in other TMDs such as WSe_2 and $MoSe_2$
- This work relies on identifying flakes of very specific thicknesses, typically done with atomic force microscopy, which is time-consuming. I am developing a quicker method based on thin-film interference and color contrast to identify flake thicknesses rapidly in an optical microscope.
- These findings provide critical insights into unlocking power regimes of long-range transport in TMDs

Future Work

- Enhanced transport in MoS_2 can lead to the improvement of TMD-based photocatalytic and photovoltaic devices — this implementation is a point of future investigation

energy harvesting and storage

(quantum) computing

33% → 66%　60 min → 1 min　3 GHz → 3 THz

Figure 4. *Addressing limitations in energy transport (inefficiency in speed and direction) can open powerful new regimes in energy harvesting, storage, and even computing.*

Acknowledgements

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