REPU 2020

Plasmonic enhancement of single quantum emitters (SQE) in TMDs heterostructures

Presenter: Sebastian Escalante

Quantum Matter and Devices Lab

Mentor: Andres Llacsahuanga

Universidad de Ingeniería y Tecnología - Purdue University

Esquema

Introducción

- **Desafíos**
- **Single Quantum Emitters**
- **Sources of them**
- **TMDs - WSe2 MoSe2 MoS2**

Objective

Methodology and Results

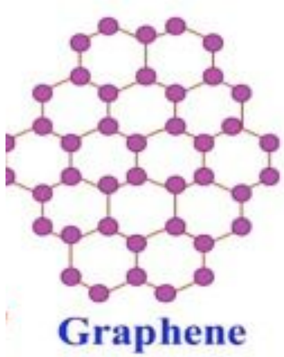
- **Sample fabrication**
-

Future Steps

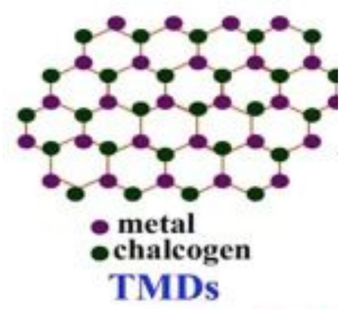
Summary

2D Materials

Semi-metal

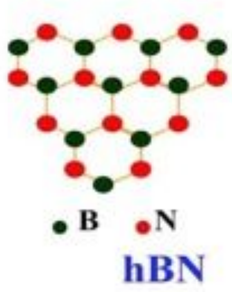


Semiconductors

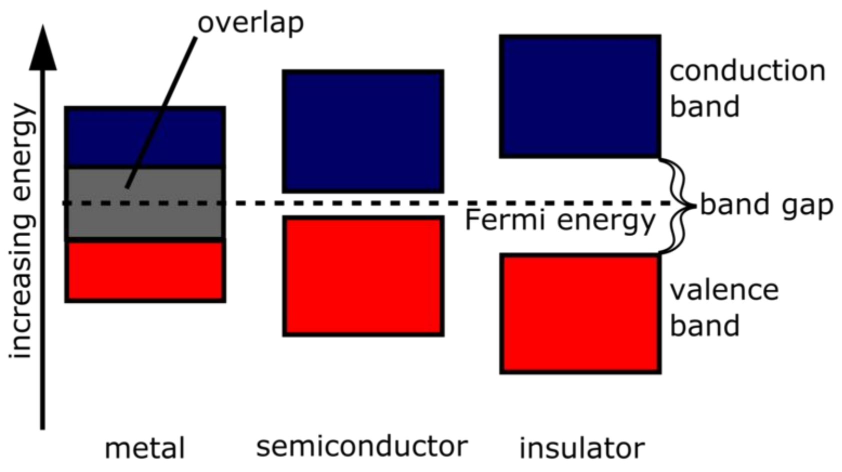


Transition Metal Dichalcogenides

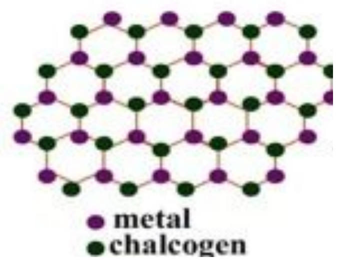
Insulators



- Atomically thin structures
- They differentiate from the band gap



Transition Metal Dichalcogenides (TMDs) Properties



Transition Metal Dichalcogenides (TMDs)

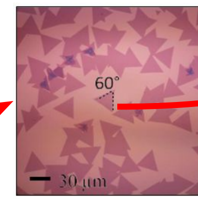
Tungsten Diselenide (WSe2)

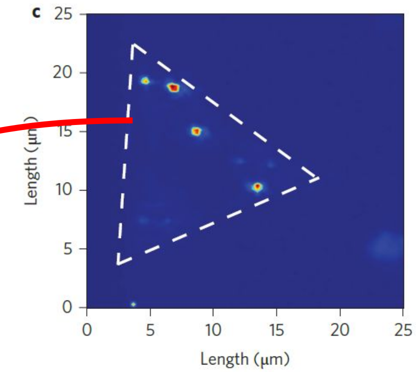
Molybdenum Diselenide (MoSe2)

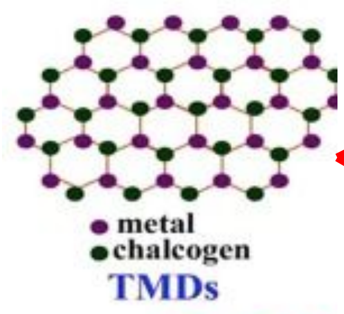
- Direct band-gap semiconductor
- Strong light-matter interactions
- Transistors, memory devices, ultrathin photodetectors, and recently Single Quantum Emitters (SQE)

Sources of Single Quantum Emitters (SQE)

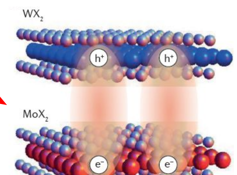
Monolayer WSe2 Grown crystals







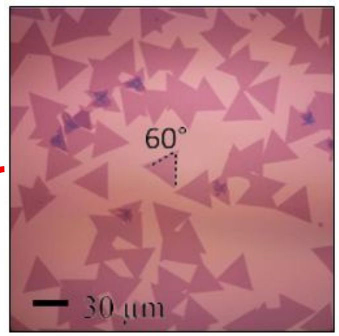
Transition Metal Dichalcogenides



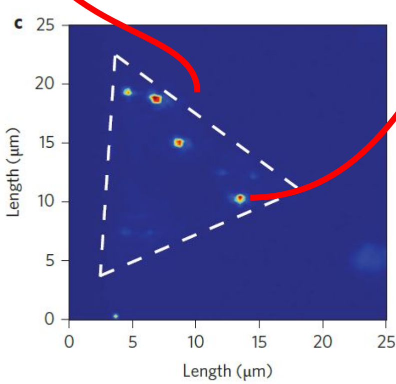
TMD heterostructure

- High purity
- Photon indistinguishability
- Efficiency

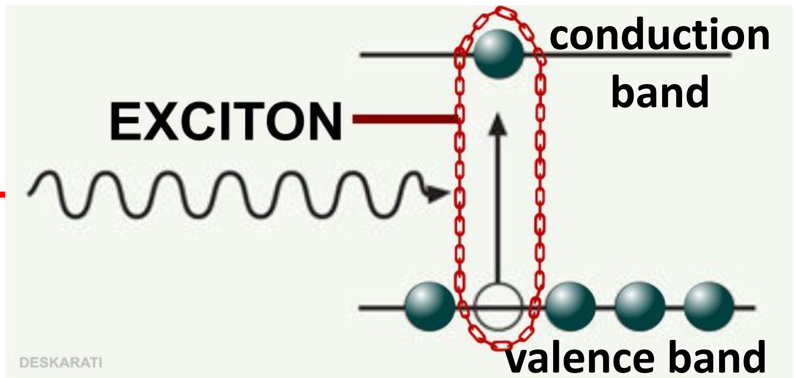
What is an exciton?



WSe2 Grown crystals

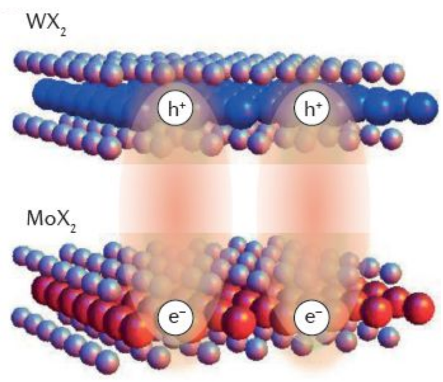


Scanning confocal microscope image of the PL (localized excitons)

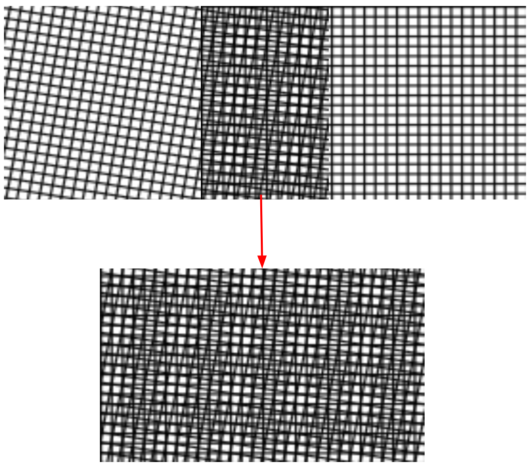


- Single quantum emitters (SQE) are thought to arise from excitons bound to defects, impurities or potential traps

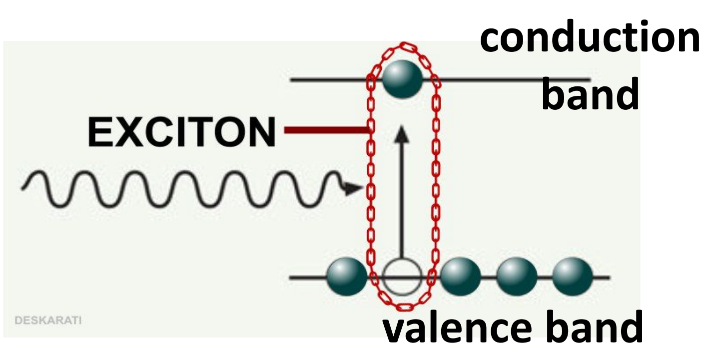
Intralayer Excitons are formed by stacking TMDs monolayers

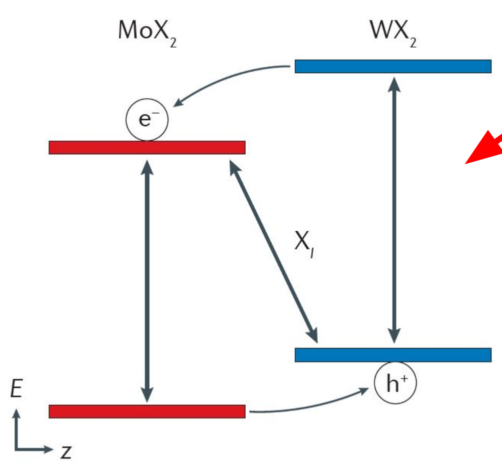


Interlayer Excitons in a MoX2-WX2 heterojunction



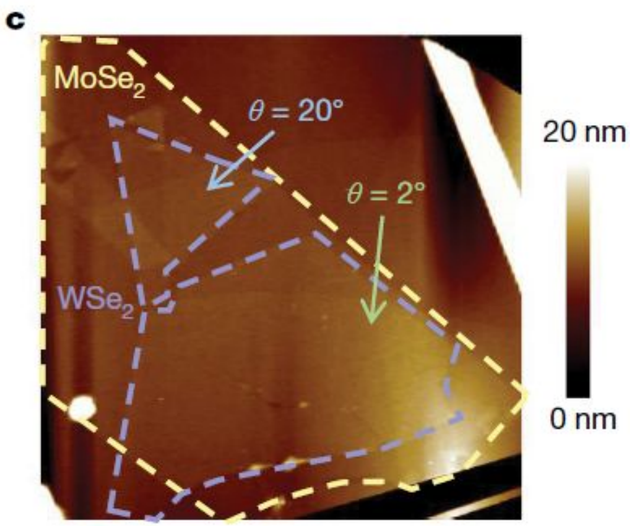
Moiré Pattern



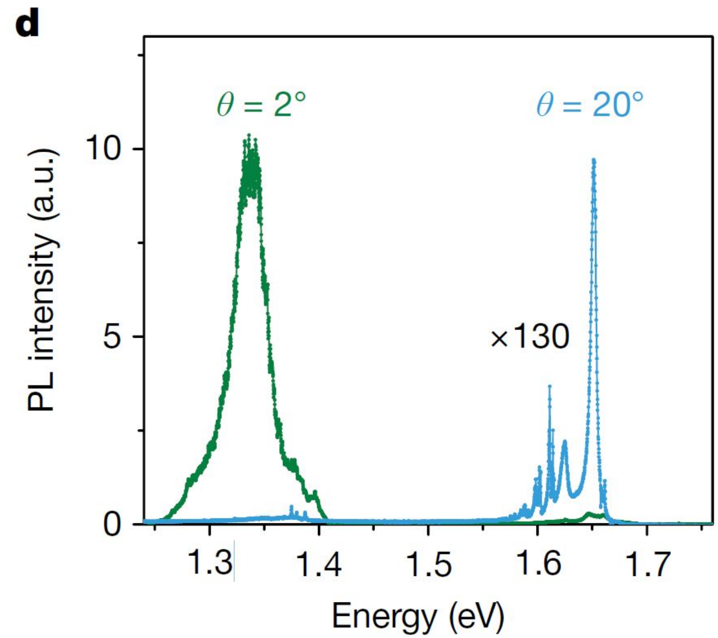


Type II alignment for a heterojunction

Crystal alignment is crucial on experiments



Bilayer heterostructure



PL comparison between different angle alignments -> 2 and 20 degrees

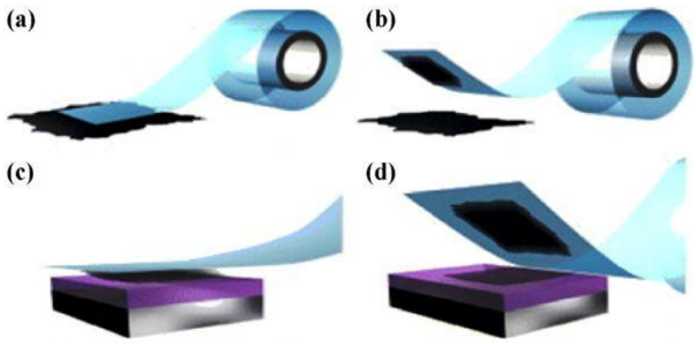
Objective

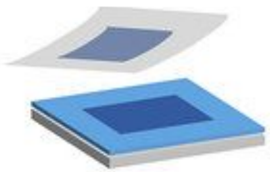
Enhance the emission of TMDs heterostructure of MoSe2-Wse2 single quantum emitters

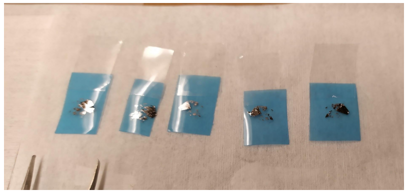
Characterization Techniques

- Optical Microscopy
- Raman Spectroscopy
- Photoluminescence (PL)
- Atomic Force Microscopy

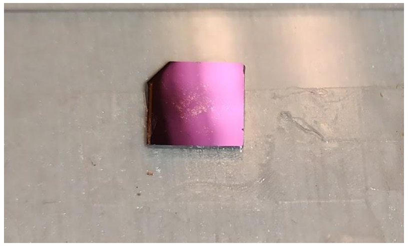
Mechanical exfoliation of TMDs



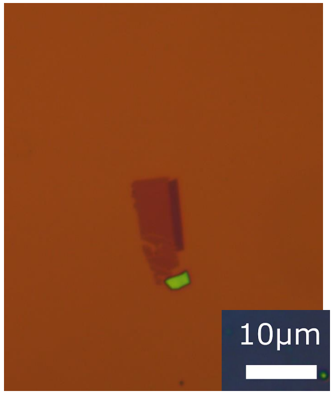




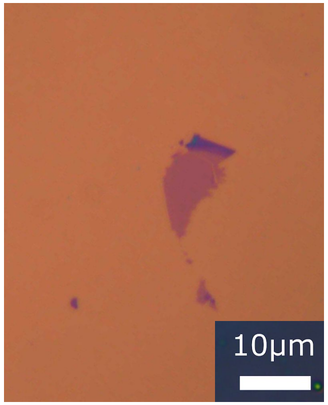
Exfoliated MoSe2



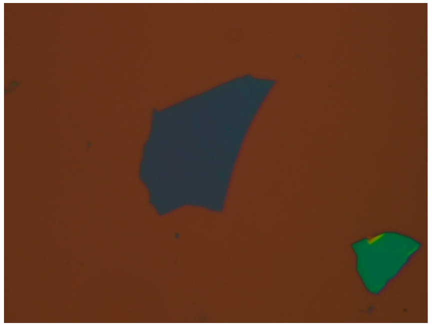
SiO2 with mechanical exfoliated MoSe2

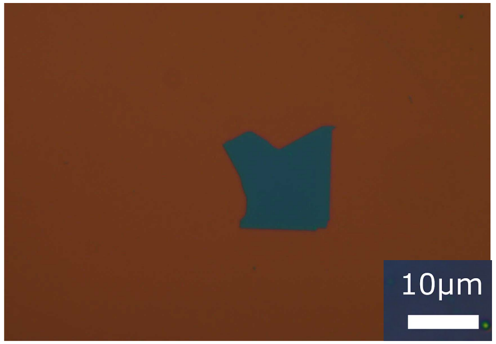


MoSe2 Monolayer



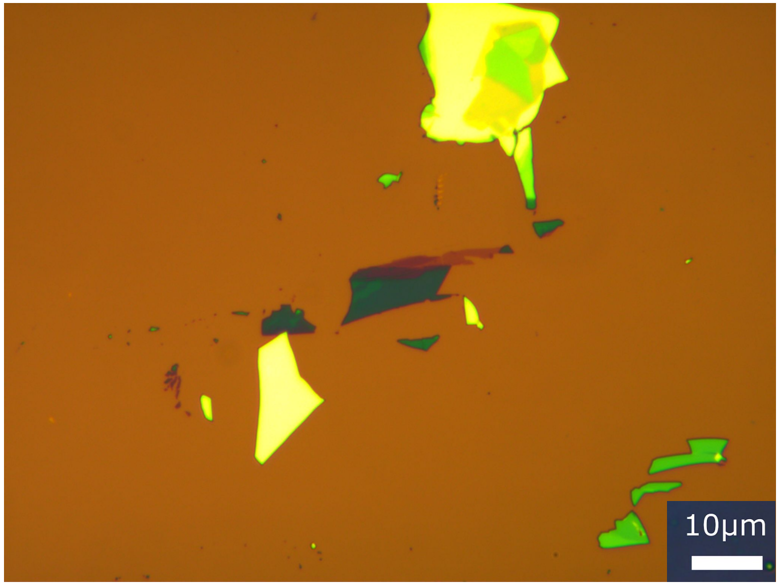
WSe2 Monolayer

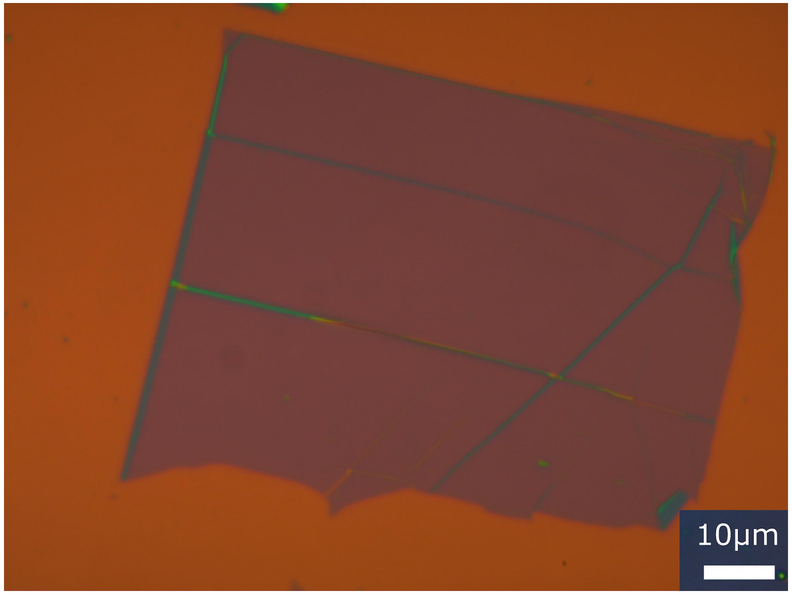




hBN few layers

Monolayer identification with Optical Microscopy

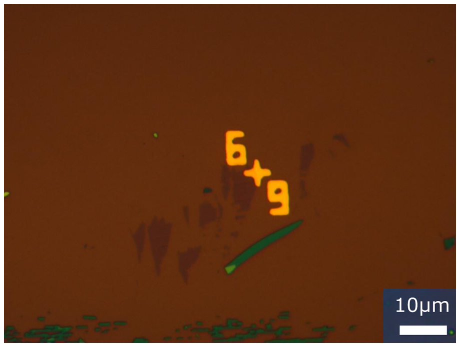




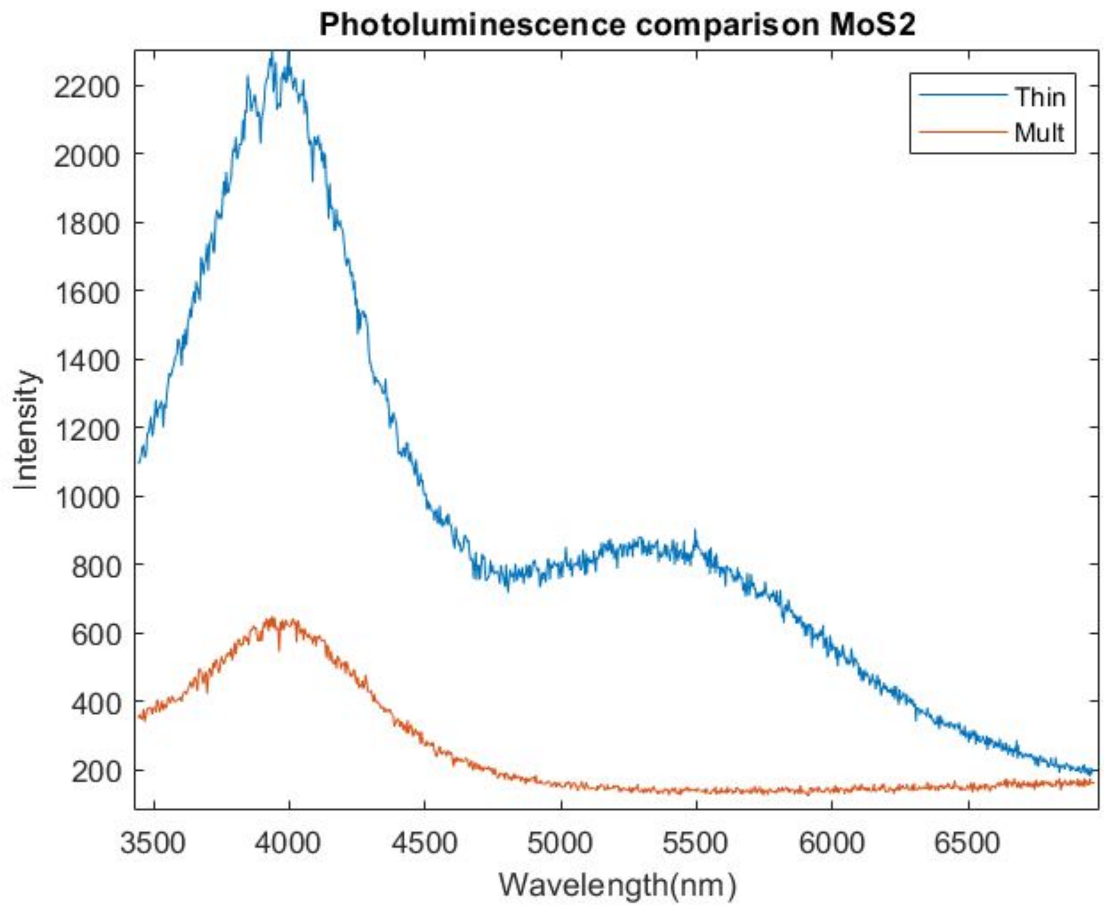
Thin layer of MoSe2 at 100x

Thin layer of hBN at 100x

Photoluminescence Characterization

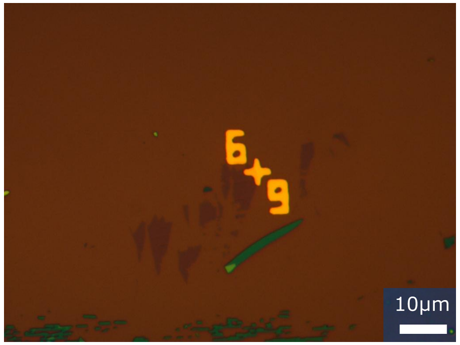


Monolayer MoS2 crystals

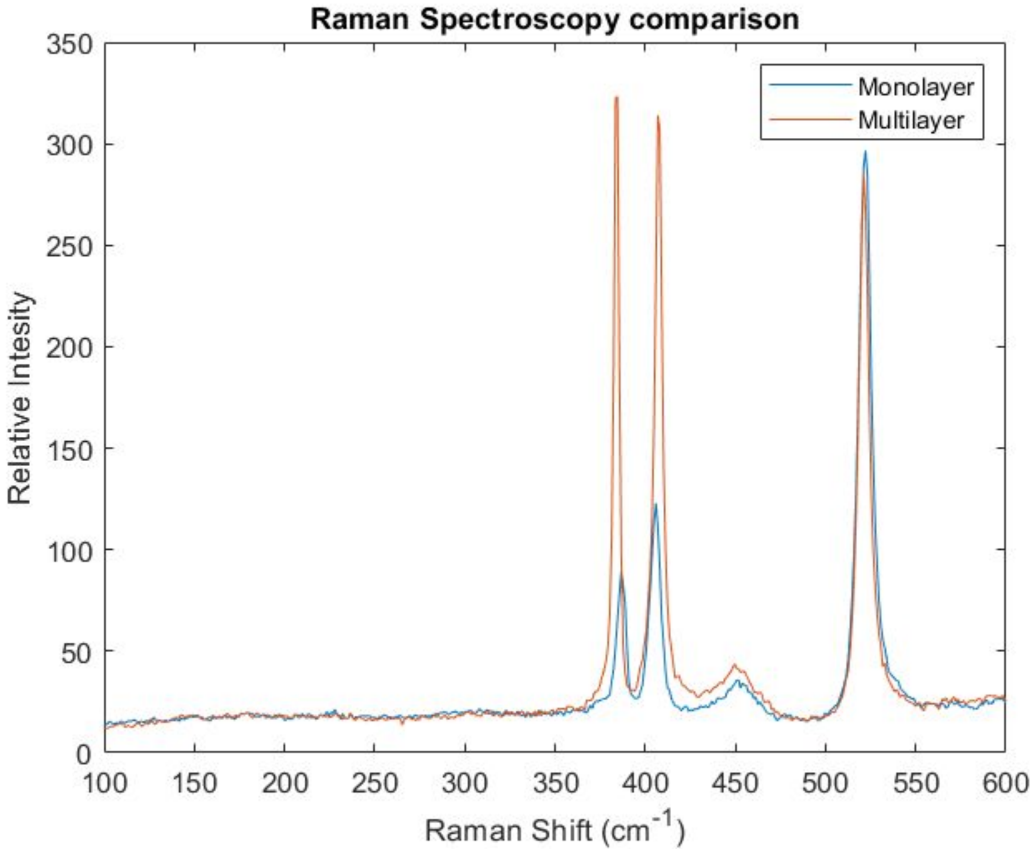


Photoluminescence

Raman Spectroscopy Tests

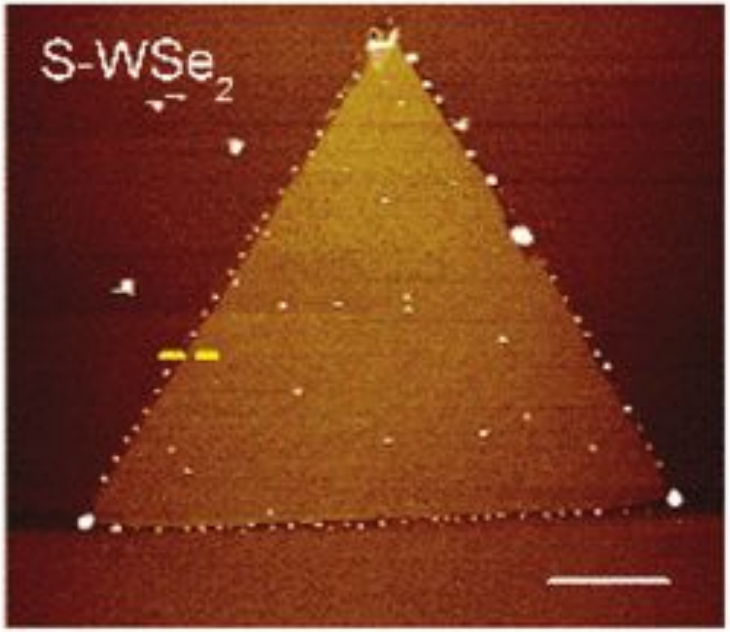


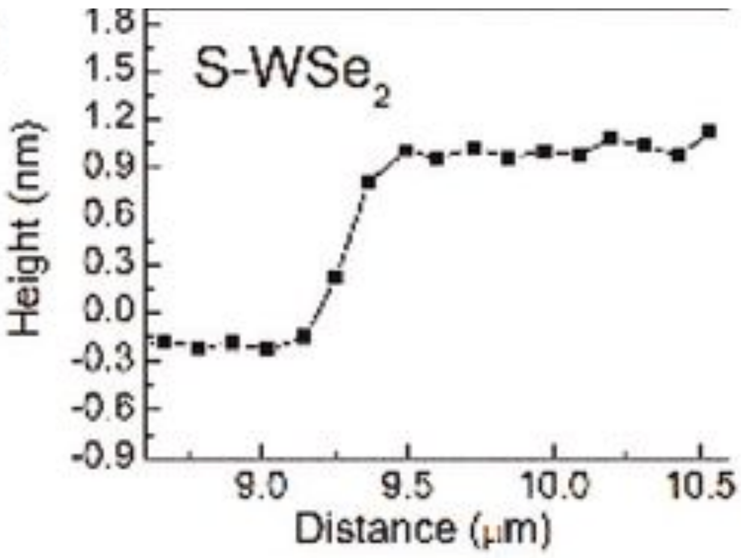
Monolayer MoS2 crystals



Raman Spectroscopy

Atomic Force Microscopy Tests

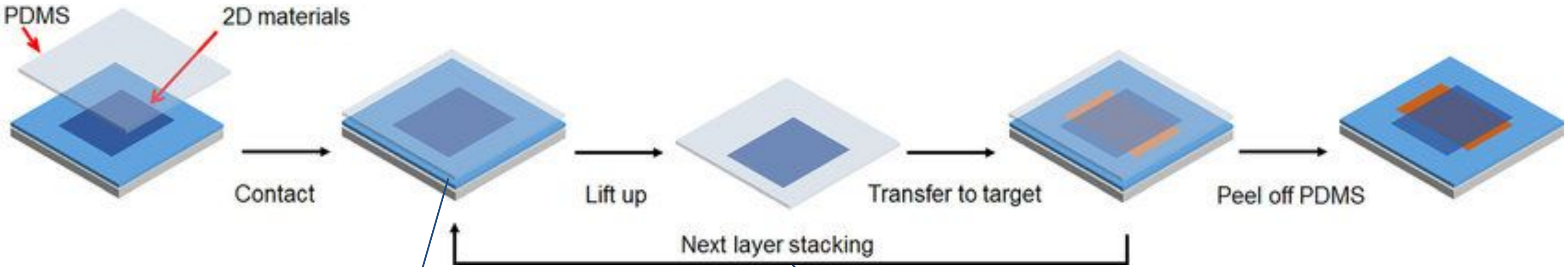


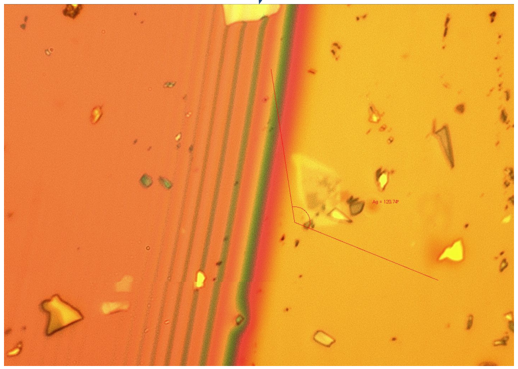


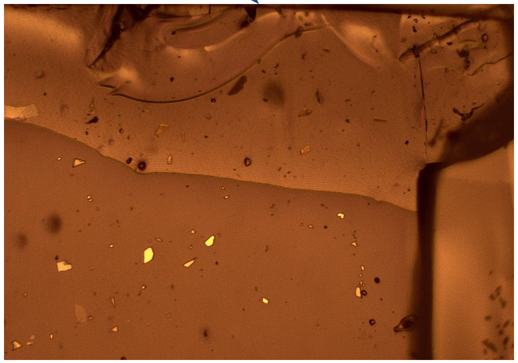
WSe2 Atomic Force Microscope image

Heterostructure fabrication

Dry-Transfer

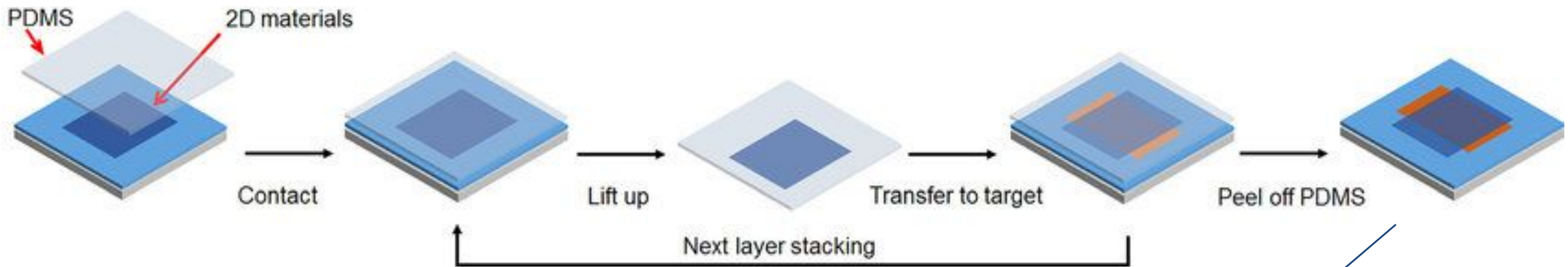


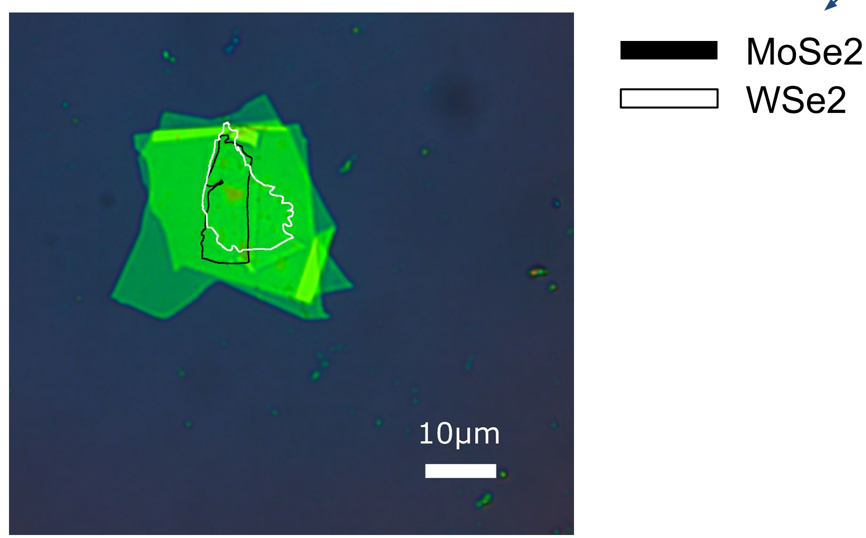




Heterostructure fabrication

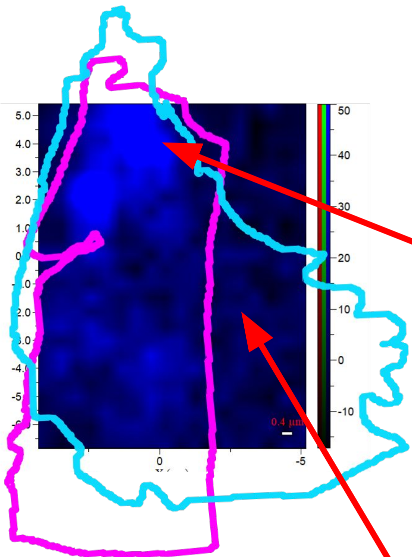
Dry-Transfer





Mose2 - WSe2 Heterostructure

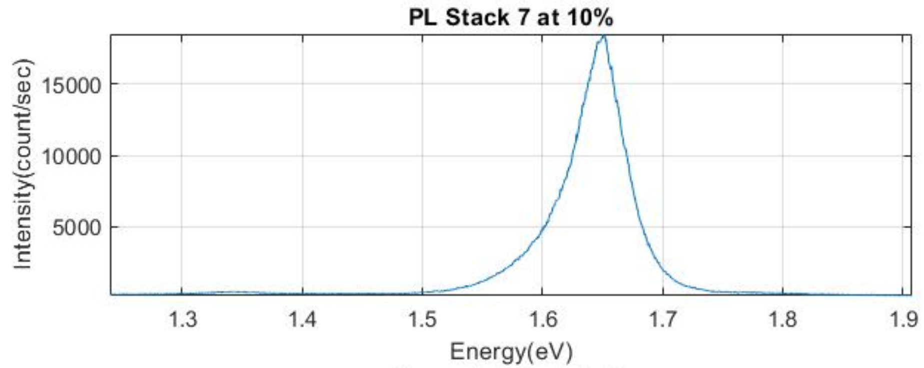
PL at Room temperature and 10% laser power

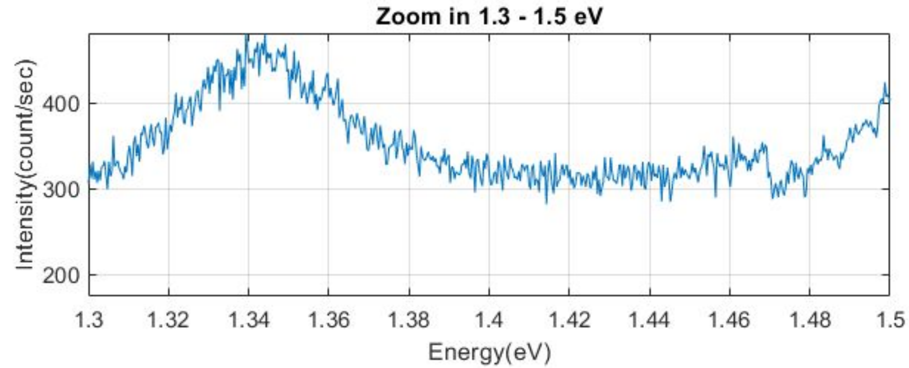


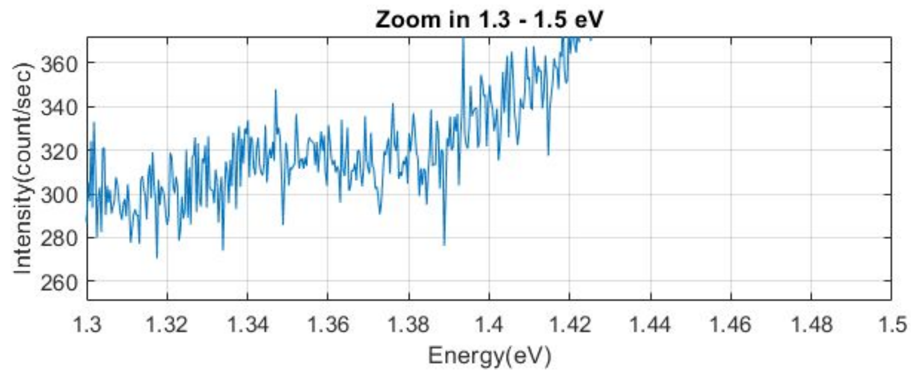
1.30 - 1.38 eV
Integration

MoSe2

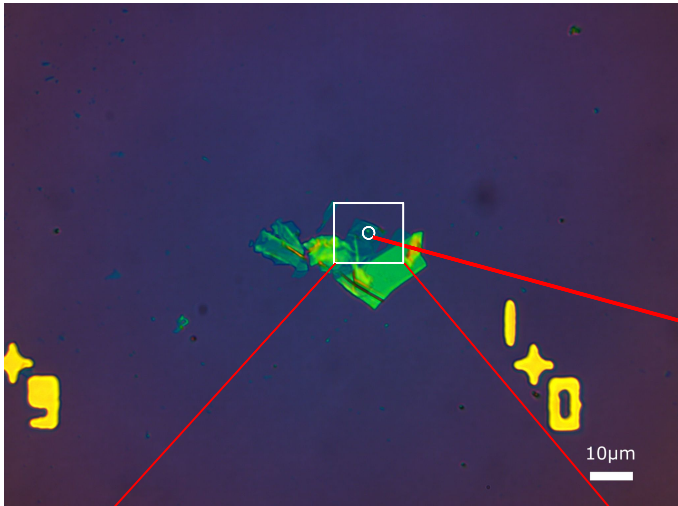
WSe2



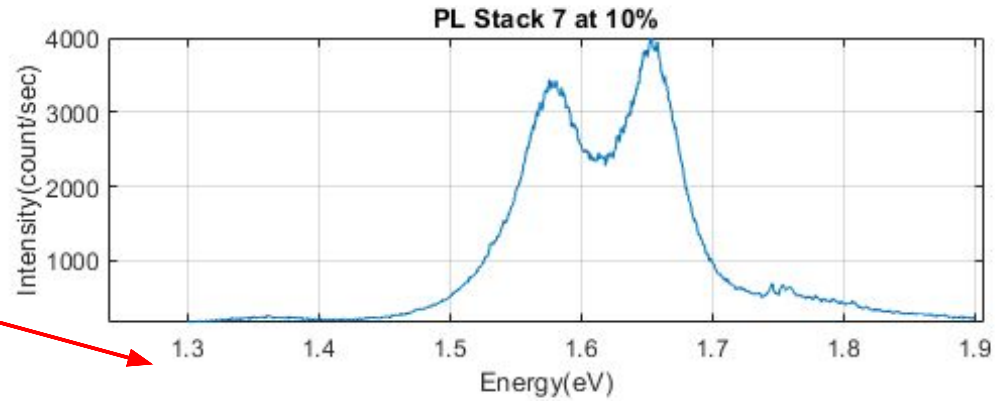


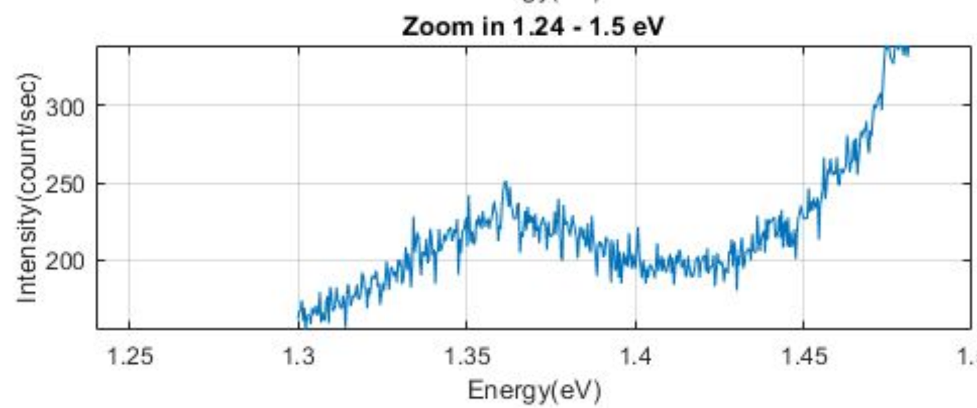


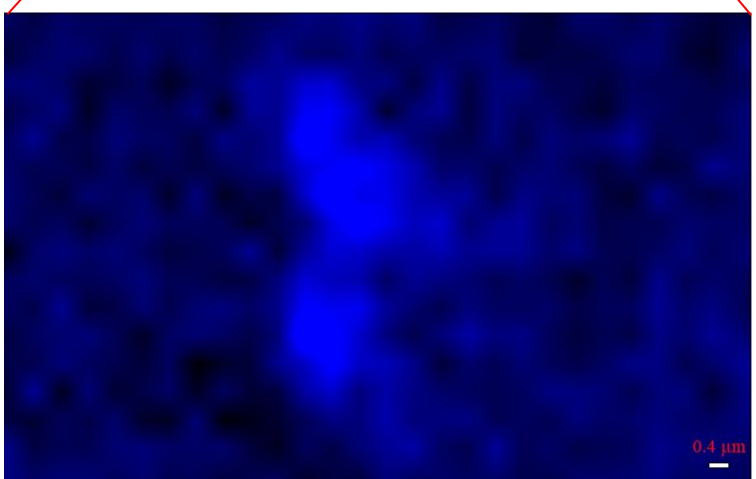
Last heterostructure



Mose2 - WSe2 Heterostructure

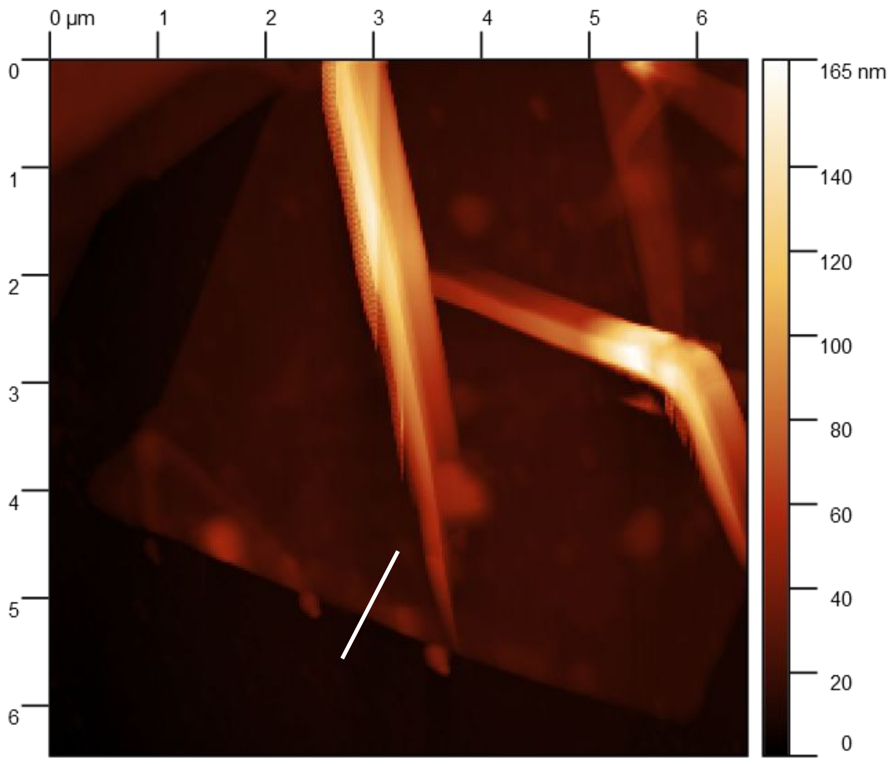






1.30 - 1.38 eV Integration

Atomic Force Microscopy confirmed the transfer



AFM Microscopy of a Mose2 - WSe2 Heterostructure

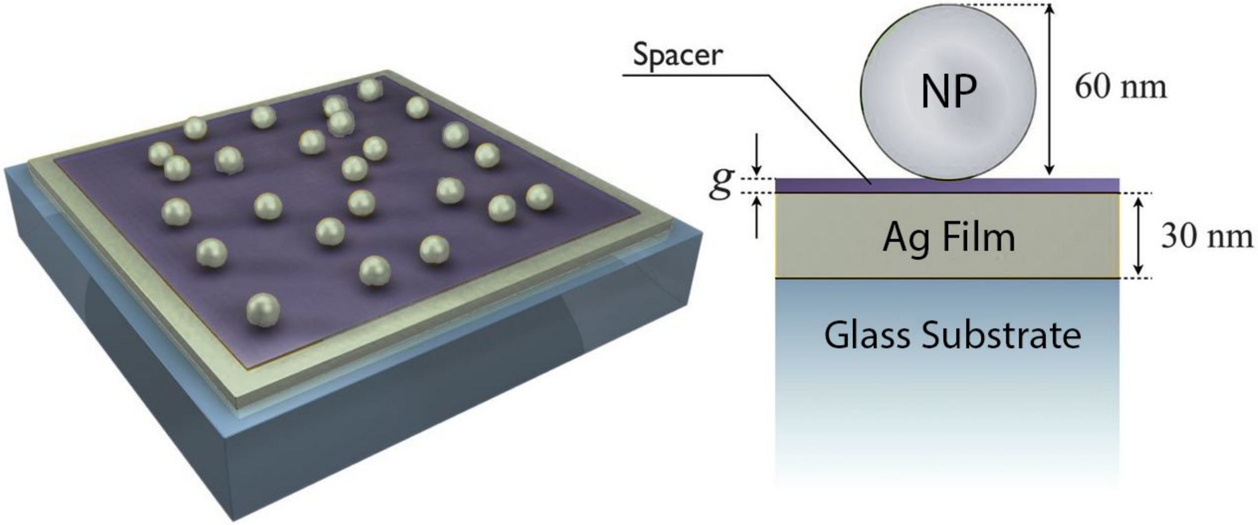
Δz [nm]
-9.29

hBN ~ 6 nm
MoSe2 ~ 1 nm
WSe2 ~ 1.5nm

+ Vander Waals Forces (Extra Thickness)

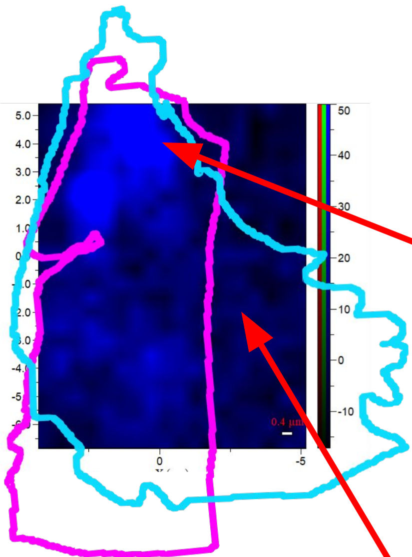
Plasmonic enhancement to improve SQE

Trap and squeeze light into nanometer sized gaps between the metal nanocube and metal surface.



- Shorter lifetime, desirable for applications
- Higher efficiency of emission

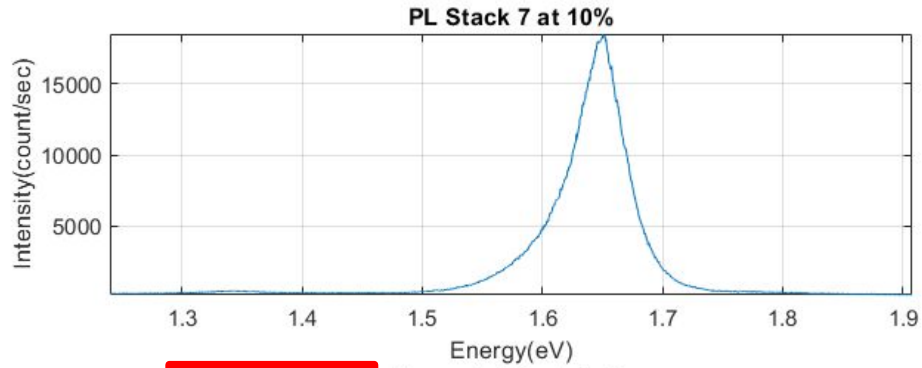
PL at Room temperature and 10% laser power

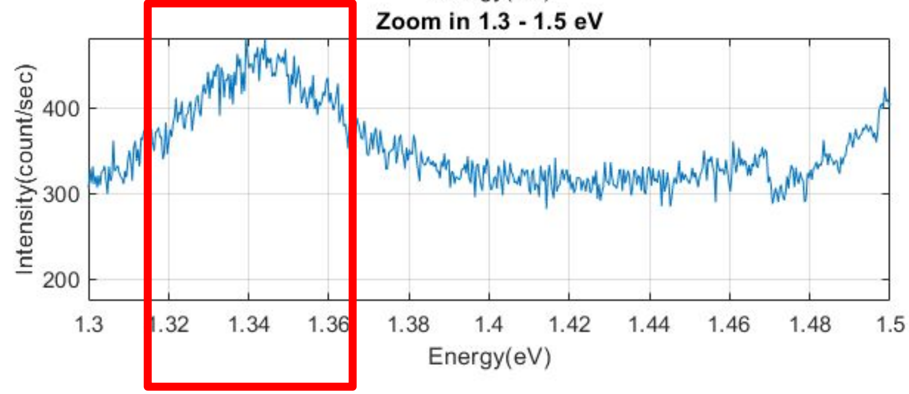


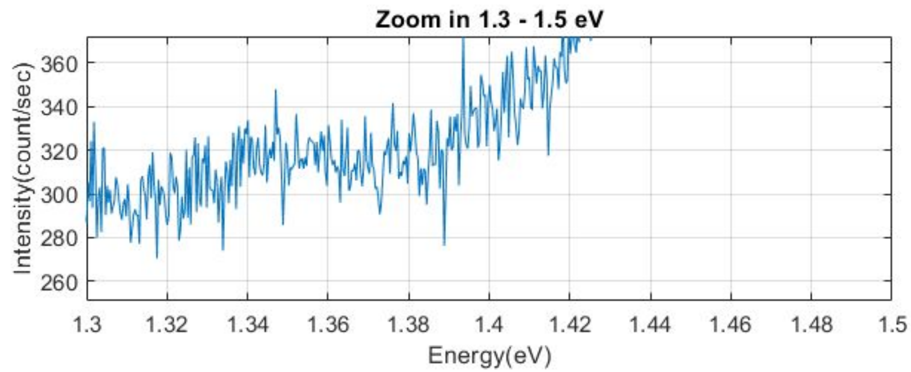
1.30 - 1.38 eV
Integration

MoSe2

WSe2





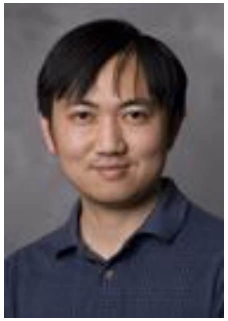


Summary

- Two TMDs Heterostructures were manufactured.
- Experiments and literature suggest that alignment of the crystals in the heterostructure affect the response of the single quantum emitters.
- Impurities in the heterostructure can significatively quench the emission of SQE. Thus, a cleaning technique is required.
- SQE formed from TMDs is a promising field because of its scalability, efficiency and its application to Quantum Information Technologies.

Acknowledgement

Mentor
Andres Llacsahuanga
Msc.



PI
Yong P. Chen PhD.

Post doc
Demid Sychev

Thank you!

Questions?