Optical identification using imperfections in 2D materials

Introduction

- The ability to uniquely identify an object or device is important for authentication. Imperfections, locked into structures during fabrication, can be used to provide a fingerprint that is challenging to reproduce.

- A **physical unclonable function**, or **PUF**, is a “digital fingerprint” that serves as a unique identity for a semiconductor device.

- Not all proposed PUFs are unclonable
- Difficult to produce

- Using variations originatined from atomic level defects for implementing unique optical identifiers, using TMDs monolayers as optically varying physical unclonable functions (OPUFs).

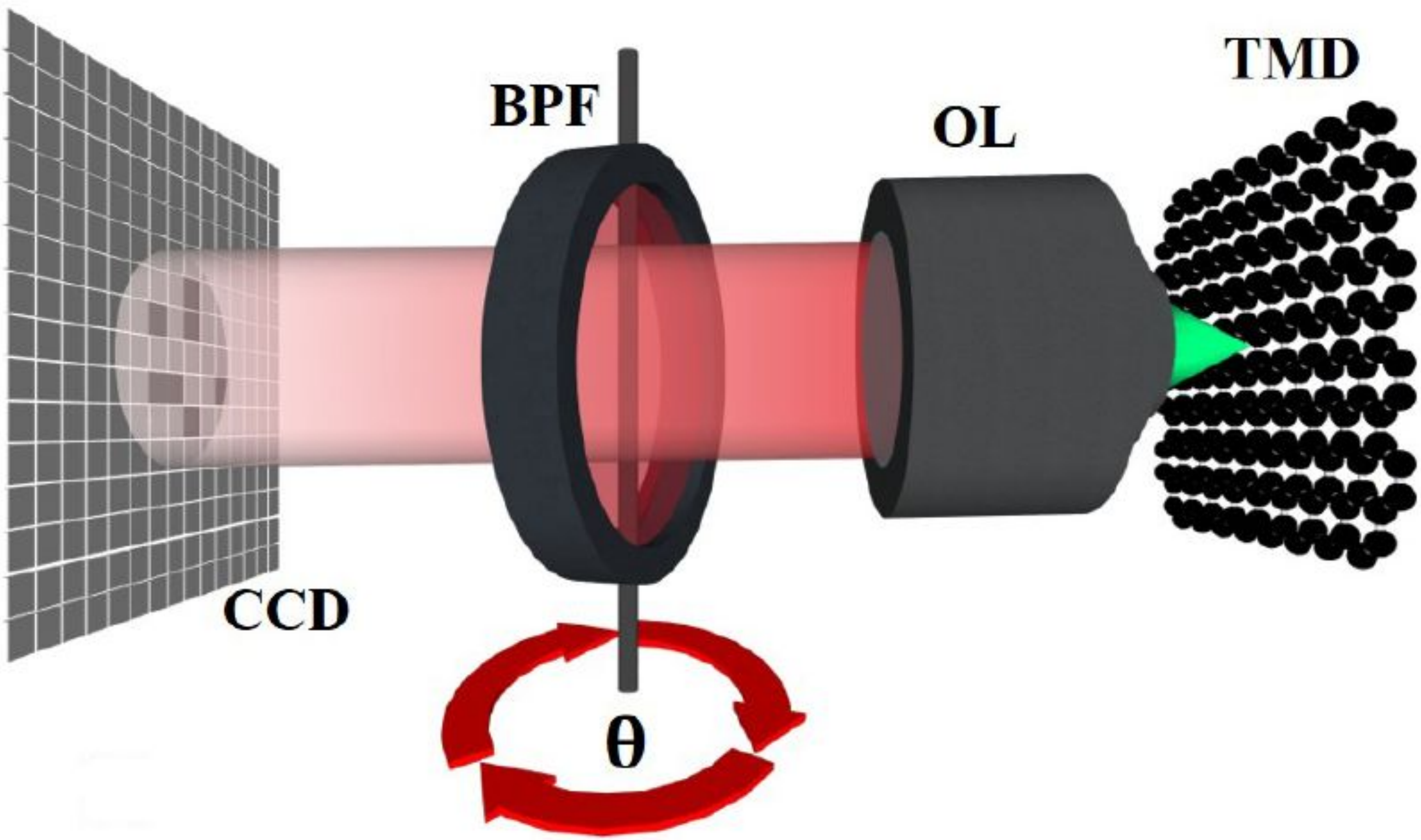
Objective

- To analise a proposed simple optical technique to read unique information from nanometer-scale defects in 2D materials.

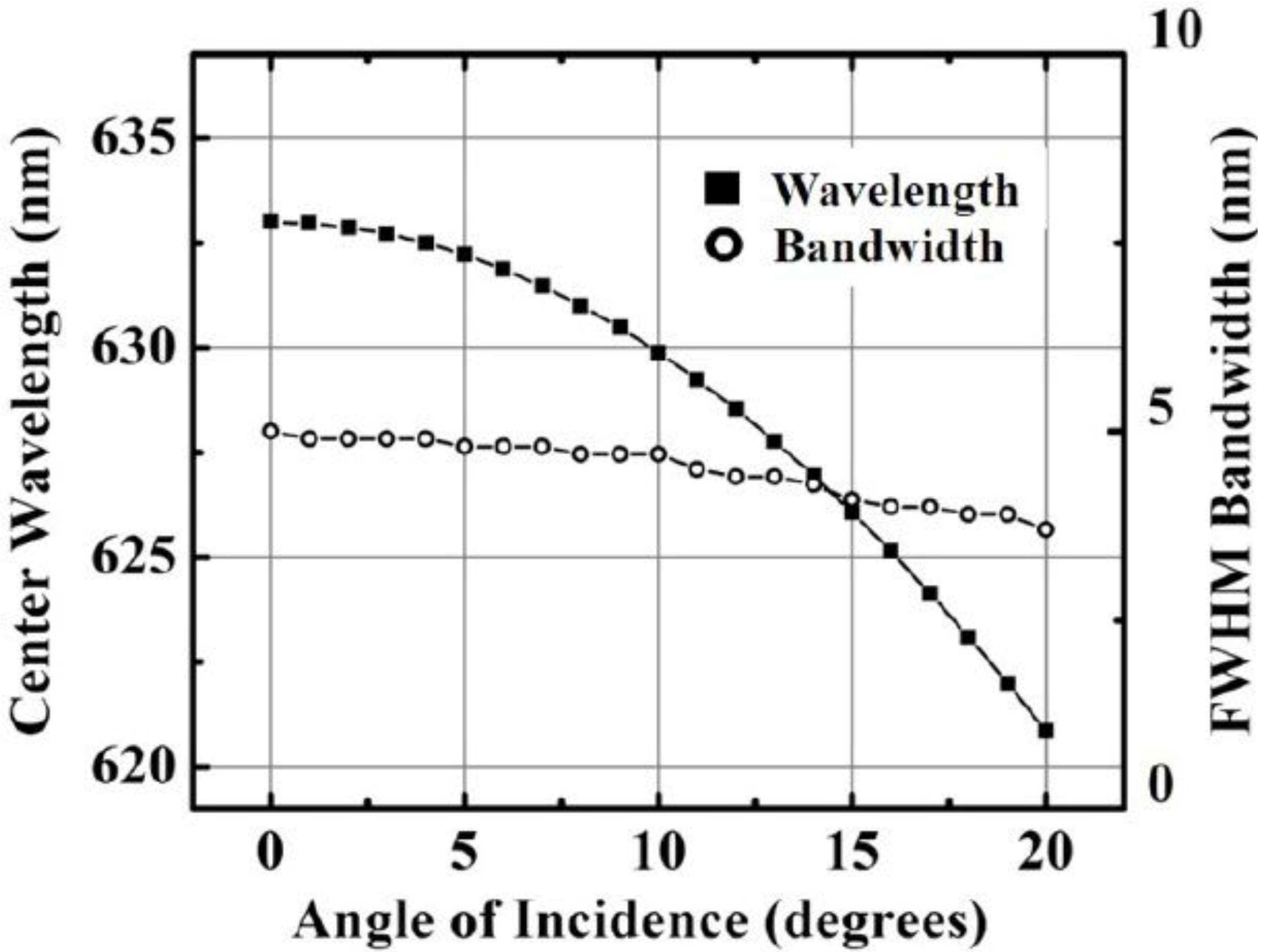
Tasks

- Method
- Results for WS_2 from mechanically exfoliation
- Results for WS_2 from chemical vapor deposition
- Conclusion

Method

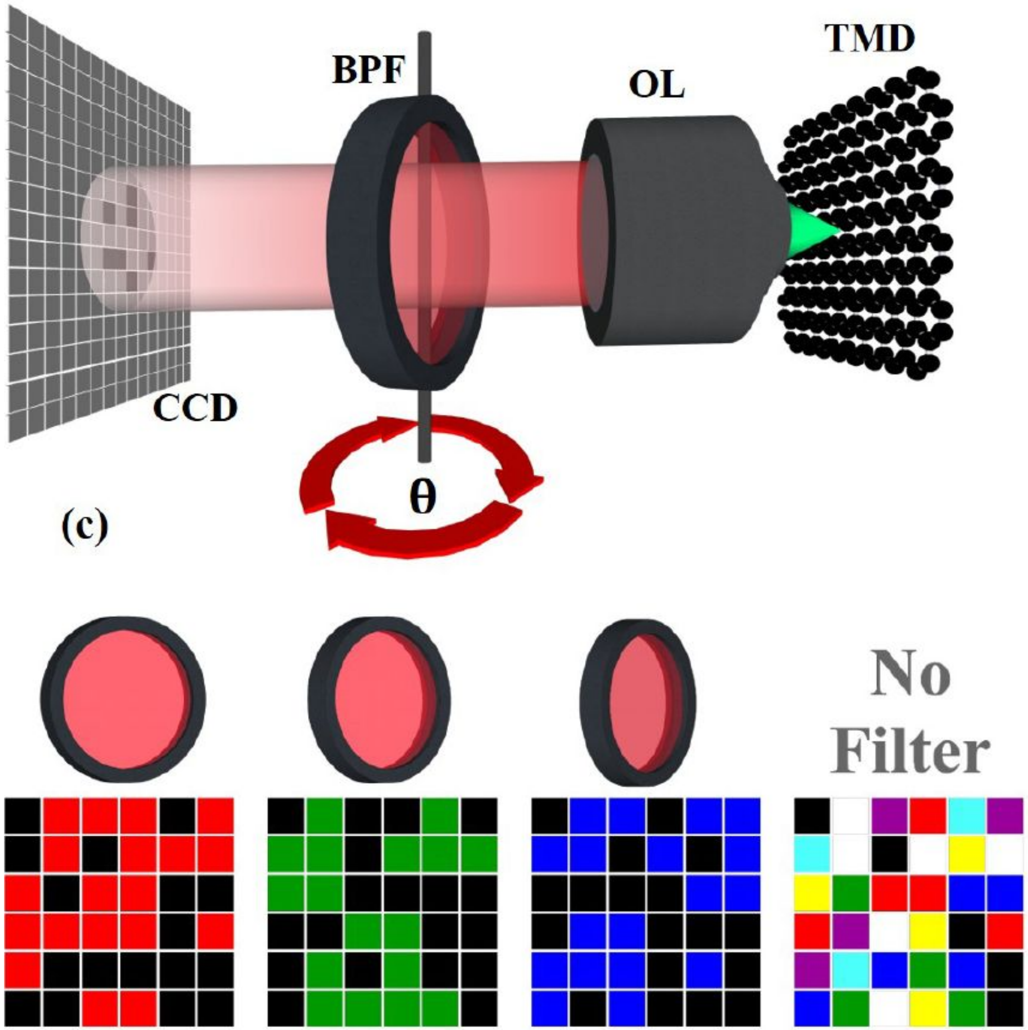


- Measurement apparatus, in which the photoluminescence from a monolayer TMD is collected by an objective lens (OL), selectively transmitted through a rotatable optical bandpass filter (BPF), finally imaged on a CCD sensor.



- Angular orientations of the BPF determines the center-wavelength of its pass band, which varies with incidence angle

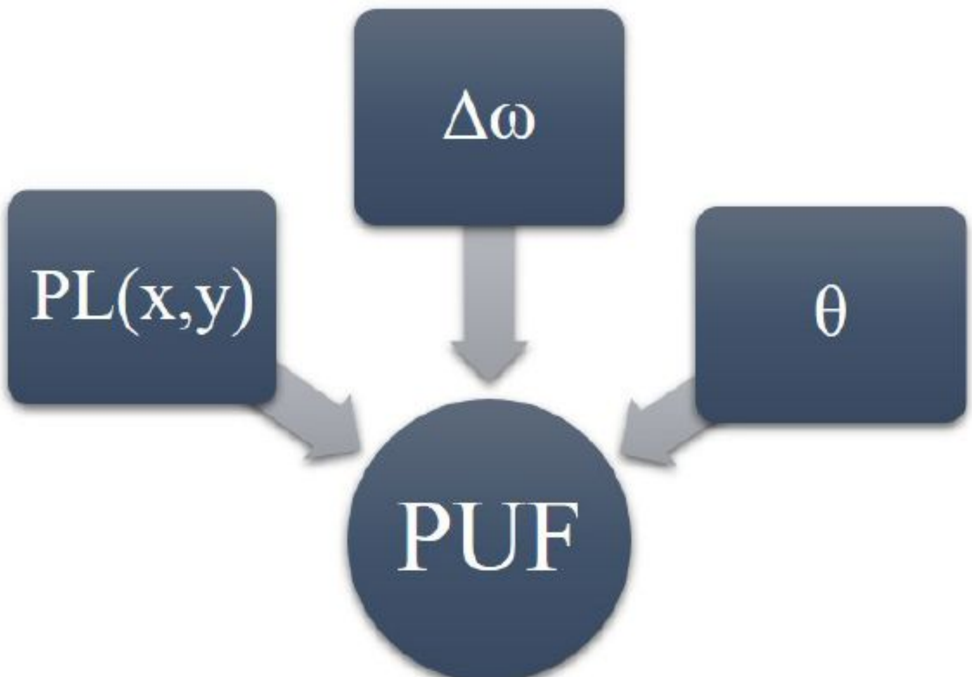
Concept of the angular selective transmission



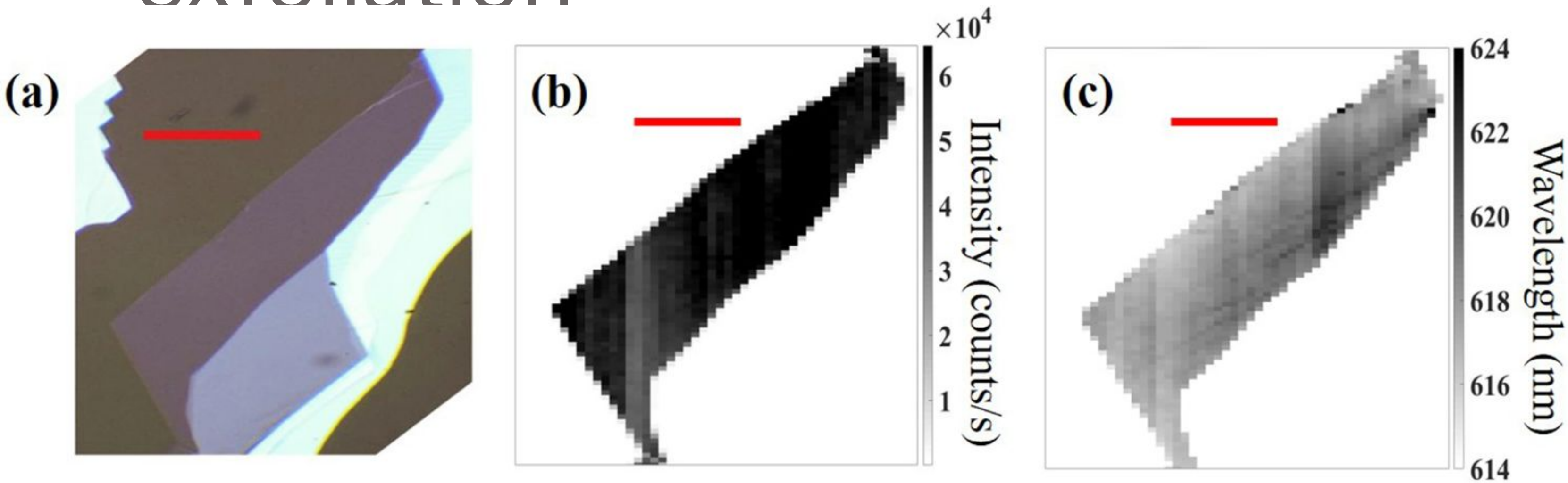
- Changing the BPF angle lights up a random subset of pixels on the CCD; red, green and blue conceptually correspond to positions on the monolayer TMD that emits in differing energy ranges. When no filter is present, all energies are picked up.

Makeup of PUF

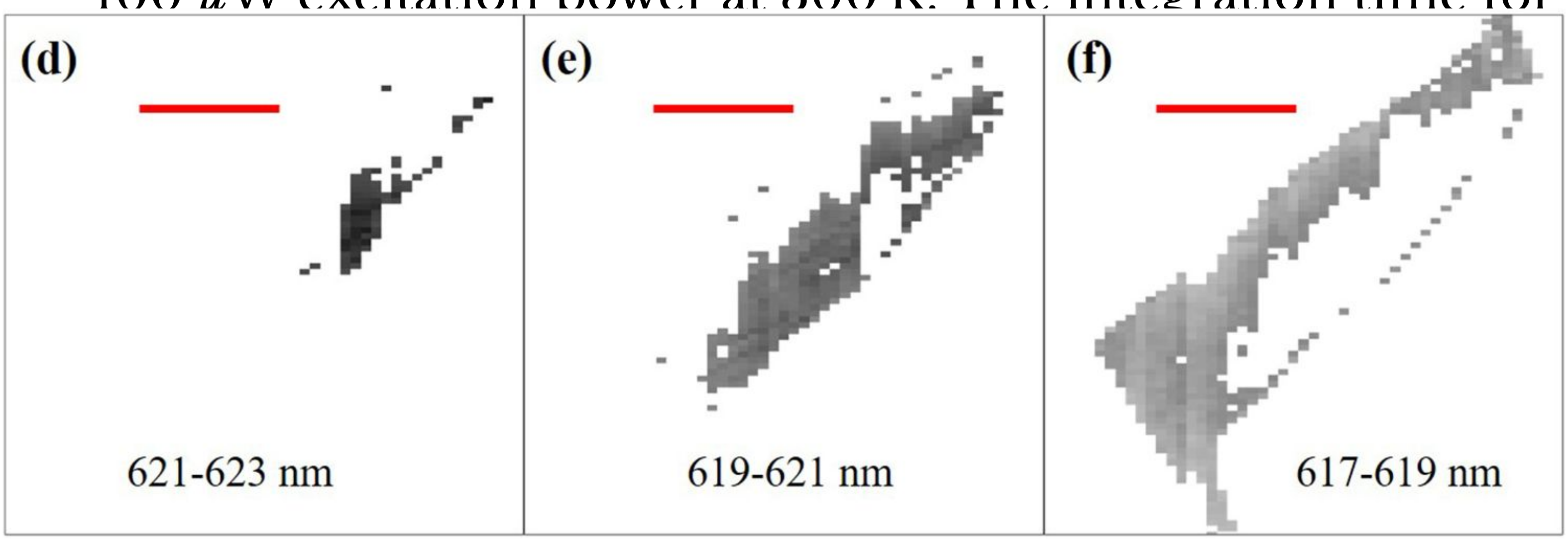
- The BPF angular orientation θ, the corresponding BPF bandwidth, and the spatially varying photoluminescence of the monolayer TMD PL makes up the physical unclo



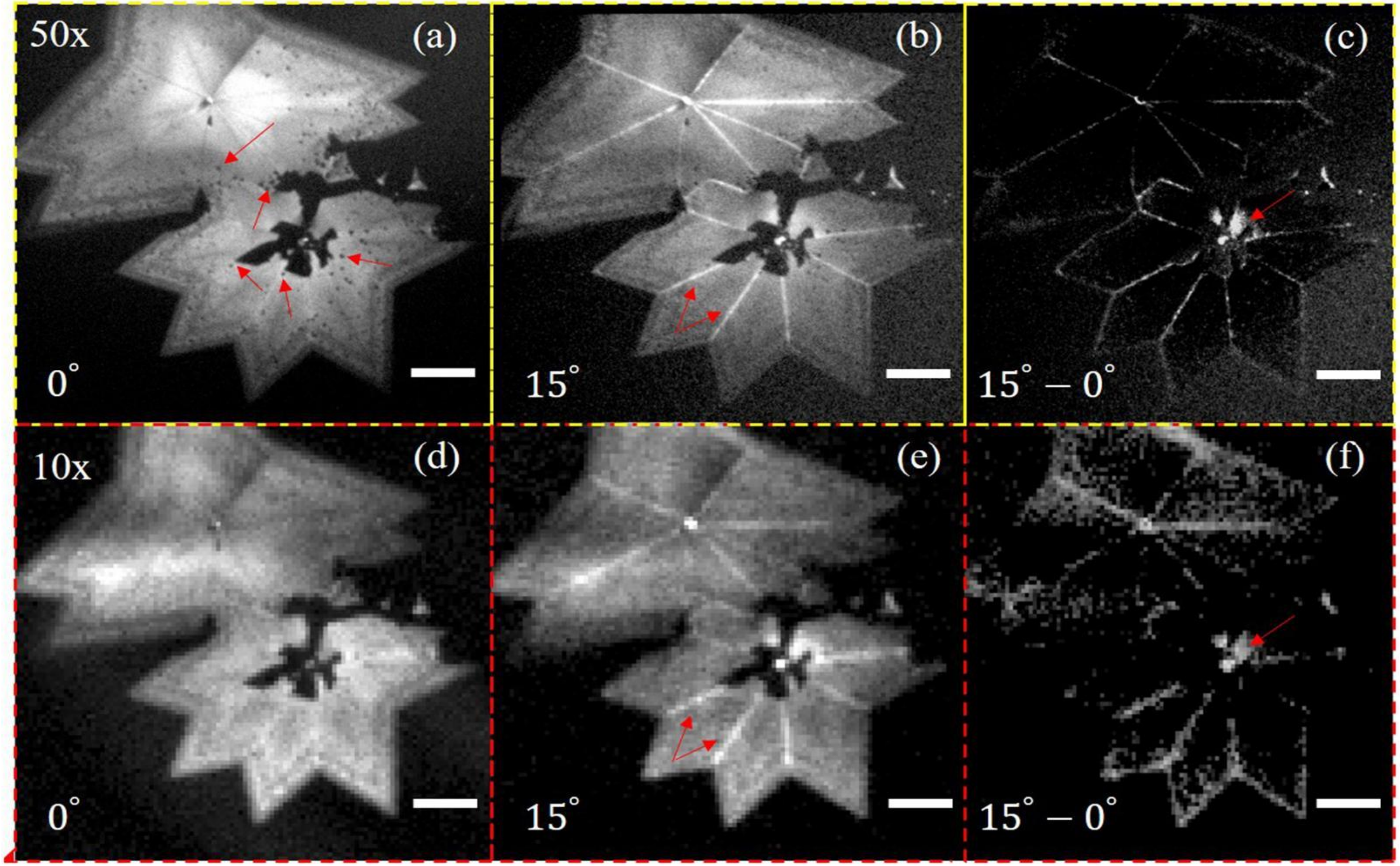
Results for WS_2 from mechanically exfoliation



50× Optical image of the exfoliated flake on PDMS. μ-PL map of this flake was recorded with 532 nm excitation and 100 μW excitation power at 300 K. The integration time for

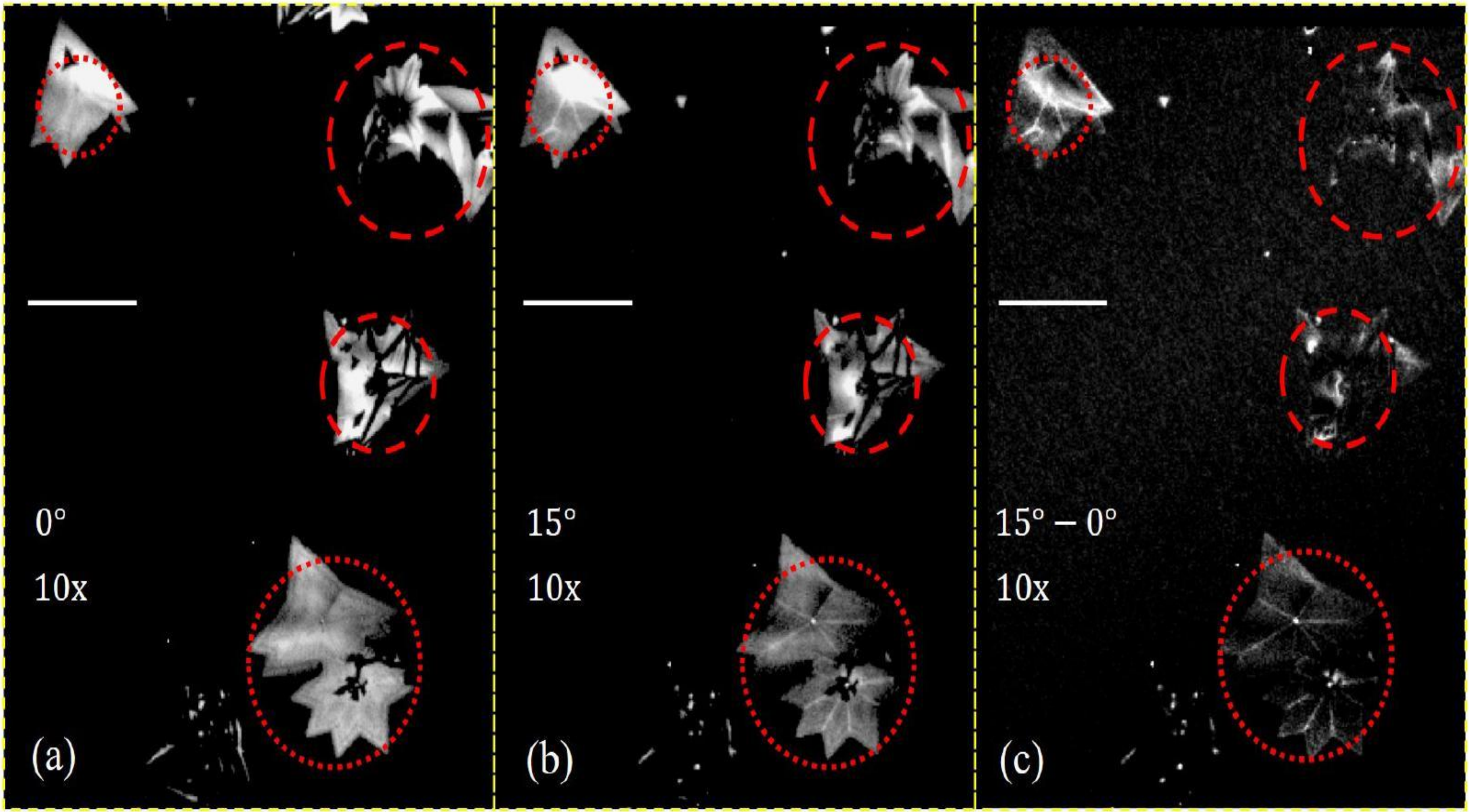


Results for WS_2 from chemical vapor deposition



- Angular-dependent PL images of monolayer flake, excited by 450 nm laser, collected using 50× (a)–(c) and 10× (d)–(f) respectively.

- Angular dependent PL images of WS_2 monolayer flake, excited by 450 nm laser, imaged by a 10× objective lens



Conclusion

- Spatial non-uniform photoluminescence is more pronounced for chemical vapor grown flakes than those created using mechanical exfoliation.
- The key to implementing a real authentication or identification system based on an optical PUF, such as the one we described, is to capture the random response or physical characteristics and generate unique fingerprints. So far we have discussed a method to capture the response from 2D materials, based on imaging the fluorescence from structural defects with a bandpass filter at different detection angles.