Studying nanoscale vibrations using lasers (E, Nakamura)

Can we exploit lattice vibrations in nanoscale to quantum-mechanically control optoelectronic devices? We aim to answer this question by studying nanomaterials consisting of a few molecular layers, and tune its optical process by an interlayer vibration.

Bilayer 2D transition metal dichalcogenides (TMDs) could be an ultimate unit of nano-scale junction which emits light. It is known that there are dark (un-emitting) and bright exciton states in TMDs, but little is known how to control the quantum transfer between these states to further enhance the optical efficiency, or potentially utilizing them for quantum optics. We are interested in lattice vibrations which may trigger interactions between bright and dark exciton states.

The REU project will be integrated into our project aimed at steering lattice vibrations in few-atomic-layer thick 2D materials (TMDs or others) via so-called Raman process. After covering the basics of Raman scattering using conventional continuous-wave (cw) lasers, we move on to either apply ultrafast (femto-second) lasers to probe vibrations in time, or extend the capability of cw-Raman measurement by modifying the wavelength using non-linear crystals.

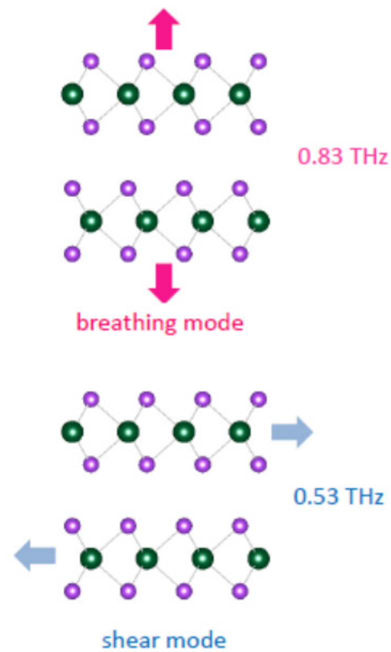

Fig. 1 Schematic diagram for lattice vibrations in bilayer TMD (WSe_2).

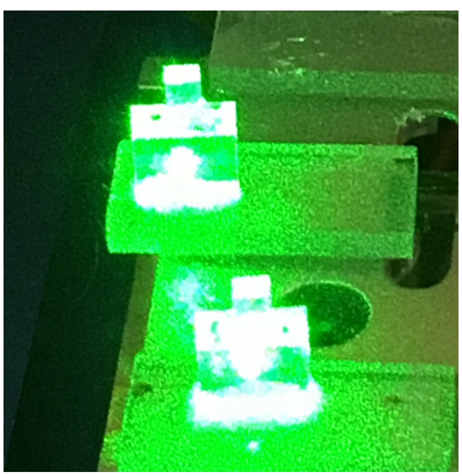

Fig. 2 Green laser used for cw-Raman measurement (taken by iphone).

What you will learn

- Laser basics: how to manipulate lasers
- cw-Raman and stimulated Raman processes
- Designing and assembling optics for Raman measurement
- How to handle nano-materials

Advanced topics (depending on time and interest)

- fs laser basics: manipulating optical paths, measuring pulse shape
- pump-probe measurement using fs laser
- non-linear optics and second harmonic generation
- Simulation of a cavity for frequency conversion (using Matlab or other software)