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Thickness Controlled Spatiotemporal Mapping of Phonon Transport in Suspended $MoSe_2$

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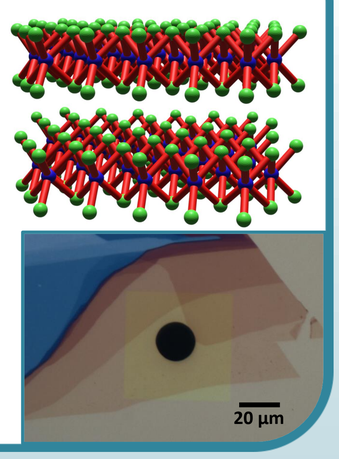
Ultrafast Dynamics in Nanoscale Systems

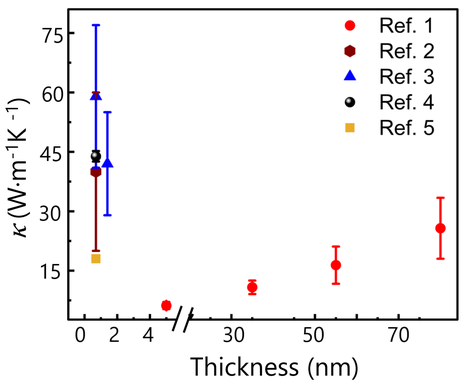
Introduction

- Atomically thin layered materials are promising in thermoelectric and related applications.
- We developed a novel experimental method for probing the thermal transport properties of these materials.
- We observed a thickness dependence in phonon diffusion in $MoSe_2$ (suspended over large circular apertures of 15 microns)

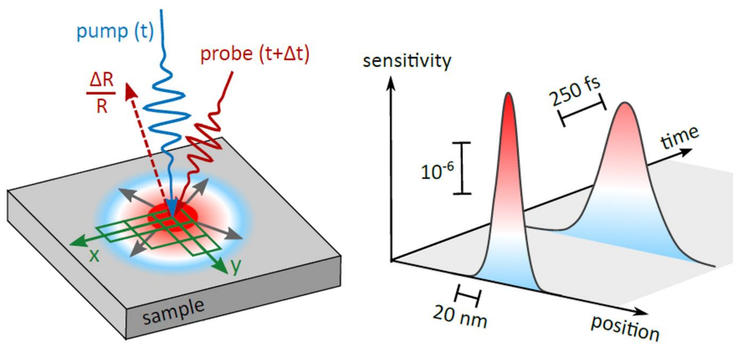


Research Background

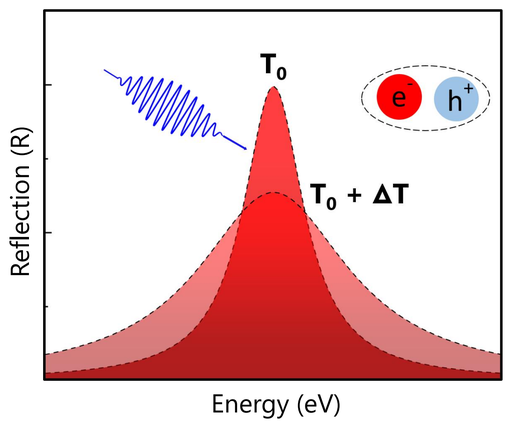
- Effect of thickness on heat transport in TMD's is debated and not conclusive
  - Frequency domain energy resolved Raman [1]
  - Optomechanical Measurements [2]
  - Refined optothermal Raman [3]
  - Molecular dynamics simulations [4,5]

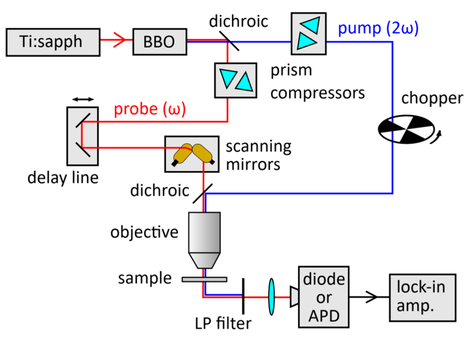


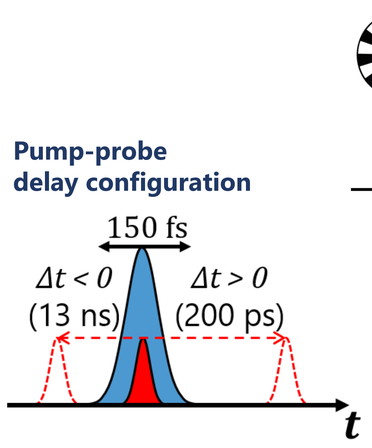
Novel Technique: Exciton Mediated Spatiotemporal Phonon Mapping

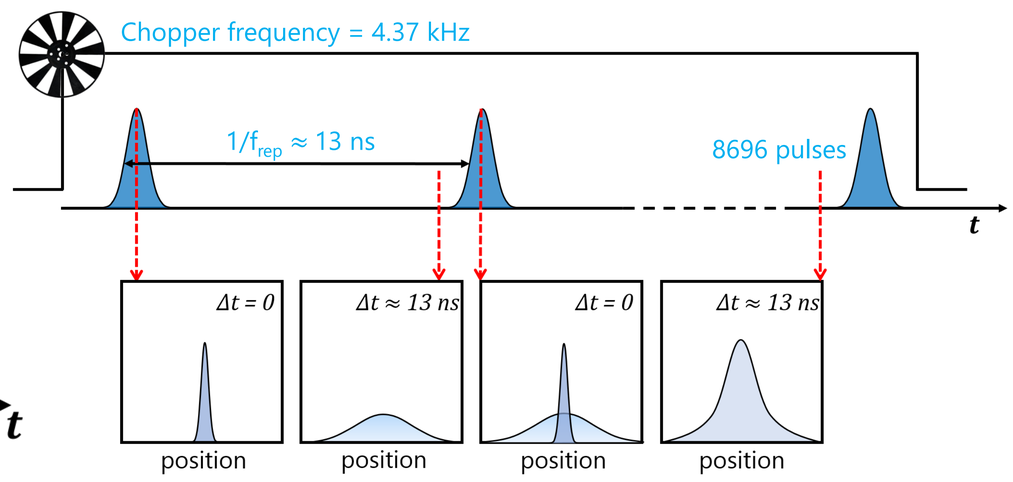


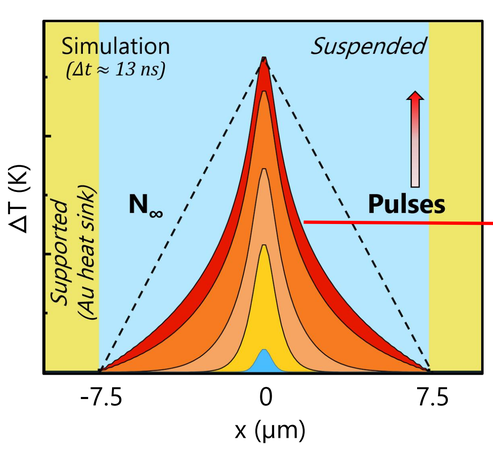
- Local charge carriers created by optical pump pulse (405 nm) which rapidly form excitons
- Decay of excitons to phonon heat
- Temperature-dependent broadening of exciton linewidth
- Phonon diffusion extracted by tracking spatial spread of transient reflectivity signal (ΔR/R) in time [6]

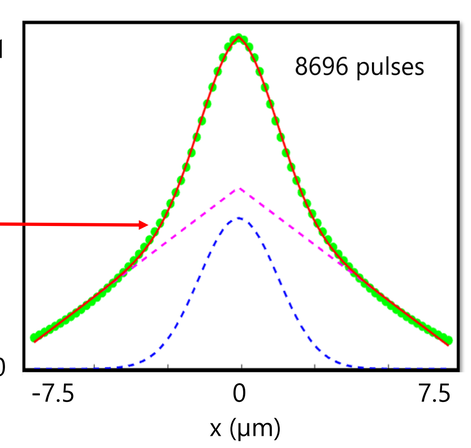






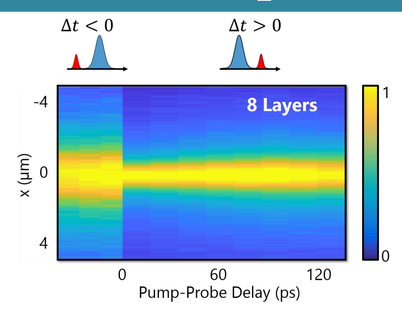




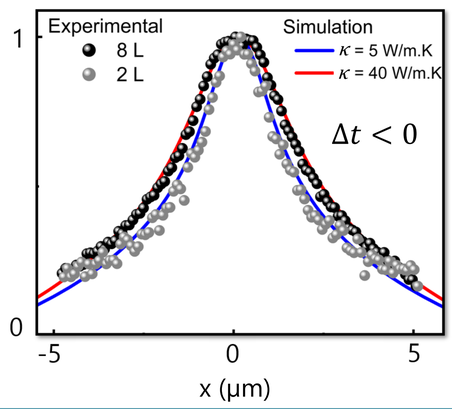


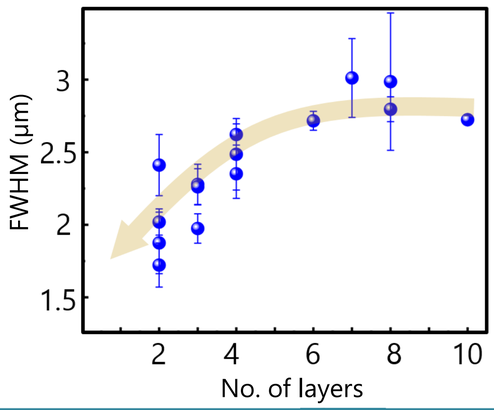
- Triangle component: Steady state heat accumulation
- Gaussian part: Width related to thermal diffusivity

Experimental Observations



- Spatial profile (broad) before time zero is the accumulated phonon heat
- Pre-t_0 spatial profiles of suspended $MoSe_2$ flakes are more narrow for 2 layers (i.e. low diffusivity) compared with 8 layers





Conclusions & Outlook: Specific Heat Capacity

- Developed novel optical technique to track energy transport in two dimensional materials using optical pulses in the visible
- **Contactless optical determination of specific heat capacity:-**
  - Diffusion of heat carried by phonons (D) is directly resolved in space and time for $MoSe_2$ of varying thickness
  - Thermal conductivity (κ) via Raman thermometry (*ePoster: D. Saleta Reig*)

$$C_v = \frac{\kappa}{D}$$

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