Next-Gen Near-Field Optical Nanoscopy for Quantum Materials Research

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Background

- Scanning near-field optical microscopy (SNOM) combines the spatial resolution of scanning probe microscopy (SPM) with the spectroscopic capabilities of optical microscopy.
- SNOM is used to study optical properties of quantum materials, including transition-metal dichalcogenides (TMDs), superconductors, etc.

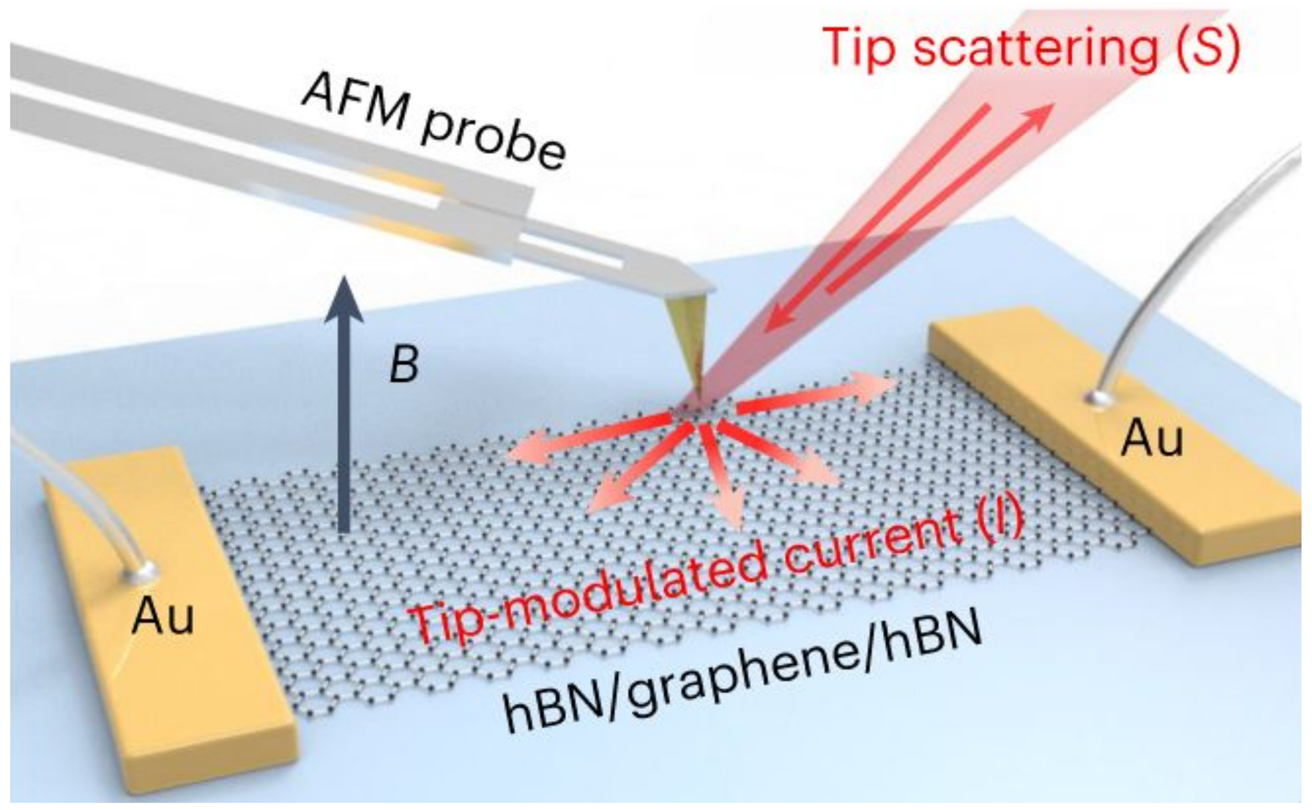

Fig. 1: m-SNOM schematic. [1]

Strain Cell

- **Reason:** 2D nanomaterials possess unique electrical, magnetic, and optical properties that can be tuned with mechanical strain.
- **Objective:** Design and construct a strain cell compatible with our SNOM setup to apply tunable strain to 2D quantum materials.
- **Method:** Utilizes piezoelectric actuators to apply uniform, controllable strain to a sample.

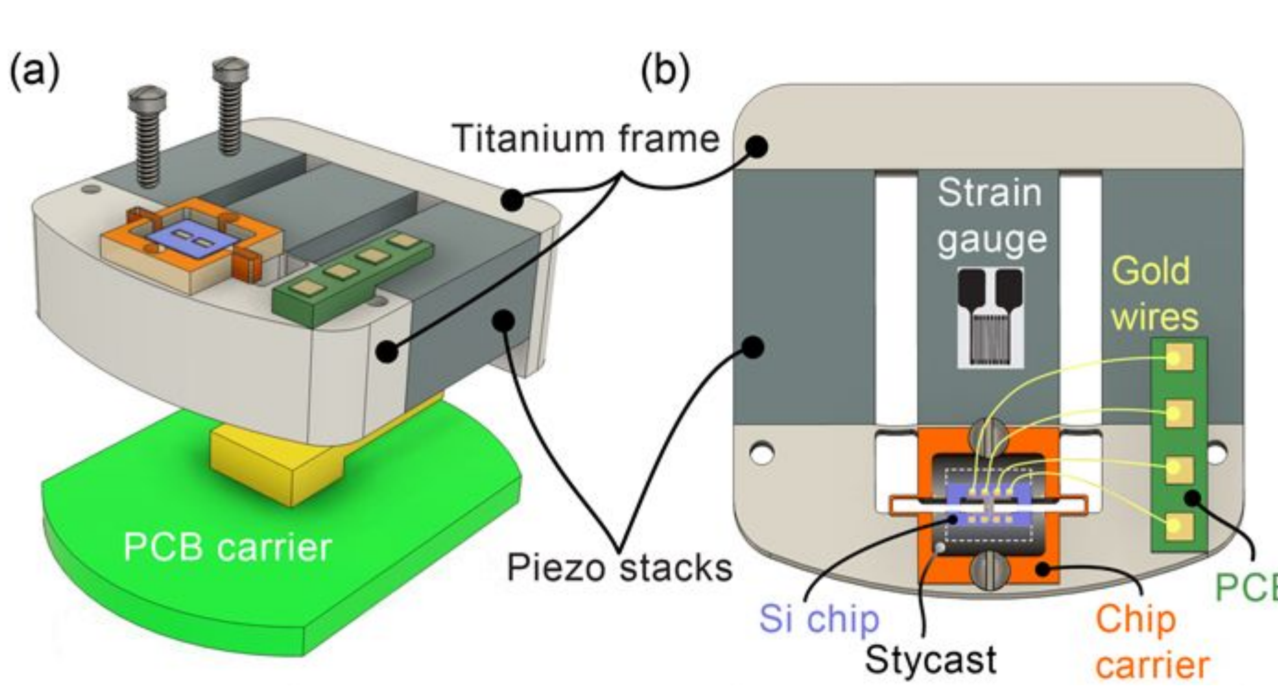

Fig. 2: Strain cell schematic. [2]

QPD Interferometry

- Nearly all current atomic force microscopes (AFMs) measure the change in cantilever angle. This is known as optical beam deflection.
- Vertical tip displacement can be measured directly through interferometry.
- Using a quadrature phase differential (QPD) interferometer (Fig. 3), the tip position can be measured from sub-picometer to microns.

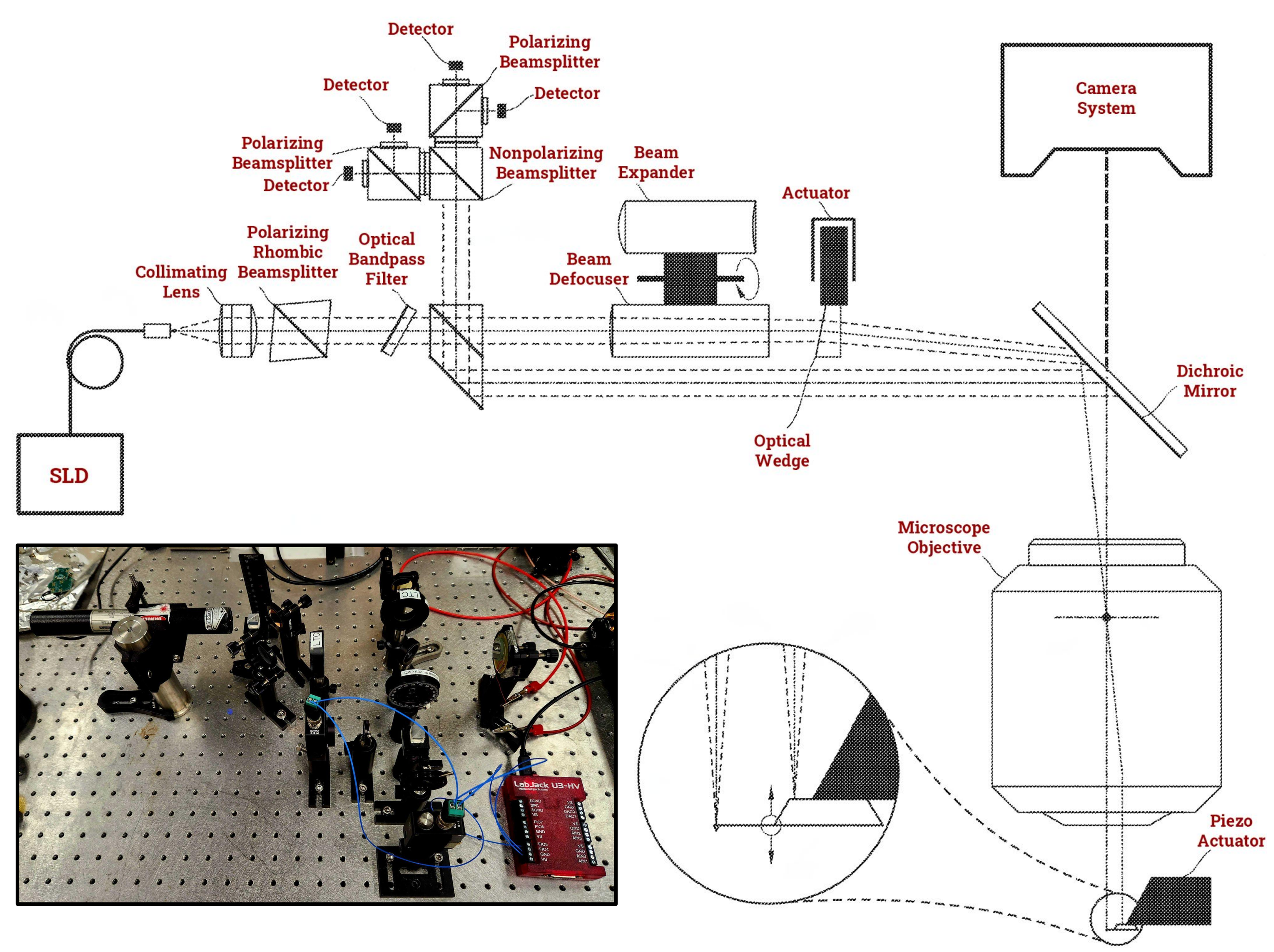

Fig. 3: Optical diagram and setup of a QPD interferometer. [3]

- This design measures cantilever displacement relative to the stationary "chip," reducing low frequency vibrational noise between the tip and the detecting optics.
- The phase between the signal contrast in each "arm" can be calculated and used to determine the displacement of the tip (Fig. 4).

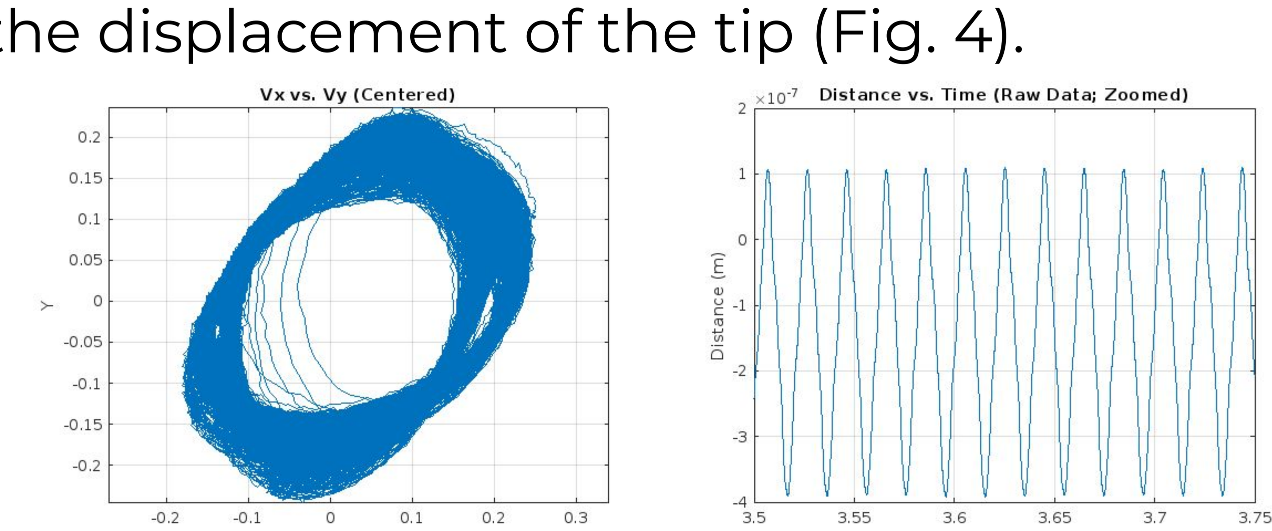

Fig. 4: Lissajous curve and distance data.

Discussion & Future Work

- The strain cell will enable the study of strain-induced effects in 2D nanomaterials within the m-SNOM setup.
- The successful implementation of a QPD interferometer will significantly improve sensitivity and resolution in SNOM measurements (Fig. 5).
- Future work includes completing the strain cell fabrication and optimizing the QPD interferometer assembly for stable usage.

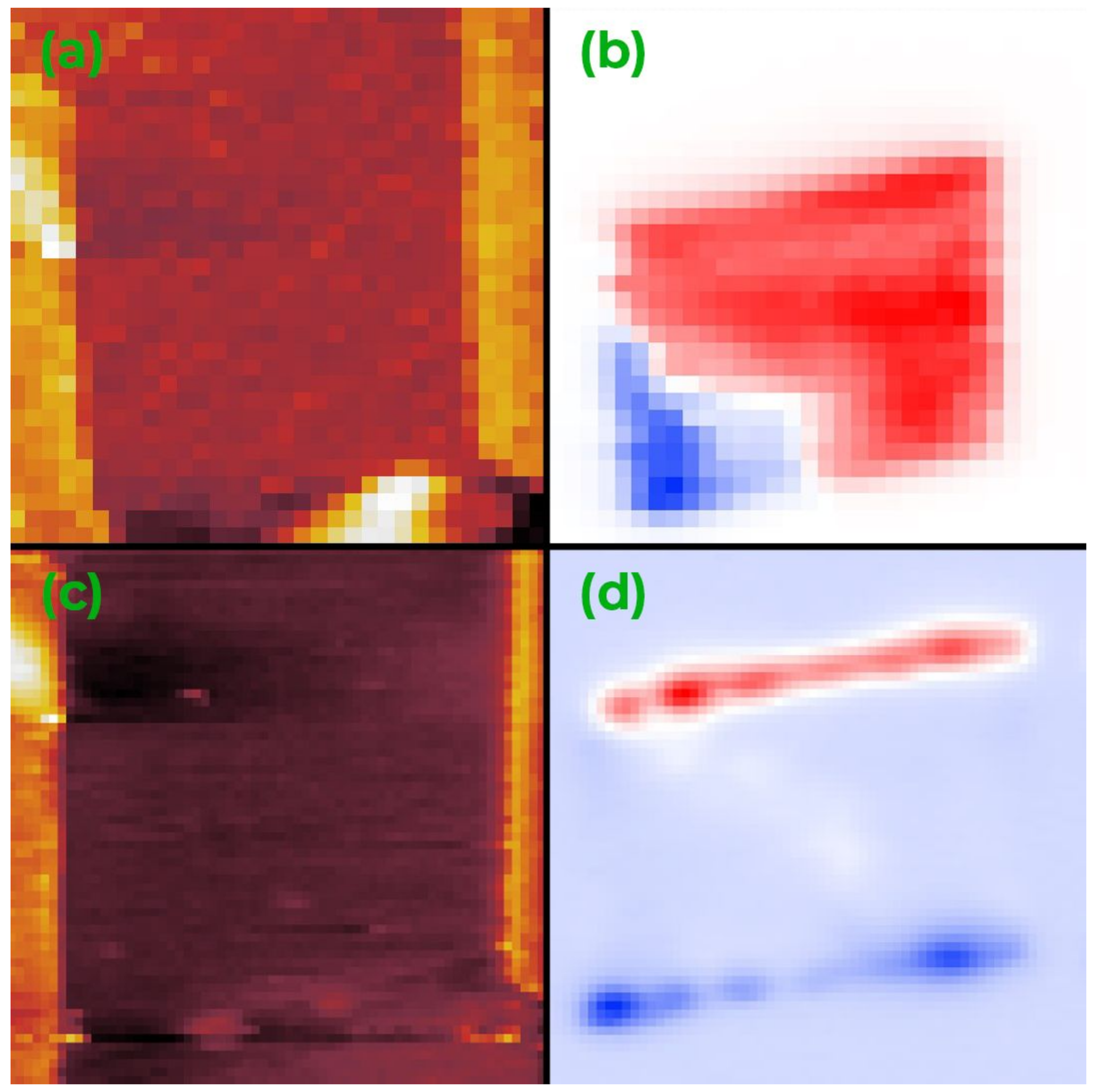

Fig. 5: SNOM scan of hBN/graphene/hBN topography (a, c) and photocurrent (b, d) at 0 T (a, b) and 7 T (c, d) at 20 K.

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