Pushing the limits of high-resolution terahertz near-field techniques for 2D-material inspection

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Ensuring material quality is paramount in high-performance device fabrication, particularly for 2D materials like graphene. Terahertz Time-Domain Spectroscopy (THz-TDS) [1] is a valuable technique for non-destructive thin-film inspection, complementing surface-sensitive methods like Raman spectroscopy. Near-field techniques, particularly those based on photoconductive near-field microprobes (PC-NFMs) [2], overcome the diffraction limit of conventional THz-TDS, thereby offering µm-scale spatial resolution and full-wafer access for 2D material characterization [3].
Here we introduce a significant advancement: a novel THz scattering-type Scanning Near-field Optical Microscopy (s-SNOM) system with integrated photo-switches for THz generation and detection. Our approach targets a major reduction in coupling losses by implementing compact THz transmitter (Tx) and receiver (Rx) modules directly with the AFM cantilever. This innovative architecture is engineered to achieve nanoscopic spatial resolution and increased data acquisition speed compared to existing THz s-SNOM approaches. We envision this advanced s-SNOM system as a transformative tool for high-throughput, high-resolution inspection tasks, facilitating the development of next-generation devices.
In a succeeding step we will combine our approach with self-actuated (Akiyama-type) atomic force microscope (AFM) cantilevers for improved control of tip-to-sample interaction, facilitated operation and improved applicability for 2D material inspection.
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References

[1] P. Bøggild, D. M. A. Mackenzie, P. R. Whelan, D. H. Petersen, J. D. Buron, A. Zurutuza, J. Gallop, L. Hao and P. U. Jepsen, 2D Materials, 2017, vol. 4, no. 4, p. 042003
[2] M. Wächter, M. Nagel and H. Kurz, Applied Physics Letters 2009, vol. 95, no. 4, 041112
[3] A. Quellmalz, X. Wang, S. Sawallich. et al., Nat. Commun. 12, 2021, no. 917

Figures

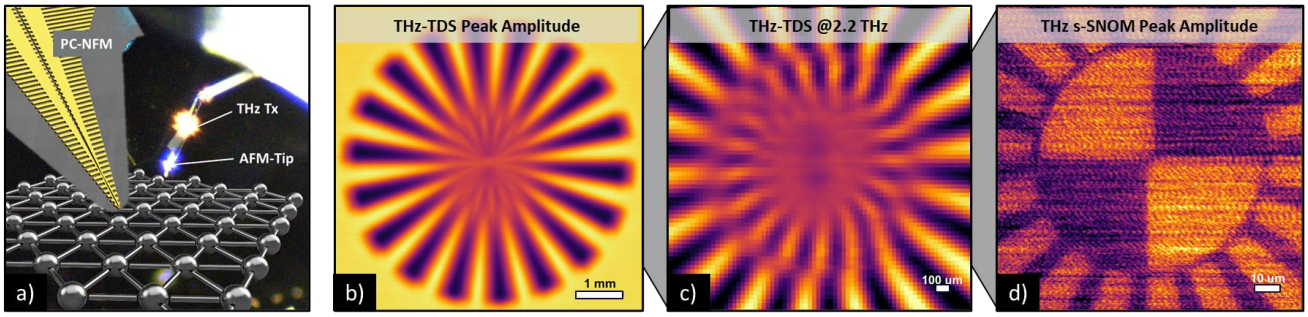

Figure 1: (a) Schematic of the integrated THz s-SNOM concept. (b) High-resolution THz-TDS transmission mode "white-light peak" signal and (c) zoomed-in frequency-domain signal at 2.2 THz. (d) Improved spatial resolution demonstration of the THz s-SNOM system with integrated near-field excitation and read-out. The scale bars are 1000µm, 100µm and 10µm respectively.