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Detector Development for Far-Infrared Near-Field Nanospectroscopy*

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DISCLAIMER

Detector Development for Far-Infrared Near-Field Nanospectroscopy*

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***Abstract*—A facility for performing infrared nanospectroscopy over the spectral range from 3 microns to 55 microns (3400 cm^{-1} to 180 cm^{-1}) has been developed at the 22IR2/MET infrared beamline at NSLS-II. The broad spectral range, including the unprecedented reach into the far-IR beyond 30 microns, is due to the high spectral radiance synchrotron infrared source combined with custom detectors operating at 4.2K.**

I. INTRODUCTION

THE National Synchrotron Light Source (NSLS-II) at Brookhaven National Laboratory (Upton, NY, USA) is a facility used for probing materials on the nanoscale. We describe here the operation of NSLS-II beamline 22IR2 (MET) for near-field nanospectroscopy, including into the far-infrared using boron-doped silicon (Si:B) and $Hg_{1-x}Cd_xTe$ (MCT) photoconductors achieving the >1 MHz electrical bandwidth necessary for the apertureless scattering technique.

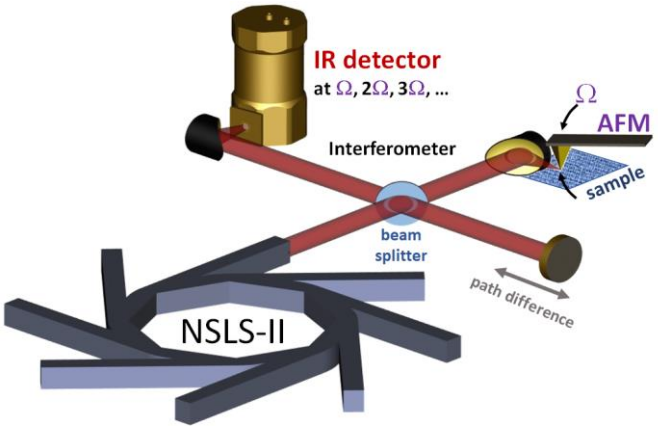

Fig. 1. Standard configuration for near-field nanospectroscopy using the synchrotron infrared source, consisting of an asymmetric Michelson interferometer with one arm using the scattered light from an AFM tip interacting with a sample surface.

II. FAR-INFRARED DETECTOR DEVELOPMENT

In the apertureless scattering approach[1,2,3], infrared is scattered from the oscillating tip of an AFM as it interacts with the surface of a material (see fig. 1). Sensitivity to the more localized scattering is achieved by detecting at harmonics of the tip oscillation frequency Ω (e.g. 2nd, 3rd, 4th). With Ω potentially at 100s of kHz, the detector's response bandwidth needs to be as high as 1 MHz and not readily achieved by most commercial composite bolometers – the standard detector for far-infrared spectroscopy. To solve this, we use narrow-gap photoconductors such as extrinsic Si:B and MCT. For the latter, we chose an alloy composition of x~0.173 having detection onset near 400 cm^{-1} (at 77K), but shifting to below 200 cm^{-1} when cooled to 4.2K. This was confirmed, along with a 5X improvement in the overall signal-to-noise, using a standard FTIR spectrometer[4] and thermal source.

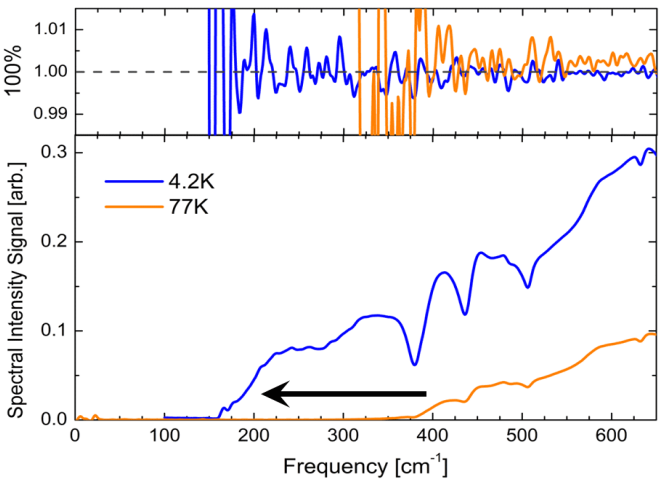

Fig. 2. [*bottom*] Spectroscopic signal for the MCT detector at T=4.2K (blue) and at T=77K (orange). [*top*] 100% lines to illustrate S/N. Note that the source aperture (diameter) for T=4.2K was half that for T=77K.

Additionally, we have used a single electron bunch from the synchrotron as a source of ~15ps RMS infrared pulses to confirm a bandwidth greater than 15 MHz[4], exceeding the requirements for AFM based near-field nanospectroscopy. As an example, we show the polaritonic NFIR response for ZnSe.

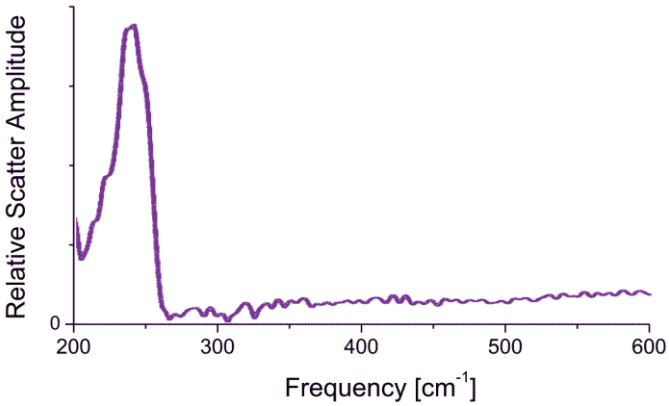

Fig. 3. 2nd harmonic signal showing the phonon-polariton below 300 cm^{-1} in ZnSe, as measured using the 4.2K MCT detector.

III. SUMMARY

Broadband nanospectroscopy from ~200 cm^{-1} to >3000 cm^{-1} is now available at beamline 22IR2/MET. For information on requesting beamtime, see https://www.bnl.gov/nsls2.

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