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Imaging single nanoparticles using laser terahertz emission microscopy[1]

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Laser Terahertz Emission Microscopy (LTEM) is a terahertz imaging method providing an improved imaging resolution, limited by the spot size of the incident laser beam i.e. typically a few m. Inspired by recent results in terahertz nano-spectroscopy, we have improved the resolution of the LTEM technique by three orders of magnitude, by exploiting plasmonic coupling to a metallic Atomic Force Microscope (AFM) tip with a diameter on the order of 20 nm. Our setup is based on a commercial AFM which is coupled to a femtosecond laser (100 fs, 80 MHz repetition rate, 820 nm). The AFM uses an 80 m-long metal probe tip, tapping at 18 kHz with an amplitude of 110 nm. The back-scattered laser light is detected with a photodiode while the forward-scattered terahertz signal is detected with electro-optic sampling in ZnTe. By performing lock-in detection to the tapping frequency of the AFM probe, we can simultaneously record a near-field image at 820 nm, an LTEM image, and an AFM topography image. By locking to a higher harmonic of the tip oscillation the background of scattered light can be suppressed for both the optical and terahertz signals. Our sample is prepared by drop-casting an aqueous solution of surfactant-stabilized gold nanorods onto a wafer of lightly p-doped InAs (N_c˜10^{16}) which is known to work well as a THz emitter. We measure a region of this wafer in the vicinity of a single nanorod. We observe that the LTEM image of the nanorod, formed using emission from the underlying substrate, is in excellent agreement with the other more conventional measurements, with an image resolution of ˜20 nm, limited by the size of the AFM tip. We note that the LTEM signal is highest from the bare InAs wafer and drops when the tip is on top of the gold particle, suggesting that the gold nanoparticle partially screens the emission from the InAs surface. Our measurements clarify the emission mechanism, and the role of the extended metal tip in transducing the THz signal into the far field.

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