Resonant THz near-field probes

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Many terahertz (THz) applications require strong THz field concentrations, for example high-resolution THz imaging or THz sensing of small amounts of matter [1]. While far-field optics is only able to focus radiation on length scales of the wavelength, near fields at the nanometer-sized apex of metal tips, or in sub-wavelength apertures or slits, can be concentrated to deep sub-wavelength length scale [2].
Here we report the development of THz-resonant scanning near-field probes, yielding strongly enhanced and nanoscale confined THz near fields at their very tip apex. We employ focused ion beam (FIB) machining to fabricate sharp platinum/iridium tips of a length in the order of the THz wavelength, and attach them to standard atomic force microscopy (AFM) cantilevers (SEM image, Fig. 1a). The tips are illuminated with THz radiation from a gas laser. A graphene based near-field detector is used to measure the near-field intensity directly at the tip apex of differently long probes, all of them exhibiting an apex diameter of 50 nm (inset of Fig. 1a). Measurements at 3.11 THz reveal their first and second antenna resonances for probes of 33 and 78 μm length (Fig. 1c), which provide up to one order of magnitude enhanced near-field intensity at the tip apex compared to tips that have a length of 17 μm (standard AFM tip length). The results are corroborated by numerical simulations (electric filed plot Fig. 1b, solid line in Fig. 1c), which predict remarkable field intensity enhancements of about 10^7 relative to the incident field. We envision exciting future applications, including scattering-type THz near-field nanoscopy [3] and THz photocurrent nano-imaging [4] with enhanced sensitivity, nanoscale nonlinear THz imaging or nanoscale control and manipulation of matter employing ultrastrong and ultrashort THz pulses [5].

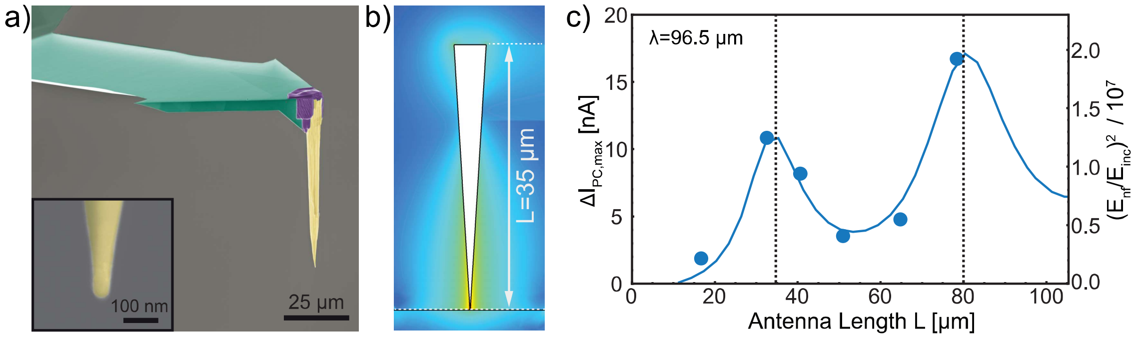

Figure 1: a) False color SEM image of a FIB fabricated THz antenna tip showing Si cantilever (green), FIB deposited Pt (purple) and the Pt/Ir antenna tip (yellow). b) Electric near-field distribution (logarithm of the electric field enhancement) of a L = 35 long tip, showing the first antenna resonance. c) Measured photocurrent $\Delta I_{PC,max}$ as a function of antenna length (blue dots) compared to numerical simulation of the near-field intensity enhancement at the tip apex (blue solid line).

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