Sub-wavelength focusing of mid-IR light using metal/diamond/metal campanile probe for ultra-broadband SPM

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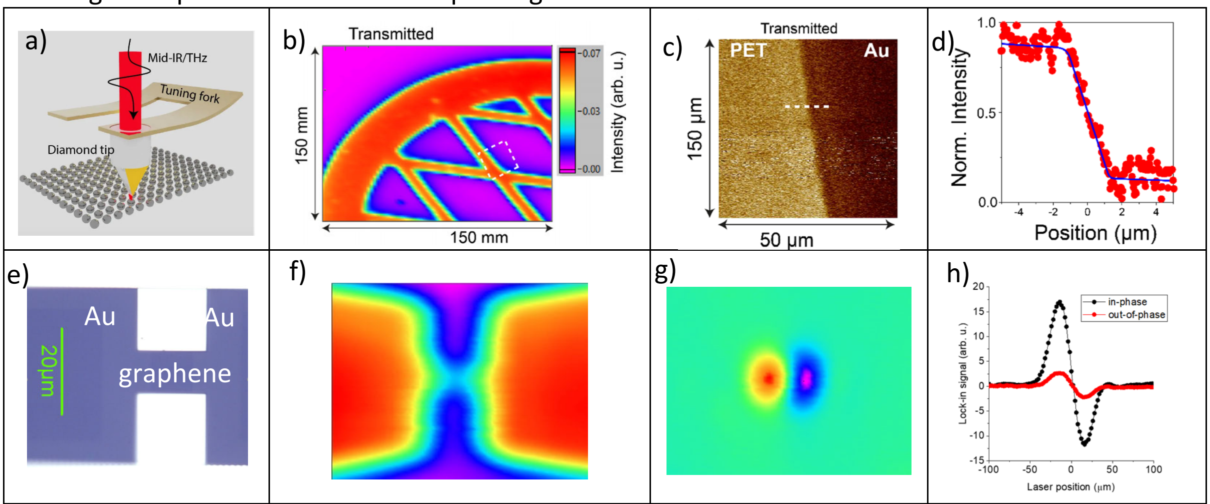
Developing methods for efficient nanoscale probing of light-matter interaction, especially in the Mid-IR and THz spectral range, is essential for studying fundamental physical phenomena as well as chemical properties at micrometer to nanometer length scales. A highly efficient nanoscale focusing of visible and near-IR radiation light was reported recently using Au-SiO_2-Au tapered gap campanile plasmon waveguide with an 830 nm wavelength that couples free space light into the nanoscale domain, enabling probing of materials in the visible and near-IR spectral range [1].

We expand this capability to the highly important mid-IR through THz range providing valuable information on local nanoscale chemistry and physical processes of materials and devices using a campanile shaped diamond tetragonal pyramid [2]. Our finite difference time domain (FDTD) simulation reveals that nanoscale focusing of mid-IR light is possible within the range of geometries and metal coatings including Au, Al and Cu. Here we report linked modeling and experimental results showing the confining efficiency of diamond pyramid to sub-walength areas (2-4 um) in the mid-IR range (l=8-10 µm). Furthermore, we demonstrate the integration of Au/diamond/Au light concentrator into a scanning probe microscope for performing sub-wavelength spectroscopy of various materials in both reflection and transmission geometries. We also demonstrate probing of the field photoresistive and photovoltaic response of active graphene device using far field optical focusing as a aplatform for near-field probing.



a) Schematics of the near-field microscope for IR through THz radiation concentration b) far field response of the probe scanned over mid-IR detector (9.5 um excitation wavelength) through the Au pattern on PET substrate, c) near-field image and d) of the scan across the PET-Au boundary obtained via the scanning probe microscopy showing ~2 um spot size for 10 um radiation wavelength, e) schematics of the active device consisting of Graphene bridge between Au electrodes, f) scan of the reflected far field optical signal, g) 2D and h) profile of the response of the active Graphene device.

References:

1) H. Choo *et al*., Nature Photonics **6**, 838 (2012).
2) M. Mrejen et al., *Nature Commun.* **6,** 7565 (2015)
3) https://hiwin-felix.org/

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