THz near-field microscopy of semiconductor and metal bowtie antennas

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***Abstract*— We perform THz near-field measurements on bowtie antennas made of doped Si and gold. The measurements show a similar local field enhancement for the different materials. These measurements constitute the first demonstration of plasmonic near-field enhancement using semiconductors at THz frequencies. Semiconductors offer the possibility of ultrafast optical switching of plasmonic resonances (on a ps time scale), which will enable the active control of sub-wavelength fields. Since this excitation can be implemented in picoseconds time scale, these structures can be used as a tool for ultrafast sub-wavelength THz spectroscopic purposes.**

I. INTRODUCTION

The coupling of free-space electromagnetic waves to surface plasmon polaritons depends on the plasma frequency of the material. The coupling strength decreases as the frequency of the radiation is detuned from the plasma frequency. Typically, the plasma frequencies of metals are in the visible or ultraviolet part of the electromagnetic spectrum, whereas for semiconductors these frequencies are at the mid-infrared and depend on the doping concentration. Therefore, there is a stronger coupling of THz radiation (0.1 – 10 THz) to surface plasmons in semiconductors at these low frequencies and a concomitant increase of the confinement of THz local fields in semiconductor plasmonic structures. The larger electromagnetic field penetration in semiconductor antennas is also responsible for larger Ohmic losses when compared to metals [1]. Semiconductors provide the option of controlling their permittivity either actively, e.g. by optical or electrical pumping of free charge carriers, or passively by chemical doping [1,2]. Hence, semiconductors are very versatile materials for plasmonics at low frequency.

II. RESULTS

In this work we present a comparative study of the THz near field associated to resonances in Au and doped-Si antennas on quartz using a near-field THz microscope. Figure 1 illustrates a simulation of the THz near field for a gold (a) and a doped Si (b) bowtie antenna of the same dimensions. The simulations have been done at the respective resonant frequencies of the antennas. Both structures exhibit a large enhancement of the THz field intensity in the gap defined by the apex of the two triangles. The near field measurements were done in a scanning microscope that uses THz pulses generated with a NIR fs-oscillator for illuminating the sample from below. A fraction of the same NIR beam is used to gate a near-field photo-conductive probe [3]. As it will be discussed, the spectra for different distances between the probe and the antenna show the strong confinement of the near field to the gap of the bowtie. Spatial maps also demonstrate the distribution of the field and its local confinement. The field enhancements measured on the Au and doped Si structures are similar, which validates the use of semiconductors for THz plasmonics in spite of their larger losses in comparison to noble metals.

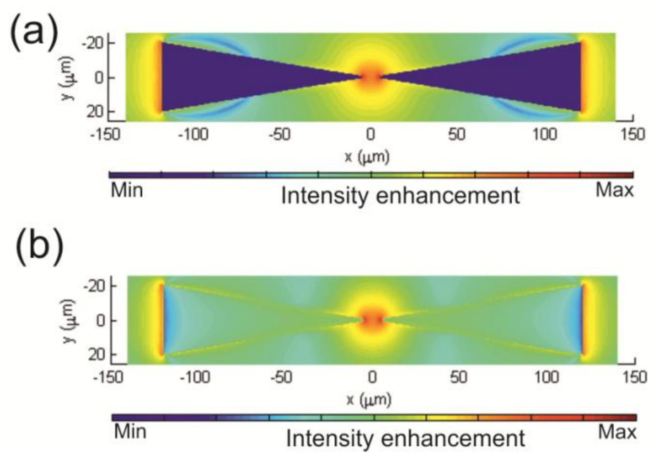

Fig 1: Simulated near-field intensities for axial THz illumination on bow-tie antennas showing enhancement of near-fields in (a) gold and (b) doped-Si both on quartz substrate. The intensity is calculated at the upper surface of the antennas.

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