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Terahertz near-field measurements of subwavelength antenna structures and metamaterials

Aurèle J. L. Adam[1], Joseph R. Knab[1], Lucie A. Guestin[1], Eric A. Shaner[2] and Paul C. M. Planken[1]

1. Delft University of Technology, Delft, The Netherlands.
2. Sandia National Laboratories, Albuquerque, New Mexico, USA

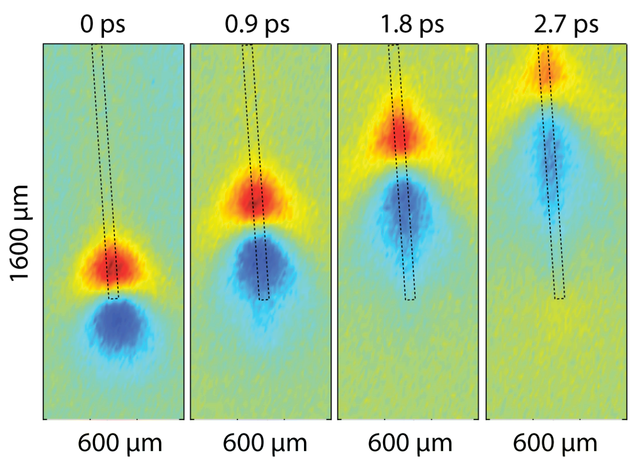
Broadband THZ near-field measurements were performed on different types of antennas and meta materials structures, all having sub-wavelength dimensions. The time and frequency dependence of the electric near-field are presented and compared with numerical calculations.

Using terahertz time-domain spectroscopy (THz-TDS), we measure the electric near-field components $E_x(t)$, $E_y(t)$ and $E_z(t)$ in the vicinity of antenna structures for wave vectors k corresponding to ka$\ll$1, ka$\approx$1 and ka >1, where *a* is the typical dimension of the structure. As an example, we present the time evolution of the longitudinal component $E_z(t)$ in Fig. 1A, which shows the propagation of a THz pulse along a semi-infinite wire. Our measurements reveal how the extremity of the wire generates propagating fields resembling a Sommerfeld wave on a cylindrical wire. From these measurements we can calculate the propagation speed of the wave for frequencies between 0.1 to 1.5 THz.

We also measure the near-field of a rod antenna (diameter = 40 µm, length = 620 µm), illuminated with a single cycle THz pulse. We observe a resonance at 120 GHz, which is different from the predicted vacuum resonance of 240 GHz. We will provide an explanation for this, apparently, surprising measurement.

We have also applied our THz near-field measurement technique to more complicated antenna structures found on metamaterials. Recently there has been an increasing interest in studying these structures at THz frequencies [1]. Metamaterials are scalable, and their potential has been demonstrated over the years from RF to optical frequencies.

Fig. 1B shows the measured two-dimensional near-electric field distribution at a frequency of 900 GHz at a fixed phase underneath an inverse, split ring resonator deposited on our electro-optical crystal. The arrows represents the vector $E_x(x,y)+E_y(x,y)$ while the color plot represents the $E_z(x,y)$ component of the near field. The color dotted line provides an outline of the open ring. The spatial field distribution of E_z is directly proportional to the instantaneous charge distribution on the metal surface. Different patterns occur at different frequencies suggesting resonant behavior. Results of these measurements are compared with FDTD calculations. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.



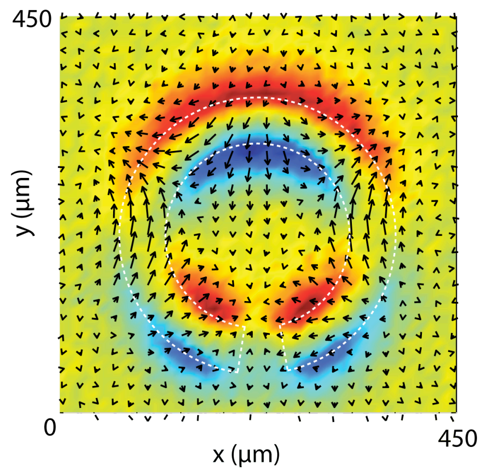


Fig. 1 A) 2D distribution of the electric-field amplitude E_z, measured underneath a semi-infinite rod (40 µm diameter), at four different times after illumination of the rod with a THz pulse. B) Time frame of the full near field electric field measured under an inverted split ring resonator deposited on our electro-optical detection crystal. The arrows represent the E_x and E_y components and the color-plot represents the E_z component. The polarization of the incident field is along the *y*-axis in both cases.

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