Advanced Photonics Congress, Sensors 2011, 12.-15. June 2011, Toronto, Canada

Time and frequency-resolved terahertz microscopy with a photoconductive near-field probe

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Abstract: By terahertz microscopy based on a photoconductive antenna as scanning near-field probe we demonstrate mapping of electromagnetic fields close to microstructures. Our approach visualizes electric and magnetic near-fields with sub-ps temporal and sub-wavelength spatial resolution.

OCIS codes: (110.6795) Terahertz imaging; (180.4243) Near-field microscopy; (300.6495) Spectroscopy, terahertz

Manipulating light fields by their controlled interaction with metallic micro- or nano-structures promises a multitude of revolutionary applications, such as efficient waveguiding, improved focussing or enhanced spectroscopic sensitivity. Whereas most studies investigate the light distribution in the far-field of the structures, gaining a comprehensive understanding of the underlying mechanisms requires monitoring the near-field. In contrast to studies at visible frequencies where near-field investigations are highly challenging, experiments with long-wavelength radiation, e.g. terahertz waves, can overcome many potential limitations.

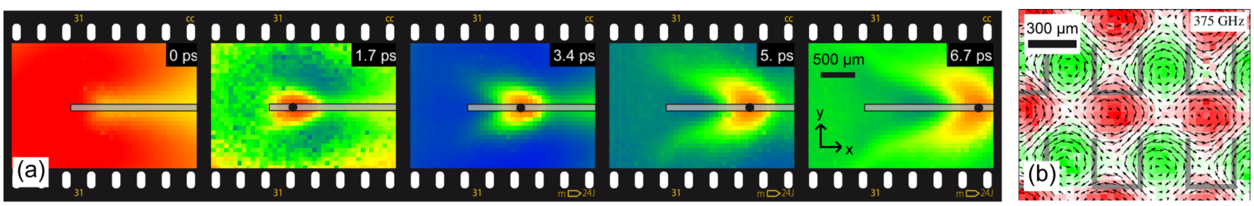

Fig. 1. (a) Time sequence of electric field distribution, E_x, measured close to a long microwire after illumination by a THz pulse. (b) Measured electromagnetic near-field at 375 GHz of a resonantly excited micro-resonator array (metamaterial) consisting of subwavelength-sized U-shaped metallic split-rings. Arrows correspond to the in-plane electric, E_{xy}, and the color code to the out-of-plane magnetic field, B_z.

The technique used here is based on the THz time-domain approach, with THz pulses being emitted and detected by photoconductive antennas optically gated by the output of a mode-locked Ti:sapphire laser (< 20 fs, 800 nm, 75 MHz repetition rate). Our detector unit features a near-field scanning probe consisting of a movable detector close to the sample surface. By raster scanning the probe the electric field close to the structures can be traced on sub-ps time scales with sub-wavelength spatial resolution $< \lambda/25$ [1]. As an example Fig. 1 (a) shows a time sequence of the x-component of the electric field measured behind a long microwire after illumination by a THz pulse. On the wire end part of the field diffractively couples into a guided mode of the wire launching a THz wave packet propagating along the microwire in positive x-direction. Two consecutive measurements of the x- and y-polarized electric fields allow determining the entire in-plane electric vector field. From the measured in-plane electric field the out-of-plane magnetic field can be reconstructed [2]. As a result we obtain a comprehensive microscopic picture of the electromagnetic near-field response of a microstructured sample as shown in Fig. 1 (b) for a metallic split-ring resonator array. As we will show, THz near-field microscopy represents a useful tool for the investigation and optimization of designs for plasmonic and metamaterial applications [3,4].

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