OMICS International
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Max Eisele, J Nanomed Nanotechnol 2015, 6:4
http://dx.doi.org/10.4172/2157-7439.S1.021

Nanotechnology Congress & Expo

August 11-13, 2015 Frankfurt, Germany

Field-resolved multi-terahertz nano-spectroscopy

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Understanding the underlying physical properties of solid state systems has always been the key challenge in disentangling the origins of complex emergent phenomena like high-temperature superconductivity, insulator-to-metal phase transitions and charge density waves. Such effects strongly depend on the precise interplay between low-energy excitations such as phonons, excitons and plasmons. The development of terahertz time-domain spectroscopy has provided a way to directly couple to these far to mid-infrared excitations and study their dynamics with the ultimate time resolution – faster than a single cycle of light. However, the spatial resolution of far-field terahertz studies is intrinsically limited to the scale of the probing wavelength by diffraction. Scattering-type near-field scanning optical microscopy (s-NSOM) has the potential to overcome this limitation. Here, we demonstrate a unique combination of ultrafast terahertz spectroscopy with s-NSOM. Phase-stable mid-infrared pulses are scattered off the tip of an atomic force microscope and detected by electro-optic sampling, enabling the observation of the oscillating electric near-field with 10-nm spatial resolution and 10-fs temporal resolution. We apply our novel microscope to study the ultrafast local carrier dynamics in an indium arsenide nanowire. By resolving the oscillating scattered near-field as a function of pump-probe delay time and position, we record an ultrafast movie of the local evolution of the electron density with sub-cycle time resolution. The development of field-sensitive spectroscopy with sub-nanoparticle spatial resolution marks the dawn of a new era for sub-cycle measurements, where nanoscale experiments can be envisioned for virtually any process suitable for time-resolved studies in the mid-infrared.

Biography

Max Eisele has been working since 2011 as a PhD student in the group of Rupert Huber at the University of Regensburg, where he has developed a novel ultrafast microscope tracing femtosecond dynamics of low-energy elementary excitations at the surface of nanometer-sized solids. He studied physics at the Technical University of Munich and at the Max Planck Institute of Quantum Optics, where he worked on femtosecond electron emission from sharp metal tips.

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