# HL 29: Symposium THZ interactions

Time: Wednesday 14:15–16:45 Location: H15

**Invited Talk** HL 29.1 Wed 14:15 H15

**Interaction of semiconductor laser dynamics with THz radiation** — •Martin Hofmann — AG Optoelektronische Bauelemente und Werkstoffe, Ruhr-Universität Bochum, 44780 Bochum

We discuss the generation and detection of THz radiation with semiconductor diode lasers. First, we analyse the generation of THz radiation by investigating a semiconductor laser in an external cavity arrangement that supports two colour operation with tunable difference frequency. Weak tunable THz emission is detected directly out of the diode laser, i.e. without external photomixing. We discuss the physical mechanisms underlying this direct THz emission and the potential of this concept in terms of THz bandwidth and an increase of the emitted THz power.

In the second part of the talk, the opposite process, i.e. THz detection with diode lasers is investigated. For that purpose, we inject THz radiation into the active region of a diode laser and analyse its dynamics under this injection. We observe a voltage variation over the p-n-junction depending on the injected THz power and compare the measured signal to the response of a standard Golay cell.

Finally, we review our results with particular emphasis on completely diode-laser based THz imaging or spectroscopy systems.

**Invited Talk** HL 29.2 Wed 14:45 H15

**Ultrafast THz Spectroscopy of Carrier Correlations in Complex Materials** — •Robert A. Kaindl — Department of Physics, UC Berkeley and Materials Sciences Division, E. O. Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

Coulomb interactions in a many-body system can lead to correlated states with fundamentally new physical properties. I will discuss experiments that employ coherent THz pulses and direct field-resolved detection to probe time-varying correlations of photoexcited electron-hole pairs and Cooper pair condensates. The THz electromagnetic response of short-lived exciton states in bulk and nanoscale semiconductors shows characteristic inter-level transitions in analogy to atoms. Intra-excitonic spectroscopy provides new tools to measure and control exciton gases. I will review experiments that trace the temperature, density, excitation energy, and time dependence of intra-excitonic resonances, to directly map out excitonic phase diagrams and to follow exciton formation and ionization kinetics. Moreover, in single-walled carbon nanotubes, THz pulses enable a contact-less detection of charge conductivity. In high-Tc superconductors, the THz-frequency electromagnetic response couples directly to Cooper pair condensates and to quasiparticle excitations. We observe transient changes in the THz conductivity of Bi-2212 that occur after ultrafast depletion of the superconducting condensate. The temporal decay reveals a bimolecular kinetics of charge pair formation. Work performed in collaboration with M. A. Carnahan, D. Hägele, R. Huber, B. A. Schmid, Y. Ma, G. Fleming, S. Oh, J. Eckstein, and D. S. Chemla.

**Invited Talk** HL 29.3 Wed 15:15 H15

**Interaction of THz Radiation with Semiconductor Nanostructures: Microscopic Theory** — •Stephan Koch and Mackillo Kira — Fachbereich Physik, Philipps-Universität Marburg, Renthof 5, 35032 Marburg

In this talk we review our microscopic approach to treat the interaction of excited semiconductor nanostructures with THz radiation. We use a systematic expansion of the relevant many-body interaction contributions, showing that THz absorption must involve at least two- or more-particle correlations. This feature uniquely qualifies THz spectroscopy as a method to directly detect and identify many-body correlations in a system of incoherent quasi-particle excitations. Applications of the theory to analyze excitonic population generation [1,2], the dynamic build-up of plasmon excitations [3,4], excitonic population inversion and THz gain [5], as well as THz generation in two-color semiconductor lasers [6] will be discussed.

[1] R. A. Kaindl et al., Nature 423, 734 (2003) [2] M. Kira et al., Solid State. Com. 129, 733 (2004) [3] R. Huber et al., Nature 414, 286 (2001) [4] M. Kira and S.W. Koch, Prog. Quant. Electron. (2007) [5] M. Kira and S.W. Koch, Phys. Rev. Lett. 93, 076402 (2004) [6] S. Hoffmann et al., Appl. Phys. Lett. 84, 3585 (2004)

**Invited Talk** HL 29.4 Wed 15:45 H15

**Nonlinear terahertz and midinfrared response of n-type GaAs** — •Michael Woerner[1], Peter Gaal[1], Wilhelm Kühn[1], Klaus Reimann[1], Thomas Elsaesser[1], Rudolph Hey[2], and Klaus Ploog[2] — [1]Max-Born-Institut , Berlin — [2]Paul-Drude-Institut, Berlin

In most THz experiments the THz radiation is used as a linear probe. Using THz radiation for nonlinear excitation requires the ability to generate high enough THz intensities. Our recent development of a simple and reliable method to generate THz pulses with high electric field amplitudes [1] has paved the way for nonlinear optics in the THz regime. We present two experiments on n-type GaAs which are in strong contrast to the predictions of Drude theory: (i) Nonlinear propagation of intense THz pulses through a thin n-type GaAs layer shows a coherent emission at 2 THz with a picosecond decay of the emitted field, despite the ultrafast carrier-carrier scattering at a sample temperature of 300 K [2]. While the linear THz response is in agreement with the Drude response of free electrons, the nonlinear response is dominated by the super-radiant decay of optically inverted impurity transitions. (ii) A nonlinear THz pump–midinfrared probe experiment shows a quantum kinetic phenomenon of the electron–LO phonon dynamics. Ultrafast acceleration of free carriers in n-type GaAs in a strong THz field results in an oscillatory occurrence of midinfrared gain/absorption with the LO phonon frequency. [1] T. Bartel et al., Opt. Lett. 30, 2805 (2005). [2] P. Gaal et al., Phys. Rev. Lett. 96, 187402 (2006).

**Invited Talk** HL 29.5 Wed 16:15 H15

**Terahertz near-field microscopy** — •Roland Kersting[1], Federico Buersgens[1], and Gyu Cheon Cho[2] — [1]University of Munich, Munich, Germany — [2]IMRA America, Ann Arbor, MI, USA

Many efforts in modern semiconductor physics target the integration of nano-objects and one important step towards this goal is the characterization of the nano-materials' electronic properties. Terahertz spectroscopy allows for studying the electronic response directly in the time domain, but the long wavelength of THz radiation (1 THz corresponds to about 0.3 mm) limits the spatial resolution to rather macroscopic scales.

In this contribution we present an apertureless near-field scanning optical microscope (ANSOM) for the THz range, which allows for spatial resolutions down to 150 nm. These extreme subwavelength resolutions are achieved by concentrating the incident THz radiation with a metal tip to a near-field spot, which's diameter is comparable to the tip's apex. The unexpected high image contrast of the THz-ANSOM results from a novel imaging process where the dielectric response of the material shifts the THz resonance of the sampling metal tip. The method is suitable for investigating the dielectric response of electrons in semiconductors. Currently, the sensitivity is sufficient to map as few as 5000 electrons. Further developments in apertureless terahertz microscopy may open up new vistas towards the contactless characterization of electronic quantum states in semiconductors.