HL 52: THz and MIR Physics in Semiconductors

Time: Friday 9:30–10:45 Location: POT/0006

HL 52.1 Fri 9:30 POT/0006

Probing Terahertz Emission and Structural Dynamics in Quasi-two-dimensional $NbOI_2$ — •Daniel Geyer[1], Rieke von Seggern[1], Soufiane El-Kabil[1], Zouchen Fu[3], and Sascha Schäfer[1,2] — [1]Department of Physics, University of Regensburg, Germany — [2]Regensburg Center for Ultrafast Nanoscopy (RUN), Germany — [3]Nankai University, Tianjin, China

Optically induced processes in matter, captured via time-resolved imaging methodologies, uncover a variety of transient phenomena evolving on ultrafast time scales. Layered ferroelectric niobium oxide dihalides $NbOX_2$ (X=I, Cl, Br) have garnered significant interest in this context, as they combine pronounced optical nonlinearities [1,2] with a ferroelectric order parameter that can be controlled via optical stimuli [3]. In this work, we investigate the $NbOI_2$ compound as a material platform in which both regimes of ultrafast light-matter interaction can be accessed within different experimental approaches.

At first, we explore thin $NbOI_2$ flakes as promising stackable terahertz (THz) emitters. We demonstrate broadband THz generation via nonlinear optical rectification, characterized using a time-domain THz emission spectroscopy setup.

Secondly, we discuss the photoinduced evolution of the material's ferroelectric polarization, employing time-resolved electron diffraction in an ultrafast transmission electron microscope (UTEM).

[1] Guo et. al., Nature **613**, 53-59 (2023)
[2] Chen et. al., Adv. Mater. **36**, 2400858 (2024)
[3] Wang et. al., Nat. Comm. **16**, 8132 (2025)

HL 52.2 Fri 9:45 POT/0006

AlGaN/GaN-based grating-gate plasmonic crystals for nonlinear THz applications — Pavlo Sai[1], Vadym V. Korotyeyev[2], Serhii Kukhtaruk[2], Dmytro B. But[1], Maksym Dub[1], Alexej Pashkin[3], Stephan Winnerl[3], Wojciech Knap[1], and •Martin Mittendorff[4] — [1]Institute of High Pressure Physics PAS ul. Sokołowska 29/37, Warsaw 01-142, Poland — [2]V. Ye. Lashkaryov Institute of Semiconductor Physics (ISP) NASU prospect Nauky 41, Kyiv 03028, Ukraine — [3]Helmholtz-Zentrum Dresden-Rossendorf 01328 Dresden, Germany — [4]Universität Duisburg-Essen Fakultät für Physik 47057 Duisburg, Germany

We present time-resolved THz measurements on grating-gate plasmonic crystals, based on the two-dimensional interface electron gas in epitaxial GaN/AlGaN heterostructures. The free-electron laser FELBE at Helmholtz-Zentrum Dresden-Rossendorf served as tunable source for intense, narrowband THz pulses at about 1.8 THz, the plasmon frequency was tuned via the grating-gate. The strongest pump-probe signals are observed at resonance, where a rather low pump fluence of about $200\, nJ/cm^2$ leads to a pump-induced change in transmission of more than 40% [1]. The signal decays within about 50 ps. The experimental results are complemented by a finite-difference time-domain electrodynamic simulation, allowing to identify the main driving mechanisms for the observed strong nonlinearity, e.g. near-field effects and hot charge carriers.

[1] P. Sai et al., Adv. Optical Mater. 2025, 13, 2500716; https://doi.org/10.1002/adom.202500716

HL 52.3 Fri 10:00 POT/0006

Plasmonic nonlinearity in AlGaN/GaN-based rectangular patches — •Nandita Bajpai[1], Pavlo Sai[2,4], Maksym Dub[2,4], Alexej Pashkin[3], Stephan Winnerl[3], Wojciech Knap[2,4], and Martin Mittendorff[1] — [1]Department of Physics, University of Duisbur-Essen,Duisburg,Germany — [2]Institute of HighPressure-Physics,Warsaw,Poland — [3]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [4]Center for Terahertz Sciences and Applications CENTERA -CEZAMAT Warsaw University of Technology, Warsaw, Poland

Recent observation of enhanced nonlinear THz absorption by resonant excitation of 2D plasmons in the AlGaN/GaN based plasmonic crystal has revealed a strong pump-induced transparency of probe upto 45%[1].Here, we investigate the nonlinear coupling between the perpendicular plasmonic modes in AlGaN/GaN-based rectangular patches. To this end, we performed a two colour pump probe experiment at the free-electron laser facility at the Helmholtz-Zentrum Dresden-Rossendorf. The spectrally narrow pump pulse was used to drive the plasmonic resonance at 1.95 THz whereas a broadband THz pulse from a synchronized table-top time domain spectroscopy setup was exploited to probe the plasmonic mode at 1.38 THz. We observed a relative pump - induced change in transmission of probe upto 12%, which is attributed to the excitation of hot carriers that decays within 25ps.

[1] P.Sai et al., Adv. Optical Matter.2025,13,2500716; https://doi.org/10.1002/adom.202500716

HL 52.4 Fri 10:15 POT/0006

Elucidating carrier dynamics in bismuth thin film with time-resolved terahertz spectroscopy — •Gurivireddy Yettapu, Fabian Thiemann, Michael Horn-von Hoegen, and Martin Mittendorff — University of Duisburg-Essen, Duisburg, Germany

Bismuth (Bi) is a Peierls distorted semimetal in its bulk state that transforms into a semiconductor for thicknesses below ~30 nm [1]. Time-resolved terahertz spectroscopy is an ideal tool to investigate the charge carrier dynamics by following the pump-induced change in electric field with pump-probe delay. Herein, we employed optical-pump terahertz-probe spectroscopy to elucidate the carrier dynamics in single crystalline Bi film with a thickness ~36 nm, including spectrally resolved measurements to determine the frequency dependent complex conductivity. At a pump fluence of 30 uJ/cm2, we observe a pump-induced change of the electric field of about 20 %, followed by an exponential decay with a relaxation time of ~7 ps. Our results reveal that carrier relaxation times are hardly affected by the pump fluence, the complex conductivity can be well described by the Drude model. Our future studies include thickness- and temperature-dependent measurements to gain insights about the carrier-lattice interactions in the semiconductor and semimetal phase. [1] C. A. Hoffman et al., Phys. Rev. B. 48, 11431-11434 (1993).

HL 52.5 Fri 10:30 POT/0006

Identifying the semiconductor doping range addressable by terahertz time-domain spectroscopy — •Joshua Hennig[1,2], Jens Klier[1], Stefan Duran[1], Mirco Kutas[1,2], Georg von Freymann[1,2], and Daniel Molter[1] — [1]Department for Materials Characterization and Testing, Fraunhofer Institute for Industrial Mathematics ITWM, 67663 Kaiserslautern, Germany — [2]Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Semiconductors are essential materials for the technological advancements of the 21st century. With the growing demand for semiconductor devices going along with this, the need for fast and non-destructive characterization techniques is growing quickly, too. Terahertz time-domain spectroscopy (THz-TDS) has proven to be capable of measuring the desired properties of various semiconductors over the last decades. Yet, it is still not widely established for this purpose. One reason is that for each combination of material, doping concentration and thickness the possibility to characterize the sample has to be evaluated individually. Therefore, we are developing a simulation-based tool that can help identify the accessible doping ranges. Based on simulations of the interaction between a terahertz pulse and an arbitrary layer stack of doped semiconductor materials, a well-founded estimate of the characterizability with reflection THz-TDS is retrieved. These simulations allow for a better understanding of the suitability of a THz-TDS characterization for specific semiconductor samples and hence to establish THz-TDS further in the semiconductor industry.