O 20: Poster Scanning Probe Microscopy: Light-Matter Interactions at the Atomic Scale

Time: Monday 18:00–20:00 Location: P2

O 20.1 Mon 18:00 P2

Generation of single cycle terahertz pulses for a THz-STM and improvement of the current measurement noise — •Paul Wiechers, Christian Lotze, Florian Faaber, Vibhuti Rai, and Katharina J. Franke — Freie Universität Berlin, Fachbereich Physik,Arnimallee 14, 14195 Berlin, Germany

Terahertz Scanning Tunneling Microscopy (THz-STM) aims to combine the atomic spatial resolution of STM with the sub-picosecond time resolution commonly achieved through optical pump-probe techniques.

We generate single-cycle terahertz pulses by optical rectification and short optical pulses of various wavelengths. Particular care is taken to minimize pointing deviations of the beams, ensuring proper focusing in the STM junction, even under varying beam delay positions.

In a THz-STM experiment, the measured quantity is the low-bandwidth tunneling current. The THz-induced part of that current, due to the low duty cycle ($\sim 10^{-5}$) of the THz pulses, is very small. Thus, a thorough understanding of the limiting noise sources in the measurement is important. Here, we characterize a cryogenic low-noise ammeter and increase its prohibitively low bandwidth by more than two orders of magnitude.

O 20.2 Mon 18:00 P2

Local excitation of coherent phonons in 2H-$MoTe_2$ by THz driven scanning tunnelling microscope — Vibhuti Rai, Junyoung Sim, •Florian Faaber, Sergey Trishin, Nils Bogdanoff, Tom Seifert, Tobias Kampfrath, Christian Lotze, and Katharina J. Franke — Freie Universität Berlin, Department of Physics, Arnimallee 14,14195 Berlin, Germany

The coupling of THz pulses into a scanning tunnelling microscope has emerged as a unique technique to achieve picosecond time resolution while maintaining sub nanometer spatial resolution [1,2]. By delaying one THz pulse with respect to the other while recording the current rectified by the two pulses, a pump-probe scheme can be realized [3]. In this work, we use this scheme to investigate the quasi 2D semiconducting transition metal dichalcogenide (TMD) 2H-$MoTe_2$ at 7K in ultra-high vacuum and find a large oscillatory rectified current that is slowly decaying over 50 ps. We attribute these oscillations to the excitation of coherent phonons and discuss the effect of defects and DC bias voltage on the excited modes.

[1] Cocker, et al., Nature Photonics 7, 620*625 (2013)
[2] V. Jelic et al., Nature Physics 13, 591 (2017)
[3] T. L. Cocker et al., Nature 539, 263 (2016)

O 20.3 Mon 18:00 P2

Charging of atomic defects in 2H-$MoTe_2$ under infrared illumination — •Friedemann Lohss, Florian Faaber, Vibhuti Rai, Junyoung Sim, Christian Lotze, and Katharina J. Franke — Freie Universität Berlin, Department of Physics, Arnimallee 14,14195 Berlin, Germany

The electronic properties of semiconductors are heavily shaped by the concentration and type of defects present in the material. The sub-nanometer resolution of scanning tunneling microscopy (STM) allows to locally probe such defects. Here we characterize the response of the semiconductor 2H-$MoTe_2$ to infrared illumination in an STM at cryogenic temperature. We observe the formation of disc-shaped regions of increased conductivity around some local defects, likely stemming from charging and tip-induced band bending. We characterize the different defect states occuring in this material.

O 20.4 Mon 18:00 P2

Two-Color Pump-Probe STM of Coherent Phonon Dynamics in Ultrathin ZnO/Ag(111) — •Henrik Wiedenhaupt[1], Shuyi Liu[2], Akitoshi Shiotari[1], Adnan Hammud[1], Daniel Wegkamp[1], Martin Wolf[1], Takashi Kumagai[3], and Melanie Müller[1] — [1]Fritz Haber Institute of MPG, Berlin, Germany. — [2]Huazhong University of Science & Technology, Wuhan, China. — [3]Institute for Molecular Science, Okazaki, Japan.

We use photon-assisted ultrafast scanning tunneling microscopy (ph-USTM) to study coherent phonon (CP) dynamics in optically excited ZnO/Ag(111). In recent work, we have shown that resonant single-color ph-USTM enables CP spectroscopy on 3ML-ZnO/Ag(111) with nanometer spatial resolution [1], where the optical resonance between an interface state (IS) and the ZnO conduction band edge (CBE) appears to play an important role, as also observed in tip-enhanced Raman spectroscopy (TERS) [2]. However, the detailed mechanisms by which the CPs modulate the photocurrent and of their local excitation remain unclear. To gain further insight, we implement two-color ph-USTM for the selective on- and off-resonant ultrafast excitation of the IS-CBE transition on 2ML-ZnO and 3ML-ZnO. Besides demonstrating local CP spectroscopy also on 2ML-ZnO, our results show that CPs can also be excited off-resonantly, while optically resonant photon-assisted tunneling seems to be more crucial for local CP detection via ph-USTM. We explain our observations by phonon-induced transient changes in the local dielectric response. [1] S. Liu et al., Sci. Adv. 8, 42, eabq5682 (2022) [2] S. Liu et al., Nano Lett. 19, 8, 5725 (2019)

O 20.5 Mon 18:00 P2

Plasmonic STM-luminescence driven by a high-power spintronic THz emitter — •Alkisti Vaitsi, Luis Enrique Parra López, Vivien Sleziona, Martin Wolf, and Melanie Müller — Fritz Haber Institute of the Max Planck Society, Berlin, Germany

We demonstrate THz-induced STM-luminescence (THz-STML) from a plasmonic tunnel junction driven by broadband single-cycle THz pulses generated from a high-power rotating spintronic THz emitter (STE). By measuring the dependence of the plasmonic luminescence on the static STM bias and the THz-STM bias, we aim for a purely data-driven approach to calibrate the THz peak bias via reconstruction of the THz-STML spectra from the static reference STML spectra. Our results proof the capability of the rotating STE to generate several Volts peak THz bias in a metallic STM junction and pave the way for future time-resolved gating of STM-luminescence from excitonic quantum emitters.

[1] Kimura et al., ACS Photonics 8, 4, 982-987 (2021)
[2] Vaitsi et al., Appl. Phys. Lett. 125, 071107 (2024)

O 20.6 Mon 18:00 P2

Scanning Quantum Microscopy for Emergent Phases of Matter — •Ruoming Peng[1], Sreehari Jayaram[1], Malik Lenger[1], King Cho Wong[1], Xuankai Zhou[1], Yan Tug Kong[1], and Joerg Wrachtrup[1,2] — [1]3. Physikalisches Institut, University of Stuttgart, 70569 Stuttgart, Germany — [2]Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany

Scanning quantum microscopy using NV centers in diamond enables direct visualization of condensed matter phenomena. Applying this technique, we uncover the emergence of a super-Moiré magnetic texture in twisted double bilayer CrI3, distinct from the geometric Moiré periodicity at small twist angles. Additionally, we investigate vortex dynamics in thin-layer 2H-NbSe2, revealing vortex melting behaviors during different thermal cycling and unconventional magnetic noise arising from the vortex dynamics. Our findings highlight the strong capability of scanning quantum microscopy to unravel nanoscale magnetic interactions and dynamic phases in 2D materials.

O 20.7 Mon 18:00 P2

A theoretical perspective on electroluminescence, photoluminescence and photocurrent generation in a scanning tunneling microscope — •Tomáš Neuman[1], Sofia Canola[1], Rodrigo Ferreira[1], Anna Roslawska[2], Katharina Kaiser[3], Alex Boeglin[4], Andrei Borisov[5], Guillaume Schull[4], and Martin Švec[1] — [1]Institute of Physics of the Czech Academy of Sciences, Prague, Czechia — [2]Max Planck Institute for Solid State Research, Stuttgart, Germany — [3]Georg-August-Universität Göttingen, Göttingen, Germany — [4]Université de Strasbourg, IPCMS, CNRS, UMR 7504, Strasbourg, France — [5]Université Paris-Saclay, Institut des Sciences Moléculaires d'Orsay, CNRS, UMR 8214, Orsay, France

The phenomena occurring in a scanning tunneling microscope (STM) that lead to the generation of light or are triggered by light (STM+light, STM+L), including the STM-induced luminescence and photocurrent generation in single molecules, allowed for studying excited states of molecules in a STM. As the underlying principles of these phenomena involve electron tunneling, plasmon-enhanced optical absorption and spontaneous emission, and vibronic effects, interpreting these STM+L experiments hinges on the development of theoretical models. I will show such modelling strategies and showcase

its application to recent experiments. In particular, I will focus on the theory of mapping of orbitals of a multireference excited state of a small molecule (perylene tetracarboxylic dianhydride - PTCDA) via photocurrent generation, whose explanation requires all the mentioned ingredients.

O 20.8 Mon 18:00 P2

Neutral Exciton-Libron Coupling via Resonant Energy Transfer in Single Molecules — •Thiago G. L. Brito[1], Klaus Kuhnke[1], Klaus Kern[1,2], and Anna Rosławska[1] — [1]Max Planck Institute for Solid State Research, Heisenbergstr. 1, 70569 Stuttgart, Germany — [2]École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

The optical properties of single molecules can vary depending on their environment. In some surroundings, vibrations due to frustrated rotations (librations) may occur if the molecules feature some rotational freedom. In this study, we provide evidence of coupling between neutral excitons and libration modes (librons). We observed this coupling through light emission resulting from resonant energy transfer (RET). We measured neutral and charged exciton emissions in isolated zinc phthalocyanine (ZnPc) and ZnPc-platinum phthalocyanine (PtPc) assemblies deposited on NaCl/Ag(111) using scanning tunneling microscopy induced luminescence (STML). For isolated ZnPc, we observed a broad peak from the neutral exciton and exciton-libron coupling for the charged exciton. In contrast, in ZnPc-PtPc structures, we found libronic signatures in the neutral emission of ZnPc when excited via RET from PtPc. This study is providing deeper insights into exciton-libron dynamics in single molecules.

O 20.9 Mon 18:00 P2

Mapping adsorbed states of iron(II) phthalocyanine on Ag surfaces by plasmon-enhanced Raman spectroscopy — Borja Cirera[1], •Rodrigo Cezar de Campos Ferreira[2,3], Amandeep Sagwal[2], Jiří Doležal[3], Martin Švec[2,3], and Pablo Merino[1] — [1]Instituto de Ciencia de Materiales de Madrid, Spain — [2]Institute of Physics, Czech Academy of Sciences, Czech Republic — [3]Institute of Organic Chemistry and Biochemistry, Czech Academy of Sciences, Czech Republic

The high spatial confinement of a plasmonic field in LT-SPM has become a valuable tool for near-field spectroscopies. Among the techniques, Raman scattering enables chemical identification, investigation of relations between adsorption geometry and vibrational fingerprints in real space at single-molecule level.[1,2] Here we studied different adsorption configurations of iron(II) phthalocyanines (FePc) on Ag(110) and Ag(111) crystal surfaces. Real-space mapping reveals the appearance of shifted Raman states when adsorbed in specific geometries. Results and simulations suggest that the breaking in symmetry with respect to the main crystallographic directions of the substrates are the leading reason for this phenomenon. [1] Y. Zhang et. al. Nature 498, 82-86 (2013). [2] R. Zhang et. al. National Science Review, Volume 6, 2019, 1169-1175.

O 20.10 Mon 18:00 P2

Investigations of the plasmon excitation of C60 multilayers on Au(111) using STM induced luminescence — •Andreas Reutter, Yannis Hilgers, Markus Etzkorn, and Uta Schlickum — Institute of Applied Physics - LENA, TU Braunschweig

In recent years, Scanning Tunneling Microscopy induced luminescence (STML) has gathered great interest, as it allows to investigate optical properties in addition to normal STM measurements, both with atomic spatial resolution. Since its development, the main challenge of this method is to obtain reasonable photon intensities.

We succeeded in building a setup with a greatly increased detection efficiency by using a parabolic mirror inside the STM, that covers 75% of the upper hemisphere.

Here, we present STML measurements of surface plasmons on C60 on Au(111) as a model system for the effects of an organic semiconductor on a metal surface [1]. We will present conductance and optical spectroscopy measurements as well as photon yields for different number fo C60 layers and different applied voltages.

[1] Große, Christoph; Merino, Pablo; Rosławska, Anna; Gunnarsson, Olle; Kuhnke, Klaus; Kern, Klaus; ACS Nano, 11, 1230 (2017).

O 20.11 Mon 18:00 P2

Resonant energy transfer as a function of distance between metal-phthalocyanine molecules — •Roel Burgwal, Nikhil Seeja Sivakumar, Joëlle J. A. Schrijer, Alexander A. Khajetoorians, and Daniel Wegner — Institute for Molecules and Materials, Radboud University, 6500 GL Nijmegen, The Netherlands

Resonant transfer of energy (RET) between molecules is a process ubiquitous in nature that also has interesting technological applications. The rate of RET decreases as the molecules involved are spaced further apart, with the distance dependence determined by the exact mechanism responsible for energy transfer. Two possible mechanisms are electrodynamical Förster energy transfer (FRET) and the electron tunneling-based Dexter energy transfer (DET). Recent advances in scanning tunneling microscope-induced luminescence (STML) have made it possible to observe energy transfer between single molecules and to control the spacing between these with sub-nanometer precision. So far, STML measurements of RET distance dependence resemble more the exponential behavior of DET, in contrast with the commonly assumed FRET mechanism. However, it has been proposed this apparent behavior may be a plasmonic effect arising from the varying distance between STML-tip and acceptor molecule. Here, we study RET between different metal-phthalocyanine molecules while elucidating the role of the plasmon through complementary measurements.