KFM 5: New Methods and Developments: Scanning Probe Techniques 1 (joint session O/KFM)

Time: Monday 10:30–13:00 Location: S053

Topical Talk KFM 5.1 Mon 10:30 S053

Identification of active electrocatalytic centers using EC-STM under reaction conditions — •Aliaksandr Bandarenka — Technical University of Munich, Department of Physics, James-Franck-Str 1, 85748 Garching bei München, Germany

Identification of so-called active electrocatalytic centres can be very complicated under reaction conditions. In many cases, electrochemical scanning tunnelling microscopy can be efficiently used to do so by comparing the tunnelling noise in the presence and the absence of the electrocatalytic reactions. I the presentation, I will discuss examples, which deal with finding the active sites at the surface of various electrodes for hydrogen evolution, oxygen reduction, and oxygen evolution reactions. Pt, HOPG, Pt-alloys, and transition metal oxides are used as the model systems.

KFM 5.2 Mon 11:00 S053

Coherent Noise Removal for Scanning Probe Microscopy — Jens Oppliger, Danyang Liu, and •Fabian Donat Natterer — Department of Physics, University of Zurich, Winterthurerstrasse 190, CH-8057, Switzerland

Despite the best efforts to isolate the weak signals in scanning probe microscopes from sources of noise, white and coherent noise remain major nuisances. While the presence of Gaussian white noise can be handled with temporal averaging, the influence of high-Q coherent noise, such as coming from ground-loops or mechanical resonances, is less straightforward to delete when rastering along the surface. Such noise leads to characteristic streaks and spurious Bragg peaks in the Fourier transform of two-dimensional data. Here we demonstrate a straightforward method to remove coherent noise using data-labelling and exemplify its working for quasiparticle interference and topographic imaging.

KFM 5.3 Mon 11:15 S053

General, Strong Impurity-Strength Dependence of Quasiparticle Interference — •Seung-Ju Hong[1], Jae-Mo Lihm[1,2,3], and Cheol-Hwan Park[1,2,3] — [1]Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea — [2]Center for Correlated Electron Systems, Institute for Basic Science, Seoul 08826, South Korea — [3]Center for Theoretical Physics, Seoul National University, Seoul 08826, South Korea

Quasiparticle interference patterns induced by impurities contain information about electronic structures in momentum space. In this presentation, we show that the interpretation of quasiparticle interference patterns is not trivial and needs special care. Even in the simple case of a single-site impurity on the square lattice, the pattern is strongly dependent on the strength of impurity potential. For example, the wave vector with the strongest scattering differs by about 16% in spin-dependent JDOS and exact QPI computations. We also showed that this dependence can be analyzed by decomposing the pattern into the impurity-dependent T-matrix part and momentum-dependent Green function part. We applied our formalism to TaAs, an archetype Weyl semimetal with first-principles calculations. We find that the strong dependence on impurities is also present in TaAs. Thus, our work demonstrates that these quasiparticle interference patterns must be analyzed with care and needs more attention.

Reference [1] S.-J. Hong, J.-M. Lihm, and C.-H. Park, J. Phys. Chem. C 2021, 125, 13, 7488-7494

KFM 5.4 Mon 11:30 S053

Real-space sub-femtosecond imaging of quantum electronic coherences in molecules — Manish Garg[1], •Alberto Martin-Jimenez[1], Michele Pisarra[2], Yang Luo[1], Fernando Martin[2,3,4], and Klaus Kern[1,5] — [1]Max Planck Institute for Solid State Research, Stuttgart, Germany — [2]Instituto Madrileño de Estudios Avanzados en Nanociencia (IMDEA Nano), Madrid, Spain — [3]Universidad Autonoma de Madrid (UAM), Madrid, Spain — [4]Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Madrid, Spain — [5]Institut de Physique, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

Tracking electron motion in molecules is the key to understand and control chemical transformations. Contemporary techniques in attosecond science have the capability to generate and trace the consequences of this motion in real time, but not in real space. Scanning tunnelling microscopy (STM), on the other hand, can locally probe the valence electron density in molecules, but cannot provide by itself dynamical information at this ultrafast time-scale. Here we show that, by combining STM and attosecond technologies, quantum electronic coherences induced in molecules by $<$ 6 femtosecond long carrier-envelope-phase (CEP) stable near-infrared laser pulses can be directly visualized with angstrom-scale spatial and sub-femtosecond temporal resolutions. We demonstrate concurrent real-space and real-time imaging of coherences involving the valence orbitals of perylene-tetracarboxylic dianhydride (PTCDA) molecules, and full control over the population of the involved orbitals.

KFM 5.5 Mon 11:45 S053

Femtosecond Tip-Enhanced Coherent Anti-Stokes Raman Spectroscopy of a Single Graphene Nanoribbon — •Yang Luo[1], Alberto Martin-Jimenez[1], Manish Garg[1], and Klaus Kern[1,2] — [1]Max Planck Institute for Solid State Research, Stuttgart, Germany — [2]Institut de Physique, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

By integration of ultrashort laser pulses with a scanning tunneling microscope (STM) one can study the electronic and carrier dynamics with very high spatial and temporal resolution. Nevertheless, molecular vibrational modes at the single-molecule level are difficult to track, owing to the lack of energy resolution. To overcome this barrier, we have now integrated a local spectroscopic tool, combining ultrafast laser pulses with an STM-based tip-enhanced Raman spectroscopy (TERS). By performing TERS with femtosecond laser pulses, we have tracked vibrational coherences and phonon dephasing dynamics in a single graphene nanoribbon (7-GNR). The decoherence time (T2/2 ~ 440 fs) of the phonons in a GNR has been obtained from the time-resolved coherent anti-Stokes Raman spectra. Temporal evolution of vibrational coherences (beatings) between different phonon modes in the GNR has been measured, which evolve on time scales as short as ~ 100 fs. This work lays the foundation for investigating intramolecular vibrational coherences and vibronic dynamics with utmost spatial, temporal and energy resolutions, simultaneously.

KFM 5.6 Mon 12:00 S053

Coherent phonon spectroscopy on the nanoscale — Shuyi Liu[1], Adnan Hammud[1], Ikutaro Hamada[2], Martin Wolf[1], •Melanie Müller[1], and Takashi Kumagai[3] — [1]Fritz-Haber-Institut, Berlin, Germany — [2]College of Materials Science and Engineering, Hunan, China — [3]Institute for Molecular Science, Okazaki, Japan

Coherent phonon (CP) spectroscopy is a powerful tool to monitor ultrafast lattice dynamics under nonequilibrium conditions, providing insight into microscopic interactions that dictate macroscopic material properties. In imperfect crystals, the excitation and relaxation of CPs will be susceptible to the nanoscale environment, calling for real-space observation of ultrafast lattice dynamics. We demonstrate nanoscale coherent phonon spectroscopy by means of ultrafast laser-induced scanning tunneling microscopy (STM) in a plasmonic junction. Comparison of the CP spectra with tip-enhanced Raman spectroscopy allows us to identify the involved phonon modes. In contrast to the Raman spectra, the relative CP intensities exhibit strong nanoscale spatial variations, which correlate with changes in the local density of states recorded via scanning tunneling spectroscopy. Our work introduces a new approach to study the ultrafast structural response at solid surfaces using optical STM.

KFM 5.7 Mon 12:15 S053

Construction of a dry low temperature STM — •Simon Gerber[1] and Wulf Wulfhekel[2] — [1]Physikalisches Institut, Karlsruhe Institute of Technology — [2]Physikalisches Institut, Karlsruhe Institute of Technology

Driven by rising helium prices, we design a dry, low temperature Scanning Tunneling Microscope with a closed helium cycle. We designed a compact dry four stage cryostat with an integrated dilution refrigerator which is cooled using helium from a 400 mW cold head. The STM is

connected to the dilution refrigerator and allows measurements down to millikelvin temperatures. The system is mechanically decoupled at several points to minimize vibrations from the cold head reaching the STM. The microscope is positioned inside a split-coil magnet with magnetic fields up to 4T. Optical Access to the STM is possible in the parked position and allows fast tip and sample exchange. The tips and samples can then be prepared under UHV conditions. The complete cryostat and and the STM are home-built.

KFM 5.8 Mon 12:30 S053

Probing tunneling processes into YSR states with microwaves — •Janis Siebrecht[1], Haonan Huang[1], Piotr Kot[1], Sujoy Karan[1], Ciprian Padurariu[2], Björn Kubala[2], Joachim Ankerhold[2], Alfredo Levy Yeyati[3], Juan Carlos Cuevas[3], and Christian R. Ast[1] — [1]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany — [2]Institut für Komplexe Quantensysteme and IQST, Universität Ulm, Ulm, Germany — [3]Departamento de Física Teórica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Madrid, Spain

Microwaves are an important tool in the manipulation of multi-level systems such as single spins on a surface, nitrogen vacancies in diamond or double quantum dots. Here we use a scanning tunneling microscope (STM) at a base temperature of 0.56 K to probe the intrinsic YSR states in a Vanadium tip in contact with a V(100) surface. The addition of an E-Band (60-90 GHz) microwave antenna at the junction opens the possibility to study the behavior of YSR states with AC driving- a scenario which has been subject to many theoretical but very few experimental studies. Using microwave-assisted tunneling, we gain insight into how the excited state participates in the tunneling process and how this is related to Andreev processes and parity conservation. Our results point at a new path, namely microwave manipulation of YSR states, which could be an important step towards using YSR states as qubits.

KFM 5.9 Mon 12:45 S053

Compressed fingerprint spectroscopy based on scanning microscopy — •Bernd Kästner[1], Manuel Marschall[1], Arne Hoehl[1], Andrea Hornemann[1], Gerd Wübbeler[1], Selma Metzner[1], Piotr Patoka[2], Eckart Rühl[2], and Clemens Elster[1] — [1]Physikalisch-Technische Bundesanstalt, Berlin, Germany — [2]Freie Universität Berlin, Germany

The infrared spectral region between 400 and 4000 cm^{-1} is called the fingerprint region, because the absorption features are unique to individual organic substances. Such a spectrum usually contains many peaks, making it difficult to link individual peaks to the substance. Consequently, the spatial mapping of substances requires spectral imaging, where at each point in space a complete spectrum needs to be recorded. Usually this can be achieved by spectrometers equipped with array detectors. Recently, scanning methods based on the optical nearfield and local thermal expansion with nanoscale spatial resolution have been developed allowing sub-diffraction spectral imaging. However, the inherently serial recording severely limits their imaging application due to long acquisition times involved and the resulting stability issues. In this work we demonstrate different strategies to significantly reduce the measurement time in spectral imaging measurement by compressing the measurement combined with a low-rank matrix reconstruction. Several examples from different fields of application will be discussed.