TECHNISCHE UNIVERSITÄT DRESDEN

IFMP
Institut für Festkörper- & Materialphysik

Fakultät Physik

Datum: 19.02.2020

SFB 1143
Quantum Materials
Workshop

When: **25. & 26.2.2020, 10:00–12:10**
Where: **25.02. - REC/C213**
26.02. – REC/B214

<u>**25.2.2020**</u>

10:00 – 10:40	**Prof. Jan Hugo Dil** Ecole Polytechnique Fédérale de Lausanne
10:45 – 11:25	**Prof. Sven Friedemann** University of Bristol
11:30 – 12:10	**Jun.-Prof. Benjamin Stadtmüller** Technische Universität Kaiserslautern

<u>**26.2.2020**</u>

10:00 – 10:40	**Prof. Rolf Walter Lortz** Hong Kong University of Science and Technology
10:45 – 11:25	**Dr. Anna Böhmer** Karlsruher Institut für Technologie
11:30 – 12:10	**Jun.-Prof. Stefan Kaiser** Universität Stuttgart

Kontakt: Prof. Jochen Geck

Prof. Jan Hugo Dil
Ecole Polytechnique Fédérale de Lausanne

Title:
Spin-resolved spectroscopy for the study of topological and correlated materials

Abstract:

Electron-based spectroscopy techniques have, for many decades, been playing an important role in the study of materials with novel electronic properties. Especially angle-resolved photoemission spectroscopy (ARPES) has provided important insights in the understanding of correlated materials. The addition of spin resolution (SARPES) has received much attention with the study of topological materials, but before these results it was already used to investigate ferromagnets and Rashba systems. After a short overview of results for systems with strong spin-orbit interaction, it will be shown how SARPES can be used to study hidden observables and to obtain additional information on correlated systems. To indicate how the use of spin-resolved spectroscopy can develop in the near future, examples of quantum time measurements, operando manipulation of multiferroics, and entanglement spectroscopy will be given.

Prof. Sven Friedemann
University of Bristol

Title:
Tuning Electronic Quantum Materials

Abstract:
Electronic Quantum Materials are characterised by strong interactions between electrons giving rise to exciting new phenomena and properties. For instance, many ordered states are formed due to the electronic interactions including superconductivity and magnetism. Such states are the basis for applications like magnetic resonance imaging used in medicine. We use measurements of magnetic, thermodynamic, and electronic bulk properties whilst tuning the materials in extreme conditions of high pressure, large magnetic fields, and low temperatures to unravel the mechanism and underlying electronic interactions. The comparison of our results with models and theories contributes to a better understanding and may provide the basis for future applications.
In my talk, I will present an overview of our studies of electronic quantum materials ranging from magnetic phase transitions at zero temperature to high-temperature superconductivity at high pressures. For instance, we have discovered a new class of magnetic phase transitions at zero temperature: a so-called quantum tricritical point giving rise to quantum fluctuations associated with two ordered states1. We demonstrate how this arises in the ferromagnet NbSe2. As another example, I will present results from our high-pressure studies of conventional and unconventional superconductors where we observe peculiar competition between superconductivity and charge order. I will conclude with and outlook including record superconductors with transition temperatures approaching room temperature.

Jun.-Prof. Benjamin Stadtmüller
Technische Universität Kaiserslautern

Title:
Ultrafast Spin and Charge Transfer Phenomena in Magnetic and Functional Materials

Abstract:
The growing demand for information technology with higher data processing speed and data storage capacity has started the quest to control and functionalize materials on smaller length and shorter timescales. In this context, optical excitations with femtosecond light pulses offer the intriguing opportunity to control materials on ever-shorter timescales, ultimately down to the duration of the optical excitation itself. In most cases, however, the optically induced dynamics evolve on significantly longer timescales that are dominated by the intrinsic energy, charge and spin transfer processes of the materials.

After a detailed introduction into our research, I will focus on two exemplary cases, for which the timescale of the optically induced material response is dominated by spin and charge transfer processes.

For magnetic materials, I will introduce a novel approach to control the spin order of magnetic alloys by optically induced spin transfer processes. I will show that fs light pulses with selected photon energies can trigger an ultrafast exchange of spin carriers between the magnetic sub-systems of alloys that can instantly enhance or reduce their spin order [1]. This highly energy efficient process results in a strong non- equilibrium in the combined spin-system of the material that severely affects the subsequent magnetization dynamics medicated by secondary processes such as exchange or spin-flip scattering.

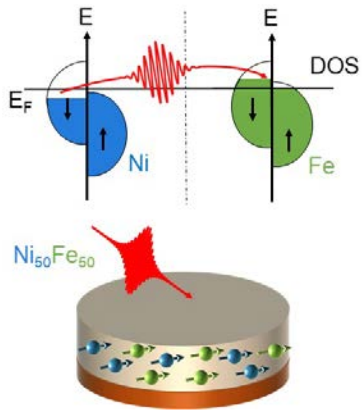

Illustration of the optically induced spin transfer process in magnetic alloys.

Subsequently, I will turn to the optically induced charge carrier dynamics in functional molecular materials. They are particularly interesting due to their complex photo physics that is dominated by bound electron-hole pairs, called excitons. These excitonic quasi-particles can be responsible for a long-lived trapping of charge carriers in these materials. For fullerene complexes, I will demonstrate that the exciton dissociation time of charge transfer excitons [2] in molecular materials can be significantly reduced by additional charge transfer processes due to alkali-metal doping.

In this way, my presentation will provide a clear vision for manipulating low dimensional quantum materials, topological systems and spin-ordered functional materials by optically induced and chemically engineered spin and charge transfer processes.

[1] M. Hofherr et al. Sci. Adv. 6 eaay8717 (2020)
[2] B. Stadtmüller et al. Nat. Commun. 10, 1470 (2019)

Prof. Rolf Walter Lortz
Hong Kong University of Science and Technology

Title:
Topological superconducting phases in 2D and 3D materials

Abstract:
In this talk I give an overview of our recent research on 2D and 3D topological superconducting materials. I will focus on the doped topological insulator Bi2Se3 and on heterostructures between a quantum anomalous Hall insulator and a superconductor.
A nematic topological superconductor has an order parameter symmetry, which spontaneously breaks the crystalline symmetry in its superconducting state. This state can be observed, for example, by thermodynamic or upper critical field experiments in which a magnetic field is rotated with respect to the crystalline axes, but also directly from the anisotropic gap symmetry in scanning tunneling probe experiments. We present a study on the upper critical field of the Nb-doped Bi2Se3 for various magnetic field orientations parallel to the basal plane of the Bi2Se3 layers. The data clearly demonstrate a two-fold symmetry that breaks the three-fold crystal symmetry. This provides strong experimental evidence that Nb-doped Bi2Se3 is a nematic topological superconductor similar to the Cu- and Sr-doped Bi2Se3, and rules out earlier suggestions that the finite magnetic moment of the intercalated Nb ions could instead induce a chiral superconducting state.
We then show that in doped Bi2Se3, the nematic order arises from a multicomponent order parameter where superconductivity is the primary order and the nematic order an intertwined secondary order. Such a state of matter with a multi-component order parameter can give rise to a vestigial order. In the vestigial phase, the primary order is only partially melted, leaving a remaining symmetry breaking behind, an effect driven by strong classical or quantum fluctuations. We present the observation of a partially melted superconductor in which pairing fluctuations condense at a separate phase transition and form a nematic state with broken Z3 symmetry. High-resolution thermal expansion, specific heat and magnetization measurements reveal that this symmetry breaking occurs at Tnem≃3.8 K above Tc≃3.25 K, along with an onset of superconducting fluctuations. Thus, before Cooper pairs establish long-range coherence at Tc, they fluctuate in a way that breaks the rotational invariance at Tnem and induces a distortion of the crystalline lattice.
With the recent discovery of the quantum anomalous Hall insulator, which exhibits the conductive quantum Hall edge states without external magnetic field, it becomes possible to create a novel topological superconductor by introducing superconductivity into these edge states. In this case, two distinct topological superconducting phases with one or two dispersive chiral Majorana edge modes were theoretically predicted, characterized by Chern numbers (N) of 1 and 2, respectively. We present spectroscopic evidence from Andreev reflection experiments for the presence of chiral Majorana modes in a Nb / (Cr0.12Bi0.26Sb0.62)2Te3 heterostructure with distinct signatures attributed to two different topological superconducting phases. The results are in qualitatively good agreement with the theoretical predictions.

Dr. Anna Böhmer
Karlsruher Institut für Technologie

Title:
Tuning iron-based superconductors

Abstract:
The occurrence of widespread high-temperature superconductivity in the iron-based materials, realized in 2008, came as a surprise. Their competing electronic phases and complex phase diagrams characterized by significant electron-lattice coupling are intriguing examples of correlated electronic properties. I will discuss how we can tune and manipulate these properties and rationalize the effect of the various tuning parameters.

Jun.-Prof. Stefan Kaiser
Universität Stuttgart

Title:
Ultrafast Optical Control of Quantum Materials

Abstract:
Advances in non-liner optics open new ways of investigating and controlling ultrafast dynamics in the solid state. Ultrashort light pulses manipulating the interplay of multiple degrees of freedom in quantum materials allow triggering competing orders or stabilise novel non-equilibrium states; e.g. most remarkable I will discuss light induced superconductivity. As new tool I will introduce Higgs-Spectroscopy to trace collective order parameter dynamics in condensates and its potential to expose their coupling to external modes.