MA 43: Magnetic Semiconductors, Magnetization Dynamics and Damping

Time: Thursday 15:00–17:15 Location: EB 202

MA 43.1 Thu 15:00 EB 202

Low-energy properties of electrons and holes in CuFeS2 — •Bjørnulf Brekke[1], Roman Malyshev[2], Ingeborg-Helene Svenum[3,4], Sverre M. Selbach[5], Thomas Tybell[2], Christoph Brüne[1], and Arne Brataas[1] — [1]Center for Quantum Spintronics, Department of Physics, NTNU Norwegian University of Science and Technology, Trondheim, Norway — [2]Department of Electronic Systems, NTNU Norwegian University of Science and Technology, Trondheim, Norway — [3]Department of Chemical Engineering, NTNU Norwegian University of Science and Technology, Trondheim, Norway — [4]SINTEF Industry, Trondheim, Norway — [5]Department of Materials Science and Engineering, NTNU Norwegian University of Science and Technology, Trondheim, Norway

The antiferromagnetic semiconductor CuFeS2 belongs to a magnetic symmetry class that is of interest for spintronics applications. In addition, its crystal lattice is compatible with Si, making it possible to integrate it with nonmagnetic semiconducting structures. Therefore, we investigate this material by finding the effective k*p Hamiltonian for the electron and hole bands. We base this description on ab initio calculations and classify the electronic bands by their symmetry. As a result, we find that CuFeS2 exhibits spin-polarized bands. We also find that the crystal symmetry allows for the anomalous Hall effect. Finally, we suggest using cyclotron resonance to verify our proposed effective mass tensors at the conduction band minimum and valence band maximum.

MA 43.2 Thu 15:15 EB 202

Gate-Controlled Magnetic Properties of the 2D Semiconductor $CrPS_4$ — •Nicolas Ubrig[1], Fan Wu[1], Ignacio Gutiérrez lezama[1], Marco Gibertini[2], and Alberto Morpurgo[1] — [1]Department of Quantum Matter Physics, University of Geneva — [2]Dipartimento di Scienze Fisiche, Informatiche e Matematiche, University of Modena and Reggio Emilia

Using field-effect transistors (FETs) to explore atomically thin magnetic semiconductors with transport measurements is difficult, because the very narrow bands of most 2D magnetic semiconductors cause carrier localization, preventing transistor operation. Here, we show that exfoliated layers of $CrPS_4$ –a 2D layered antiferromagnetic semiconductor whose bandwidth approaches 1 eV– allow the realization of FETs that operate properly down to cryogenic temperature. Using these devices, we perform conductance measurements as a function of temperature and magnetic field, to determine the full magnetic phase diagram, which includes a spin-flop and a spin-flip phase. We find that the magnetoconductance depends strongly on gate voltage, reaching values as high as 5000 % near the threshold for electron conduction. The gate voltage also allows the magnetic states to be tuned, despite the relatively large thickness of the $CrPS_4$ multilayers employed in our study. Our results show the need to employ 2D magnetic semiconductors with sufficiently large bandwidth to realize properly functioning transistors, and identify a candidate material to realize a fully gate-tunable half-metallic conductor.

MA 43.3 Thu 15:30 EB 202

Electronic structure of bulk and ultrathin CrSBr: an ARPES study — •Marco Bianchi[1], Swagata Acharya[2,3], Florian Dirnberger[4], Julian Klein[5], Kimberly Hsieh[1], Esben J. Porat[1], Dimitar Pashov[6], Kseniia Mosina[7], Zdenek Sofer[7], Alexander Rudenko[3], Mikhail I. Katsnelson[3], Mark van Schilfgaarde[6,2], Yong P. Chen[1,8], Malte Rösner[3], and Philip Hofmann[1] — [1]Dep. of Phys. & Astro., ISA, iNANO, Aarhus Univ., DK — [2]National Renewable Energy Labb., Golden, CO, USA — [3]Inst. for Molecules & Matt., Radboud Univ., Nijmegen, NL — [4]Inst. App. Phys. & ct.qmat, Tech. Univ. Dresden, DE — [5]Dep. Matt. Sci. & Eng., MIT, Cambridge, MA, USA — [6]Kings College, Theory & Simulation of Cond. Mat., London, UK — [7]Dep. Inorganic Chem., Univ. of Chem. & Tech., Prague, CZ — [8]Dep. of Phys. & Astro., Purdue Quantum Sci. & Eng. Inst., Purdue Univ., West Lafayette, IN, USA

We explore the electronic structure of paramagnetic bulk and ultrathin flakes of CrSBr, exfoliated in situ on Au(111) and Ag(111) using angle-resolved photoemission spectroscopy. The observed band structure in the two cases is drastically different: While the bulk charges up at temperatures lower than 200 K and requires ab-intio GW calculation to be interpreted, the ultrathin flakes can be measured down to 35 K, are n-doped and well described by DFT calculations if local Coulomb interactions are taken into account.

MA 43.4 Thu 15:45 EB 202

Light-induced alignment of Mn spins in hybrid metal halide perovskite matrix — •Stanislav Bodnar, Jonathan Zerhoch, Shangpu Liu, Andrii Shcherbakov, and Felix Deshcler — Physikalisch-Chemisches Institut, Universität Heidelberg, Im Neuenheimer Feld 229, 69120 Heidelberg, Germany

Hybrid organic-inorganic metal-halide perovskites (HOIPs) are prospective semiconductor materials for a new generation of solar cells and light emission diodes (LEDs) as well as a new class of material for data storage applications. In our work, we investigated highly Mn-doped MAPbBr3 (MA=methylamine) with a nominal doping level of Mn2+ at the level of 50%. The incorporation of Mn atoms has led to the presence of a new paramagnetic state of the Mn-doped material without forming a ferromagnetic or antiferromagnetic spin order. Our studies have revealed that the transient Faraday signal in the Mn-doped sample is 3 times higher than in the case of undoped MAPbBr3. We attribute this additional Faraday signal in the Mn-doped sample to the magnetic moments associated with Mn spins which are aligned by an effective magnetic field caused by light-induced spin-polarized charge carriers. Additionally, we discovered that the presence of Mn atoms in the MAPbBr3 has led not only to the enhanced amplitude of the transient Faraday signal but also to the extended spin lifetime. For the moderate fluence regime of 100 uJ/cm2 spin lifetime of the Mn-doped sample has been extended by 3 times (15ps) compared to the undoped sample. We attribute this extended spin lifetime to the presence of the additional aligned Mn spins.

15 min. break

MA 43.5 Thu 16:15 EB 202

Transmission Line Resonators and Lumped Element Resonators for Strong Coupling — •Anoop Kamalasanan — Martin Luther University Halle-Wittenberg

Superconducting (SC) resonators and their seamless integration have proven critical in recent progress of on-chip quantum systems. Specifically, they are commonly implemented as a primary component in hybrid quantum systems due to their high-Q resonance properties and their ability to couple various quantized excitations (e.g. magnons, photons, phonons). Devices based on SC resonators have demonstrated numerous instances of strong coupling. Coupled microwave photon-magnon systems have received great attention as an alternative approach to realize strong light-matter interactions using magnetic dipole coupling.

In this work, we present the fabrication and characterization of superconducting resonators, namely $\lambda/2$ resonator and lumped-element resonator, alongside simulations of their microwave transmission properties. After optimizing the design of these waveguides with finite element method simulations, NbN-based superconducting resonators are fabricated for magnon-based investigations of strong coupling.

MA 43.6 Thu 16:30 EB 202

Magnetoelastic coupling to transverse and longitudinal phonons revealed by broadband ferromagnetic resonance — •Luise Siegl[1], Julie Střihavková[2], Richard Schlitz[1], Hans Huebl[3,4,5], and Sebastian T. B. Goennenwein[1] — [1]Department of Physics, University of Konstanz — [2]Faculty of Mathematics and Physics, Charles University, Prague — [3]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching — [4]TUM School of Natural Sciences, Technische Universität München, Garching — [5]Munich Center for Quantum Science and Technology (MCQST), München

In ferromagnetic thin films, magnetization dynamics driven, e.g. by ferromagnetic resonance, can coherently couple to phonons. These phonons are subsequently "pumped" into the underlying substrate, such that the process is also referred as phonon pumping. When opposite sides of the sample stack are parallel and polished, the sample forms a bulk acoustic resonator, so that standing sound waves are formed. The magnetoelastic coupling to longitudinal and transverse

phonons should exhibit a particular dependence on the orientation of the magnetic field [1]. In this work, we analyze the magnetoelastic coupling depending on the magnetic field orientation in thin yttrium iron garnet films on single crystal gadolinium gallium garnet substrates. From our broadband ferromagnetic resonance measurements, we extract the coupling strength as a function of field orientation and critically compare them to the theoretical predictions.
[1] T. Sato, et al., Phys. Rev. B **104**(1), 014403 (2021).

MA 43.7 Thu 16:45 EB 202

Lattice damping: a first attempt from tight-binding — •Zhiwei Lu[1], Ivan Miranda[2], Manuel Pereiro[2], Anders Bergman[2], Erik Sjöqvist[2], Olle Eriksson[2], Anna Delin[1], and Danny Thonig[3] — [1]Department of Applied Physics, School of Engineering Sciences, KTH Royal Institute of Technology, Sweden — [2]Department of Physics and Astronomy, Uppsala University, Sweden — [3]School of Science and Technology, Örebro University, Sweden

In recently emerging coupled spin-lattice dynamics, it has been revealed that the energy dissipation in lattice dynamics (lattice damping) has a strong impact on the demagnetization rate [1]. However, the lattice damping remains the only parameter yet to be theoretically quantified. Here we present a new method to calculate the nonlocal lattice damping tensor using a Tight-binding approach implemented in Cahmd [2], with application on iron and cobalt. The lattice damping is calculated with a range of electron lifetimes and electron temperature. Given that the dissipation force's sum rule must adhere to Newton*s third law, the effective lattice damping (as observed in coherent phonon code) is zero. Furthermore, our results reveal that the lattice damping shows significant correlation to the density of states at Fermi level, which is similar to spin damping. Our work not only proposes a novel methodological framework to calculating lattice damping but also paves the way for deeper insights into the lattice dynamics of materials.

[1]Phys. Rev. B 106, 174407(2022) [2]available at https://cahmd.gitlab.io/cahmdweb/

MA 43.8 Thu 17:00 EB 202

Anisotropic Gilbert damping in reduced dimensions from theoretical calculations — Balázs Nagyfalusi[1,2], László Szunyogh[2], and •Krisztián Palotás[1,2] — [1]Wigner Research Center for Physics, Budapest, Hungary — [2]Institute of Physics, Budapest University of Technology and Economics, Budapest, Hungary

The energy-dissipative damping process plays an important role in magnetization dynamics. The in-depth understanding of the magnetization damping is crucial for the development of spintronic applications in the future. Based on a recently implemented ab initio calculation method of the diagonal elements of the atomic-site-dependent Gilbert damping tensor within the real-space Screened Korringa-Kohn-Rostoker (SKKR) framework, anisotropy effects of the Gilbert damping are studied. For (001)-oriented surfaces of ferromagnetic Fe and Co it is pointed out that in the vicinity of the surface the corresponding transverse Gilbert damping tensor components are substantially varied depending on the magnetization direction. This effect is even more enhanced considering monolayer-thick 2D films of Fe and Co studied on noble metal surfaces. Finally, taking Fe and Co single adatoms and magnetic dimers, the occurrence of anisotropic damping is also demonstrated. The effect of the identified anisotropic dampings should be included into future spin dynamics simulations aiming at an improved accuracy.