HL 6: Focus Session: Magnon Polarons - Magnon-Phonon Coupling and Spin Transport (joint session MA/HL)

The coupling of spin waves and atomic lattice vibrations in solid magnetic states, so-called magnon polarons (MPs), can have large impact on spin transport properties as recently explored for spin Seebeck effect, spin pumping and nonlocal spin transport. This resonant enhancement can be reached when the magnon dispersion is shifted by a magnetic field and crosses the phonon dispersion with sufficient overlap. While initially observed at low temperatures and large magnetic fields, further material and device developments have led to MPs at room temperature and moderate magnetic fields. Thus, MPs become important for the manipulation and amplification of spin currents in spintronic and spin caloritronic devices, e.g. by carrying the spins much further than using uncoupled magnons. This focus session highlights the main important research outcomes for MPs, state-of-the-art techniques to detect MPs, such as Brillouin light scattering, and to study MP transport, e.g. by spin Seebeck effect and nonlocal spin transport, as well as the investigation of MPs in different material classes such as garnets, ferrites and antiferromagnets. In addition, the excessive theoretical work on MPs performed recently is addressed in this focus session.

Organizer: Timo Kuschel (Bielefeld University)

Time: Monday 13:30–17:00 Location: H5

Invited Talk HL 6.1 Mon 13:30 H5

Magnon-polarons in magnetic insulators — •Benedetta Flebus — Boston College, Chestnull Hill, USA

We theoretically study the effects of strong magneto-elastic coupling on the transport properties of magnetic insulators. We develop a Boltzmann transport theory for the mixed magnon-phonon modes, i.e., magnon-polarons, and determine transport coefficients of the composite quasi-particles. Magnon-polaron formation causes anomalous features in the magnetic field and temperature dependence of the spin Seebeck effect when the disorder scattering in the magnetic and elastic subsystems is sufficiently different. We discuss how experimental data by Kikkawa et al. [PRL 117, 207203 (2016)] on yttrium iron garnet films can be explained by an acoustic quality that is much better than the magnetic quality of the material.

Invited Talk HL 6.2 Mon 14:00 H5

Spin-phonon coupling in non-local spin transport through magnetic insulators — •Rembert Duine — Institute for Theoretical Physics, Utrecht University, The Netherlands

Long-range spin transport through ferromagnetic and antiferromagnetic insulators has recently been demonstrated. In this talk I will discuss how spin-phonon interactions influence this transport. In the first part of the talk I will discuss how bulk spin-phonon interactions lead to magnon-polaron formation and how this composite boson influences the non-local transport. In the second part, I will discuss how spin-phonon interactions across an interface give rise to long-distance spin transport that is carried purely by phonons.

Invited Talk HL 6.3 Mon 14:30 H5

Double accumulation and anisotropic transport of magneto-elastic bosons in yttrium iron garnet films — •Alexander A. Serga — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaisersalutern, Germany

Interaction between quasiparticles of a different nature, such as magnons and phonons, leads to mixing their properties and forming hybrid states in the areas of intersection of individual spectral branches. In garnet ferrite films, such hybridization results in a resonant increase in the efficiency of the spin Seebeck effect and the spontaneous bottleneck accumulation of hybrid magnetoelastic bosons—magnon polarons.

Similar to the Bose-Einstein magnon condensation (BEC), the latter phenomenon occurs in a yttrium iron garnet film exposed to microwaves. However, unlike the BEC, which is a consequence of the equilibrium Bose statistics, the bottleneck accumulation is determined by changing interparticle interactions. Studying the transport properties of accumulated quasiparticles, we found that such accumulation occurs in two frequency-distant groups: quasiphonons and quasimagnons. These quasiparticles propagate in the film plane as spatially localized beams with different group velocities. The developed theoretical model qualitatively describes the double accumulation effect, and the analysis of the two-dimensional quasiparticle spectrum makes it possible to determine the wavevectors and frequencies of each group.

Funded by the ERC Advanced Grant 694709 SuperMagnonics and by the DFG within TRR 173 – 268565370 (project B04).

HL 6.4 Mon 15:00 H5

enhancement of the spin seebeck effect by magnon-phonon resonance in a partially compensated magnet — •R. Ramos[1,2], T. Hioki[3,4], Y. Hashimoto[1], T. Kikkawa[1,3,4], P. Frey[5], A.J.E. Kreil[5], V.I. Vasyuchka[5], A.A. Serga[5], B. Hillebrands[5], and E. Saitoh[1,3,4] — [1]WPI AIMR, Tohoku University, Japan — [2]CIQUS, Departamento de Química-Física, Universidade de Santiago de Compostela, Spain — [3]Department of Applied Physics, The University of Tokyo, Japan. — [4]IMR, Tohoku University, Japan — [5]Fachbereich Physik and Landesforshungszentrum OPTIMAS, Technische Universität Kaiserslautern, Germany

The spin Seebeck effect (SSE) refers to the generation of a spin current in magnetic materials by the application of a thermal gradient. Recently, the effect of magnon-phonon hybridization, resulting from the crossing of the magnon and phonon dispersions, has been detected in the SSE and named magnon-polaron SSE. This is experimentally observed as spikes of the SSE-voltage at the magnetic field values for which the hybridization between the magnon and phonon dispersions is maximized over k-space. In this talk, we will report the detection of magnon-polaron SSE in a nonmagnetic-ion-substituted garnet system at room temperature and low magnetic fields [1]. The effect is 8 times larger than that observed in a YIG film. We show that the magnon dispersion can be strongly affected by the nonmagnetic-ion substitutions, thus resulting in a clear modification of the magnetic field condition for the observation of magnon-polarons. [1] R. Ramos et al. Nature Comm. 10, 5162 (2019).

Invited Talk HL 6.5 Mon 15:15 H5

Magnon polarons and the low-temperature spin-Seebeck effect — •Piet Brouwer and Rico Schmidt — Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Freie Universität Berlin, 14195 Berlin, Germany

Using a simplified microscopic model of coupled spin and lattice excitations in a ferromagnetic insulator we evaluate the magnetic-field dependence of the longitudinal spin Seebeck effect at low temperatures. We find that at low temperatures, large magnetic fields, and for not-too-large system sizes the spin Seebeck effect is almost completely mediated by magnon polarons, superpositions of magnon and phonon excitations, with frequency close to the crossing points of magnon and phonon dispersions. We find an enhancement of the spin-Seebeck effect for "critical" values of the magnetic field, for which magnon and phonon dispersions touch. Such an enhancement of the longitudinal spin-Seebeck effect was observed experimentally by Kikkawa et al. [Phys. Rev. Lett. 117, 207203 (2016)]. We find that the existence of this enhancement is independent of the relative strength of magnon-impurity and phonon-impurity scattering.

Invited Talk HL 6.6 Mon 15:45 H5

Magnon-Polarons in different flavors: (anti)ferromagnetic to

topological — •Akashdeep Kamra — Condensed Matter Physics Center (IFIMAC) and Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, E-28049 Madrid, Spain

Due to magnetoelastic coupling, magnons and phonons in a magnet can combine to form hybrid quasiparticles, inheriting properties from both, called magnon-polarons. We will begin by examining and clarifying the essential requirements for their hybridization in terms of the spin conservation laws and the nature of the magnetoelastic coupling. This will allow us to deduce the properties, such as spin, of the magnon-polarons thus formed and provide guidance on how to engineer magnon-polarons. In carrying out this general discussion, we will analyze the cases of magnon-polarons in ferromagnets as examples. Then, we will apply the general principles developed to the cases of antiferromagnets and topological magnonic insulators thereby demonstrating magnon-polarons with novel, tunable, and chiral properties. We will conclude our discussion with recent experiments suggesting spin-phonon coupling to underlie collective quantum phenomena in the high-Tc superconductor YBCO.

References: [1] A. Kamra, H. Keshtgar, P. Yan, and G. E. W. Bauer. Phys. Rev. B 91, 104409 (2015). [2] H. T. Simensen, R. E. Troncoso, A. Kamra, and A. Brataas. Phys. Rev. B 99, 064421 (2019). [3] E. Thingstad, A. Kamra, A. Brataas, and A. Sudbø. Phys. Rev. Lett. 122, 107201 (2019).

Invited Talk HL 6.7 Mon 16:15 H5

Magnon polarons in antiferromagnetic insulator Cr2O3 — •Jing Shi — Department of Physics & Astronomy, University of California, Riverside, USA

While magnon polarons in ferrimagnetic materials have been experimentally investigated by various meanings including the spin Seebeck effect, nonlocal transport, inelastic neutron scattering, spin pumping, etc., similar hybridized excitations in antiferromagnets have not been well explored. For typical antiferromagnets, the magnon dispersion lies well above the acoustic phonon dispersion, which prevents the formation of magnon polarons under accessible magnetic fields. In this talk, I will first review the main magnon polaron results in yttrium iron garnet [1], a ferrimagnetic insulator. My focus will be on a special antiferromagnetic insulator: Cr2O3. In this uniaxial antiferromagnet, the left-handed magnon branch can be effectively lowered to zero at ~6 T, the spin-flop transition, allowing for thermodynamic measurements. In our study of Cr2O3 spin Seebeck effect [2], We observe magnon polaron anomalies right below the spin flop transition. where the left-handed magnon dispersion intersect both longitudinal and transverse acoustic phonon dispersions. I will present our experimental data and analysis in my talk.

[1] H.R. Man et al., Direct observation of magnon-phonon coupling in yttrium iron garnet. Phys. Rev B 96, 100406(R) (2017). [2] J.X. Li et al., Observation of magnon-polarons in a uniaxial antiferromagnetic insulator Cr2O3. Phys. Rev. Lett. 125, 217201(2020).

HL 6.8 Mon 16:45 H5

Revealing thermally driven distortion of magnon dispersion by spin Seebeck effect in Gd3Fe5O12 — •Bin Yang[1], Si Yu Xia[1], Hui Zhao[1], Gan Liu[1], Jun Du[1], Ka Shen[2], Zhiyong Qiu[3], and Di Wu[1] — [1]National Laboratory of Solid State Microstructures, Jiangsu Provincial Key Laboratory for Nanotechnology, Collaborative Innovation Center of Advanced Microstructures and Department of Physics, Nanjing University, Nanjing 210093, China — [2]Center for Advanced Quantum Studies and Department of Physics, Beijing Normal University, Beijing 100875, China — [3]School of Materials Science and Engineering, Dalian University of Technology, Dalian 116024, China

We report a systematic study of the temperature and field dependences of the spin Seebeck effect (SSE) in a bilayer of Pt/Gd3Fe5O12. An anomalous structure is observed in the magnetic field dependent measurements at temperatures between ~60 and ~210 K.We attribute these anomalies to the contribution from the quasiparticles hybridized between the Gd moment dominated spin wave (α mode) and the transversal acoustic phonon, known as the magnon polarons, and explain these rich phenomena by an increase of the group velocity of the α-mode magnon with increasing temperature and the nonparabolic magnon dispersion of Gd3Fe5O12. Our results demonstrate that the magnon polaron induced SSE is helpful for the investigation of the magnon dispersion evolution with a simple transport approach.