HL 38: 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 neutron scattering, and to study MP transport, e.g. by spin Seebeck effect and nonlocal spin transport, as well as the investigation of MPsin 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: Wednesday 9:30–13:00 Location: HSZ 04

Invited Talk HL 38.1 Wed 9:30 HSZ 04

Magnon-polaron transport in magnetic insulators — •Benedetta Flebus — University of Texas at Austin, Austin, USA

In this talk, I will introduce the anomalous features in the magnetic field and temperature dependence of the spin Seebeck effect observed by Kikkawa et al. [PRL 117, 207203 (2016)] and explain how they can be interpreted as a signature of magnon-polaron transport.

Specifically, I will discuss how magnetoelastic coupling between magnetic moments and lattice vibrations in ferromagnets can gives rise to magnon-polarons, i.e., hybridized magnon and phonon modes. I will derive a Boltzmann transport theory for the mixed magnon-phonon modes and show that magnon-polaron formation can lead to transport anomalies when the disorder scattering in the magnetic and elastic subsystems is sufficiently different.

Invited Talk HL 38.2 Wed 10:00 HSZ 04

Spin-phonon coupling in non-local spin transport through magnetic insulators — •Rembert Duine — Institute for Theoretical Physics, Utrecht University, Princetonplein 5, 3584 CC Utrecht, The Netherlands — Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, 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 38.3 Wed 10:30 HSZ 04

Anisotropic transport of spontaneously accumulated magneto-elastic bosons in yttrium iron garnet films — •Alexander A. Serga — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaisersalutern, Germany

It is well known that bosonic quasiparticles as excitons, polaritons or magnons are able to spontaneously form Bose-Einstein condensates (BECs). However, interactions between quasiparticles of a different nature, for example, between magnons and phonons, can significantly alter their properties and, thus, modify the condensation scenarios.

Here, I present a novel condensation phenomenon mediated by the magnon-phonon interaction: a bottleneck accumulation of hybrid magneto-elastic bosons—magnon polarons. Similar to the magnon BEC, the phenomenon is observed in a microwave-driven single-crystal ferrimagnetic film. However, unlike BEC, which is a consequence of equilibrium Bose statistics, the bottleneck accumulation is determined by varying interparticle interactions. Furthermore, the accumulated quasiparticles possess a nonzero group velocity. Our recent 2D transport measurements show the simultaneous formation of a few distinct magnon-polaron groups, which propagate in film plane as spatially localized beams with different group velocities. The role of the magnetoelastic anisotropy in the beam formation and interaction of the accumulated quasiparticles with the magnon BEC are discussed.

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HL 38.4 Wed 11:00 HSZ 04

Formation of magnon polarons in ferromagnetic nanogratings — •Felix Godejohann[1], Alexey Scherbakov[1,2], Serhii Kukhtaruk[1,3], Alexander Poddubny[2], Dmytro Yaremkevych[1], Mu Wang[5], Achim Nadzeyka[4], Dmitri Yakovlev[1,2], Andrew Rushforth[5], Andrey Akimov[5], and Manfred Bayer[1,2] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44227 Dortmund, Germany. — [2]Ioffe Inst., RAS, St. Petersburg, Russia — [3]Dept. of Theo. Phys., V.E. Lashkaryov Inst. of Semiconductor Phys., Kyiv, Ukraine — [4]Raith GmbH, 44263 Dortmund, Germany — [5]School of Phys. and Astronomy, Univ. of Nottingham, UK

In our time-resolved experiments with ferromagnetic nanogratings (NGs), the formation of coherent magnon polarons is confirmed by direct evidence of the avoided crossing effect, as well as by several bright indirect manifestations. The NGs have been produced by focused ion beam milling into a 105 nm-thick $Fe_{0.81}Ga_{0.19}$ film. They have a lateral period of 200 nm and consist of parallel grooves of 100-nm width and 7-21 nm depth milled along the [100]-crystallographic direction. We perform transient magneto-optical measurements in a conventional pump-probe scheme with micron spatial resolution, where the femtosecond pump pulse excites the NGs, while the probe pulse serves to detect coherent lattice and magnetic responses. Using an external magnetic field, the magnon modes can be brought into resonance with the localized phonon modes of the NG resulting in the formation of magnon polarons, where the coupling strength is determined by the spatial overlap of the interacting modes.

Invited Talk HL 38.5 Wed 11:15 HSZ 04

Boltzmann approach to the longitudinal spin Seebeck effect — Piet Brouwer and •Rico Schmidt — Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Freie Universität Berlin, 14195 Berlin, Germany

We develop a Boltzmann transport theory of coupled magnon-phonon transport in ferromagnetic insulators. The explicit treatment of the magnon-phonon coupling within the Boltzmann approach allows us to calculate the low-temperature magnetic-field dependence of the spin-Seebeck voltage. We consider both a high-temperature regime, in which magnon and phonon branches are coupled incoherently, and a low-temperature regime, which has strongly coupled magnon-polaron excitations. For the magnetic field dependence of the spin Seebeck voltage in both limits we observe similar features as found by Flebus et al. [Phys. Rev. B 95, 144420 (2017)] for a strongly coupled magnon phonon system that forms magnon-polarons, consistent with experimental findings in yttrium iron garnet by Kikkawa et al. [Phys. Rev. Lett. 117, 207203 (2016)].

Invited Talk HL 38.6 Wed 11:45 HSZ 04

Magnon-polaron excitations in the noncollinear antiferromagnet Mn_3Ge — •Aleksandr Sukhanov — Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

In this talk, the detailed inelastic neutron scattering measurements of the noncollinear antiferromagnet Mn_3Ge will be discussed. Time-of-flight and triple-axis spectroscopy experiments showed that the magnetic excitations in Mn_3Ge have a 5-meV gap and display an anisotropic dispersive mode reaching $\simeq$ 90 meV at the boundaries of the magnetic Brillouin zone. The spectrum at the zone center shows two additional excitations that demonstrate characteristics of both magnons and phonons. The *ab initio* lattice-dynamics calculations show that these can be associated with the magnon-polaron modes resulting from the hybridization of the spin fluctuations and the low-energy optical phonons. The observed magnetoelastic coupling agrees with the previously found negative thermal expansion in this compound and resembles the features reported in the spectroscopic studies of other antiferromagnets with the similar noncollinear spin structures.

Invited Talk HL 38.7 Wed 12:15 HSZ 04

Magnon-Polarons in different flavors: (anti)ferromagnetic to topological — •Akashdeep Kamra — Center for Quantum Spintronics, Norwegian University of Science and Technology, Trondheim, Norway

Due to magnetoelastic coupling, magnons and phonons in a magnetic material can combine to form hybrid quasiparticles, inheriting properties from both, called magnon-polarons. In this talk, we will examine and clarify the essential requirements for their hybridization in terms of the typical 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 by examining the general symmetries of the material and excitation propagation direction. In carrying out this general discussion, we will refer to the cases of magnon-polarons in ferromagnets as examples. What is their spin? What kind of phonons can the magnons hybridize with? 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 the discussion with an outlook on some open questions and possible future avenues in this context.

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).

HL 38.8 Wed 12:45 HSZ 04

Topological Magnon-Phonon Hybrid Excitations in Two-Dimensional Ferromagnets with Tunable Chern Numbers — •Gyungchoon Go[1], Se Kwon Kim[2], and Kyung-Jin Lee[1,3] — [1]Department of Materials Science and Engineering, Korea University, Seoul 02841, Korea — [2]Department of Physics and Astronomy, University of Missouri, Columbia, Missouri 65211, USA — [3]KU-KIST Graduate School of Converging Science and Technology, Korea University, Seoul 02841, Korea

We theoretically investigate magnon-phonon hybrid excitations in two-dimensional ferromagnets. The bulk bands of hybrid excitations, which are referred to as magnon polarons, are analytically shown to be topologically nontrivial, possessing finite Chern numbers. We also show that the Chern numbers of magnon-polaron bands and the number of band-crossing lines can be manipulated by an effective magnetic field. For experiments, we propose to use the thermal Hall conductivity as a probe of the finite Berry curvatures of magnon-polarons. Our results show that a simple ferromagnet on a square lattice supports topologically nontrivial magnon polarons, generalizing topological excitations in conventional magnetic systems.