MA 7: INNOMAG e.V. Prizes 2025 (Diplom-/Master and Ph.D. Thesis)

Die Arbeitsgemeinschaft Magnetismus der DPG hat einen Dissertationspreis und einen Diplom-/Masterpreis ausgeschrieben, welche auf der Tagung der DPG 2025 in Regensburg vergeben werden. Ziel der Preise ist die Anerkennung herausragender Forschung im Rahmen einer Diplom-/Masterarbeit beziehungsweise einer Promotion und deren exzellente Vermittlung in Wort und Schrift. Im Rahmen dieser Sitzung tragen die besten der für ihre an der Hochschule eines Mitgliedslands der European Physical Society durchgeführten Diplom-/Masterarbeit beziehungsweise Dissertation Nominierten vor. Im direkten Anschluss entscheidet das Preiskomitee über den Gewinner bzw. die Gewinnerin des INNOMAG e.V. Diplom/Master-Preises und des Dissertationspreises 2025. Talks will be given in English!

Time: Monday 15:00–18:00 Location: H18

Invited Talk MA 7.1 Mon 15:00 H18

Realizing Reservoir Computing with skyrmions in geometrical confinements tuned by ion irradiation — •Grischa Beneke — Institut für Physik, Johannes Gutenberg-Universität Mainz, 55128 Mainz, Germany

Physical reservoir computing (RC) is a beyond von-Neumann computing paradigm that harnesses complex physical systems' dynamics for efficient information processing. Magnetic skyrmions, topological spin textures, show promise for RC systems due to their non-linear interactions and low-power manipulation capabilities. Previous spin-based RC implementations either focused on static detection or required rescaling of real-world data to match intrinsic magnetization dynamics timescales. In this thesis, we demonstrate time-multiplexed skyrmion RC by adjusting the reservoir's intrinsic timescales to match real-world temporal patterns [1]. Using hand gestures recorded via range-Doppler radar in collaboration with industry, we show that our hardware solution outperforms conventional software-based neural networks while consuming less energy. The system's ability to directly integrate sensor data without temporal conversion enables real-time applications. To structure the geometrical confinement, we investigate how high-energy ion irradiation influences magnetic properties in skyrmion-hosting multilayers. By locally modifying the perpendicular magnetic anisotropy, we create attractive and repulsive regions that enable controlled skyrmion nucleation, manipulation and confinement, enabling novel devices and, enhancing device functionality. [1] G. Beneke et al., Nat. Commun. 15, 8103 (2024).

Invited Talk MA 7.2 Mon 15:20 H18

Low-energy spin excitations of the Kitaev candidate material $Na_2Co_2TeO_6$ probed by high-field/high-frequency electron spin resonance spectroscopy — •Luca Bischof[1], Jan Arneth[1], Kwang-Yong Choi[2], Raju Kalaivanan[3], Raman Sankar[3], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Germany — [2]Department of Physics, Sungkyunkwan University, Republic of Korea — [3]Institute of Physics, Academia Sinica, Taiwan

The realization of a Kitaev spin liquid state in the Co-based honeycomb magnet $Na_2Co_2TeO_6$ is circumvented by magnetic ordering due to Heisenberg and off-diagonal interactions. The nature of these interactions and the magnetic ground state in $Na_2Co_2TeO_6$ are still under debate. We report high-frequency/high-field electron spin resonance (ESR) measurements of single-crystal $Na_2Co_2TeO_6$ probing the low-energy spin excitations of the ordered phase below $T_N \simeq 27\,K$. A complex magnon spectrum for in-plane magnetic fields $B \parallel a^*$ indicates field-induced phase transitions. For out-of-plane magnetic fields $B \parallel c$, we observe one softening and two hardening magnon modes. They share a magnon excitation gap of $\Delta = 219(13)\,GHz$. We performed spin wave calculations for the extended Heisenberg-Kitaev model to compare the observed magnon modes to the low-energy excitations expected for zigzag and triple-q ground states in an applied magnetic field.

Invited Talk MA 7.3 Mon 15:40 H18

Tailoring the first-order magnetostructural phase transition in Ni-Mn-Sn for caloric applications by microstructure — •Johannes Puy, Enrico Bruder, Oliver Gutfleisch, and Franziska Scheibel — TU Darmstadt, Darmstadt, Germany

Ni-Mn-Sn Heusler alloys show a large inverse magnetocaloric (MCE) and conventional elastocaloric effect (ECE), making them a promising candidate for multicaloric cooling. The caloric effects arise from a first-order magnetostructural phase transition (FOMST) from high-magnetic austenite to low-magnetic martensite, driven by a nucleation and growth process. Optimizing the multicaloric performance of these materials requires tailoring the FOMST, which implies a comprehensive understanding of the role of microstructure and coupling factors, such as atomic, magnetostatic, and stress coupling. In this study, the influence of microstructure and defects (grain boundaries, pores, sintering necks) on the temperature-driven FOMST is investigated in single- and polycrystalline particles, as well as in spark-plasma-sintered Ni-Mn-Sn. By adjusting the relative density, the effect of porosity on the FOMST is studied. Temperature-dependent magnetometry reveals that an increase of the relative density from 88 % to 99 % narrows the transition ranges from 18 K to 9 K and decreases the transition temperature from 263 K to 254 K. Temperature-dependent in-situ optical and in-situ scanning electron microscopy reveal preferential martensite nucleation at free particle surfaces in powder and sintered, 88% dense Ni-Mn-Sn, while nucleation in 99 % dense Ni-Mn-Sn is favored at sintering necks. We thank the CRC/TRR 270 'HoMMage' for funding.

15 min. break

Invited Talk MA 7.4 Mon 16:15 H18

Tuning the properties of two-dimensional magnetic heterostructures via interface engineering with molecular and inorganic van der Waals crystals. — •Carla Boix-Constant[1], Samuel Mañas-Valero[2], and Eugenio Coronado[1] — [1]Institute of Molecular Science, 46980 Paterna (Valencia), Spain. — [2]Kavli Institute of Nanoscience - TU Delft, Delft 2628 CJ, The Netherlands.

Two-dimensional (2D) materials offer unprecedented opportunities for fundamental and applied research in several condensed matter physics areas. For this purpose, state-of-the-art techniques were employed in this thesis (divided in two blocks) to fabricate van der Waals heterostructures based on mainly 2D magnets (both inorganic and molecular systems) and to characterize the resulting devices by magneto-transport techniques. On the one hand, new chemically designed molecular building blocks were combined with 2D materials to afford hybrid devices offering a new playground for exploiting the potential of spin transition molecular systems to control the properties of the 2D material. On the other hand, we focused on purely 2D magnetic materials: the quantum spin liquid candidate 1T-TaS2 - where our results throw some light in the debate about the exotic behaviour of the material - and the metamagnet CrSBr - results that afford a new generation of van der Waals heterostructures with programmable properties.

Invited Talk MA 7.5 Mon 16:40 H18

Theoretical Prediction for Probing Magnon Topology — •Robin R. Neumann — Johannes Gutenberg University Mainz — Martin Luther University Halle-Wittenberg

Magnons, the bosonic quasiparticles of collective spin excitations, hold potential as information and energy carriers in spintronic devices. Although the magnonic counterpart of the electronic quantum Hall states was predicted over a decade ago [1, 2], experimental evidence remains absent because established methods fail to probe them [3].

In my thesis I have studied the signatures of topological magnons in transport and spectroscopic observables. While I demonstrated that the thermal Hall effect can be sensitive to topological phase transitions in the magnon band structure [4], magnon-phonon hybridization may obscure their contributions [5]. I present a specific proposal for using electrical probes to detect topological magnons [6]. Despite their charge neutrality, magnetoelectric effects grant magnons an electrical

dipole moment. Consequently, edge magnons give rise to an electric polarization at the edges driven by thermal spin fluctuations. Furthermore, magnons are predicted to interact with alternating electric fields, opening up the possibility of resonantly exciting topological magnons. The resulting absorption spectrum encodes footprints of topological magnons that might assist in their detection.
[1] Zhang *et al.*, PRB **87**, 144101 (2013), [2] Shindou *et al.*, PRB **87**, 174427 (2013), [3] Malz *et al.*, Nat. Commun. **10**, 3937 (2019), [4] **RRN** *et al.*, PRL **128**, 117201 (2022), [5] **RRN** *et al.*, PRB **108**, L140402 (2023), [6] **RRN** *et al.*, PRB **109**, L180412 (2024)

Invited Talk MA 7.6 Mon 17:05 H18

Multiphysics-Multiscale Simulation of Additively Manufactured Functional Materials — •Yangyiwei Yang — Technische Universität Darmstadt, Darmstadt, Germany

The progress of additive manufacturing (AM) technologies has led to a growing interest in AM-produced magnetic functional materials with tailored properties, including magnetic coercivity, remanence and saturation magnetization. However, the lack of comprehensive research on the process-microstructure-property (PMP) relationship poses a significant challenge to the production of magnetic materials with designed properties by AM. In this work, a multiphysics-multiscale simulation framework has been developed to thoroughly investigate the PMP relationships in magnetic functional materials and to further facilitate simulation-driven property tailoring. The framework is methodically structured to ensure clarity and depth, with emphasis on key concepts with corresponding physical backgrounds. By employing the established framework, phenomenological relationships between AM processing parameters and the resulting material properties are obtained, notably magnetic hysteresis. The sensitivity of the local magnetic coercivity to residual stress states in AM-produced Fe-Ni permalloy is also revealed. In particular, the relationship between the average residual stress and the magnetic coercivity within the melt zone are shown to obey an exponential growth law, suggesting a strategy for tailoring the magnetic coercivity by controlling the residual stress within an AM-produced permalloy.

30 min. discussion break and bestowal of INNOMAG e.V. Diplom-/Master Prize and Ph.D. Thesis Prize