Symposium Quantum Signatures in Magnetism (SYQS)

jointly organized by
the Magnetism Division (MA),
the Low Temperature Physics Division (TT),
the Semiconductor Physics Division (HL), and
the Surface Science Division (O)

Hans Hübl
Walther-Meissner-Institut
Bayerische Akademie der Wissenschaften
Walther-Meißner-Straße 8
85748 Garching
Hans.Huebl@wmi.badw.de

Sebastian Gönnenwein
Walther-Meissner-Institut
Bayerische Akademie der Wissenschaften
Walther-Meißner-Straße 8
85748 Garching
Sebastian.Goennenwein@wmi.badw.de

Rudolf Gross
Walther-Meissner-Institut
Bayerische Akademie der Wissenschaften
Walther-Meißner-Straße 8
85748 Garching
Rudolf.Gross@wmi.badw.de

Magnetism is a quantum phenomenon. Nevertheless, most studies investigate large samples containing many spins, such that the magnetic properties can be described and understood in terms of classical physics. Of particular current interest are magnetization dynamics viz. magnetization relaxation and damping, since the dynamical properties of magnets are key for the fast magnetic switching employed in a manifold of applications. Magnetization dynamics are typically studied using magnetic resonance techniques. The advent of quantum information technologies based on superconducting circuits has triggered a revolution in magnetic resonance spectroscopy. Single photon viz. single spin sensitivity, and the possibility to probe magnetization dynamics employing tailored quantum states, offer a completely new toolbox for modern experiments addressing the quantum properties of magnets. This symposium brings together experts from different but overlapping fields of magnetization dynamics, superconducting quantum circuits, quantum metrology in semiconductors, and in a broader sense quantum technology based solid-state spectroscopy aiming to provide an overview of the recent exciting developments.

Overview of Invited Talks and Sessions

(Lecture room H1)

Invited Talks

SYQS 1.1	Wed	15:00–15:30	H1	**Magnonic macroscopic quantum states and supercurrents** — •Burkard Hillebrands, Dmytro A. Bozhko, Alexander A. Serga
SYQS 1.2	Wed	15:30–16:00	H1	**Elementary excitations of magnetic insulators and its heterostructures with metals** — •Gerrit Bauer
SYQS 1.3	Wed	16:00–16:30	H1	**Cavity Spintronics** — •Can-Ming Hu
SYQS 1.4	Wed	16:45–17:15	H1	**Hybrid Quantum Systems - Coupling Color Centers to Superconducting Cavities** — •Johannes Majer
SYQS 1.5	Wed	17:15–17:45	H1	**Quantum enhanced sensing with single spins in diamond** — •Fedor Jelezko

Sessions

SYQS 1.1–1.5	Wed	15:00–17:45	H1	**Quantum Signatures in Magnetism**

SYQS 1: Quantum Signatures in Magnetism

Time: Wednesday 15:00–17:45 Location: H1

Invited Talk SYQS 1.1 Wed 15:00 H1

Magnonic macroscopic quantum states and supercurrents — •Burkard Hillebrands[1], Dmytro A. Bozhko[1,2], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Germany

Magnons, the quanta of spin waves, are bosons and can form a Bose-Einstein condensate (BEC) - a spontaneous coherent ground state - established independently of the magnon excitation mechanism. The magnon BEC has zero group velocity and, thus, cannot be directly used for information transport. However, a collective motion of condensed magnons driven by a phase gradient in the condensate wavefunction - a magnon supercurrent - is a most promising candidate for the utilization of magnon macroscopic quantum phenomena at room temperature for spin information transport and processing. We report experimental evidence for the generation of a magnonic supercurrent obtained using Brillouin light scattering experiments. Here the phase gradient is induced by a thermal gradient. A rate equation model describes the experimental findings very well. Several other means to generate the needed gradient of the phase of the condensate wave function will be discussed. The work is supported by the DFG within the SFB/TR 49.

Invited Talk SYQS 1.2 Wed 15:30 H1

Elementary excitations of magnetic insulators and its heterostructures with metals — •Gerrit Bauer — Institute for Materials Research, Tohoku University, Sendai, Japan

Magnetic insulators such as yttrium iron garnet (YIG) are prime candidates for the search of quantum signatures in magnetism due to their superiors magnetic quality. Metal contacts to magnetic insulators are a possible route to observe them electrically.

In this talk I will review the knowledge about the elementary excitations of magnetic insulators, i.e., magnons, magnon-polarons and magnon-polaritons, as well as their coupling to metal contacts. While to date most experiments can be explained by semiclassical concepts, these excitations offer a route to observe up to now elusive quantum effects.

Invited Talk SYQS 1.3 Wed 16:00 H1

Cavity Spintronics — •Can-Ming Hu — Department of Physics and Astronomy, University of Manitoba, Winnipeg, Canada R3T 2N2

Strong coupling between magnons and microwave photons has recently been theoretically proposed [1] and experimentally investigated using both microwave transmission [2-4] and electrical detection methods [5]. These works build the foundation for the emerging field of Cavity Spintronics [6], where the development of spintronics merges with the advancement in cavity quantum electrodynamics and cavity polaritons, thereby creating new theoretical and experimental avenues for studying wave physics, developing quantum technology, and facilitating spintronics applications.

Based on the remarkable achievements of the pioneers of Cavity Spintronics, this talk aims to provide a brief introduction of this exciting new frontier of condensed matter research to colleagues working on magnetism, spintronics, and microwave technologies. Related work recently done by our group at the University of Manitoba will be reported [5-8].

[1] Ö. O. Soykal et al., Phys. Rev. Lett. 104, 077202 (2010). [2] H. Huebl, et al., Phys. Rev. Lett. 111, 127003 (2013). [3] Y. Tabuchi, et al., Phys. Rev. Lett. 113, 083603 (2014). [4] X. Zhang, et al., Phys. Rev. Lett. 113, 156401 (2014). [5] L.H Bai, et al., Phys. Rev. Lett. 114, 227201 (2015). [6] C.-M. Hu, arXiv: 1508.01966. [7] B.M. Yao, et al., Phys. Rev. B, 92, 184407 (2015). [8] For more information, please check: http://www.physics.umanitoba.ca/~hu/

15 min. break

Invited Talk SYQS 1.4 Wed 16:45 H1

Hybrid Quantum Systems - Coupling Color Centers to Superconducting Cavities — •Johannes Majer — TU Wien / Atominstitut

Hybrid quantum systems based on spin-ensembles coupled to superconducting microwave cavities are promising candidates for robust experiments in cavity quantum electrodynamics (QED) and for future technologies employing quantum mechanical effects. The main source of decoherence in this systems is inhomogeneous dipolar spin broadening and a full understanding of the complex dynamics is essential and has not been addressed in recent studies yet. We investigate the influence of a non-Lorentzian spectral spin distribution in the strong coupling regime of cavity QED. We show for the first time experimentally how the so-called cavity protection effect influences the decay rate of coherent Rabi oscillation by varying the coupling strength in our experiment. We then demonstrate how the Rabi oscillation amplitude can be enhanced by two orders of magnitude by pulsing the strongly coupled system matching a special resonance condition. Giving a way improving the coherent manipulation of the spin polarization helping to improve fidelity and performance in hybrid quantum systems.

Invited Talk SYQS 1.5 Wed 17:15 H1

Quantum enhanced sensing with single spins in diamond — •Fedor Jelezko — Institute of Quantum Optics, Ulm University

I will discuss recent developments transforming quantum control tools into quantum technologies based on single nitrogen-vacancy (NV) centers in diamond. I will present ultrasensitive MRI at nanoscale and recently developed magnetometry protocols that use quantum error correction as a resource. Experiments with novel colour centers including silicon-vacancy (SiV) will also be presented.