Quantum Beam Science:
bio, materials and fundamental physics with neutrons and X-rays

This session has been organised in collaboration with the Swiss Society for Neutron Science (SGN).

Thursday, 29.08.2019, Room G 85

Time	ID	Quantum Beam Science: bio, materials and fundamental physics with neutrons and X-rays I: Neutrons from Fundamental Physics to Novel Imaging Methods *Chair: Markus Strobl, PSI Villigen*
14:00	701	**Weak measurements in neutron interferometry and experimental tests of general uncertainty relations** *Stephan Sponar, Hartmut Lemmel, Yuji Hasegawa, Atominstitut, TU Wien* Weak measurements [1], introduced more than 30 years ago, underwent a metamorphosis from a theoretical curiosity to a powerful resource for exploring foundations of quantum mechanics, as well as a practical laboratory tool. However, unlike in the original textbook experiment, where an experiment with massive particles is proposed, experimental applications are realized applying photonic systems. We have overcome this gap by developing a new method to weakly measure a massive particle's spin component. Our neutron optical approach is realized by utilizing neutron interferometry, where the neutron's spin is coupled weakly to its spatial degree of freedom [1]. This scheme was then applied to study a new counter-intuitive phenomenon, the so-called quantum Cheshire Cat: If a quantum system is subject to a certain pre- and post-selection, it can behave as if a particle and its property are spatially separated, which is demonstrated in an experimental test [2,3]. State tomography, the usual approach to reconstruct a quantum state, involves a lot of computational post-processing. So in 2011 a novel more direct method was established using weak measurements. Because of this weakness the information gain is very low for each experimental run, so the measurements have to be repeated many times. Our procedure is based on the method established in 2011, without the need of computational post processing, but at the same time uses strong measurements, which makes it possible to determine the quantum state with higher precision and accuracy. We performed a neutron interferometric [4] experiment, but our results are not limited to neutrons, but are in fact completely general. In our latest experiment [5] we investigated the paths taken by neutrons in a three-beam interferometer by means of which-way measurements, realized by a partial energy shift of the neutrons so that faint traces are left along the beam path. Final results give experimental evidence that the (partial) wave functions of the neutrons in each beam path are superimposed and present in multiple locations in the interferometer. [1] S. Sponar, T. Denkmayr, H. Geppert, H. Lemmel, A. Matzkin, J. Tollaksen, and Y. Hasegawa, Phys. Rev. A 92, 062121 (2015). [2] T. Denkmayr, H. Geppert, S. Sponar, H. Lemmel, A. Matzkin, J. Tollaksen, and Y. Hasegawa, Nat. Commun. 5, 4492 (2014). [3] S. Sponar, T. Denkmayr, H. Geppert, and Y. Hasegawa, Atoms 4, 11 (2016). [4] T. Denkmayr, H. Geppert, H. Lemmel, M. Waegell, J. Dressel, Y. Hasegawa, and S. Sponar, Phys. Rev. Lett. 118, 010402 (2017). [5] H. Geppert ,T. Denkmayr, S. Sponar, H. Lemmel, T. Jenke, and Y. Hasegawa, Phys. Rev. A 97, 052111 (2018).
14:30	702	**Yet another approach to tackle the phase problem of diffraction experimentally** *Martin Fally [1], Jürgen Klepp [1], Joachim Kohlbrecher [2], Jinxin Guo [3,4], Yasuo Tomita [3]* *[1] Faculty of Physics, University of Vienna, AT-1090 Wien* *[2] Laboratory for Neutron Scattering and Imaging, Paul Scherrer Institut, 5232 Villigen PSI* *[3] Department of Engineering Science, University of Electro-Communications, 1-5-1 Chofugaoka, Chofu, Tokyo 182, Japan* *[4] Institute of Information Photonics Technology and College of Applied Sciences, Beijing University of Technology, Beijing 100124, China* Standard diffraction experiments are routinely used to investigate the (PERIODIC) structure of materials. However, they only yield information on the amplitudes while the phase information is lost ('phase problem' of diffraction).

		In this talk we will experimentally demonstrate by the example of a simple one-dimensional holographic grating how the entire information - amplitude and phase - of the Fourier components for this periodic structure can be retrieved. The wavelength of scattered radiation is intentionally chosen much smaller than the grating spacing so that diffraction occurs in the nonstandard multi-wave regime. By employing the so-called rigorous coupled wave analysis to model the angular dependence of the diffraction efficiencies we are able to determine the refractive-index profile (= the structure) of the holographic grating completely.
15:00	**703**	**Status of the Beam EDM experiment** *Estelle Chanel, Universität Bern* The search for a neutron electric dipole moment (EDM) is of significant interest in understanding the observed baryon asymmetry in the universe. Historically, two methods have been employed to measure an EDM, storage of ultracold neutrons (UCN) and cold neutron beams, with the latter being abandoned in the 1980s due to a limiting relativistic systematic effect. The BeamEDM experiment developed at the Universität Bern represents a novel concept to overcome this limitation with cold neutron beams using time-of-flight measurement. The ultimate goal of this project aims to reach a sensitivity competitive with future UCN experiments. This talk presents an overview of the experiment and the latest results.
15:20	**704**	**High resolution neutron imaging at Paul Scherrer Institut** *Pavel Trtik, Paul Scherrer Institut* Recent detector developments lead to enhancement of spatial resolution capabilities of neutron imaging to single digit micrometer level. At PSI, a device that enabled imaging with better than 5 micrometers spatial resolution was developed in the framework of a Neutron Microscope project and is now available to a broad neutron imaging user community at various beamlines. The progress achieved within the framework of this project will be concisely presented. The above mentioned progress enabled new science to be pursued. Several applications of the high resolution neutron imaging will be presented, namely defects in additively manufactured gold alloys and in uranium oxide TRISO particles,hydrogen distribution in Zircaloy tubes for nuclear fuel element, and others.
15:40	**705**	**The PERC facility - prospects of high-precison neutron beta decay experiments** *Erwin Jericha, TU Wien, and the PERC collaboration* Neutron beams enable a large variety of studies in fundamental physics research. In particular, neutron beta decay allows for a detailed study of the weak interaction within the standard model of particle physics and possible extensions beyond it. Among other observables, a number of correlation coefficients may be determined, providing a complementary way to high-energy accelerator experiments. PERC, a new facility for the high-precison experimental study of neutron decay is currently constructed. It consists of a specifically tailored superconducting magnet system to guide the charged neutron decay products and a special neutron guide arrangement to conserve the initial neutron phase space density. The concept and design of the facility, various components, and information of the current status will be presented.
16:00	**706**	**From omnidirectional sensitivity to polarized dark-field image with neutron grating interferometry** *Jacopo Valsecchi, Ralph P. Harti, Matias Kagias, Markus Strobl, Christian Grünzweig* *Paul Scherrer Institut* Neutron grating interferometry (nGI) is an established neutron imaging method that has found successful application in a wide range of scientific fields such as soft matter, magnetism and superconductors. Here we present the latest developments that enable to achieve directional sensitivity of the scattering signal and retrieve quantitative information about the phase shift induced by the magnetic potential.
16:20		
16:30		***Coffee Break***

Time	ID	**Quantum Beam Science: bio, materials and fundamental physics with neutrons and X-rays II: New Spectroscopies of quantum matter** *Chair: Luc Patthey, PSI Villigen*
17:00	**711**	**Ultrafast quenching of phase coherence in cuprates revealed by TR-ARPES** *Elia Razzoli [1], Fabio Boschini [2], Eduardo Da Silva Neto [3], Marta Zonno [2], Andrea Damascelli [2]* *[1] Paul Scherrer Institut, [2] UBC, [3] UC Davis* Angle-resolved photoemission spectroscopy (ARPES), and its extension in the time-resolved regime (TR-ARPES), has revealed to be a powerful technique to study of unconventional superconductivity. In this contribution I will present our TR-ARPES measurements on the cuprate $Bi_2Sr_2CaCu_2O_{8+\delta}$. By employing a pulse of duration comparable to the timescales of the superconducting state we demonstrate the capability of the pump pulse to manipulate the phase fluctuations [1] and the electron-bosons coupling [2] independently of the pairing. [1] F. Boschini, E. H. da Silva Neto, E. Razzoli, et al., “Collapse of superconductivity in cuprates via ultrafast quenching of phase coherence” Nature Materials 17, 416(2018). [2] E. Razzoli, F. Boschini et al., “Ultrafast reduction of electron-boson kink induced by phase coherence loss in cuprates” in submission(2019).
17:30	**712**	**Nonequilibrium Dynamics of Collective Excitations in Quantum Materials** *Edoardo Baldini, Fabrizio Carbone, Majed Chergui, EPFL* Revealing the dynamics of collective excitations (e.g. excitons, phonons, plasmons, magnons…) in quantum materials is a central topic in condensed matter physics, as collectivity lies at the origin of several cooperative phenomena that lead to profound transformations, instabilities and phase transitions. Here, we will explore the dynamics of such collective excitations from the perspective of ultrafast science, presenting novel spectroscopic methods that can track the real-time evolution and the interactions of distinct collective modes. Special emphasis will be given to the rising fields of excitonics and phononics in materials governed by strong interactions and correlations.
18:00	**713**	**Time resolved Resonant Inelastic X-ray Scattering and Soft X-Ray Diffraction on Quantum Materials at Furka experimental station at Athos SwissFEL** *Cristian Svetina [1], Elia Razzoli [1], Thorsten Schmitt [1], Claude Monney [2], Urs Staub [1], Luc Patthey [1]* *[1] Paul Scherrer Institut, [2] University of Fribourg* Furka, the end-station for condensed matter and quantum materials at Athos beamline, will be dedicated to time resolved Resonant Inelastic and Elastic X-ray Scattering (tr-RIXS and tr-REXS) and time-resolved soft X-ray diffraction (tr-SXRD) studies. The intriguing properties of correlated materials originate from the strong coupling between charge, orbital, spin, and lattice degrees of freedom. Ultrafast spectroscopy and tr-SXRD are unique tools to disentangle different degrees of freedom. After a brief overview of the Athos project describing its unique features, we will present the Furka's scientific case giving a general concept of the instrument. In the future it will be investigated the option to perform experiments in the nonlinear optics regime, taking advantage of the multicolour and TeraWatt-attosecond pulses provided.
18:20	**714**	**Spin wave dynamics in ultrathin yttrium iron garnet measured with x-ray microscopy** *Joe Bailey [1,2], Sebastian Wintz [1,3], Simone Finizio [1], J. Förster [4], Korbinian Baumgärtl [2], M. Weigand [4], Carsten Dubs [5], G. Schütz [4], Dirk Grundler [2], Jörg Raabe [2], Gabriel Aeppli [1,2,6]* *[1] Paul Scherrer Institute, CH-5232 Villigen PSI, [2] EPFL, CH-1015 Lausanne* *[3] Helmhotz-Zentrum Dresden-Rossendorf, Germany* *[4] Max-Planck-Institute for Intelligent Systems, DE-70569 Stuttgart* *[5] INNOVENT e.V., Technologieentwicklung Jena, DE-07745 Jena* *[6] Laboratory for Solid State Physics, ETH Zürich, CH-8093 Zürich* Magnonics, the study and development of devices utilising collective spin excitations, is a rapidly growing field, covering both fundamental topics (antiferromagnetism, quasiparticle condensates) and technological applications (MRAM, spintronics). Yttrium iron garnet (YIG) is a ferrimagnetic insulator with the lowest known magnon damping factor of any material. This low damping leads to

		a prevalence of nonlinear effects and notably the room temperature Bose-Einstein condensation (BEC) of magnons first reported by Demokritov et al in 2006, and subject of a number of investigations since. Ultrathin structures will be required for applications but remain largely unexplored. Here I report on the design, fabrication and characterization of microwave devices based on such ultrathin structures (YIG thickness~100 nm). The spin wave dynamics were measured using both Brillouin Light Scattering (BLS) and time resolved scanning transmission x-ray microscopy (TR-STXM), locked in phase with microwave stimulation of the devices. A number of milestones are reached for our novel devices. First, we have explicitly measured the spin wave dispersion in YIG, and demonstrated the existence of the finite momentum minimum required for magnon BEC. Second, the BLS data demonstrate that the condensate exists in our samples. These results are a key development towards adding condensate phenomena to the thin film magnonics toolbox.
18:40	**715**	**Ultrafast electron vortex beam and temporal holography in ultrafast electron microscope** *Ivan Madan, Gabriele Berruto, Giovanni Maria Vanacore, Fabrizio Carbone, Enrico Pomarico* *EPFL* Ultrafast electron microscopy provides the possibility to conduct time-resolved experiment in three independent dimensions: real space, reciprocal space and energy domain. Being promising for condensed matter and material research it also serves as a platform for electron-light interaction. There are two mechanisms which facilitate the strong interaction regime: interaction with near-fields and interaction via inverse transition radiation. We utilise these effects to demonstrate: 1) Momentum exchange between electron and photon; 2) Generation of electron vortex facilitated by orbital angular momentum conservation upon absorption of circularly polarized photons 3) Coherence interaction involving multiple optical fields, used for time-holography of optical fields.
19:00		***END; Transfer to Dinner***
19:30		***Conference Dinner***

ID	QUANTUM BEAM SCIENCE: BIO, MATERIALS AND FUNDAMENTAL PHYSICS WITH NEUTRONS AND X-RAYS POSTER
721	**Correlation between O-vacancies and electrochemical activity of $PrBaCo_2O_{5+x}$ ($0.17 \leq x \leq 0.79$)** *Elena Marelli, Emiliana Fabbri, Thomas Schmidt, Marisa Medarde, Paul Scherrer Institut* Cobalt-based layered perovskites have emerged as promising electrocatalysts for the oxygen evolution reaction (OER), but fundamental questions regarding the design principles for highly active perovskite electrocatalysts are still open. A recent study demonstrated that oxygen vacancies play a critical role in the OER mechanism and on the perovskite electrochemical activity. Double perovskite oxides, such as $PrBaCo_2O_{5+x}$ (PBCO), are able to incorporate large amounts of oxygen vacancies with high oxygen mobility. We combine high-resolution neutron and X-ray diffraction, XAS, magnetic and electrochemical analysis to understand the correlation between catalyst activity and oxygen vacancy amount and distribution.

722	**Design rules for high-temperature magnetic spirals in layered perovskites**

Tian Shang [1], Emmanuel Canévet [2,3], Mickaël Morin [1,4], Denis Sheptyakov [3], María Teresa Fernández-Díaz [5], Ekaterina Pomjakushina [1], Marisa Medarde[1]
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In the past years, magnetism-driven ferroelectricity and gigantic magnetoelectric effects have been reported for a number of frustrated magnets with spiral magnetic orders. Such materials are of high current interest due to their potential for spintronics and low-power magnetoelectric devices. However, their low magnetic order temperatures (typically < 100 K) greatly restrict their fields of application.
Recently, we have established that chemical disorder is a powerful tool that can be used to stabilize magnetic spiral phases up to 310 K [1]. Here we explore the design space opened up by this novel stabilization mechanism, recently rationalized in terms of random magnetic exchanges [2]. We show that in CuFe-based layered perovskites Tspiral can be further increased up to 400 K, and we reveal a scaling law between this quantity and the spiral wave vector [3]. This linear relationship ends at a paramagnetic–collinear–spiral multicritical point, which defines the highest spiral-order temperatures that can be achieved in this kind of materials. Based on our findings, we propose a general set of rules for designing magnetic spirals in layered perovskites using external pressure, chemical substitutions and/or epitaxial strain, which should guide future efforts to engineering spiral phases with order temperatures suitable for technological applications.

[1] M. Morin et al., Nature Communications 7, 13758 (2016)
[2] A. Scaramucci et al., Physical Review X, 8, 011005 (2018)
[3] T. Shang et al., Science Advances, 4, eaau6386 (2018)

723	**Spin-Rotation Coupling Observed in Neutron Interferometry**

Armin Danner [1], Bülent Demirel [1], Wenzel Kersten [1], Hartmut Lemmel [1,2], Richard Wagner [1], Stephan Sponar [1], Yuji Hasegawa [1,3]
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Spin-rotation coupling is an extension of the Sagnac effect, based upon the inertia of intrinsic spin. To confirm its existence, a neutron interferometer experiment was proposed [1,2] coupling the spin to the rotation of a magnetic field. The results of a neutron polarimeter experiment comply with the prediction but can also be explained semi-classically.
A spin manipulator for a respective interferometer experiment is developed [3] which produces a rotating field while ensuring a non-adiabatic transition, necessary to induce Larmor precession. The observed phase shift of interferograms [4] is linearly dependent on the frequency of the rotating field. This result is purely quantum mechanical.

[1] B. Mashhoon, Neutron interferometry in a rotating frame of reference, Phys. Rev. Lett. 61, 2639 (1988)
[2] B. Mashhoon and H. Kaiser, Inertia of intrinsic spin, Physica B 385–386, 1381 (2006)
[3] A. Danner et al., Development and perfomance of a miniaturised spin rotator suitable for neutron interferometer experiments, J. Phys. Commun. 3, 035001 (2019)
[4] A. Danner et al., Spin-Rotation Coupling Observed in Neutron Interferometry, arXiv 1904.07085