MA 2: Focus Session: Antiferromagnetic Spintronics

Organized by Karin Everschor-Sitte and Jairo Sinova (Johannes Gutenberg Universität Mainz)

The common view of antiferromagnets as *interesting but useless* materials was verbalized by Louis Ne*el in his 1970 Nobel lecture on the discovery of antiferromagnetism. This view has changed a lot in recent years as antiferromagnets are becoming active elements in spintronic devices. The established knowledge in ferromagnets has allowed for rapid theoretical developments and a lot of successes recently in this field of research. An antiferromagnet is by far more than just two coupled ferromagnets and thus allows for new features. When highlighting differences between antiferromagnets and ferromagnets, one has to mention, that i) all effects in antiferromagnets are enhanced due to antiferromagnetic exchange coupling and ii) antiferromagnets obey a different current induced dynamics, namely inertia-like instead of the gyroscopic-like ferromagnetic dynamics. In addition, its natural coupling to Dirac fermion physics makes them good candidates to explore topological properties in these materials from novel perspectives. The goal of this Focus Session is to bring together the leading scientist in the field of antiferromagnetic spintronics and exploit further their potential of applications.

Time: Monday 9:30–12:15 Location: HSZ 01

Invited Talk MA 2.1 Mon 9:30 HSZ 01

Electrical Control of Quantum Coherent Phenomena in Insulating Antiferromagnets — •Arne Braatas — Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

Usually, antiferromagnets only function as passive spintronics components. However, antiferromagnets' markedly different properties as compared to ferromagnets make them interesting and attractive in a more dynamic role. Furthermore, in insulators, there are no moving charges involved so that the power reduction can be significant.

Antiferromagnetic insulators couple strongly to electric currents in adjacent normal metals. Therefore, antiferromagnets can fulfill the role as active components in spintronics devices despite their lack of a macroscopic magnetic moment, and even when they are insulating.

We explore routes for electrical control of quantum coherent magnon phenomena in insulating antiferromagnets.

First, we describe the formation of steady-state magnon condensates controlled by a spin accumulation in adjacent normal metals. Spin-transfer by this spin accumulation affects the staggered field of the antiferromagnet. The resulting condensation may occur even at room temperature when the spin transfer to the metal is faster than the relaxation processes in the antiferromagnet.

Second, we will discuss how antiferromagnets may exhibit long-range spin superfluidity in insulators, which studies indicate are good spin conductors. The spin superfluidity can be detected in non-local geometries and can reach several micrometers.

MA 2.2 Mon 10:00 HSZ 01

Route towards topological antiferromagnetic spin-orbitronics — •Libor Šmejkal[1,2], Jairo Sinova[1,2], and Tomáš Jungwirth[2] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany — [2]Institute of Physics of the Czech Academy of Sciences, CZ-16253 Prague, Czech Republic

We present our recent theoretical predictions of topologically nontrivial antiferromagnets (AF) useful for spin-orbitronics. We start with derivation of symmetry criteria and minimal models for the nontrivial bulk and surface topologies in AF. We identify real material candidates by using the first-principles calculations, e.g. CuMnAs.[1]

We discuss in detail an emergent electric control of Dirac fermions by Néel spin orbit torques (NSOT) in an AF preserving the combination of spatial and time inversion symmetry.[1] We explain physical mechanism of the control of the bands-topology by tuning the non-symmorphic crystal symmetry via the staggered order reorientation. We reveal the necessary criteria to accommodate Dirac quasi-particles and NSOT simultaneously in single material platform.

In the last part we demonstrate the merits of Dirac and Weyl fermions for spin-orbitronics transport effects in collinear and non-collinear AF by first-principles calculations. We suggest novel magneto-transport effects, for instance topological anisotropic magnetoresistance (AMR). We propose experimental setup for the observation of the topological AMR as clear signature of Dirac fermions.

[1] L. Šmejkal et al., eprint arXiv:1610.08107 (2016)

Invited Talk MA 2.3 Mon 10:15 HSZ 01

Electronic and magnonic spin transport in antiferromagnets — Lamprini Frangou[1], Guillaume Forestier[1], Stephane Auffret[1], Serge Gambarelli[2], and •Vincent Baltz[1] — [1]SPINTEC (Univ. Grenoble Alpes / CNRS / INAC-CEA), F-38000 Grenoble, France — [2]SYMMES (Univ. Grenoble Alpes / INAC-CEA), F-38000 Grenoble, France

Through spin-pumping experiments we investigated how spin currents can be injected, transmitted and converted in antiferromagnets and what is the influence of the magnetic order. Spin pumping results from the magnetization dynamics of a ferromagnetic spin injector, which pumps a spin current into an adjacent spin sink. This spin sink filters, absorbs and converts the current to an extent which depends on its interface and bulk spin-dependent properties. This can be recorded either through the changes induced in ferromagnetic damping or through direct electrical means by measuring the inverse spin Hall effect. Whether the transport regime is electronic or magnonic depends of the electrical nature of the spin-sink and how strongly injector and sink are coupled. Due to magnetic coupling transfer/sink and propagation of spin angular momentum involves magnons from the oscillating ferromagnet feeding into the antiferromagnet. Measurements of the spin penetration were obtained for several antiferromagnetic metals and insulators. Interestingly, spins propagate more efficiently in layers where the magnetic order is fluctuating rather than static. Magnonic spin transport is also more efficient than its electronic counterpart. The experimental data were compared to some of the recently developed theories.

15 min. break

Invited Talk MA 2.4 Mon 11:00 HSZ 01

Staggering antiferromagnetic domain wall velocity in a staggered spin-orbit field — •Olena Gomonay — Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany

Future applications of antiferromagnets (AFs) in many spintronics devices rely on the precise manipulation of domain walls. Here we discuss different approaches to manipulate and control the domain walls in AF. We demonstrate the possibility to drive an AF domain-wall at high velocities by field-like Néel spin-orbit torques. Such torques arise from the current-induced local fields that alternate their orientation on each sub-lattice of the AF and whose orientation depend primarily on the current direction, giving them their field-like character. The domain-wall velocities that can be achieved by this mechanism are two orders of magnitude greater than the ones in ferromagnets. This arises from the efficiency of the staggered spin-orbit fields to couple to the order parameter and from the exchange-enhanced phenomena in AF texture dynamics, which leads to a low domain-wall effective mass and the absence of a Walker break-down limit. We also discuss other possibilities based on application of spin-polarised current and/or time-dependent magnetic field. We believe that our approaches pave a way for the development of AF-based devices based on controlled motion of AF domain walls.

MA 2.5 Mon 11:30 HSZ 01

Terahertz spectroscopy of femtosecond spins currents in magnetic heterostructures — •Tom Seifert and Tobias Kampfrath — Fritz Haber Institut, MPG, Berlin, Deutschland

Spin-orbit interaction (SOI) will be of central importance for future spin-based electronics (spintronics) as it permits, for example, the conversion of charge into spin currents and vice versa via the spin Hall effect [1]. It is highly interesting to study spin dynamics at terahertz (THz) frequencies because spintronic devices should eventually operate at THz rates. In our experiments, we employ femtosecond optical pulses to trigger ultrafast spin transport in magnetic thin-film stacks. Due to SOI, the spin current is partially converted into a transverse charge current which is monitored by detecting the concomitantly emitted THz electromagnetic radiation [2,3]. In particular, we study THz emission from bilayers consisting of a magnetic and a nonmagnetic metallic layer. By varying the magnetic layer material from conducting to insulating and from ferromagnetic to antiferromagnetic, we aim at identifying the different mechanisms that can lead to the ultrafast generation of spin currents across those structures.

The results shown here were obtained in close collaborations with the research groups of J. Barker, C. Ciccarelli, M. Kläui, Y. Mokrousov, M. Münzenberg, P.M. Oppeneer, I. Radu and D. Turchinovich.

References
[1] S.A. Wolf et al., Science 294.5546 (2001)
[2] T. Kampfrath et al., Nature Nanotech. 8, 256 (2013)
[3] T. Seifert et al., Nature Phot. 10, 483 (2016)

Invited Talk MA 2.6 Mon 11:45 HSZ 01

Current induced switching of an antiferromagnet — Peter Wadley[1], Michal J. Grzybowski[2], Carl Andrews[1], Sonka Reimers[1], Richard P. Campion[1], Vit Novak[3], Francesco Maccherozzi[4], Sarnjeet S. Dhesi[4], •Kevin W. Edmonds[1], Bryan L. Gallagher[1], Jakub Zelezny[3], and Tomas Jungwirth[3] — [1]University of Nottingham, Nottingham, UK — [2]Institute of Physics, Polish Academy of Sciences, Warsaw, Poland — [3]Institute of Physics, Czech Academy of Sciences, Prague — [4]Diamond Light Source, Oxford, UK

The pioneer of the field of antiferromagnetism, Louis Neel, noted in his Nobel lecture that while abundant and interesting from the theoretical viewpoint, antiferromagnets did not seem to have any applications. The alternating directions of magnetic moments and the resulting zero net magnetization make them difficult to detect and manipulate. Remarkably, Neel also pointed out the equivalence of antiferromagnets with ferromagnets in effects that are an even function of the magnetic moment, but an efficient means of controlling the magnetic order has been elusive. Zelezny et al predicted a mechanism, by which an alternating field-like torque can be produced in crystals of specific symmetries [1]. In some materials these torques can coincide with the spin sub-lattices of the AF, and offer the prospect of current induced switching of the spin axis. This talk reports the demonstration of electrical reading and writing of an all-AF memory device, and complementary X-PEEM imaging[2]. [1] J. Zelezny, et al., Physical Review Letters 113, 157201 (2014). [2] P. Wadley, et al., Science 351, 587-590 (2016)