

TT 8: Topological Phenomena (joint session MA/TT)

Time: Monday 9:30–11:30

Location: POT 6

TT 8.1 Mon 9:30 POT 6

Complex magnetism and colossal magnetoresistance in wall-paper fermion candidate $\text{Eu}_5\text{In}_2\text{Sb}_6$ — ●MAREIN RAHN^{1,2}, SONIA FRANCOUAL⁴, ALESSANDRO BOMBARDI⁵, PASCAL MANUEL⁶, LARISSA VEIGA⁷, MORGAN ALLISON¹, MARC JANOSCHEK³, JOCHEN GECK¹, FILIP RONNING², and PRISCILA ROSA² — ¹IFMP, Technische Universität Dresden, 01069 Dresden, Germany — ²LANL, Los Alamos, NM 87545, USA — ³PSI, 5232 Villigen, Switzerland — ⁴DESY, 22607 Hamburg, Germany — ⁵Diamond Light Source, Didcot OX11 0DE, UK — ⁶ISIS Neutron and Muon Source, Didcot OX11 0QX, UK — ⁷LCN, University College London, London WC1H 0AH, UK

A new type of hourglass topological surface state has been predicted to be protected by non-symmorphic structural symmetries in $\text{Ba}_5\text{In}_2\text{Sb}_6$. Following this prediction, we synthesized the isostructural $\text{Eu}_5\text{In}_2\text{Sb}_6$, which promises to combine the potential for novel electronic topology with the 8 μB magnetic moment of Eu^{2+} . Indeed, we find unusual unusual electronic properties, such as 99% negative magnetoresistance and a two-step magnetic ordering process. We present our complementary use of neutron powder diffraction, Eu L3-edge resonant elastic x-ray scattering and muon spin-rotation to reveal the mechanism of this unusual magnetic ground state, which may form a basis for understanding of the relevance of topological surface states in this material.

TT 8.2 Mon 9:45 POT 6

Large magnetic gap at the Dirac point and spin polarization control in $\text{Bi}_2\text{Te}_3/\text{MnBi}_2\text{Te}_4$ heterostructures — ●FRIEDRICH FREYSE¹, EMILE RIENKS¹, STEFAN WIMMER², ANDREAS NEY², HUBERT STEINER², VALENTINE VOLOBUEV², HEIKO GROISS², GÜNTHER BAUER², ANDREI VARYKHALOV¹, OLIVER RADER¹, GUNTHER SPRINGHOLZ², and JAIME SÁNCHEZ-BARRIGA¹ — ¹Helmholtz-Zentrum Berlin für Materialien und Energie, BESSY II, Berlin, Germany — ²Institut für Halbleiter und Festkörperphysik, Johannes Kepler Universität, Linz, Austria

Using spin- and angle-resolved photoemission, we investigate the electronic and spin structure of the topological surface state (TSS) of $\text{Bi}_2\text{Te}_3/\text{MnBi}_2\text{Te}_4$ heterostructures as a function of temperature. By cooling below the Curie temperature T_C , we observe how a magnetic surface gap opens at the Dirac point of the initially gapless TSS, a requirement which is crucial to enable the quantum anomalous Hall effect. The spectrum of the gapped Dirac point measured in remanence after field cooling (M+) is clearly spin polarized, with spin orientation perpendicular to the surface plane and spin split by a large value of $\Delta = 56 \pm 4$ meV at 6 K. Subsequent measurement at room temperature shows that the spin polarization completely disappears, whereas subsequent cooling in an oppositely oriented field (M-) leads to a reversal of the spin polarization.

[1] J.Sánchez-Barriga *et al.* Nature (2019), in press

TT 8.3 Mon 10:00 POT 6

Magnetic properties of antiferromagnetic topological insulators — ●MARTIN HOFFMANN¹, MIKHAIL M. OTROKOV^{2,3,4,5}, ARTHUR ERNST¹, and EVGUENI V. CHULKOV^{2,4,5,6} — ¹Institute for Theoretical Physics, Johannes Kepler Universität, Linz, Austria. — ²Centro de Física de Materiales (CFM-MPC), Centro Mixto CSIC-UPV/EHU, San Sebastián, Spain. — ³IKERBASQUE, Basque Foundation for Science, Bilbao, Spain. — ⁴Donostia International Physics Center (DIPC), San Sebastián, Spain. — ⁵Saint Petersburg State University, Saint Petersburg, Russia. — ⁶Departamento de Física de Materiales UPV/EHU, San Sebastián, Spain.

The doping of nonmagnetic topological insulators with magnetic transition metal elements exhibits less desired strongly inhomogeneous magnetic and electronic properties, which restricts the observation of important effects to very low temperatures. Well ordered intrinsic magnetic topological insulators can be the solution to those problems as they show higher magnetic phase transition temperatures as theoretically predicted and experimentally confirmed for the antiferromagnetic (AFM) topological insulator MnBi_2Te_4 . Here, we report about the *ab initio* results and calculated magnetic properties of this prediction. MnBi_2Te_4 forms septuple-layer blocks including a Mn layer. A three-dimensional AFM order establishes below the Néel temperature of $T_N = 25.4$ K obtained by Monte Carlo simulations. This AFM order causes the different Mn layer to align their moments antiparallel due

to weak out-of-plane magnetic exchange coupling constants, while the intralayer magnetic order is ferromagnetic.

TT 8.4 Mon 10:15 POT 6

A Family of Intrinsic Magnetic Topological Insulators $(\text{MnBi}_2\text{Te}_4)(\text{Bi}_2\text{Te}_3)_n$, $n = 0, 1, 2$ — ●ANNA ISAEVA^{1,2}, ALEXANDER ZEUGNER³, ANJA U. B. WOLTER¹, BERND BÜCHNER¹, and HENDRIK BENTMANN⁴ — ¹Institute for Solid State and Materials Research, Leibniz IFW Dresden, Dresden, Germany — ²Faculty of Physics, Technische Universität Dresden, Dresden, Germany — ³Faculty of Chemistry and Food Chemistry, Technische Universität Dresden, Dresden, Germany — ⁴Experimental Physics VII, Universität Würzburg, Würzburg, Germany

In a quest to harness quantum effects for technological advances, new realizations of materials for quantum anomalous Hall effect are pursued. A family of van-de-Waals $(\text{MnBi}_2\text{Te}_4)(\text{Bi}_2\text{Te}_3)_n$ compounds derive from the 3D topological insulator Bi_2Te_3 and feature an ordered Mn sublattice. They are the first intrinsic magnetic topological insulators [1]. We obtain high-quality crystals for all n . $(\text{MnBi}_2\text{Te}_4)(\text{Bi}_2\text{Te}_3)_n$ are thermodynamically stable in narrow temperature ranges near 873 K. We establish ubiquitous off-stoichiometry of the materials, e.g. $\text{Mn}_{1-x}\text{Bi}_{2+2x/3}\text{Te}_4$ ($x = 0.15$). Temperature- and field-dependent magnetization measurements show a 3D antiferromagnetic order ($T_N = 24$ K) in MnBi_2Te_4 . It originates from an AFM interlayer coupling of Mn(II) layers with ferromagnetic intralayer coupling. This magnetic ground state and a centrosymmetric space group $R\bar{3}m$ entail the $Z_2 = 1$ topological classification and render MnBi_2Te_4 the first AFM TI [1]. [1] M. Otrokov *et al.* Nature (2019), in press, arxiv.org:1809.07389.

TT 8.5 Mon 10:30 POT 6

Intriguing magnetic ground state of MnBi_4Te_7 : a Bi_2Te_3 derivative with a periodic Mn sublattice — ●LAURA T. CORREDOR-BOHÓRQUEZ¹, VILMOS KOCIS¹, ANJA U. B. WOLTER¹, M. HOSSEIN HAGHIGHI¹, NICOLÁS PÉREZ², JORGE FACIO³, BERND BÜCHNER^{1,4}, and ANNA ISAEVA^{1,4} — ¹Institute for Solid State and Materials Research, Leibniz IFW Dresden, 01069 Dresden, Germany — ²Institute for Metallic Materials, Leibniz IFW Dresden, 01069, Dresden, Germany — ³Institute for Theoretical Solid State Physics, Leibniz IFW Dresden, 01069, Dresden, Germany — ⁴Faculty of Physics, Technische Universität Dresden, Dresden, Germany

Materials with a combination of non-trivial band topology and long-range magnetic order have been long desired, since it is expected the appearance of novel spintronic phenomena. Following theoretical advances material candidates are emerging. MnBi_2Te_4 is the first antiferromagnetic topological insulator [1] and the progenitor of a modular $(\text{Bi}_2\text{Te}_3)_n(\text{MnBi}_2\text{Te}_4)$ series. For $n = 1$, it is established an antiferromagnetic state below 13 K followed by a state with net magnetization and ferromagnetic-like hysteresis below 5 K. Through static and dynamic magnetic characterization of single crystals, we build up a picture of the intriguing magnetic ground state of this new compound. Our results render MnBi_4Te_7 as a band inverted material with an intrinsic net magnetization and a complex magnetic phase diagram providing a versatile platform for the realization of different topological phases. [1] M. Otrokov *et al.* Nature (2019), in press. Arxiv.org:1809.07389.

TT 8.6 Mon 10:45 POT 6

Dynamic magnetic properties of a magnetic topological insulator material MnBi_4Te_7 — ●KAVITA MEHLAWAT^{1,3}, ALEXEY ALFONSOV^{1,3}, ANNA ISAEVA^{1,2,3}, BERND BUECHNER^{1,2,3}, and VLADISLAV KATAEV^{1,3} — ¹Institute for Solid State and Materials Research, Leibniz IFW Dresden, Dresden, Germany — ²Faculty of Physics, Technische Universität Dresden, Dresden, Germany — ³Würzburg-Dresden Cluster of Excellence ct.qmat

A van der Waals compound MnBi_4Te_7 belongs to the family of $(\text{Bi}_2\text{Te}_3)_n(\text{MnBi}_2\text{Te}_4)$, ($n = 0, 1, 2$) heterostructures and is a candidate magnetic topological insulator [1]. It is the first magnetic material that features both, the intrinsic net magnetization and a band inversion. Static magnetic susceptibility (χ) and magnetization (M) measurements as a function of the applied field (H) on MnBi_4Te_7 single-crystals show an antiferromagnetic state at $T_N = 13$ K and

a ferromagnetic-like hysteresis occurring upon cooling below 5 K [1]. We performed electron spin resonance (ESR) spectroscopy measurements in wide frequency and temperature ranges to explore the dynamic magnetic properties of MnBi_4Te_7 . From high-frequency ESR measurements, we obtain evidence that MnBi_4Te_7 is an easy-axis type ferromagnet and ferromagnetic spin correlations persist up to $T = 30$ K on the time scale of an ESR experiment (10^{-10} - 10^{-11} s). [1] Raphael C. Vidal et. al, Topological electronic structure and intrinsic magnetization in MnBi_4Te_7 : a Bi_2Te_3 -derivative with a periodic Mn sublattice, arXiv:1906.08394.

TT 8.7 Mon 11:00 POT 6

Spin orbit torque with topological insulator and ferro/anti-ferromagnetic heterostructures — ●SUMIT GHOSH^{1,2} and AURELIEN MANCHON² — ¹PGI-1 and IAS-1, Forschungszentrum, Jülich 52425, Germany — ²PSE, King Abdullah University of Science and Technology, Thuwal 23955, Saudi Arabia

Due to the robust spin-orbit coupling emerging at the surfaces, topological insulators like Bi_2Se_3 have become a strong source of spin-orbit torque [1,2]. However in the vicinity of a magnetic element the topological protection and hence the interfacial spin-orbit coupling change drastically. In this presentation, we are going to see some of the interesting phenomena arising at the interface of a topological insulator and ferro/antiferromagnet heterostructure [3,4]. Using a simplified tight binding model we are going to show how the interfacial spin texture is modified in the presence of a magnetic element and its impact on the non-equilibrium spin density within the linear response framework. We show how the non-equilibrium spin density changes while moving from surface dominated regime to bulk dominated regime. We also explain the origin of the large spin-Hall angle for the topological insulator ferromagnet heterostructure. Finally, we show their robustness

against the scalar impurity to demonstrate their superiority against their heavy metal counterpart.

- [1] A. R. Melnik et. al., Nature, 511, 449 (2014).
- [2] D. C. Mahendra et. al. Nature Materials, 17, 800 (2018).
- [3] S. Ghosh and A. Manchon, Phys. Rev. B 97, 134402 (2018).
- [4] S. Ghosh and A. Manchon, Phys. Rev. B 100, 014412, (2019).

TT 8.8 Mon 11:15 POT 6

Magneto-electrically controllable spin-orbit torque in topological insulator thin films — ●ALI G. MOGHADDAM^{1,2}, ALIREZA QAIUMZADEH³, ANNA DYRDAL^{4,2}, and JAMAL BERAKDAR² — ¹Department of Physics, Institute for Advanced Studies in Basic Sciences (IASBS), Zanjan 45137-66731, Iran — ²Institut für Physik, Martin-Luther Universität Halle-Wittenberg, D-06099 Halle, Germany — ³Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway — ⁴Faculty of Physics, Adam Mickiewicz University, ul. Umultowska 85, 61-614 Poznan, Poland

We investigate the inverse spin-galvanic effect (ISGE) in topological insulator thin films and the resulting spin-orbit torque (SOT) in the hybrid structures with magnetic layers. Considering in-plane magnetizations inside the magnetic layers which can shift the Dirac dispersion of surface states in the two sides, we find anisotropic ISGE and SOT with a strong dependence on the chemical potential and the magnetization. Then the magnetization-dependence of current-induced spin densities gives rise to a nonlinear field-like SOT which can be controlled by varying the magnetization and applying external gate voltages to change the chemical potential. Also, the mathematical relations between current-induced spin densities and the conductivity of this system results in similar anisotropic features in the magneto-conductance of TI thin film.