MA 7: Transport: Topological Insulators - 2D (Joint session of DS, HL, MA, O and TT organized by TT)

Time: Monday 15:00–17:45 Location: H18

MA 7.1 Mon 15:00 H18

Probing the spin texture of generic helical edge states with an antidot — •Alexia Rod[1,2], Giacomo Dolcetto[1], Thomas L. Schmidt[1], and Stephan Rachel[2] — [1]Physics and Materials Science Research Unit, University of Luxembourg, Luxembourg — [2]Institut für Theoretische Physik, TU Dresden, Germany

Edge states of time-reversal topological insulators are generally described as helical edge states, where the spin-axis symmetry is conserved. However, this symmetry is usually not guaranteed in experimental realizations. In its absence, the most general model to describe edge states is called generic helical liquid. Using this framework, a rotation of the spin quantization axis has been predicted, independently of the microscopic model and of the considered geometry [1, 2].

Here we propose a scheme to probe the spin texture of the edge states on a transport device. We investigate the transport properties of generic helical edge states in a two-dimensional topological insulator bar with an antidot in its center. We show that the conductance is implicitly dependent of the spin texture in the case of uniform bulk or structural inversion asymmetry. We also study sequential tunneling and cotunneling in presence of Coulomb interaction due to electron confinement on the antidot.

[1] T.L. Schmidt, S. Rachel, F. von Oppen, L. Glazman, PRL **108**, 156402 (2012).
[2] A. Rod, T.L. Schmidt, S. Rachel, PRB **91**, 245112 (2015).

MA 7.2 Mon 15:15 H18

Electron quantum optics in 2d topological insulators — •Andrea Spichtinger, Sven Essert, Viktor Krückl, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

Besides conventional quantum Hall systems [1], 2d topological insulators (TIs) are ideal systems providing ballistic channels for guiding charge carriers along edge states allowing for the study of two-particle interferometric effects. Employing wave-packet approaches we investigate correlations between indistinguishable spin pairs at opposite quantum spin Hall edges. Interconnecting opposite edges at TI constrictions or through quantum dots acting as "beam splitter" allows for realizing fermionic analogues of the famous photonic Hong-Ou-Mandel (HOM) effect. In particular, we will consider generalizations of the HOM effect since the dwell time of the quantum dot enters as a new timescale into HOM physics.

[1] E. Bocquillon et al., Ann. Phys. **526**, 1 (2014)

MA 7.3 Mon 15:30 H18

Transport in quantum spin Hall systems in parallel magnetic fields — •Michael Wimmer[1], Rafal Skolasinski[1], Dmitry Pikulin[2], and Jason Alicea[3] — [1]TU Delft, The Netherlands — [2]University of British Columbia, Canada — [3]Caltech, US

Edge states in quantum spin Hall (QSH) systems are protected by time-reversal symmetry, resulting in a qunatized conductance. A magnetic field breaks that protection, and should lead to a deviation from perfect quantization. We will discuss generic features of semiconductor-based QSH systems (such as HgTe/CdTe and InAs/GaSb) that affect the magnetic field dependence of edge state conductance, focusing on the effect of an in-plane field.

MA 7.4 Mon 15:45 H18

Spectral functions of the correlated topological insulator — •Damian Zdulski and Krzysztof Byczuk — Faculty of Physics, Institute of Theoretical Physics, University of Warsaw, ul.Pasteura 5, PL-02-093 Warsaw, Poland

In our recent paper [1], we have studied the influence of electron correlations on topological insulators (TIs) at finite temperatures. The correlated TI was represented by the Kane-Mele model with the interaction term as in the Falicov-Kimball model and it was examined within the Hartree and the Hubbard I approximations. In this talk, we will present extension of that analysis by investigating properties of the system within the dynamical mean field approximation. Our findings show that dynamical correlations yield totally new structures, which are seen in the the momentum dependent spectral functions. Namely, we see: 1) widening of Dirac nodes over finite range of **k** points in the Brillouin zone (BZ), 2) creation of almost flat subbands in a finite range of the BZ, 3) appearance of kinks, and 4) splitting of kinks with formation of overlapping bands.

[1] D. Zdulski, K. Byczuk, PRB **92**, 125102 (2015)

MA 7.5 Mon 16:00 H18

The topological Anderson insulator phase in the Kane-Mele model — Christoph P. Orth[1], •Tibor Sekera[1], Christoph Bruder[1], and Thomas L. Schmidt[2] — [1]Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland — [2]Physics and Materials Science Research Unit, University of Luxembourg, L-1511 Luxembourg

It has been proposed that adding disorder to a topologically trivial mercury telluride/cadmium telluride (HgTe/CdTe) quantum well can induce a transition to a topologically nontrivial state. The resulting state was termed topological Anderson insulator and was found in computer simulations of the Bernevig-Hughes-Zhang model.

We show that the topological Anderson insulator is a more universal phenomenon and also appears in the Kane-Mele model of topological insulators on a honeycomb lattice. We numerically investigate the interplay between the parameters characterizing intrinsic spin-orbit coupling, extrinsic Rashba spin-orbit coupling and staggered sublattice potential. We establish the parameter regimes in which the topological Anderson insulator is found. For weak enough disorder, a calculation based on the lowest-order Born approximation reproduces the numerical data. Our results thus considerably increase the number of candidate materials for the topological Anderson insulator phase.

15 min. break

MA 7.6 Mon 16:30 H18

Interplay of topology and interactions in the quantum Hall regime of topological insulators: spontaneous symmetry breaking, tunable strongly interacting Luttinger liquid — •Stefan Jürgens, Maxim Kharitonov, and Björn Trauzettel — Institute of Theoretical Physics, University of Würzburg, Germany

We consider a class of two-dimensional topological insulators, in which the single-particle edge states are preserved in the presence of the magnetic field by a symmetry (such as crystalline) other than time-reversal, relevant to such materials as HgTe-type heterostructures.

We focus on the vicinity of the topological crossing point between two Landau levels. At half-filling, Coulomb interactions lead to the formation of the quantum Hall "ferromagnetic" many-body state with gapped charge excitations in the bulk. We derive and analyze the σ-model that describes the low-energy properties of this strongly interacting state, including the effect of the edge. We obtain the bulk phase diagram and find three phases, two with preserved and one with spontaneously broken U(1) symmetry. We study the collective edge charge excitations of these phases.

We demonstrate that in one of the phases with preserved U(1) symmetry, the edge charge excitations are gapless and described by a highly tunable, strongly interacting Luttinger liquid. When U(1) symmetry is broken in this phase, edge excitations become gapped and are described by a sine-Gordon model. Our main conclusion is that continuous U(1) symmetry is a necessary condition for the existence of the gapless edge excitations in this strongly interacting system.

MA 7.7 Mon 16:45 H18

Terahertz properties of Dirac electrons and holes in HgTe films with critical thickness — •Uladzislau Dziom[1], Alexey Shuvaev[1], Nikolai Mikhailov[2], Ze Don Kvon[2], and Andrei Pimenov[1] — [1]Institute of Solid State Physics, Vienna University of Technology, 1040 Vienna, Austria — [2]Novosibirsk State University, Novosibirsk 630090, Russia

We present and discuss properties of mercury telluride (HgTe) films with critical thickness in far-infrared (THz) spectral range. Density of charge carriers is controlled, using contact-free optical gating by visible light. Transmission measurements in applied magnetic field demonstrate switching from hole to electron-like behavior, as illumination time increases. The cyclotron mass of the electrons, extracted from the data, shows a square root dependence upon the charge concentration in a broad range of parameters. This can be interpreted as a clear proof of a linear dispersion relations, i.e. Dirac-type charge carriers.

MA 7.8 Mon 17:00 H18

Topological Edge States with Zero Hall Conductivity in a Dimerized Hofstadter Model — •Alexander Lau[1], Carmine Ortix[1,2], and Jeroen van den Brink[1,3] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, Germany — [2]Institute for Theoretical Physics, Utrecht University, The Netherlands — [3]Department of Physics, TU Dresden, Germany

The Hofstadter model is one of the most celebrated models for the study of topological properties of matter and allows the study of the quantum Hall effect in a lattice system. Indeed, the Hofstadter Hamiltonian harbors the topological chiral edge states that are responsible for the quantized Hall conductivity.

Here, we show that a lattice dimerization in the Hofstadtermodel opens an energy gap at half-filling. What is more, we demonstrate that even if the ensuing insulator has a Chern number equal to zero, concomitantly a doublet of edge states appear that are pinned to specific momenta. We show that the presence of these states can be understood from the topological properties of lower dimensional cuts of the system, using a mapping of the Hofstadter Hamiltonian to a collection of one-dimensional Aubry-Andre-Harper (AAH) models. A sub-set of AAH chains in this collection preserve inversion symmetry. This guarantees the presence of topologically protected doublets of end modes to which the edge states are pinned. To explicitly prove the robustness of the emerging edge states, we define and calculate the topological invariant that protects them, which turns out to be an integer invariant for inversion-symmetric AAH models.

MA 7.9 Mon 17:15 H18

Disorder induced zero Landau level in topological insulator nanowires and its signature in conductance fluctuations — •Emmanouil Xypakis and Jens H Bardarson — Max-Planck-Institut f. Physik komplexer Systeme Noethnitzer Str. 38, 01187 Dresden, Germany

In this talk I will discuss the quantum transport properties of a disordered topological insulator in a strong magnetic field. The focus is on the case when the chemical potential is close to the Dirac point, where the transport is dominated by induced chiral modes. Disorder has a drastic role in the system electrical response by revealing a zero Landau level, which is absent for clean topological insulators. We study the dependence of the zero Landau level energy window on the system parameters, such as system size, disorder and magnetic field strength.

MA 7.10 Mon 17:30 H18

Time-resolved pure spin fractionalization and spin-charge separation in helical Luttinger liquid based devices — •Giacomo Dolcetto[1,2], Matteo Carrega[2], Alessio Calzona[2,3], and Maura Sassetti[2,3] — [1]Physics and Materials Science Research Unit, University of Luxembourg, Luxembourg — [2]SPIN-CNR, Genova, Italy — [3]Dipartimento di Fisica, Università di Genova, Italy

Helical Luttinger liquids, appearing at the edge of two-dimensional topological insulators, represent a new paradigm of one-dimensional systems, where peculiar quantum phenomena can be investigated [1]. Motivated by recent experiments on charge fractionalization [2], we propose a setup based on helical Luttinger liquids that allows one to time-resolve, in addition to charge fractionalization, also spin-charge separation and pure spin fractionalization. This is due to the combined presence of spin-momentum locking and interactions. We show that electric time-resolved measurements can reveal both charge and spin properties, avoiding the need of magnetic materials [3, 4]. Although challenging, the proposed setup could be achieved with present-day technologies, promoting helical liquids as interesting playgrounds to explore the effects of interactions in one dimension.

[1] G. Dolcetto, M. Sassetti, and T. L. Schmidt, arXiv preprint arXiv:1511.06141
[2] H. Kamata, N. Kumada, M. Hashisaka, K. Muraki, and T. Fujisawa, Nat. Nanotechnol. **9**, 177 (2014)
[3] A. Calzona, M. Carrega, G. Dolcetto, and M. Sassetti, Physica E **74**, 630 (2015)
[4] A. Calzona, M. Carrega, G. Dolcetto, and M. Sassetti, PRB **92**, 195414 (2015)