

SKM-Symposium Topological Insulators (SKM-SYTI)

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

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Before 1980 all states of matter in condensed matter systems could be classified by the principle of broken symmetry. The Quantum-Hall state provided then the first example of a quantum state that has no spontaneously broken symmetry. Its behavior depends only on its topology and not on its specific geometry; it was topologically distinct from all previously known states of matter.

The prediction in 2006 and experimental discovery in 2007 of a new class of materials known as topological insulators is a major recent event in condensed-matter physics. This symposium gives an overview over these materials, where spin-orbit coupling and time-reversal symmetry combine to form such a novel state of matter, predicted to have exciting new properties, both concerning basic physical questions and applications.

Overview of Invited Talks and Sessions

(lecture room TRE Ma)

Invited Talks

SKM-SYTI 1.1	Wed	10:30–11:00	TRE Ma	Topological insulators and topological superconductors — •SHOUCHENG ZHANG
SKM-SYTI 1.2	Wed	11:00–11:30	TRE Ma	Dirac Fermions in HgTe Quantum Wells — •LAURENS MOLENKAMP
SKM-SYTI 1.3	Wed	11:30–12:00	TRE Ma	Interaction, disorder, and quantum criticality in Z_2 topological insulators — •ALEXANDER MIRLIN
SKM-SYTI 1.4	Wed	12:00–12:30	TRE Ma	Disorder and Interactions in Topological Insulators — •ALLAN H. MACDONALD
SKM-SYTI 1.5	Wed	12:30–13:00	TRE Ma	Tunable multifunctional topological insulators in ternary Heusler and related compounds — •CLAUDIA FELSER, STANISLAV CHADOV, LUKAS MÜCHLER, JÜRGEN KÜBLER, SHOU CHENG ZHANG, XIAOLIANG QI, HAI-JUN ZHANG

Sessions

SKM-SYTI 1.1–1.5	Wed	10:30–13:00	TRE Ma	Topological Insulators
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SKM-SYTI 1: Topological Insulators

Time: Wednesday 10:30–13:00

Location: TRE Ma

Invited Talk SKM-SYTI 1.1 Wed 10:30 TRE Ma
Topological insulators and topological superconductors —
•SHOUCHENG ZHANG — Stanford

Recently, a new class of topological states has been theoretically predicted and experimentally observed. The topological insulators have an insulating gap in the bulk, but have topologically protected edge or surface states due to the time reversal symmetry. Similarly, topological superconductors or superfluids have novel edge or surface states consisting of Majorana fermions. In this talk, I shall review the recent theoretical and experimental progress in the field, and focus on a number of outstanding issues, including the quantized anomalous Hall effect, quantized magneto-electric effect, the topological Mott insulators and the search for topological superconductors.

Invited Talk SKM-SYTI 1.2 Wed 11:00 TRE Ma
Dirac Fermions in HgTe Quantum Wells — •LAURENS
MOLENKAMP — Physikalisches Institut(EP3) der Universität
Würzburg, Am Hubland, 97074 Würzburg, Germany

HgTe quantum wells have a linear band dispersion at low energies and thus mimic the Dirac Hamiltonian. Changing the well width tunes the band gap (i.e., the Dirac mass) from positive, through zero, to negative. Wells with a negative Dirac mass are 2-dimensional topological insulators and exhibit the quantum spin Hall effect, where a pair of spin polarized helical edge channels develops when the bulk of the material is insulating. Our transport data provide very direct evidence for the existence of this third quantum Hall effect. Wells with a thickness of 6.3 nm are zero gap Dirac systems, similar to graphene. However, zero gap HgTe wells possess only a single Dirac valley, which avoids inter-valley scattering. This makes them especially suitable to study quantum interference effects under a Dirac Hamiltonian.

Invited Talk SKM-SYTI 1.3 Wed 11:30 TRE Ma
Interaction, disorder, and quantum criticality in Z_2 topological insulators — •ALEXANDER MIRLIN — Karlsruhe Institute of
Technology, Germany

We study disorder and interaction effects in topological insulators with strong spin-orbit coupling. We find that the interplay of nontrivial topology, quantum interference, and Coulomb repulsion induces a novel critical state on the surface of a three-dimensional topological insulator. Remarkably, this interaction-induced criticality, characterized by a universal value of conductivity, emerges without any adjustable parameters. Further, we predict a direct quantum-spin-Hall transition in two dimensions that occurs via a similar critical state.

[1] P.M. Ostrovsky, I.V. Gornyi, A.D. Mirlin, Interaction-induced criticality in Z_2 topological insulators, Phys. Rev. Lett. 105, 036803 (2010)

[2] A. D. Mirlin, F. Evers, I. V. Gornyi, P. M. Ostrovsky, Anderson Transitions: Criticality, Symmetries, and Topologies, in "50 Years of Anderson Localization", ed. by E. Abrahams (World Scientific, 2010); reprinted in Int J Mod Phys B 24, 1577 (2010).

Invited Talk SKM-SYTI 1.4 Wed 12:00 TRE Ma
Disorder and Interactions in Topological Insulators — •ALLAN
H. MACDONALD — University of Texas, Austin TX, USA

Three-dimensional topological insulators have protected surface states that are described by massless Dirac equations. I will discuss some properties of these two-dimensional Dirac systems, emphasizing the importance of disorder and interactions. The magneto-optical properties of topological insulator thin films depend intricately on a competition between disorder and time-reversal symmetry breaking by either external magnetic fields or exchange coupling to external magnetic fields. Broken symmetry states, including notably interaction-driven spontaneous phase coherence between top and bottom surfaces are likely to occur in the absence of a magnetic field. In addition a wide variety of unusual broken symmetry states are likely to be discovered in the presence of external magnetic fields as sample qualities improve.

Invited Talk SKM-SYTI 1.5 Wed 12:30 TRE Ma
Tunable multifunctional topological insulators in ternary Heusler and related compounds — •CLAUDIA FELSER¹,
STANISLAV CHADOV¹, LUKAS MÜCHLER¹, JÜRGEN KÜBLER², SHOU
CHENG ZHANG³, XIAOLIANG QI³, and HAI-JUN ZHANG³ —
¹University Mainz — ²TU Darmstadt — ³Stanford University

Recently the quantum spin Hall effect was theoretically predicted and experimentally realized in quantum wells based on the binary semiconductor HgTe. The quantum spin Hall state and topological insulators are new states of quantum matter interesting for both fundamental condensed-matter physics and material science. Many Heusler compounds with C1b structure are ternary semiconductors that are structurally and electronically related to the binary semiconductors. The diversity of Heusler materials opens wide possibilities for tuning the bandgap and setting the desired band inversion by choosing compounds with appropriate hybridization strength (by the lattice parameter) and magnitude of spin-orbit coupling (by the atomic charge). Based on first-principle calculations we demonstrate that around 50 Heusler compounds show band inversion similar to that of HgTe. The topological state in these zero-gap semiconductors can be created by applying strain or by designing an appropriate quantumwell structure, similar to the case of HgTe. Many of these ternary zero-gap semiconductors (LnAuPb, LnPdBi, LnPtSb and LnPtBi) contain the rare-earth element Ln, which can realize additional properties ranging from superconductivity (for example LaPtBi) to magnetism (for example GdPtBi) and heavy fermion behaviour (for example YbPtBi).