Topological phases of matter (Theory and experiment)

Instructors: Aveek Bid and Tanmoy Das

1) Free electron in a magnetic field – 2 lectures
   - Pierel phase
   - Ahronov-Bohm phase: Experiment + Theory
   - Introduction to WL and WAL

2) Integer Quantum Hall effect – 4 lectures
   - Phenomena
   - Landau level
   - Wavefunction
   - Disorder, localized and extended state
   - Edge states
   - Introduction to FQHE
   - Experimental proof, Magnetic focusing, Febry-Pert Interference, MZI

3) Berry Phase, Berry connection, Berry curvature – 2 lectures
   - Kubo formula and Chern number
   - TKNN phase

4) 1D – 2 lectures
   - SSH model, winding number, Zak phase, end state
   - Kitaev model
   - Majorana, experiment

5) 2D: Graphene – 4 lectures
   - Band structure, TB model, k.p model, Dirac fermions, pseudospin, winding number, Berry phase
   - Blocking of backscattering, weak antilocatization, Klein tunneling
   - Landau level for relativistic particles, Filling factor, zeroth Landau Level, QH effect, Valley degeneracy
   - Moire pattern (Theory & Experiment) *

6) 2D – 3 lectures
   - Introduction of relevant symmetries, Rashba spin-orbit coupling, k.p model
   - BHZ model, theory of QSH effect via Chern number, band inversion
   - Molenkamp experiment, Magnetoresisitance, SHE, ISHE, QSHE
   - Quantum Anomalous Hall effect (Theory & experiment)
7) Calculation of Z2 invanriance – 3 lectures
   - Kane – Mele model
   - Calculation of time-reversal polarization and introduction to Z2 invariant
   - Topological invariance by party eigenvalue and band inversion
   - Weak and strong topological insulator

8) Experiments – 2 lectures
   - Bi2Sb3, Bi2Se3, Bi2Te3, doping, thin film effects (ARPES)
   - Observation of Edge states, observation of spin-orbit locking by spin-resolved AREPS, spin-STM, dichroism, Hanke experiments, Non-local measurements
   - QO, Berry phase, Magneto resistance, Antilocalization
   - QAH: Fe, Cr doped Bi2Se3, Bi2Te3 thin films

9) Introduction to 3D Dirac and Weyl semimetals – 2 lectures

References:

"Topological insulators", Shun-Qing Shen, Springer
"Topological insulators and topological superconductors" B. Andrei Bernevig, and T. L. Hughes, Princeton University Press
"Topological insulators- The physics of spin helicity in quantum transport" G. Tkachov, Pan Stanford publishing
"Topological insulators" Marcel Franz, and L. Molenkamp, Elsevier
"Colloquium: Topological band theory", A. Bansil. H. Lin and T. Das, Rev. Mod. Phys. **88**, 021004 (2016).
"Colloquium: Topological insulators", M. Z. Hasan, C. L Kane, Rev. Mod. Phys. 82, 3045 (2010).
"WEAK LOCALIZATION IN THIN FILMS" – Gerd Bergmann, Physics Reports **107** (1984)