DAY 4 (26 June): 9:40 – 10:20

Universal phase diagram for the quantum spin Hall systems

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Spin Hall effect has been attracting interest, because it can produce a spin current without a magnetic field or a magnet [1]. One of the recent interesting issues is the quantum spin Hall (QSH) effect. In the QSH system, the bulk is gapped and insulating, while there are gapless states on the edge (in 2D) or on the surface (in 3D) carrying a spin current. This phase is characterized by a nontrivial Z_2 topological number.

In the presentation we explain our recent theory on universal phase diagrams describing the QSH phase and the ordinary insulator (I) phase, both in 2D and in 3D [2] for systems without impurities. In particular, in 3D, a gapless phase appears between the QSH and insulator phases by changing an external parameter, when the inversion symmetry is broken. This gapless phase comes from the topological nature of the QSH-I phase transition in 3D. At the phase transition the bulk gap closes, and the gap-closing points in the 3D k space are monopoles and antimonopoles, which can be created and annhihilated only by pair-creation/annihilation. This topological consideration is confirmed by a model calculation using the tight-binding model on the diamond lattice proposed by Fu, Kane and Mele. If time allows, we also mention my recent theoretical results on candidate materials for the QSH phase, in particular on the bismuth ultrathin film [3]. The band structure calculation has been done for the bismuth ultrathin film, and is used for the calculation of the Z_2 topological number.

[1] S. Murakami, N. Nagaosa, and S.-C. Zhang, Science 301, 1348 (2003).
[2] S. Murakami et al., Phys. Rev. B76, 205304 (2007); S. Murakami, New J. Phys. 9, 356 (2007).
[3] S. Murakami, Phys. Rev. Lett. 97, 236805 (2006).