Spin Hall effect: Berry phase and topology in solids

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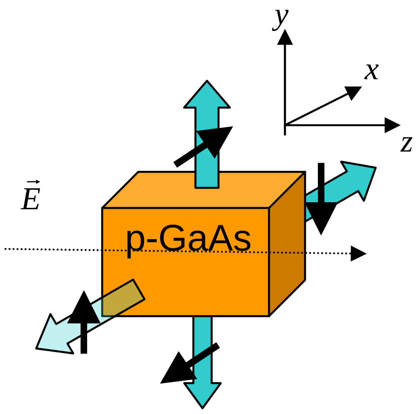

A spin Hall effect is an effect where an external electric field applied to a nonmagnetic system induces spin current in a transverse direction [1,2]. This effect has been known to occur extrinsically by impurity scattering since more than three decades ago. On the other hand, in 2003, we theoretically proposed that this effect occurs intrinsically, without impurity scattering. This is by the Berry phase of an electron in the momentum space. Since its theoretical predictions on semiconductors [1,2], it has been extensively studied theoretically and experimentally, partly due to a potential application to spintronics devices. In my presentation I review on recent progress in theories and experiments on the spin Hall effect.

One of the topics of recent interest is quantum spin Hall systems, which are spin analogues of the quantum Hall systems. These systems are insulators in the bulk, and have gapless edge states which carry a spin current. These edge states are characterized by a Z_2 topological number [3] of a bulk Hamiltonian. If the topological number is odd, there appear gapless edge states which carry spin current. This topological number protects these edge states against nonmagnetic impurities and interactions. While the quantum spin Hall systems are intensively studied theoretically, experimental reports are yet to come. We discuss general features of the quantum spin Hall systems, and explain some theoretical proposals for the candidate materials of the quantum spin Hall systems [4-7].

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