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Ten-years-journey: From classical to quantum regime of topological surface states

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Since the notion of topological insulator (TI) was envisioned about a decade ago, topology has become a new paradigm in condensed matter physics. Realization of topology as a generic property of materials has led to numerous predictions of classical and quantum topological effects. Although most of the classical topological effects, directly resulting from the presence of the spin-momentum-locked topological surface states, were experimentally confirmed soon after the discovery of TIs, topological quantum effects remained elusive. It turns out that defects, especially interfacial defects, have been the main culprit behind this impasse. With a series of interface engineering schemes, however, the density of these interface defects and the corresponding residual carrier densities have decreased by 300 times over the past ten years. Subsequently, a series of topological quantum effects such as quantized Faraday/Kerr rotations, quantum Hall effects, topological quantum phase transitions, zeroth Landau level physics etc. started to emerge. Here, I will overview this ten-years-of-journey toward the extreme quantum regime of topological surface states.