Topological (quantum) synchronization of coupled van der Pol oscillators

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For many quantum mechanical applications dissipation is often regarded as an undesirable yet unavoidable consequence because it potentially degrades quantum coherences and renders the system classical. However, interactions with the environment can also be considered a fundamental resource for striking collective effects typically impossible in Hamiltonian systems. A hallmark of such collective behavior in nonequilibrium systems is the phenomenon of synchronization: in the complete absence of any time-dependent forcing from the outside, a group of oscillators adjusts their frequencies such that they spontaneously oscillate in unison. With the recent developments in quantum technology which allow one to exquisitely tailor both the system and environmental properties, synchronization has emerged in the quantum domain with various different examples ranging from nonlinear oscillators to spin-1 systems, superconducting qubits and optomechanics. However, to observe synchronization in large networks of classical or quantum systems demands both excellent control of the interactions between nodes and accurate preparation of the initial conditions due to the involved nonlinearities and dissipation. This limits its applicability for future devices. We present a potential route towards significantly enhancing the robustness of synchronized behavior in open nonlinear systems that utilizes the power of topological insulators, which exhibit an insulating bulk but conducting surface states, known as topological edge states. These edge states display a surprising immunity to a wide range of local deformations and even circumvent localization in the presence of disorder. By combining nontrivial topological lattices with nonlinear oscillators, we show that synchronized motion emerges at the lattice boundaries in the classical (mean field) as well as the quantum regime. Furthermore, the synchronized edge modes inherit the topological protection known from closed systems with remarkably robust dynamics against local disorder and even random initial conditions. Our work demonstrates a general advantage of topological lattices in the design of potential experiments and devices as fabrication errors and longterm degradation are circumvented in this way. This is especially important in networks where specific nodes need special protection.