Topological pumping of quantum information

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Topological pumps provide a powerful method for transporting particles with remarkable precision by slowly and cyclically modulating a lattice potential. This transport is topologically protected - a feature it shares with the quantum Hall effect - making it inherently robust against noise and experimental imperfections.

In this colloquium, I will introduce a novel paradigm of this concept: moving beyond the transport of individual particles to the pumping of quantum information itself. Our experiments, which employ ultracold fermions in dynamical optical lattices [1,2], demonstrate the coherent transport of not only single atoms but also entangled Bell pairs over hundreds of lattice sites. This capability allows us to perform fundamental quantum computations during transport, including high-fidelity two-qubit gates. I will show how we can chain these operations together to build non-local quantum circuits and generate complex entanglement patterns across the lattice.

[1] arXiv:2409.02984 “Splitting and connecting singlets in atomic quantum circuits”

[2] arXiv:2507.22112 “Protected quantum gates using qubit doublons in dynamical optical lattices”