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Entanglement, quantum transport and noise-protection with cold atoms

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Ultracold atoms are well-known to have very promising applications to quantum simulations and information science, for instance concerning quantum transport, entanglement and noise-protection schemes. First of all, disorder, noise and interaction play a crucial role in transport phenomena, but they are typically hard to control and study, both theoretically and experimentally. Here, we explore the diffusion of a wavepacket with controlled noise and tunable interaction, finding that the presence of quasi-disorder leads to Anderson localization, while both interaction and noise tend to suppress localization and restore transport, although with completely different mechanisms.

Secondly, entanglement estimation in many-body systems represents a major challenge, as it requires either full-state tomography, scaling exponentially in the system size, or the assumption of unverified system characteristics such as its Hamiltonian or temperature. Here, we show the first rigorous and assumption-free experimental large-scale entanglement quantification in a scalable quantum simulator via readily accessible measurements.

Finally, although it is generally impossible to probe a quantum system without disturbing it, we experimentally exploit the back-action of quantum measurements and strong couplings to tailor and protect the coherent evolution of a quantum system. The experimental observation of this profound and counterintuitive phenomenon, known as Quantum Zeno Dynamics, is an important step forward in protecting and controlling quantum dynamics and, broadly speaking, quantum information processing.