Fast atom transport at the quantum speed limit

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I will report on the experimental demonstration of fast, high-fidelity transport of atomic wave packets in spin-dependent optical lattices. We use polarization-synthesized optical lattices, which are created using a fast polarization synthesizer [1], enabling the independent control of the spin-up and spin-down lattice potentials with angstrom precision. The precision and high bandwidth of this system allows us to apply quantum optimal control in order to speed up transport operations. Thereby, we demonstrate wave-packet manipulations at the so-called quantum speed limit, which for our system is on the timescale of 10 μs. To achieve this limit, quantum optimal control allows several motional excitations to be created during the transport process, before these excitations are then refocussed back into the ground state at the end of transport. Besides its fundamental interest, the experimental realization of quantum operations carried out at the quantum speed limit is expected to boost neutral atom applications for quantum information science.

[1] C. Robens, S. Brakhane, W. Alt, D. Meschede, J. Zopes and A. Alberti, "Fast, High-Precision Optical Polarization Synthesizer for Ultracold-Atom Experiments," Phys. Rev. Appl **9**, 034016 (2018)