# Fast optimal transport of neutral atoms in optical lattices for discrete-time quantum-walk applications

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I will report on quantum walk experiments employing ultracold Caesium atoms trapped in *polarisation-synthetized optical lattices*—a novel implementation of state-dependent optical lattices. Polarisation-synthetized optical lattices allow us to trap atoms in either spin-up or spin-down states using two distinct periodic potentials, whose position and depth can be individually controlled in time. This new setup allows us to perform arbitrary shift operations of atoms in spin-up and spin-down states in a fully independent manner, with a high modulation bandwidth (1 MHz) and a fine spatial control at the level of 1 Å.

State-dependent shift operations are key to realize discrete-time quantum walks. To outrun decoherence, transport operations must be performed as fast as possible—ideally, as fast as quantum mechanical laws permit. We have very recently implemented optimal-control state-dependent transport operations, where the position and depth of the periodic potentials are rapidly modulated in time following a seemingly erratic profile, which we calculated using optimal control theory. During transport, several motional excitations are created in our (anharmonic) optical potentials and, yet, these excitations are fully refocused to the motional ground state once the atom has reached the arrival point. We are currently searching for the quantum speed limit.

The next frontier for our ultracold-atom experiments is the realization of 2D discrete-time quantum walks. I will present the implementation of polarization-synthesized optical lattices for transport in the x-y plane. As a first application of this new x-y transport system, we have demonstrated microwave sideband cooling of atoms into the motional state ground state in the 2D polarization-synthesized optical lattice.

[1] C. Robens, J. Zopes, W. Alt, S. Brakhane, D. Meschede, and A. Alberti, "Low-Entropy States of Neutral Atoms in Polarization-Synthesized Optical Lattices," Phys. Rev. Lett. **118**, 065302 (2017).