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Enhanced quantum control for the next generation of optical lattice clocks

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Abstract

Atomic clocks operating in the optical domain are now capable of measuring time at up to eighteen digits of precision. With the level of clock stability that has also been demonstrated in optical clocks based on ultracold atoms in an optical lattice, a promising route to even higher performance exists. Here we explore new techniques for enhanced control of lattice-trapped atoms towards next-generation optical lattice clocks. First, we consider two novel laser cooling strategies that exploit the high atom-laser coherence possible with divalent atomic structure. The first is a pulsed cooling process that replaces two-photon Raman cooling techniques with single-photon velocity-selection on the clock transition. The second is an excited state Sisyphus cooling mechanism that offers efficient three-dimensional cooling in a lattice. We demonstrate sub-recoil cooling of ytterbium in both cases, which aid in loading very shallow lattices to reduce lattice-induced light shifts. We also demonstrate coherent delocalization of ytterbium through controlled tunneling in a Wannier-Stark lattice, aimed at reducing atomic interactions within the lattice. Finally, we discuss progress on the development of portable ytterbium lattice clocks for future measurements beyond the lab.