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Atomic Quantum Simulation of Abelian and non-Abelian Gauge Theories

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Gauge theories play an important role both in particle and condensed matter physics, with applications ranging from QCD to spin liquids, and Kitaev's toric code in quantum information theory. Numerical simulations of such systems on classical computers suffer from very severe sign problems. Quantum simulators are accurately controllable quantum systems that can mimic other quantum systems. They do not suffer from sign problems, because their hardware is intrinsically quantum mechanical. Recently, using
ultracold atoms in optical lattices, quantum simulators have been designed for Abelian and non-Abelian gauge theories. Their experimental realization is a challenge for the foreseeable future, which holds the promise to access physical phenomena, as, for example, the evolution of strongly coupled quantum systems in real time, whose understanding has remained beyond reach of the traditional tools of theoretical physics.

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