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Quantum information processing and quantum simulations with alkaline-earth atoms in an optical lattice ALEXEY GORSHKOV, EUGENE DEMLER, MIKHAIL LUKIN, Harvard University, Cambridge, MA 02138, USA, ANDREW DALEY, PETER ZOLLER, University of Innsbruck and IQOQI, A-6020 Innsbruck, Austria, MARTIN BOYD, JUN YE, MICHAEL HERMELE, VICTOR GURARIE, ANA MARIA REY, JILA and University of Colorado, Boulder, CO 80309, USA — We describe a method for quantum information processing and quantum simulation with alkaline-earth atoms in an optical lattice. First, we propose and analyze a novel approach to quantum information processing, in which multiple qubits can be encoded and manipulated using electronic and nuclear degrees of freedom associated with individual alkaline-earth atoms trapped in an optical lattice. We discuss potential applications of this approach to fault-tolerant quantum computation and precision measurements. In addition, we propose to use alkaline-earth atoms in optical lattices for quantum simulation of models that are beyond the generic Hubbard model and that rely on the interplay between spin and orbital degrees of freedom. In addition to being interesting and rich in their own right, such models may allow generating fundamental insights into the physics of solid-state systems such as transition metal oxides and heavy fermion materials, which exhibit numerous exotic properties including high temperature superconductivity and spin liquid phases.

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