

Abstract for an Invited Paper  
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**Novel Systems and Methods for Quantum Communication, Quantum Computation, and Quantum Simulation<sup>1</sup>**

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This talk focuses on advances in the quantum control of photons, atoms, and molecules. These advances provide fundamental insights into complex quantum phenomena and bring the realization of quantum communication, computation, and simulation closer to reality. We first present an overview of the work, covering 1) single-photon quantum memory and nonlinear coupling, 2) sub-wavelength optical addressing, and 3) control over alkaline-earth atoms and polar molecules. We then focus on ultracold alkaline-earth atoms in optical lattices. In particular, we demonstrate their use as few-qubit quantum registers, with applications to quantum computation and precision measurements. We also evince their ability to act as novel quantum simulators of highly symmetric systems exhibiting spin-orbital interactions. Such systems may provide valuable insights into the physics of strongly correlated transition-metal oxides, heavy-fermion materials, and spin-liquid phases.

<sup>1</sup>Ph.D. thesis, Harvard University, advisor Prof. Mikhail D. Lukin.