Choreographing Quantum Spin Dynamics with Light

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The dream of the quantum engineer is to have an “arbitrary waveform generator” for designing quantum states and Hamiltonians. Motivated by this vision, I will report on advances in optical control of long-range interactions among cold atoms. Our lab is exploring two approaches: photon-mediated and Rydberg-mediated interactions. By coupling atoms to light in an optical resonator, we generate tunable non-local Heisenberg interactions, characterizing the resulting phases and dynamics by real-space imaging. Notable observations include photon-mediated spin-mixing—a new mechanism for generating correlated atom pairs—and interaction-based protection of spin coherence. In a separate platform, we employ Rydberg dressing to induce Ising interactions in a gas of cesium atoms in their hyperfine clock states, enabling the realization of a Floquet transverse-field Ising model. I will discuss prospects in quantum simulation and quantum metrology promised by the versatility of optical control.