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POS-62 Waveguide QED toolboxes for synthetic quantum matter with neutral atoms

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An exciting frontier in quantum information science is the realization of complex many-body systems whose interactions are designed quanta by quanta. Hybrid nanophotonic system with cold atoms has emerged as the paradigmatic platform for engineering long-range spin models from the bottom up with unprecedented complexities. Here, we develop a toolbox for realizing fully programmable complex spin-network with neutral atoms in the vicinity of 1D photonic crystal waveguides. The enabling platform synthesizes strongly interacting quantum materials mediated by Bogoliubov phonons from the underlying collective motion of the atoms. In a complementary fashion, phononic quantum magnets can be designed through the coupling to the magnonic excitation of the atomic medium. We generalize our approach to long-range lattice models for interacting SU(n)-magnons mediated by local gauge constraints. Universal open q-body dynamics with q > 2 can be built from floquet driven-dissipation, and the dynamics of arbitrary quantum materials can be constructed with minimal overheads.

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