Quantum Many-Body Physics with Molecular Tweezer Arrays: From Magnon Dynamics to Spin-Squeezing

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Molecular tweezer arrays are an emerging platform for quantum science that combines the richness of molecules with the microscopic control of programmable optical tweezer traps. In the past few years, our group and others have significantly advanced the level of quantum control in this platform, establishing the building blocks required for quantum science. These include high-fidelity single molecule detection, high-fidelity state preparation, coherent control of interactions, and deterministic entanglement. These developments have opened the door to practical applications such as quantum simulation of interacting many-body systems, quantum information processing, and quantum-enhanced sensing.

In this talk, I will report recent work where we have entered, for the first time, the quantum many-body regime with molecular tweezer arrays. Using two new capabilities that we have developed - measurement-enhanced quantum state preparation and Floquet engineering, we have realized interacting dipolar quantum spin models with tunable XYZ interactions in mesoscopic 1D chains. I will report experiments exploring magnon dynamics in these systems, which include quantum walks of single spin excitations, dynamics of repulsive magnon bound states, and coherent pair creation and annihilation. If time permits, I will discuss our efforts to create metrologically useful entangled states via dynamical evolution under interacting spin Hamiltonians, and report on the first demonstration of spin-squeezing of molecules.

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