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Programmable arrays of ultracold molecules

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Advances in quantum manipulation of molecules bring unique opportunities: the use of molecules to search for new physics; exploring chemical reactions in the ultra-low temperature regime; and harnessing molecular resources for quantum simulation and computation. I will introduce our approaches to building individual ultracold molecules in optical tweezer arrays with full quantum state control. This work expands the usual paradigm of chemical reactions that proceed via stochastic encounters between reactants, to a single controlled reaction of exactly two atoms. The new technique allows us to isolate two molecular rotational states as two-level systems for qubits. In order to preserve coherence of the qubits, we develop magic-ellipticity polarization trapping to reduce lightshift sensitivity by three orders of magnitude. Such light-shift reduction is crucial for resonant dipolar interaction of molecules, which enable tunable interaction in an array. In combination, these ingredients allow the molecular quantum system to be fully programmable.

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