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Universal Matchgate Quantum Computing With Cold Polar Molecules

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Polar molecules in optical lattices are attractive for quantum simulation and computation due to the ability to implement a variety of spin-lattice models using static, microwave and optical fields to engineer the long-range dipolar interaction between molecular qubits. Quantum simulation of spin models requires global control over the molecular ensemble, while quantum computation requires control of individual molecules with sub-wavelength resolution. In this talk, we describe the implementation of a matchgate quantum processor with an ensemble of polar molecules in an optical lattice. The scheme uses few-body qubit encoding and sequential control of two-body dipolar interactions over small plaquetes on a square lattice to perform universal quantum computing without single-site addressing. Effective spin-spin interactions with matchgate symmetry between open-shell polar molecules (e.g., SrF, OH) are driven by two infrared control pulses in the absence of static electric fields. The resulting matchgates are robust with respect to realistic imperfections in the driving fields and lattice trapping. Applications of the architecture for the simulation of interacting fermions in quantum chemistry are discussed, considering an imperfect lattice filling.