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Quantum information processing with polar molecules

We discuss various scenarios of quantum information processing involving polar molecules. Heteronuclear molecules have (large) permanent dipole moments, which can be driven by / couple to microwave fields exciting the rotational degrees of freedom and pairs of molecules interact (strongly) via dipole-dipole interactions. In our first example we consider polar molecules in an optical lattice, where the spin-rotational couplings in the excited rotational states combined with microwave driving allow us to engineer a class of 2D spin models with (i) controllable range couplings and (ii) which are anisotropic in space and spin. This includes models discussed so far in the context of protected quantum memory with arrays of Josephson junctions. The second example is molecular ensembles coupled to strip line cavities, and in particular also Wigner crystals as a way to avoid collisional dephasing of qubits stored in collective qubits.