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Quantum information processing and non-linear optics using polar molecules

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How can one use the hierarchy of levels of polar molecules in conjunction with their permanent dipole moments to create and manipulate nonlinear interactions? One way is by changing the dipole moments - and therefore the dipole-dipole interaction strength - by simply coupling different molecular states using light. Those states, e.g., different electronic states or single and superposition rotational states, can have vastly different dipole moments. Dipole-dipole mediated phase-gates of single-molecule qubits are thus straightforward to construct. Another way is to use the same dipole-dipole nonlinearities to create effective nonlinear coupling between photons. Those photons propagate through the non-linear medium as so-called "slow-light polaritons" and thus allow to create the basis for deterministic optical quantum information processing. The particular challenges and promises of these techniques will be discussed in conjunction with the main decoherence mechanisms and possible ways to mitigate them.