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Quantum Control of Ultracold Dipolar Molecules

SEBASTIAN WILL, Columbia University

Ultracold molecules are poised to open new routes for precision measurements, quantum information, and many-body quantum physics. In particular, dipolar molecules with long-range interactions promise the creation of novel states of matter, such as quantum crystals and topological phases. A crucial prerequisite for advances in this direction is full quantum control over individual molecules and molecular ensembles. In the first part, I will present our recent work at MIT, demonstrating coherent quantum control of ultracold NaK molecules. Starting with spin-polarized molecular ensembles, we show coherent coupling into excited rotational states [1]. We demonstrate that superpositions of molecular hyperfine states can display coherence times on the scale of one second – a result which may have important implications for the use of dipolar molecules in quantum information [2]. In the second part, I will present the current status of our new experiment at Columbia University, which is geared to observe strongly interacting physics with ultracold dipolar molecules, and conclude with an outlook on the prospects of ultracold molecules. [1] Will et al., PRL 116, 225306 (2016), [2] Park et al., Science 357, 372-375 (2017)