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Laser cooling of SrOH and magneto-optical trapping of CaF

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Several promising goals of modern quantum science will be aided by the extension of precision control beyond atoms and bi-alkali molecules to a diverse set of molecular species with varying complex internal structures. Direct laser cooling and trapping of molecules is one promising route. For example, diatomic molecules with one or more unpaired electron spins and polyatomic molecules with closely spaced opposite parity levels have features advantageous for quantum simulation and precision measurement. Frontier research goals include the creation of new types of ultracold quantum molecular gases, optically trapped samples of molecules that can be read out and addressed individually, and new molecules for searches for particle physics beyond the standard model.

Toward this goal, we have recently demonstrated laser slowing and magneto-optical trapping of CaF. Using a two stage cryogenic buffer-gas beam (CBGB) and white light slowing, more than 10,000 molecules are loaded and trapped in a MOT with a temperature below 10 mK. We create a 'dual frequency' DC MOT as also demonstrated in [1] and compare its properties to a RF MOT previously achieved with SrF [2]. We will present our most recent progress with CaF.

We have also recently demonstrated laser cooling of SrOH, a molecule whose structure illuminates some of the possibilities of ultracold polyatomic molecules. With three distinct vibrational modes, SrOH can be optically prepared in excited vibrational states resulting in nearly degenerate opposite parity levels that can be easily mixed in small electric fields. Using optical cycling, we have demonstrated Doppler and Sisyphus laser cooling of this polyatomic radical. By re-pumping the molecules that decay to the excited Sr-O stretching and bending modes, we reduce the transverse temperature of molecular beam from 50 mK to below 1 mK in one dimension. We will also present other recent work on SrOH. Our approach could be applied to more complex species like $SrOCH_3$ and $SrOCH_2CH_3$, opening a path toward creating a variety of ultracold polyatomic molecules by means of direct laser cooling.

[1] Truppe *et al.*, arXiv:1703.00580 (2017). [2] Norrgard *et al.*, Phys. Rev. Lett. 116, 063004 (2016).