Laser Cooling of CaF and Rb towards a CaF BEC

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Ultracold molecules exhibit strong, long-range, and tuneable dipole-dipole interactions, making them a powerful platform for studies of quantum chemistry, quantum computation and simulation, precision measurement, and quantum control. While their rich internal structure can be exploited for such applications, it also presents experimental challenges for controlling their internal states. Ultracold molecules can be produced either through assembly from ultracold atoms or via direct laser cooling. In this work, we pursue direct laser cooling of calcium monofluoride (CaF), which benefits from a nearly diagonal Franck-Condon matrix, enabling closed transitions with only a few lasers. We are particularly interested in producing a Bose-Einstein condensate (BEC) of dipolar molecules since these can display novel quantum phases, such as supersolids and droplet arrays with interesting geometries [Phys. Rev. Res. 4, 013235 (2022)]. We have developed several stages of trapping and cooling of CaF molecules in a magneto-optical trap (MOT), lambda-enhanced molasses, a blue-detuned MOT, and an optical dipole trap (ODT). Further trapping and cooling stages for reaching the BEC will involve introducing a crossed ODT to double the power and remove the weak confinement axis, measuring the lifetime and collisional loss, introducing electric field and microwave shielding to suppress the loss [arXiv:2602.03225 (2026)], and searching for CaF-Rb Feshbach resonances to use Rb to sympathetically cool the CaF molecules to a BEC.

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