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Experiments with ultracold CaF and YbF molecules

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Ultracold molecules can be used to test fundamental physics, study collisions, simulate many-body quantum systems, and process quantum information. We produce a beam of CaF using a cryogenic buffer gas source, decelerate the beam using counter-propagating frequency-chirped laser light, then capture 2×10^4 molecules in a MOT. Here, they cool to a few mK, far above the Doppler limit, due to a competition between Doppler cooling and a Sisyphus mechanism which heats the molecules in the red-detuned light of the MOT. By switching to a blue-detuned optical molasses, we cool the molecules to 50 μK, well below the Doppler limit. We optically pump these molecules into a single state and load them into a magnetic trap. We demonstrate coherent control of the rotational and hyperfine states, in free space and in the magnetic trap. We also demonstrate 1D transverse laser cooling of YbF to a temperature below 100 μK. YbF is more difficult to cool because of its higher mass and less favourable vibrational branching ratios, but is of special interest for measuring the electron EDM. We plan to study ultracold collisions between molecules and atoms, study the behaviour of small arrays of interacting molecules, and make an EDM measurement using an ultracold molecular beam.