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Optoelectrical Cooling of Formaldehyde to Sub-Millikelvin Temperatures

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Due to their strong long-range dipole-dipole interactions and large number of internal states, polar molecules cooled to ultracold temperatures enable fascinating applications ranging from ultracold chemistry to investigation of dipolar quantum gases. However, realizing a simple and general technique to cool molecules to ultracold temperatures, akin to laser cooling of atoms, has been a formidable challenge.

We present results for opto-electrical Sisyphus cooling applied to formaldehyde (H_2CO). In this generally applicable cooling scheme, molecules repeatedly move up and down electric field gradients of a trapping potential in different rotational states to efficiently extract kinetic energy[1]. A total of about 300,000 molecules are thereby cooled by a factor of 1000 to 400uK, resulting in a record-large ensemble of ultracold molecules[2]. In addition to cooling of the motional degrees of freedom, optical pumping via a vibrational transition allows us to control the internal rotational state[3]. We thereby achieve a purity of over 80% of formaldehyde molecules in a single rotational M-sublevel. Our experiment provides an excellent starting point for precision spectroscopy and investigation of ultracold collisions.

[1]M. Zeppenfeld et al., Phys. Rev. A **80**, 041401(R) (2009).
[2]A. Prehn et al., Phys. Rev. Lett. **116**, 063005 (2016).
[3]R. Glöckner et al., Phys. Rev. Lett. **115**, 233001 (2015).