Sisyphus Cooling of Electrically Trapped Polyatomic Molecules

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Potential applications of cold and ultracold polar molecular gases ranging from many-body physics and quantum information science to precision measurements and chemistry benefit from the molecules' many internal degrees of freedom and long-range dipole-dipole interactions. Direct cooling of polar molecules to the ultracold regime remains a challenge, but allows to cool chemically diverse species. Here, optoelectrical Sisyphus cooling [1] presents a unique opportunity to even cool ensembles of polyatomic molecules.

A wide range of molecule species stored in an electric trap [2] can be cooled using only a single infrared laser along with additional microwave and radio frequencies. As a first result [3], we have demonstrated a temperature reduction by more than an order of magnitude—from 390 mK to 29 mK—of about a million CH_3F molecules. At the same time, the phase-space density is increased by a factor of 30. In the cited experiment only a pair out of a number of populated rotational states of a preselected thermal ensemble has been used. Ongoing efforts aim at a larger size of the initial ensemble accessible to cooling, an increased cooling rate, and a more efficient detection. These improvements should allow sub-mK temperatures to be reached and even cooling of the rotational states to be realized with polyatomic molecules for the first time.

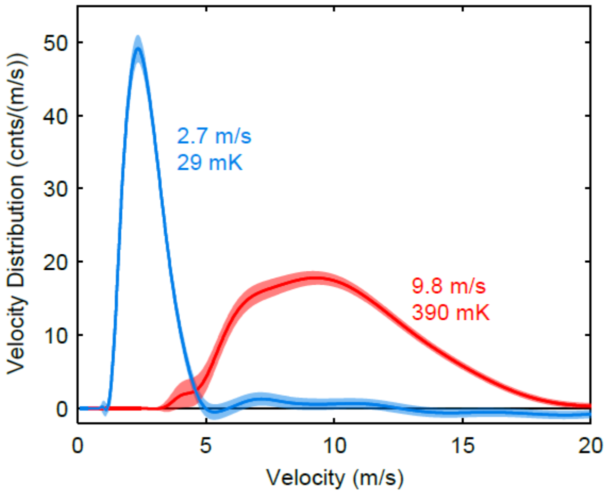

Figure 1: Measured velocity distribution of the cooled molecular ensemble in comparison with the initial sample. The mean velocities and the corresponding temperatures are stated.

References:
[1] M. Zeppenfeld *et. al.*, Phys. Rev. A **80**, 041401 (2009).
[2] B.G.U. Englert *et. al.*, Phys. Rev. Lett. **107**, 263003 (2011).
[3] M. Zeppenfeld *et. al.*, Nature **491**, 570 (2012).