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Rotational cooling of trapped polyatomic molecules ALEXANDER PREHN, ROSA GLÖCKNER, MARTIN IBRÜGGER, MARTIN ZEPPENFELD, GERHARD REMPE, Max-Planck-Institute of Quantum Optics — Potential applications of cold and ultracold polar molecules range from quantum simulations and quantum computing to precision measurements and cold chemistry. They would all benefit from the molecules' many states and long-range dipole-dipole interaction. A prerequisite for those applications is to gain and maintain control over all degrees of freedom. Here we present rotational-state cooling of methyl fluoride (CH_3F) via optical pumping. Starting from a thermal ensemble which is electrically trapped,[1] we optically pump the population from 16 rotational M-sublevels in four rotational states into a single level. Combining rotational-state control with motional Sisyphus cooling,[2] we are able to produce a cold (30 mK) and nearly pure ensemble of CH_3F molecules with more than 70 % of all molecules populating a single rotational M-sublevel. Our scheme is easily extendable to larger sets of initial states and other molecule species thus paving the way to quantum-controlled experiments with polyatomic molecules.

[1]B.G.U. Englert *et al.*, Phys. Rev. Lett. **107**, 263003 (2011)
[2]M. Zeppenfeld *et al.*, Nature **491**, 570-573 (2012)

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