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Laser Cooling of a Diatomic Molecule

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Laser cooling techniques to produce ultracold ($T<1\mu K$) atoms have lead to rapid advances in a wide array of fields. However, extending laser cooling to molecules has remained elusive. The primary problem is that laser cooling requires a large number (>104) of photon absorption/emission cycles. Molecules, however, have vibrational and rotational degrees of freedom, which typically lead to high branching probabilities into a large number of unwanted sublevels. Here we report on experiments demonstrating the laser cooling of a diatomic molecule which have overcome this problem. We use the molecule strontium monofluoride (SrF) where only three lasers and a magnetic field are necessary to scatter >105 photons. We have demonstrated 1-D transverse cooling of a beam of SrF, dominated by Doppler or Sisyphus-type cooling forces depending on experimental parameters. We observe a reduction in the velocity distribution by a factor of 3 or more, corresponding to final 1-D temperature $T < 1$ mK. This transverse cooling may be useful for a variety of experiments; in addition, our results open a path to trapping and 3D cooling of SrF to the ultracold regime.