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Getting trapped molecules into the quantum toolkit

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Obtaining control over the rotational quantum state of trapped molecules is a prerequisite for quantum information processing applications. However, this task has presented a significant challenge because of the large number of initial states typically populated and because of unwanted excitations generally occurring during optical manipulation. Using a single spectrally filtered broadband laser simultaneously addressing many rotational levels, we have optically cooled trapped AlH+ molecules from room temperature to 4 Kelvins, corresponding to an increase in ground rotational-vibrational state population from 3% to 95%. We anticipate that the cooling timescale can be reduced from 100 milliseconds to a few microseconds and that the cooling efficiency can also be improved. Our broadband cooling technique should also be applicable to a number of other neutral and charged diatomic species. Trapped AlH+, in particular, is a good candidate for future work on ultracold chemistry, coherent control and entanglement of rotational quantum states, non-destructive single-molecule state readout by fluorescence, and searches for time-variations of the electron-proton mass ratio.