Laser cooling and slowing of a diatomic molecule

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It has been roughly three decades since laser cooling techniques produced ultracold atoms, leading to rapid advances in a wide array of fields. However, straightforward extension of such techniques to molecules is problematic, and the direct laser cooling of a molecule was only demonstrated one year ago [1]. The primary problem is that laser cooling techniques require a large number of photon absorption/emission cycles ($\gtrsim 10^4$), and thus they are ideally suited for a two-level system (requiring one laser). Each additional state that can be populated by unwanted decays generally requires an additional laser to return this population to one of the primary cycling states. In the case of molecules, the same rotational and vibrational degrees of freedom which make molecules so interesting unfortunately create additional rotational and vibrational states which may be populated via unwanted decays. For typical molecules, the branching ratios to such states dictate that standard laser cooling techniques would require so many lasers ($\gtrsim 20$) as to be experimentally unfeasible.

This talk reviews our work laser cooling and slowing the diatomic molecule strontium monofluoride (SrF). Careful molecule selection suppresses decays to unwanted vibrational states [2], while driving an $X(N = 1) \rightarrow A(N = 0)$ type transition eliminates decays to unwanted rotational states [3]. The dark ground-state Zeeman sublevels created by this specific scheme are remixed via a static magnetic field [4]. Using three lasers, this scheme should allow $\sim 10^5$ photon absorption/emission cycles before molecules are lost via unwanted decays. This number of cycles should be sufficient to slow and cool our molecular beam [5] in order to load a magneto optical trap (MOT). So far, we have demonstrated 1-D transverse cooling of a beam of SrF, in both a Doppler and a Sisyphus-type cooling regime. More recently we realized longitudinal slowing. Our results provide a clear path to produce a molecular MOT.