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Laser Cooling and Inelastic Collisions of the Polyatomic Radical SrOH[1]

IVAN KOZYRYEV, Columbia University

Qualitatively new vibrational and rotational motions present in complex molecules with three and more atoms offer unique opportunities for advancing various research areas within physics, chemistry and quantum technology. We have identified a large class of polyatomic molecules, alkaline earth monoalkoxides (MOR), with diverse constituents and geometries that have strong optical transitions and diagonal Franck-Condon factors, enabling photon cycling. I will describe our experimental results on direct Doppler and Sisyphus laser cooling of the linear triatomic radical strontium monohydroxide (SrOH). Furthermore, using the bichromatic standing-wave laser field, we achieved significant force enhancement compared to radiation pressure, paving the way for rapid coherent deceleration of molecular beams. In addition to controlling the external motion, laser light was used for preparing SrOH molecules in a specific quantum state in order to study state-selective inelastic collisions with cryogenic helium gas. Finally, I will outline the prospects of using laser-cooled polyatomic molecules to probe physics beyond the Standard Model via permanent electric dipole moment search or spectroscopic effects arising from interactions with ultralight bosonic dark matter.

[1]This thesis work was supervised by Professor John M. Doyle at Harvard University.