Ro-vibrational cooling of molecules.

Towards Sisyphus cooling of molecules.

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Laser techniques applied to precision spectroscopy or to the control of chemical reactions have improved considerably our knowledge of molecular physics. One of the greatest challenges of modern physical chemistry is to push forward the limits of electromagnetic or laser techniques to probe or manipulate molecules at low temperatures where molecular interactions are dominated by pure quantum phenomena.

In this context, we have developed an original technique that enables us to manipulate the internal degrees of freedom of diatomic molecules. Basically, the principle consists in using a broadband laser to pump all the internal levels towards a target level. We performed various experiments demonstrating the feasibility of the process: vibrational cooling [1] and rotational cooling [2] were successful on the cesium dimer formed by photoassociation of cold atoms.
In our recent project, we project to apply this method to rovibrationally cool a molecule (barium monofluoride) produced in a supersonic beam. Barium monofluoride is somehow particular as it has the property to stand about twenty optical cycles without escaping to another vibrational level. Once this species is prepared in a single rovibrationnal state, it will be possible to implement a Sisyphus cooling scheme, a well-known effect/method in the realm of cold atoms that potentially removes a huge quantity of kinetic energy per photon. In other words, Sisyphus cooling applied to molecules might be a solution to slown down and thoroughly cool a supersonic molecular beam. We will discuss the various difficulties and the possible solutions.

[1] Optical pumping and vibrational cooling of molecules
M. Viteau, A. Chotia, M. Allegrini, N. Bouloufa, O. Dulieu, D. Comparat, P. Pillet
Science, 321 232 (2008).

[2] Rovibrational cooling of molecules by optical pumping
I. Manai, R. Horchani, H. Lignier, P. Pillet, D. Comparat, A. Fioretti, M. Allegrini,
Phys. Rev. Lett., 109, 183001 (2012).