Producing, trapping and controlling ultracold molecules

H. J. Williams*[1], L. Caldwell, N. J. Fitch,S. Truppe, J. Rodewald, E. A. Hinds, B. E. Sauer & M. R. Tarbutt
1. Department of Physics, Imperial College London, London, SW7 2BW, UK

Ultracold molecules promise to be important in the future of many experimental research areas; from quantum simulation, to collisions and cold chemistry, to precision measurement. The complicated internal structure of even the simplest of molecules makes them difficult to cool. However, recently a handful of diatomic molecules have been directly cooled and trapped. I will present recent work on the production, trapping and controlling of ultracold calcium monofluoride molecules. Using frequency-chirped laser slowing, molecules are decelerated toa low velocity, and then loaded into a magneto-optical trap [1][2]. The molecules are then cooled to 50 μK, well below the Doppler limit, in a blue-detuned optical molasses [3]. This temperature is achieved via polarisation gradient cooling.

Whilst in the molasses the molecules aren't trapped and they are distributed amongst 24 Zeeman sub-levels. We use optical pumping to transfer most of the molecules into a single level. From here we use microwave pulses to coherently transfer the population between different rotational levels demonstrating quantum state control over the molecules [4],[5].These quantum-state-selected molecules are loaded into a magnetic trap, where they have a lifetime of 4.5 s, limited by black-body radiation.

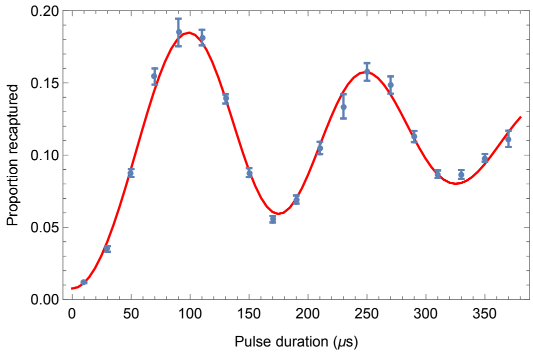

Fig. 1: Rabi oscillations between two rotational states of a CaF molecule driven by microwaves.

References

[1] An intense, cold, velocity-controlled molecular beam by frequency-chirped laser slowing. S. Truppe, H. J. Williams, N. J. Fitch, M. Hambach, T. E. Wall, E. A. Hinds, B. E. Sauer & M. R. Tarbutt. New Journal of Physics **19** 022001 (2017)
[2] Characteristics of a magneto-optical trap of molecules. H. J. Williams, S. Truppe, M. Hambach, L. Caldwell, N. J. Fitch, E. A. Hinds, B. E. Sauer & M. R. Tarbutt. New Journal of Physics **19**, 113035 (2017)
[3] Molecules cooled below the Doppler limit. S. Truppe, H. J. Williams, M. Hambach, L. Caldwell, N. J. Fitch, E. A. Hinds, B. E. Sauer & M. R. Tarbutt. Nature Physics **13**, 1173 (2017)
[4] Magnetic trapping and coherent control of laser-cooled molecules. H. J. Williams, L. Caldwell, N. J. Fitch, S. Truppe, J. Rodewald, E. A. Hinds, B. E. Sauer & M. R. Tarbutt. Physical Review Letters, **120**, 163201 (2018)
[5] Ultracold molecules: a platform for quantum simulation. J. A. Blackmore, L. Caldwell, P. D. Gregory, E. M. Bridge, R. Sawant, J. Aldegunde, J. Mur-Petit, D. Jaksch, J. M. Hutson, B. E. Sauer, M. R. Tarbutt & S. L. Cornish arXiv:1804.02372 (2018)

*Corresponding author: hjw10@imperial.ac.uk