Menagerie of MOTs

K. N. Jarvis*[1], B. E. Sauer, M. R. Tarbutt
1. Centre for Cold Matter, Blackett Laboratory, Imperial College London, Prince Consort Road, London SW7 2AZ, UK

Ever since the first demonstration of the magneto-optical trap (MOT), made over three decades ago, examples have existed of 'type-II' MOTs [1]. In contrast to a normal atomic MOT, where the hyperfine quantum number of the excited state F' is related to that of the ground state F by $F' = F + 1$, type-II MOTs have $F' \leq F$. The presence of dark ground-state sublevels in type-II systems leads to the unfavorable characteristics of high temperature and poor confinement, and so these MOTs have not been studied much. In recent years, however, the diatomic molecules SrF [2] and CaF [3],[4] have been successfully laser cooled and trapped in a MOT using type-II transitions. Despite this impressive progress, the inherently low phase-space densities are likely to hamper some of the most exciting proposed applications of laser-cooled molecules from being realized. Using ^{87}Rb we demonstrate that the properties of type-II MOTs can be dramatically improved by using a novel approach where the light is blue-detuned from the transition [5], and present a detailed characterization of the blue-detuned MOT. The phase-space density is increased by almost a factor of one million over comparable red-detuned MOTs. Additionally, we demonstrate the existence of at least eight stable magneto-optical trapping configurations, in addition to the type-I MOT, and present an overview of the properties of these new MOTs. Our findings could be used in the study of cold and ultracold collisions between atoms.

References

[1] E. L. Raab, M. Prentiss, A. Cable, S. Chu, and D. E. Pritchard. Trapping of neutral sodium atoms with radiation pressure, Physical Review Letters, 59(23):2631-2634, 1987.
[2] J. F. Barry, D. J. McCarron, E. B. Norrgard, M. H. Steinecker, and D. DeMille. Magneto-optical trapping of a diatomic moleucle. Nature, 512:286-289, 2014
[3] S. Truppe, H. J. Williams, M. Hambach, L. Caldwell, N. J. Fitch, E. A. Hinds, B. E. Sauer, and M. R. Tarbutt. Molecules cooled below the Doppler limit. Nature Physics, 13(12):1173-1176, 2017.
[4] L. Anderegg, B. L. Augenbraun, E. Chae, B. Hemmerling, N. R. Hutzler, A. Ravi, A. Collopy, J. Ye, W. Ketterle, and J. Doyle. Radio frequency magneto-optical trapping of CaF with high density. Physical Review Letters 119(10):103201, 2017.
[5] K. N. Jarvis, J. A. Devlin, T. E. Wall, B. E. Sauer, and M. R. Tarbutt. Blue-detuned magneto-optical trap, Physical Review Letters, 120(8):083201, 2018.

*Corresponding author: k.jarvis14@imperial.ac.uk