Cooling of atoms using an optical frequency comb

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Laser cooling and trapping brings atomic and molecular physics to one of the most exciting frontiers in science, with applications ranging from atom interferometry and optical frequency standards to high precision spectroscopy and ultracold chemistry. Regardless of such a great importance, laser cooling techniques are still limited to atoms with simple energy level structure and closed transitions accessible by current continuous wave (CW) laser technology. Laser cooling of more complex atomic species and molecules, or even simple atoms with strong cycling transitions in the vacuum ultraviolet (VUV) where generation of CW laser light is demanding, still remains an experimental challenge.

The aforementioned problems can be approached by using mode-locked femtosecond (fs) or picosecond (ps) lasers with high pulse repetition rates which produce stabilized optical frequency combs (FCs). FCs simultaneously provide high peak powers needed for the efficient frequency conversion, and the long coherence of CW lasers needed for the efficient cooling [1], [2].

I will present our recent results on sub-Doppler cooling of rubidium atoms on a dipole-allowed transition at 780 nm by using a frequency comb (FC) [3]. Temperatures as low as 55 μK were measured in a one-dimensional FC cooling geometry using time-of-flight spectroscopy. We attribute the sub-Doppler temperatures observed in FC cooling to the same mechanisms that produce sub-Doppler temperatures when cooling with continuous-wave lasers. Laser cooling with FCs could enable achieving sub-Doppler temperatures for the atoms with dipole-allowed transitions in the vacuum ultraviolet. This can significantly improve the precision of optical frequency standards, enable measurements of fundamental constants with unprecedented accuracy, and open up the possibility to reach quantum degeneracy with atoms that have optical transitions unreachable by continuous wave lasers such as hydrogen, deuterium and antihydrogen.

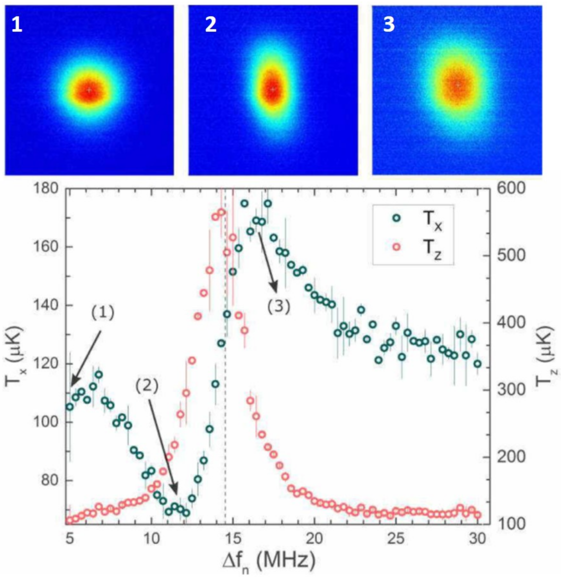

Fig. 1: Temperature obtained by TOF spectroscopy after 1D FC cooling as a function of FC detuning

References

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