Investigation of sub-Doppler cooling in the low intensity regime

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CENTRE FOR ADVANCED LASER TECHNIQUES

Hrvatska zaklada za znanost

Motaviation

Despite the great achievements we're still unable to cool atoms with transitions in UV and most prevalent atoms in ogranic chemistry - Frequency combs (FC) are proposed laser sources.

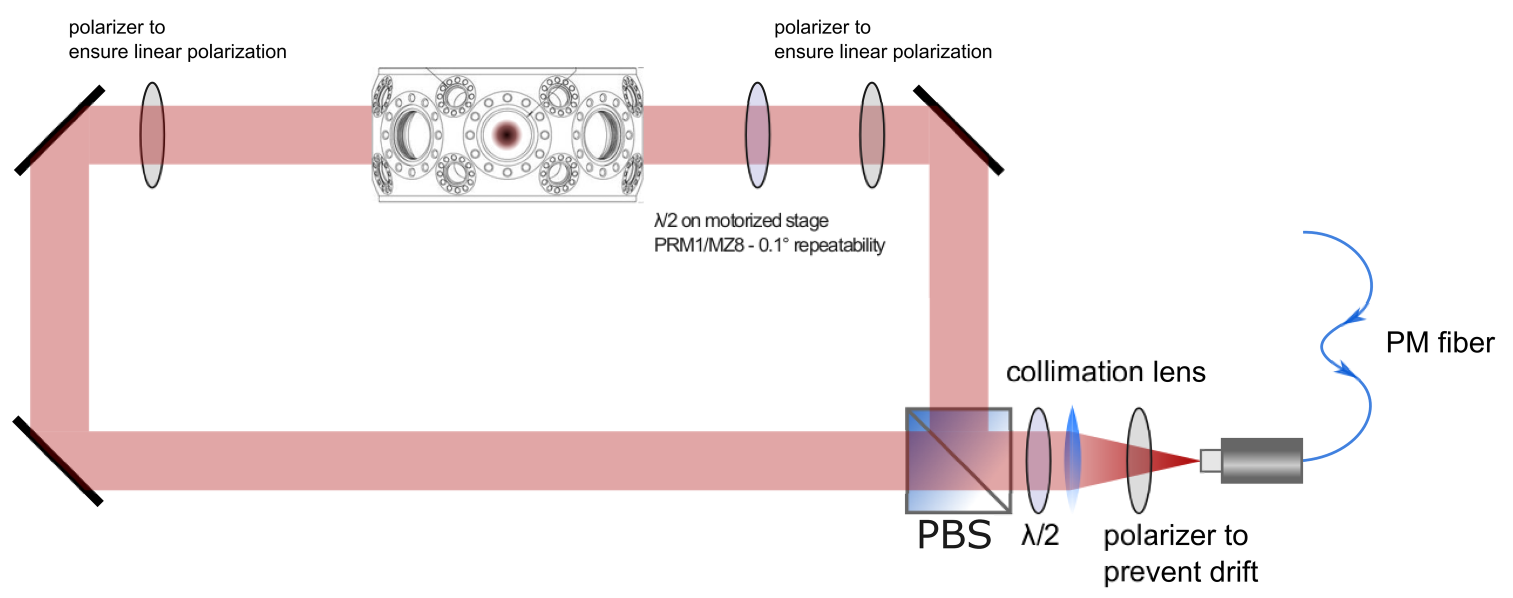
By exposing precooled rubidium cloud with counter -propagating beams, recently we investigated cooling with FC.

FC can be considered as a series of phase-coherent cw lasers - one tooth of a FC is analoguos with one cw laser.

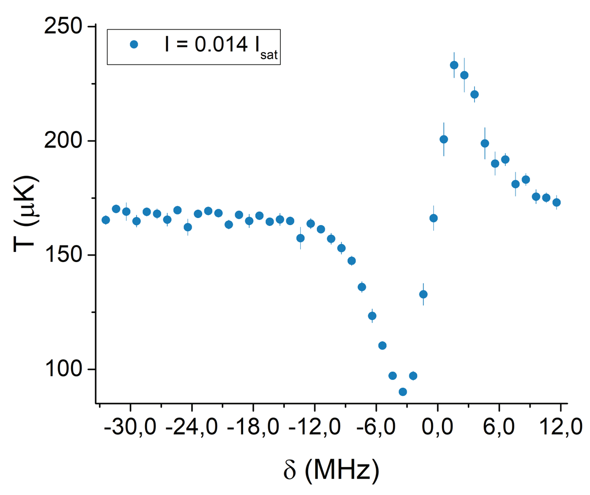
Power per comb mode is typically of the order of μW - to achieve greater flexibility we recreated measurements with a cw laser.

Experimental setup

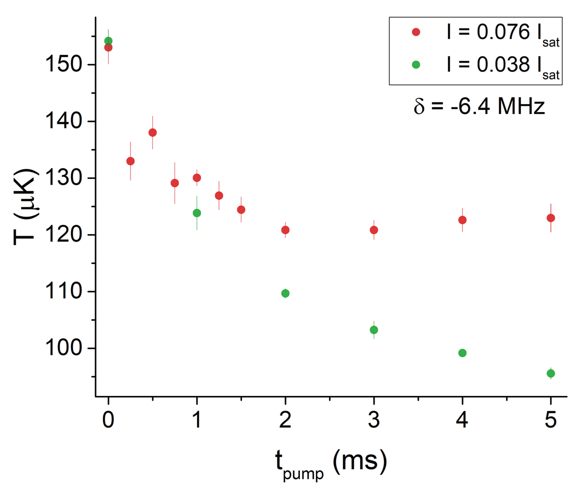
^{87}Rb magneto-optical trap in 6-beam configuration, with 10^7-10^8 atoms in initial cloud. CW laser beam has similar intensity to the intensity per comb mode of FC laser (used in previous experiment).



Results

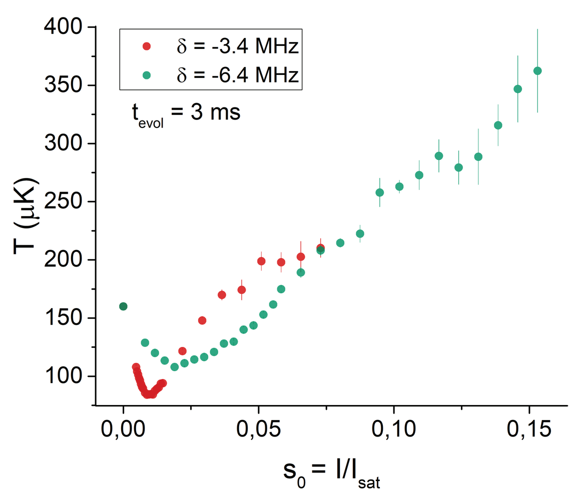


Detuning depencence is different from expected sub-Doppler dependence - with intensity low enough, far from resonance there is no significant interaction of a cloud with laser.



System evolves to the steady state - dependence as expected.

At high power cloud starts to dissipate by influence of the extra diffusion.

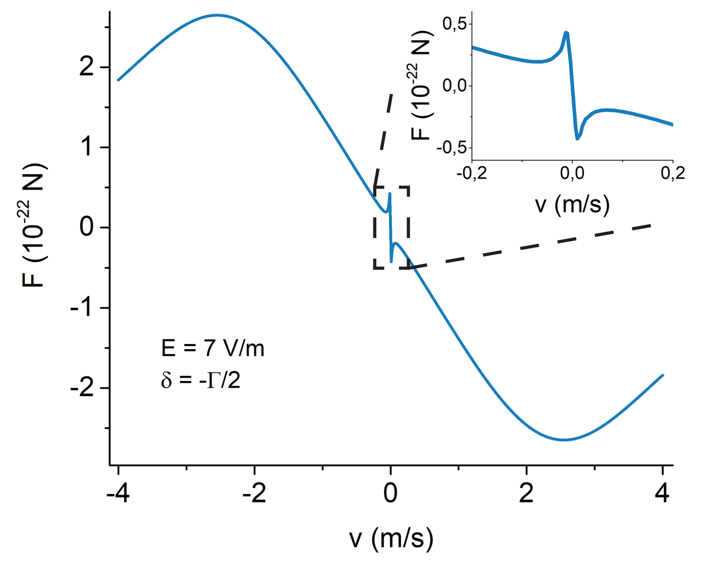


At laser intensities large enough temperature is linearly dependent with intensity, while at low intensities there is local minimum - possible décrochage effect [1]

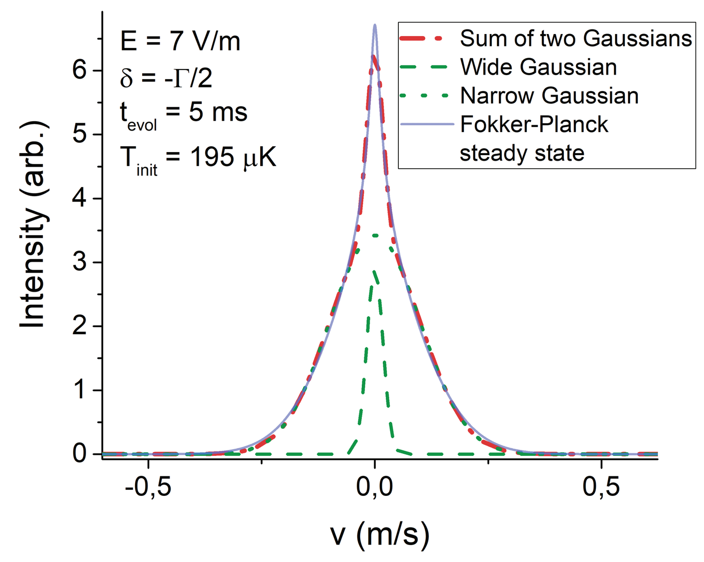
Bimodal velocity distribution

We performed evaluation of the Fokker-Planck equation for a atom with a 1/2 to 3/2 transition[2].

$$-\frac{1}{m}\frac{\partial}{\partial v}\left(F(v)\rho(v,t)\right)+\frac{1}{m^2}\frac{\partial^2}{\partial v^2}\left(D(v)\rho(v,t)\right)=\frac{\partial}{\partial t}\left(\rho(v,t)\right)$$

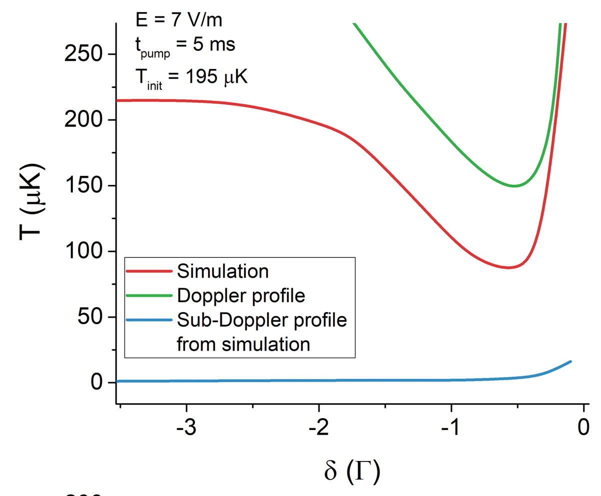


Radiation force term is a sum of semi-classical Doppler force part and sub-Doppler force part while diffusion is proportional to the excited state population.

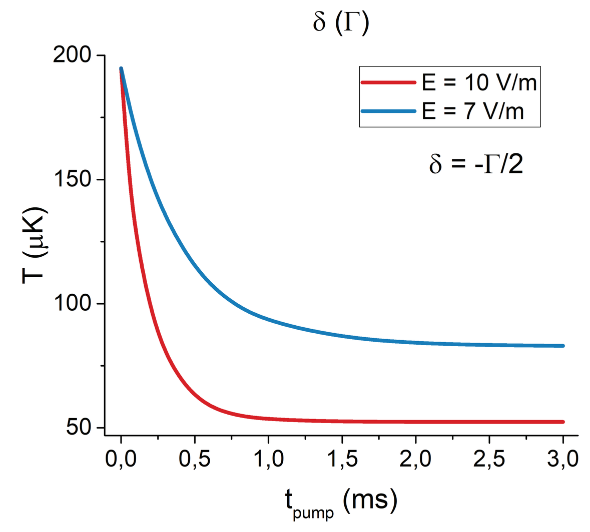


With the result velocity distribution we simulated Time of Flight method to calculate temperature of the cloud.

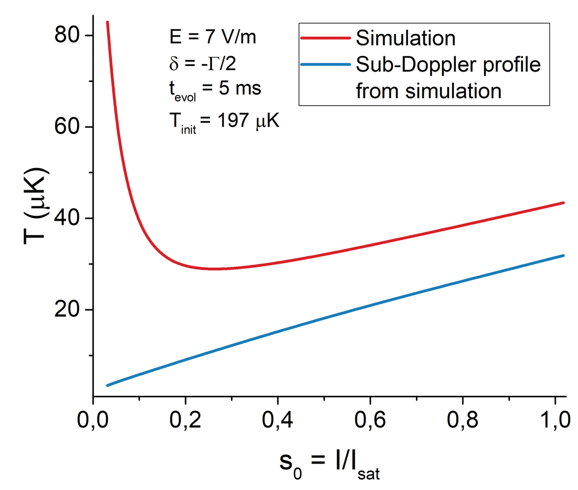
Experiment simulations



Bimodal velocity distribution lead to the temperature dependecende on intensity similar to the Doppler profile, but with temperatures bellow Doppler limit, similar to a experiment.



Steady state temperature is achieved at some time, with time similar to the experiment.



Temperature dependence on intensity is similar to the dependence measured. There is no need for the full quantum calctulation to obtain same qualitative temperature dependances.

Conclusion

Measured temperature dependecies weren't the same as theoretical predictions. With simulation of the experiment we qualitatively recreated measured dependencies.

To get better understanding of measured temperatures, we need to make simulations with complete rubidium model.

References: [1] C. M. Dion, et al., Phys. Rev. A. 93, 053416 (2016) [2] J. Dalibard, C. Cohen-Tannoudji, JOSA B, 6, 11, 2023-2045 (1989)