Frequency Comb Laser Cooling

Ana Cipriš, Neven Šantić, Ivor Krešić, Damir Aumiler and Ticijana Ban
Institute of Physics, Bijenička cesta 46, 10000 Zagreb, Croatia

INSTITUT ZA FIZIKU

Centre for Advanced Laser Techniques

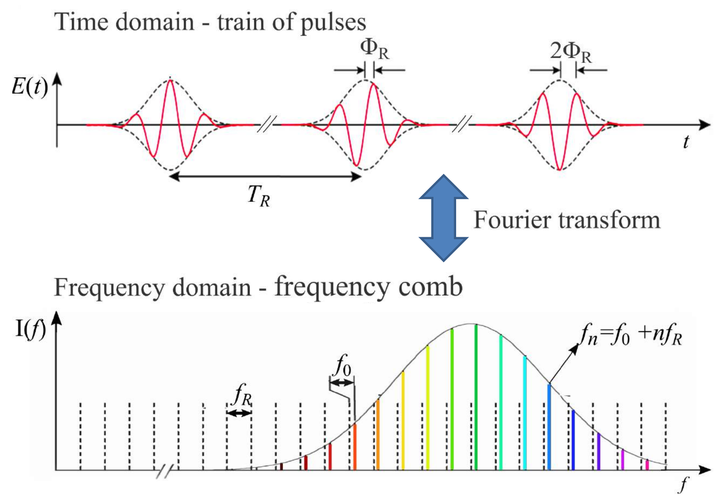
Goal and motivation

- explore *laser cooling of atoms using an optical frequency comb*
- lack of continuous-wave (cw) lasers in vacuum ultraviolet (VUV) → cw laser cooling is hardly achievable for atoms with strong dipole transitions in VUV
- cw laser cooling → very challenging for complex energy structure molecules

Frequency comb generated by ultrashort pulse laser:

- pulse high peak power → efficient nonlinear frequency conversion in VUV
- broadband spectrum consisting of a series of narrow equidistant modes
  → reduced complexity of laser systems for molecule cooling
  → simultaneous cooling of multiple species[1]

Frequency comb

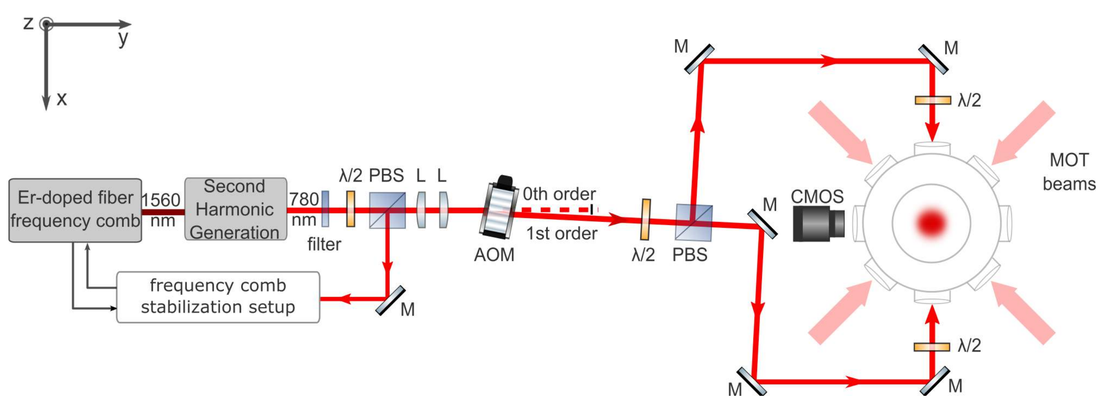


Each comb mode frequency f_n, ($n \sim 10^6$) is defined with:

- repetition frequency, f_R
- carrier-envelope offset frequency, f_0

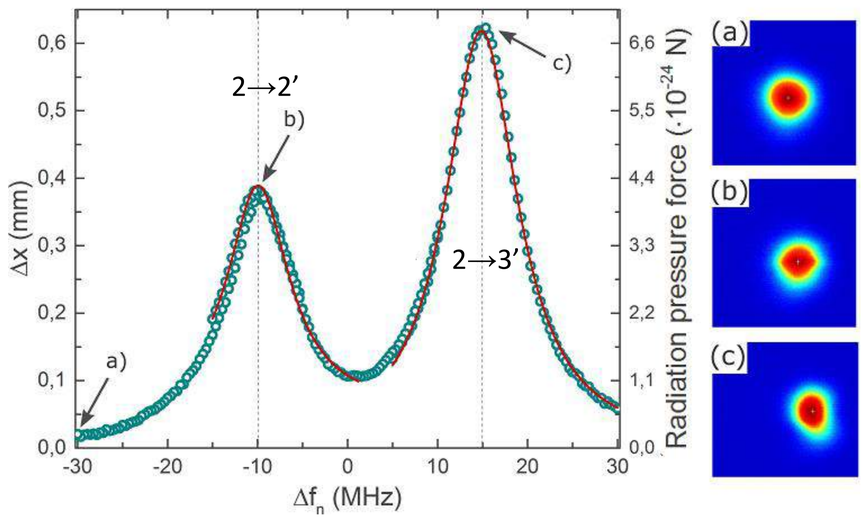
→ driving single transition in atoms/molecules

Experiment



- frequency comb laser cooling of ^{87}Rb atoms was obtained by driving $5^2S_{1/2}$ (F=2) → $5^2P_{3/2}$ (F'=3) transition
- starting point for the experiment - cold cloud of ^{87}Rb atoms generated in magneto-optical trap (MOT)
- temperature measurements - Time-of-Flight technique

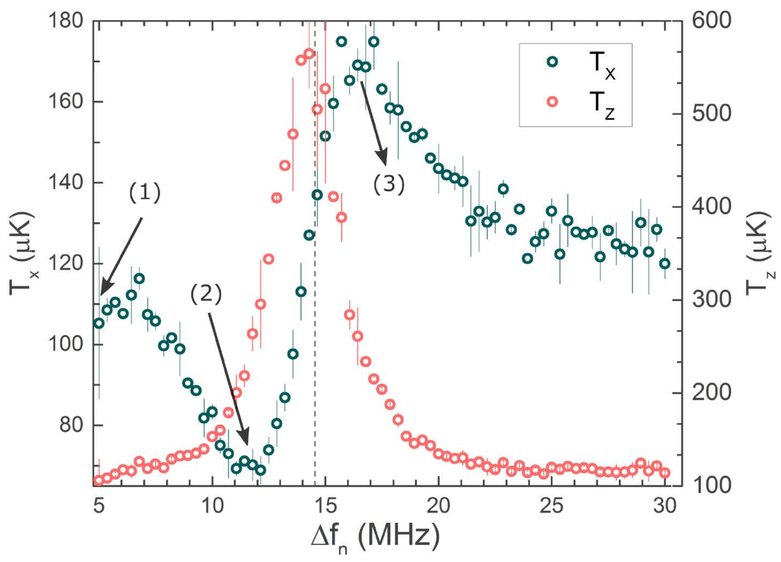
Results – Radiation pressure force



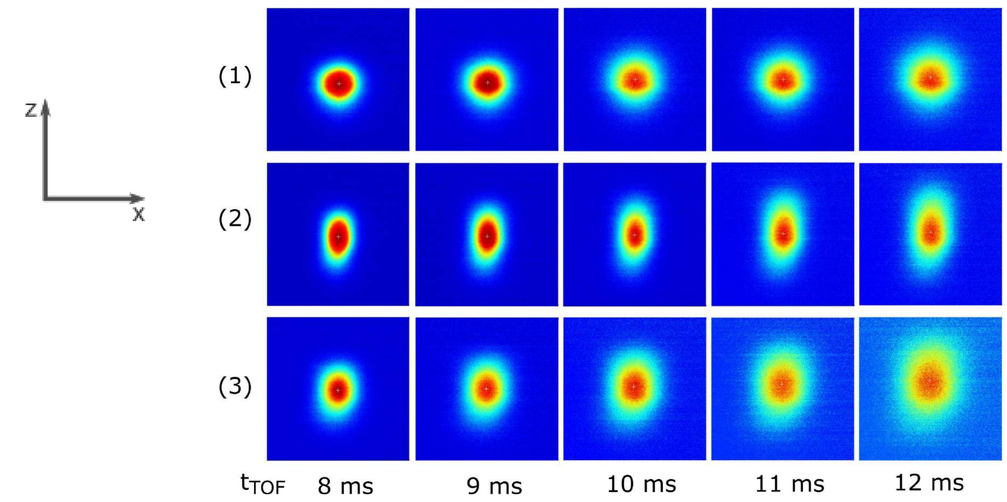
- measurements were performed with single frequency comb (fc) beam interacting for t = 3 ms with ^{87}Rb atoms
- two lines – two different comb modes driving two transitions: F=2 → F'=2 and F=2 → F'=3

Results - Temperature

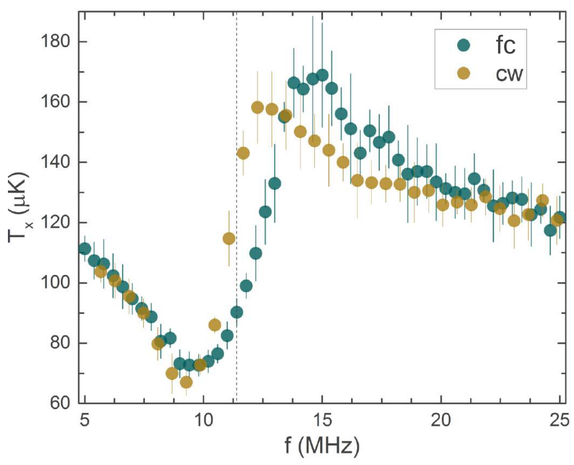
LIN ∥ LIN configuration of counter-propagating fc beams



- $T_{x,min}$ = (67 ± 2) μK
  → sub-Doppler temperature
- we obtained same results for LIN ⊥ LIN and σ^+ - σ^- configurations

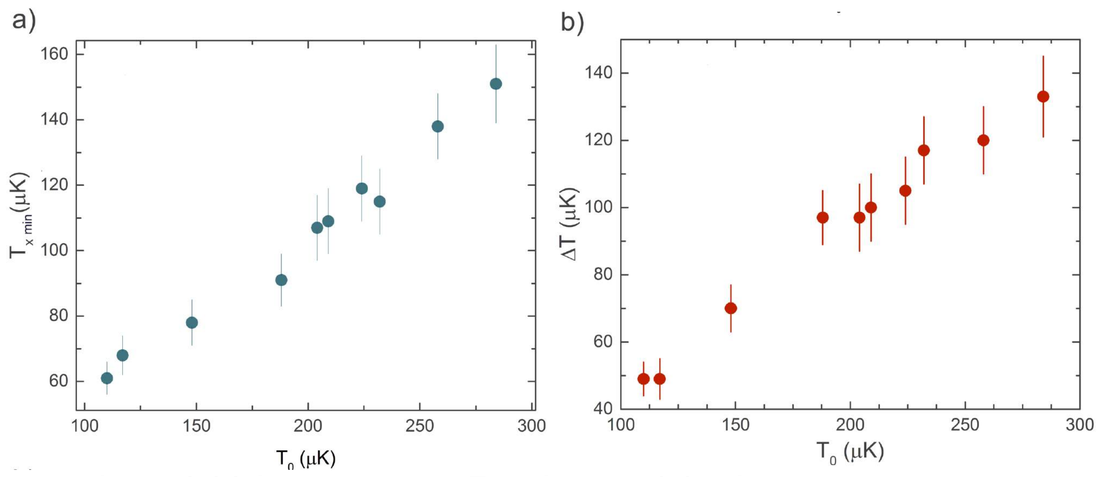


Fc laser cooling in comparation with cw laser cooling



- well agreed minimal temperatures
  → fc laser cooling is equally effective as cw laser cooling

Fc laser cooling in dependance of initial temperature of atoms



- lower initial temperature, T_0 → lower minimal temperature
- higher initial temperature → higher efficiency of cooling, $\Delta T = T_0 - T_{x,min}$

REFERENCES
[1] D. Aumiler and T. Ban, Phys. Rev. A, 85, 063412 (2012).

hrzz Hrvatska zaklada za znanost