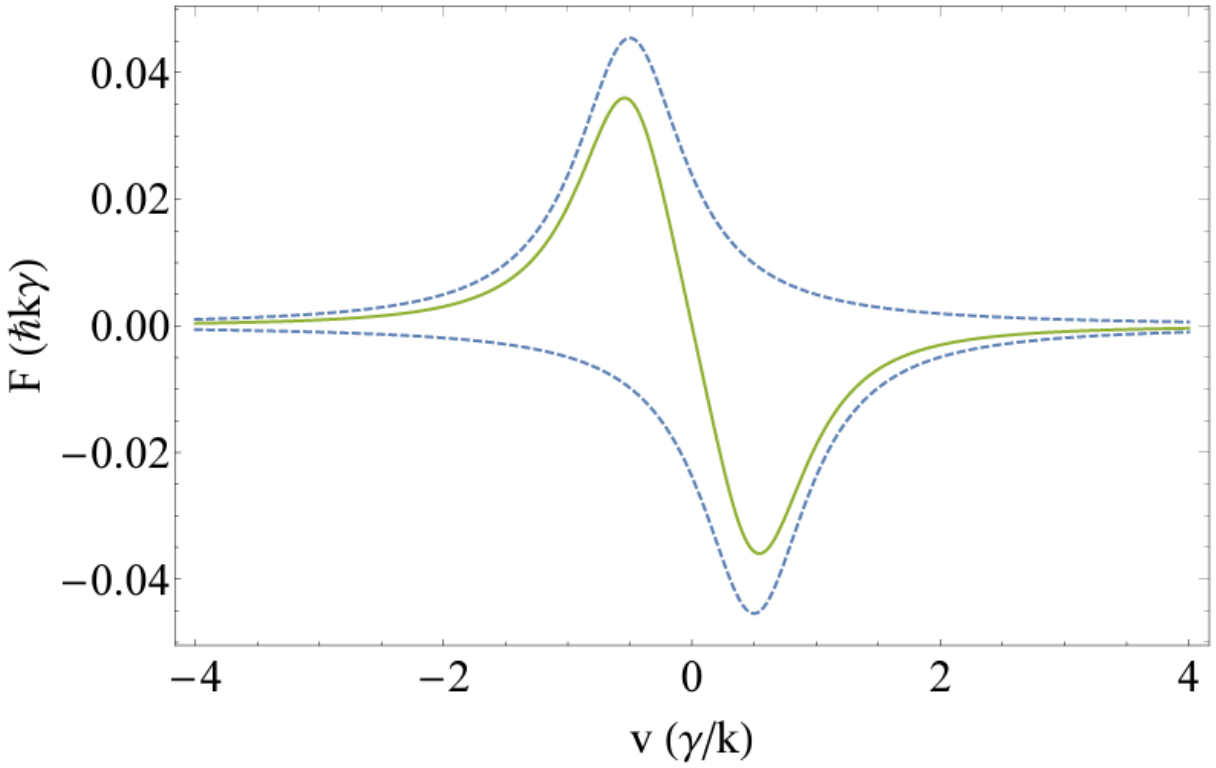
Hladni atomi rubidija u optičkoj rešetci

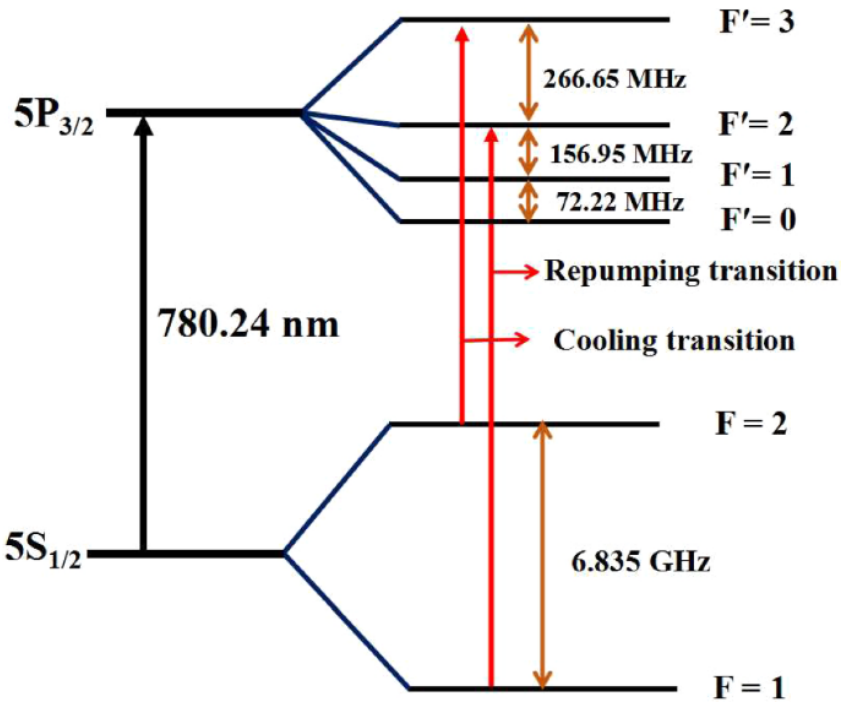
Lovre Kardum

Magneto-optička stupica

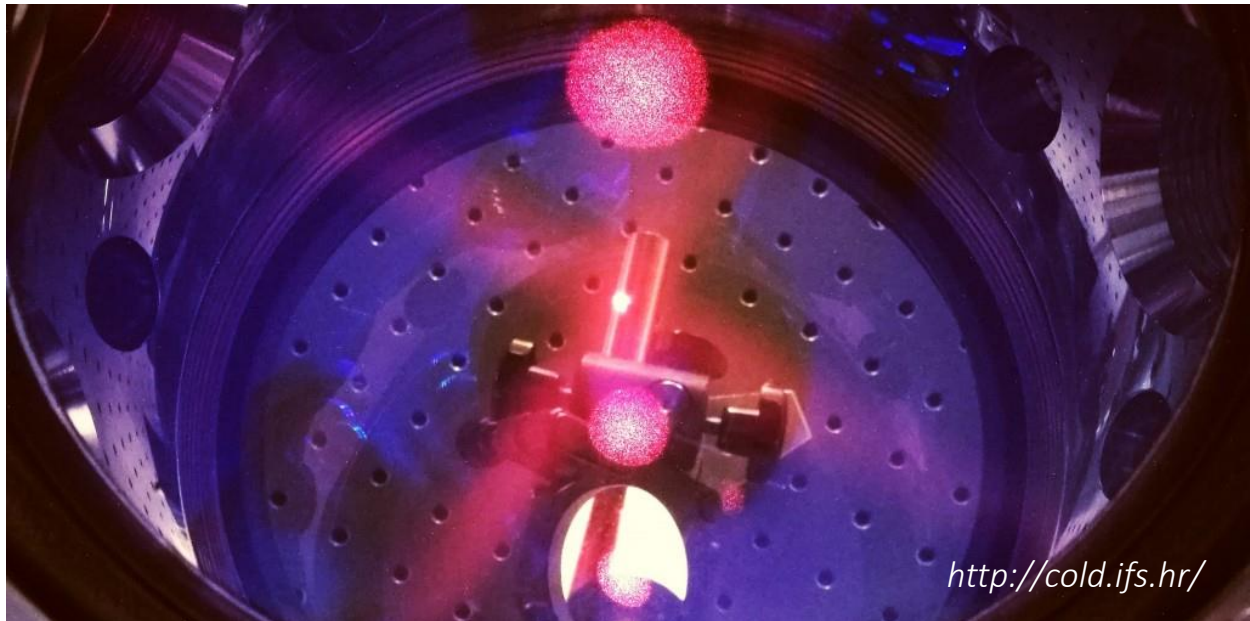
Zašto rubidij?



N. Šantić: *Synthetic Lorentz Force for Neutral Cold Atoms*

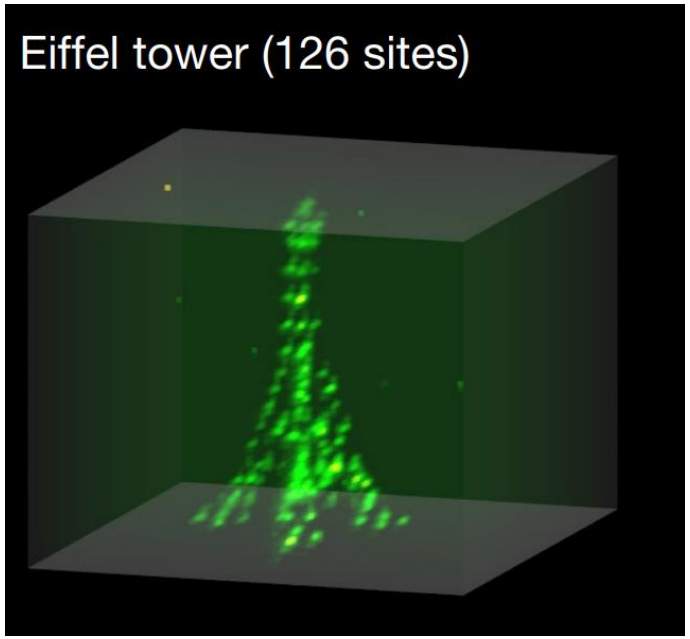


S Singh, B Jain, S P Ram, V B Tiwari & S R Mishra*: A Single Laser-operated Magneto-optical Trap for Rb Atomic Fountain*



Dipolne zamke

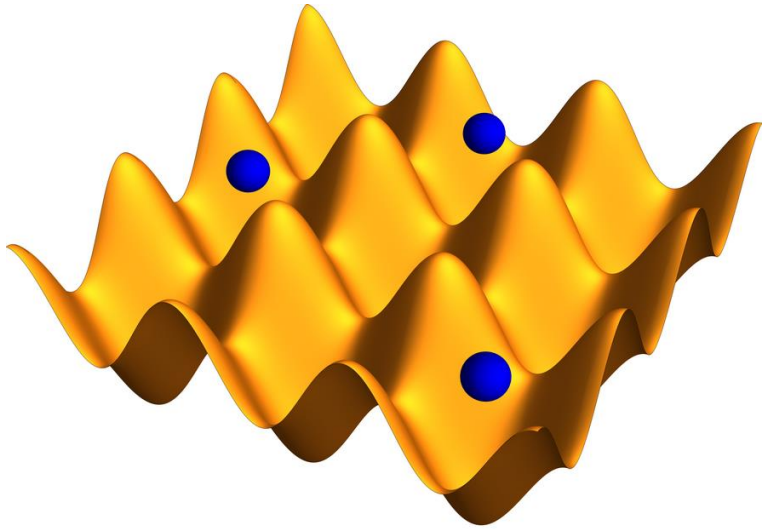
Jedna zraka



Daniel Barredo, Vincent Lienhard, Sylvain de Léséleuc, Thierry Lahaye & Antoine Browaeys: *Synthetic three-dimensional atomic structures assembled atom by atom*

Optička rešetka

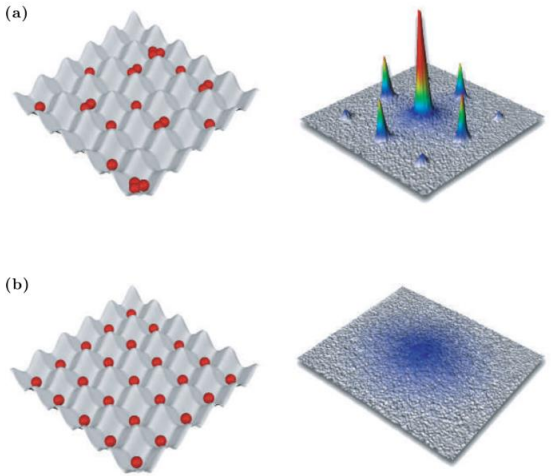
2+ zrake



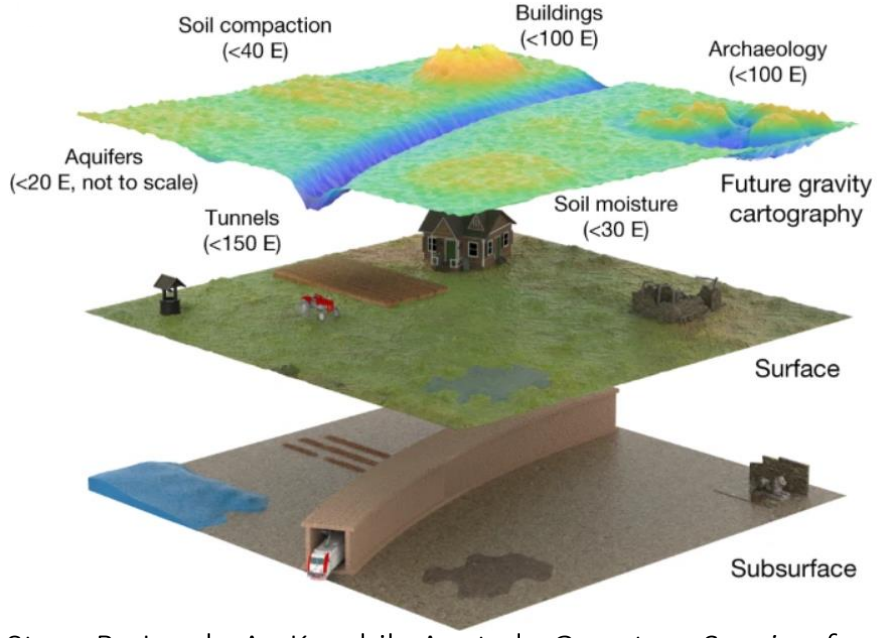
https://en.wikipedia.org/wiki/Optical_lattice

Upotreba:

- Kvantna računala
- Kvantni simulatori
- Optički satovi
- Atomska interferometrija – kvantni senzori



Philip H. Jones, Onofrio M. Maragò & Giovanni Volpe.
Optical Tweezers: Principles and Applications



Stray, B., Lamb, A., Kaushik, A. et al.: *Quantum Sensing for Gravity Cartography*

AC Stark efekt

$$\Delta E_i = -\frac{1}{2}\alpha_i |\boldsymbol{E}|^2$$

$$\alpha_i = \frac{2e^2}{\hbar} \sum_{f \neq i} \omega_{fi} \frac{|\langle f|z|i\rangle|^2}{\omega_{fi}^2 - \omega^2}$$

$$\boldsymbol{E} = \mathcal{E} e^{-\frac{r^2}{\omega(z)^2}} \left(e^{-i\kappa z} \hat{\varepsilon}_+ + \sqrt{1-\eta} e^{i\kappa z} \hat{\varepsilon}_- \right)$$

$$\Delta E = -\frac{1}{2}\alpha \mathcal{E}^2 e^{-\frac{2r^2}{\omega(z)^2}} 4\cos^2(\kappa z)$$

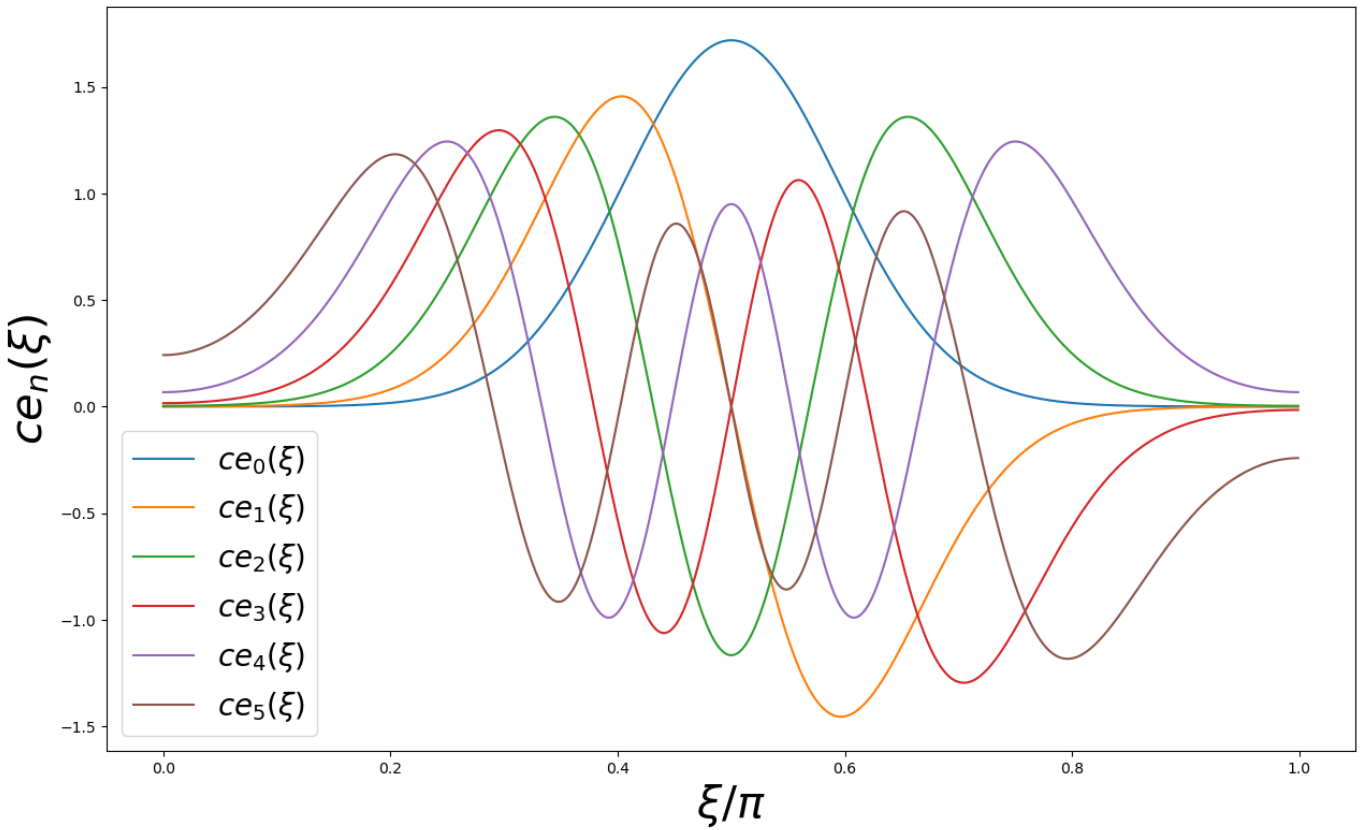
Valna funkcija

$$V(z) = V_0 \cos^2(\kappa z)$$

$$w_n^i(\xi) = \sqrt{\frac{2}{\pi}} \Theta_i(\xi) \mathrm{ce}_n(\xi)$$

$$\langle i, n | j, m \rangle = \delta_{ij} \delta_{nm}$$

$$\Theta_i(\xi) = \begin{cases} 1 & \xi \in [i\pi, (i+1)\pi\rangle \\ 0 & \text{inače} \end{cases}$$



Amplitudni šum

$$\tilde{V}(z) = V_0(1+\epsilon(t))\cos^2(\kappa z) \equiv V + V'$$

$$\epsilon(t) = \frac{I(t) - I_0}{I_0}$$

$$R_{m\leftarrow n} = \frac{1}{T}\left|\int_0^T dt e^{i\omega_{mn}t}\langle m|V'|n\rangle\right|^2$$

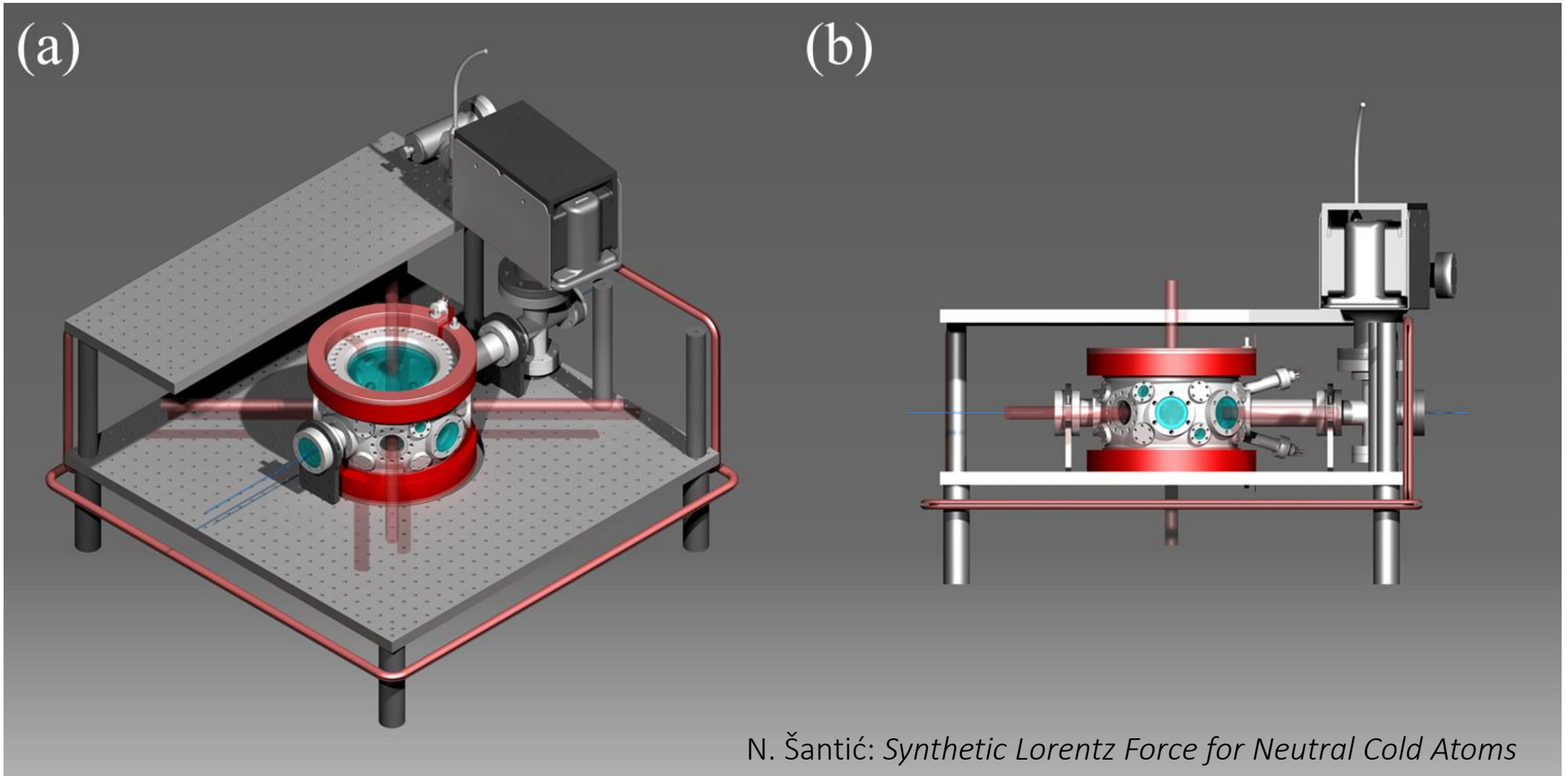
$$R_{m\leftarrow n} = \frac{\pi V_0^2}{\hbar^2} S_\epsilon(\omega_{mn})\left|\frac{2}{\pi}\int_0^\pi d\xi \mathrm{ce}_m^*(\xi)\cos^2(\xi)\mathrm{ce}_n(\xi)\right|^2$$

$$\dot{P}_n(t) = -\sum_{m \neq n} R_{m \leftarrow n} P_n(t) + \sum_{m \neq n} R_{n \leftarrow m} P_m(t)$$

$$\frac{\langle E \rangle_T}{\langle E \rangle_0} = e \qquad \Gamma := \frac{1}{T}$$

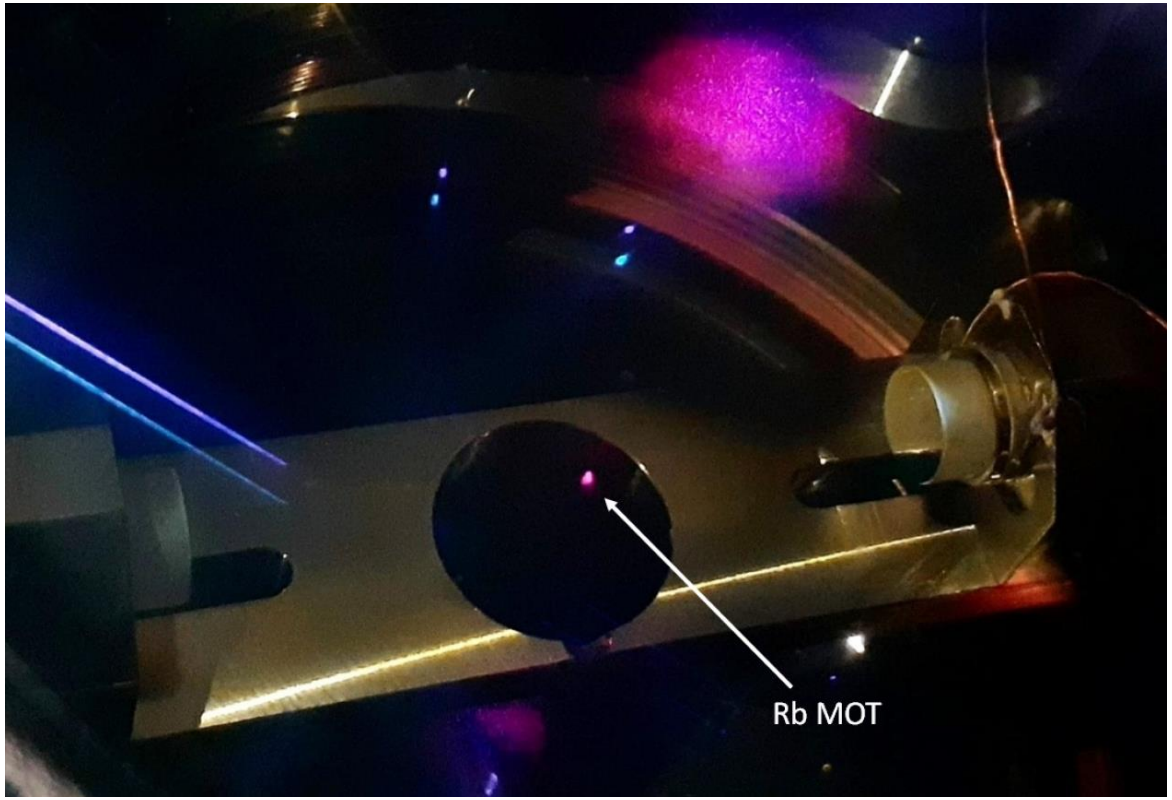
$$\langle E \rangle_t = \sum_n \hbar \omega_n P_n(t)$$

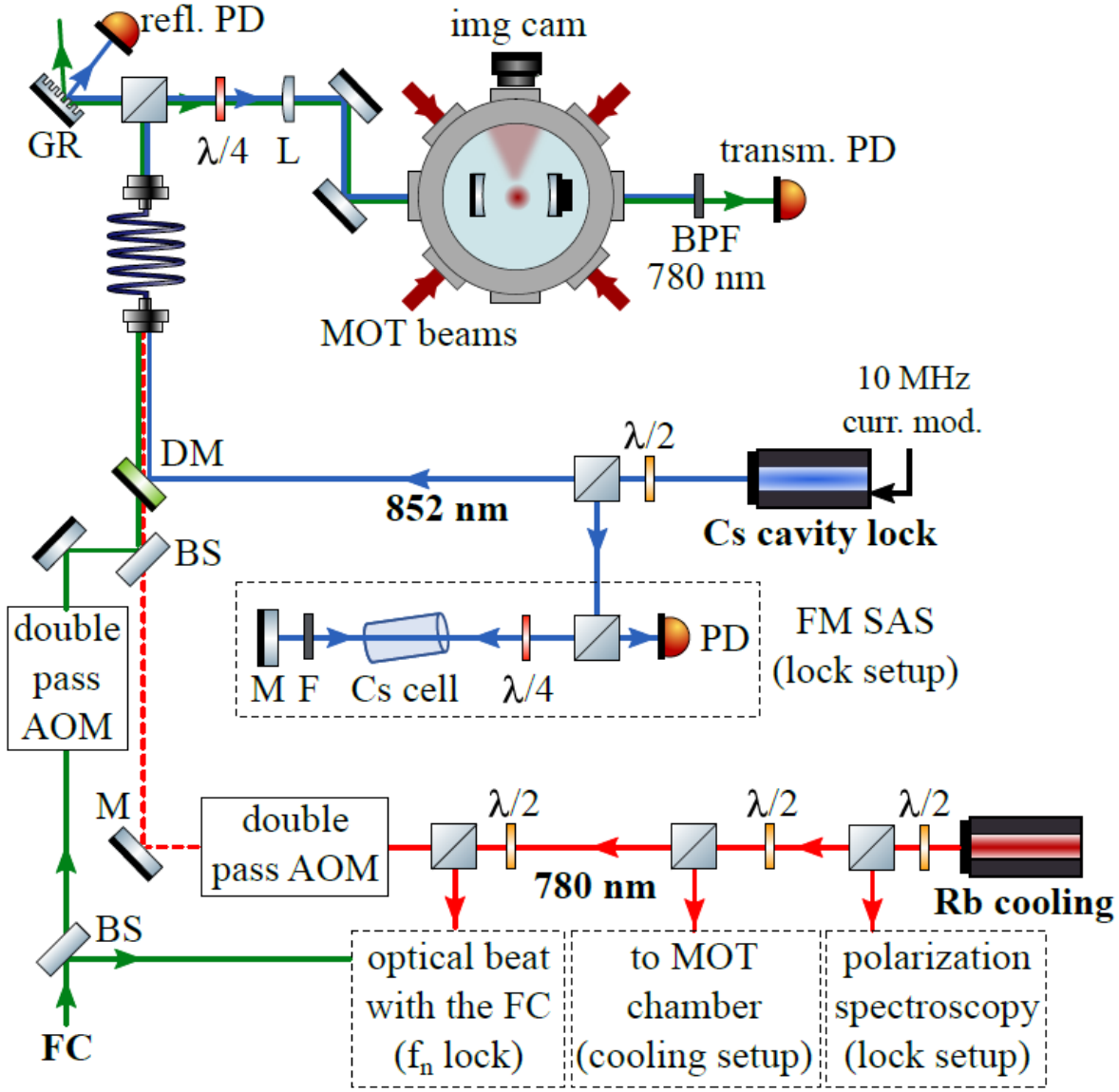
Mjerni postav: MOT



N. Šantić: *Synthetic Lorentz Force for Neutral Cold Atoms*

Optički rezonator



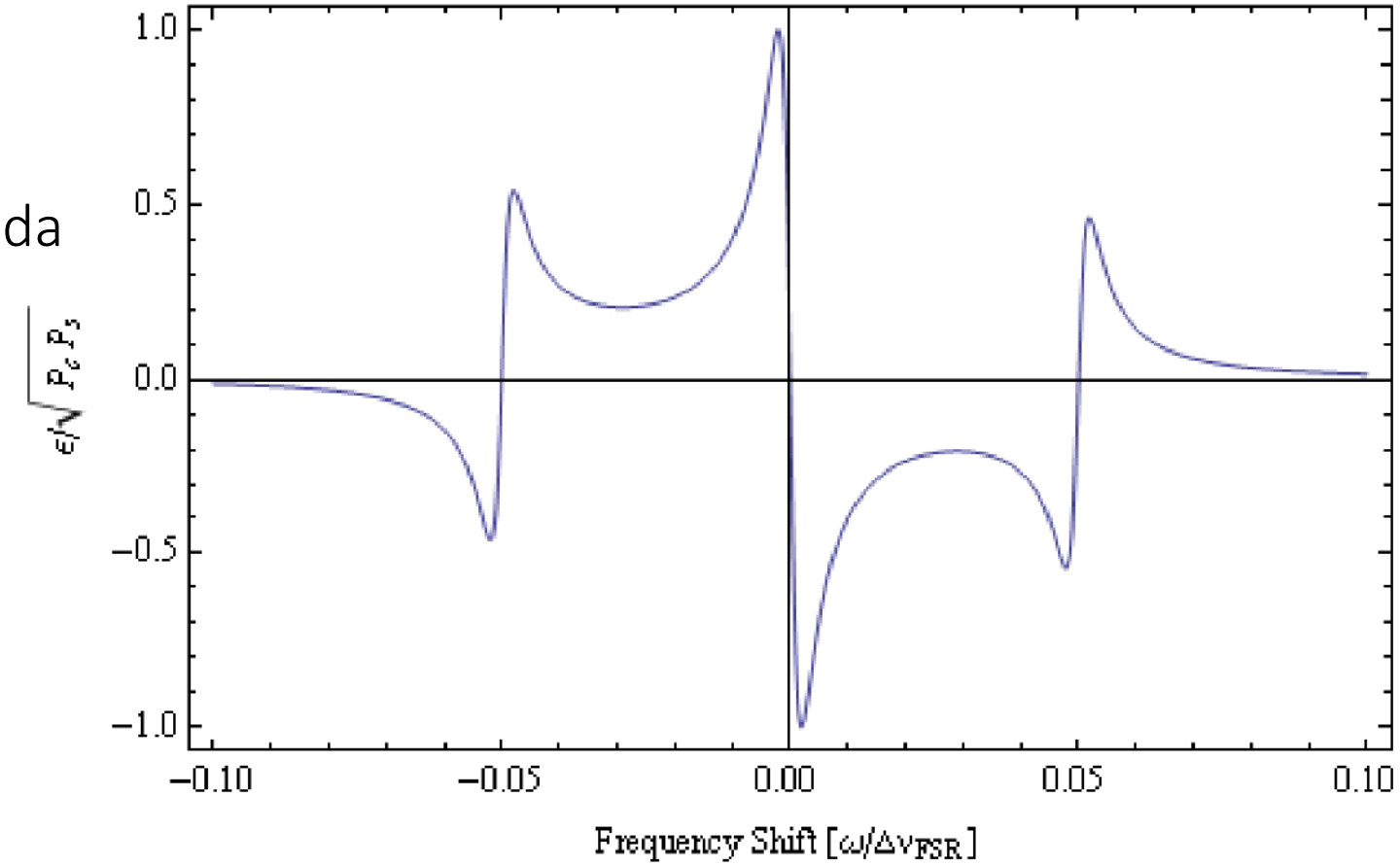


M. Kruljac: *Cavity Cooling and Self-organization of Atoms Using an Optical Frequency Comb*

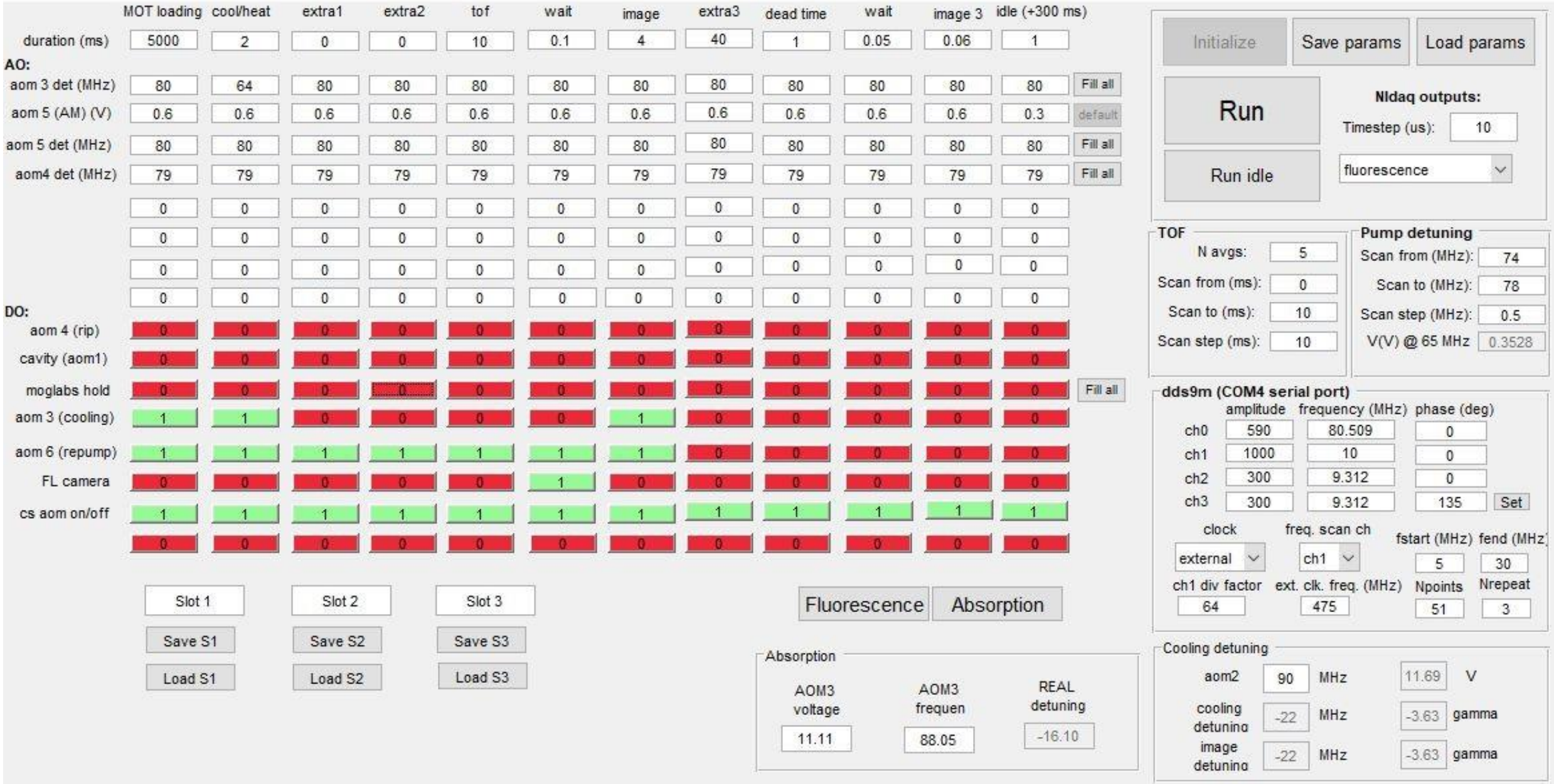
Stabilizacija

Pound-Drever-Hall (PDH) metoda

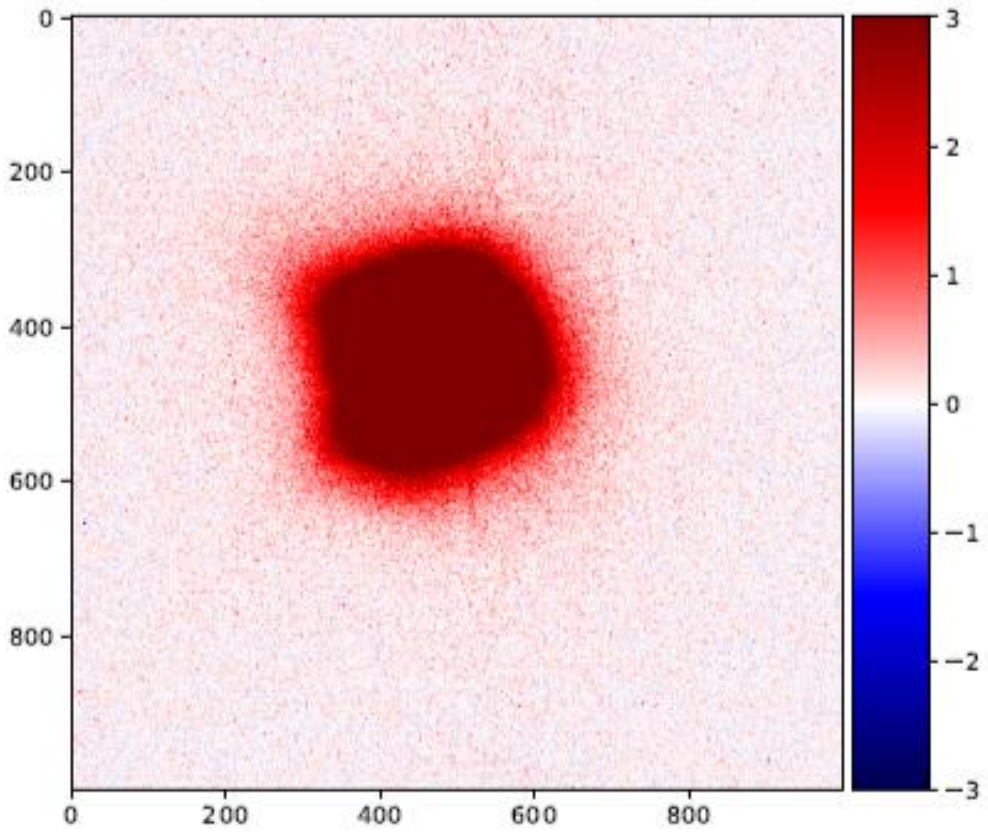
PI kontroler
(eng. *Proportional Integral*)



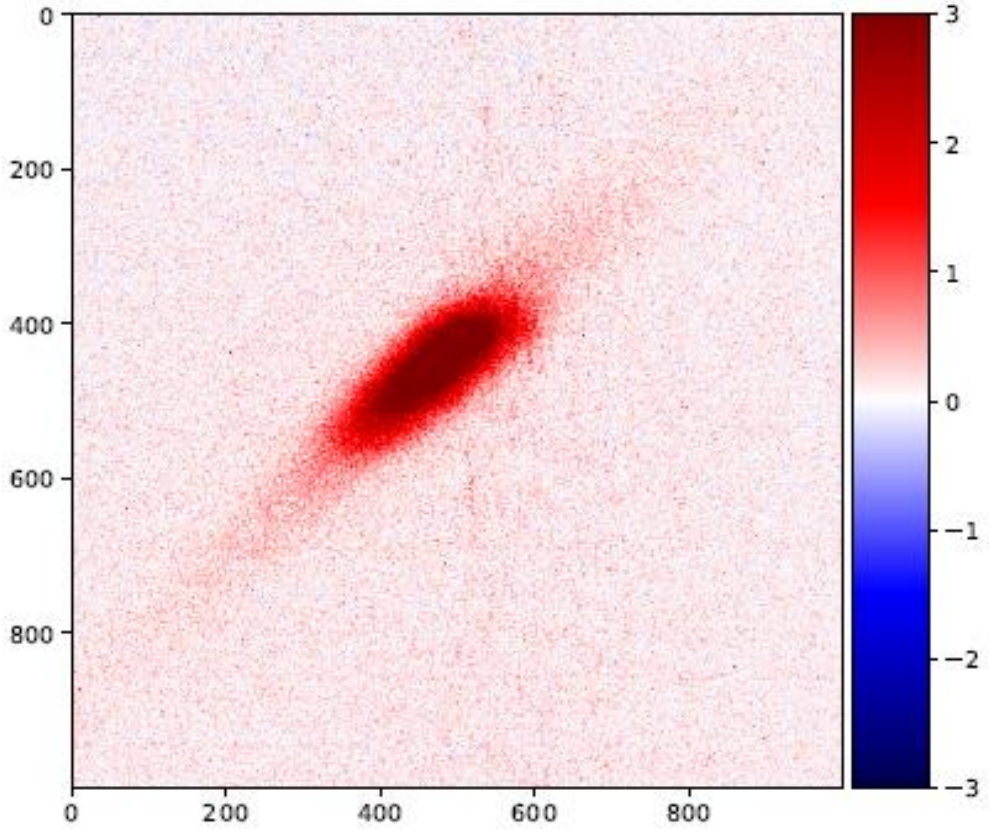
M. Nickerson: *A review of Pound-Drever-Hall laser frequency locking*


MOT loading
cool/heat
extra1
extra2
tof
wait
image
extra3
dead time
wait
image 3
idle (+300 ms)
duration (ms)
5000
2
0
0
10
0.1
4
40
1
0.05
0.06
1
AO:
aom 3 det (MHz)
aom 5 (AM) (V)
aom 5 det (MHz)
aom4 det (MHz)
Fill all
default
DO:
aom 4 (rip)
cavity (aom1)
moglabs hold
aom 3 (cooling)
aom 6 (repump)
FL camera
cs aom on/off
Slot 1
Slot 2
Slot 3
Save S1
Save S2
Save S3
Load S1
Load S2
Load S3
Fluorescence
Absorption
Absorption
AOM3 voltage
11.11
AOM3 frequen
88.05
REAL detuning
-16.10
Initialize
Save params
Load params
Run
Run idle
Nidaq outputs:
Timestep (us):
10
fluorescence
TOF
N avgs:
5
Scan from (ms):
0
Scan to (ms):
10
Scan step (ms):
10
Pump detuning
Scan from (MHz):
74
Scan to (MHz):
78
Scan step (MHz):
0.5
V(V) @ 65 MHz
0.3528
dds9m (COM4 serial port)
amplitude
frequency (MHz)
phase (deg)
ch0
590
80.509
0
ch1
1000
10
0
ch2
300
9.312
0
ch3
300
9.312
135
Set
clock
external
freq. scan ch
ch1
fstart (MHz)
5
fend (MHz)
30
ch1 div factor
64
ext. clk. freq. (MHz)
475
Npoints
51
Nrepeat
3
Cooling detuning
aom2
90
MHz
11.69
V
cooling detuning
-22
MHz
-3.63
gamma
image detuning
-22
MHz
-3.63
gamma

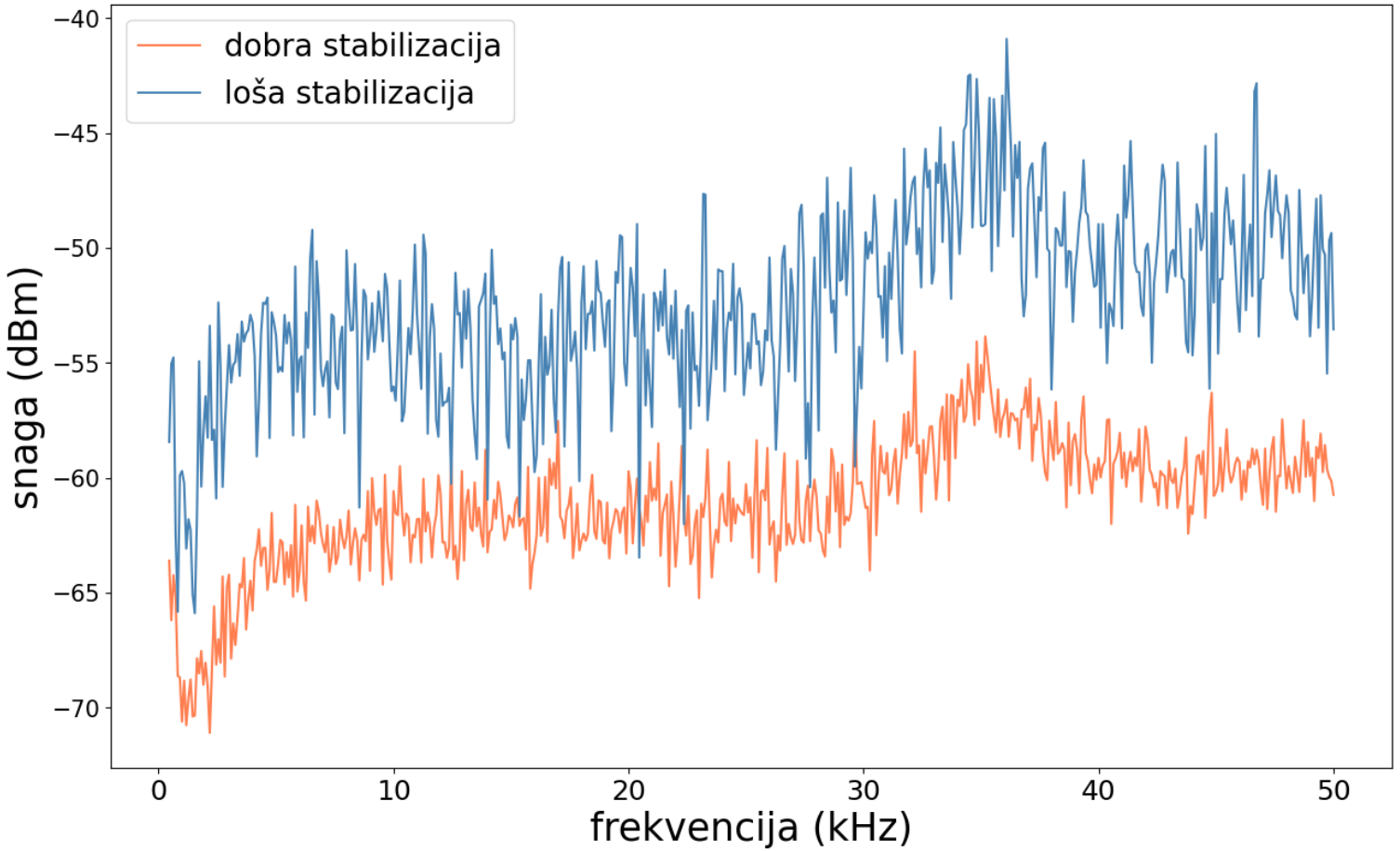
$T_{MOT} \approx 50\ \mu K$



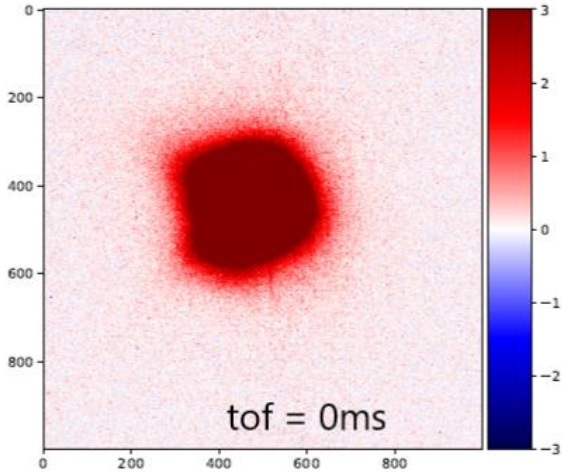
$V = 230\ \mu K$

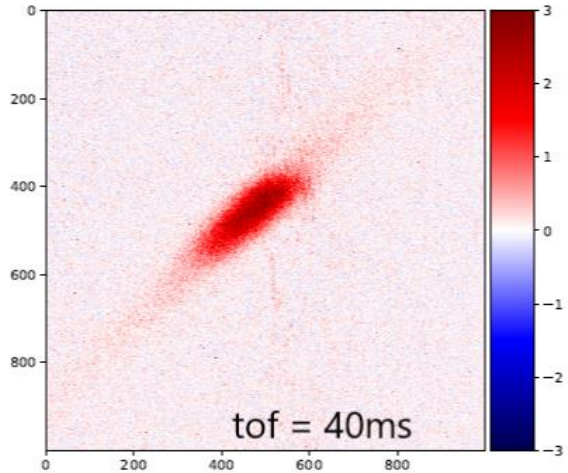


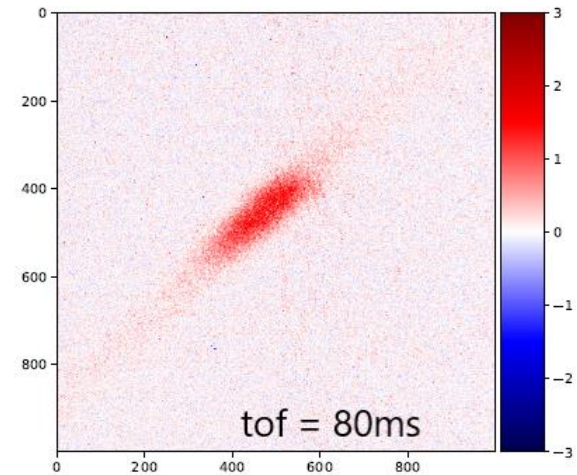
Spektar šuma

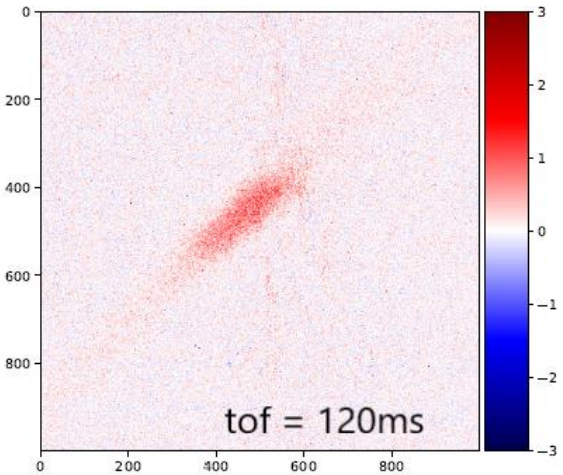


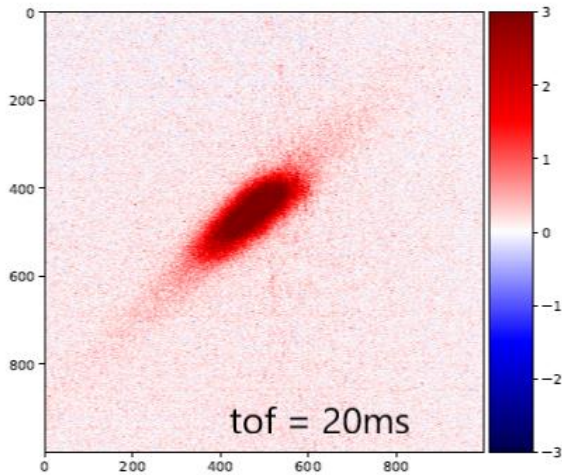
$$P_{(\mathrm{dBm})} = 10 \log_{10} \frac{P_{(\mathrm{W})}}{1\,\mathrm{mW}}$$

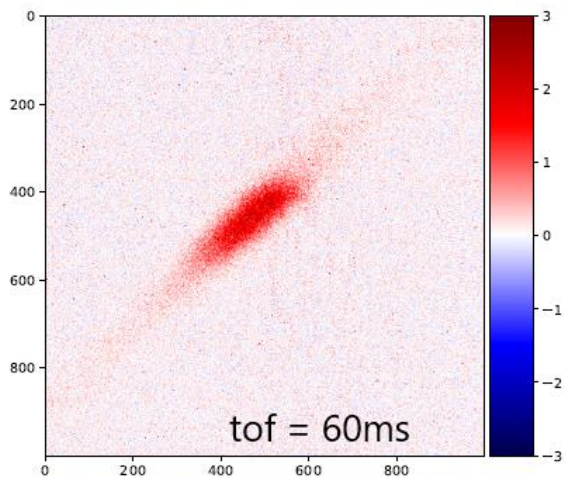

tof = 0ms

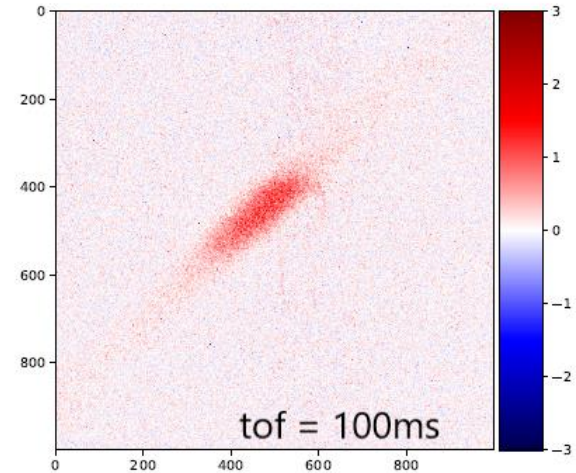

tof = 40ms

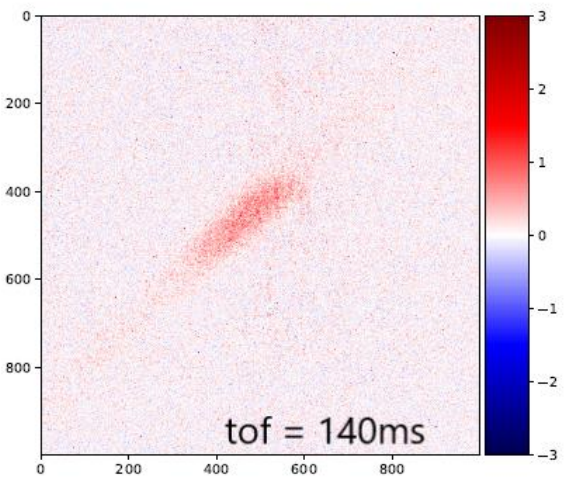

tof = 80ms


tof = 120ms

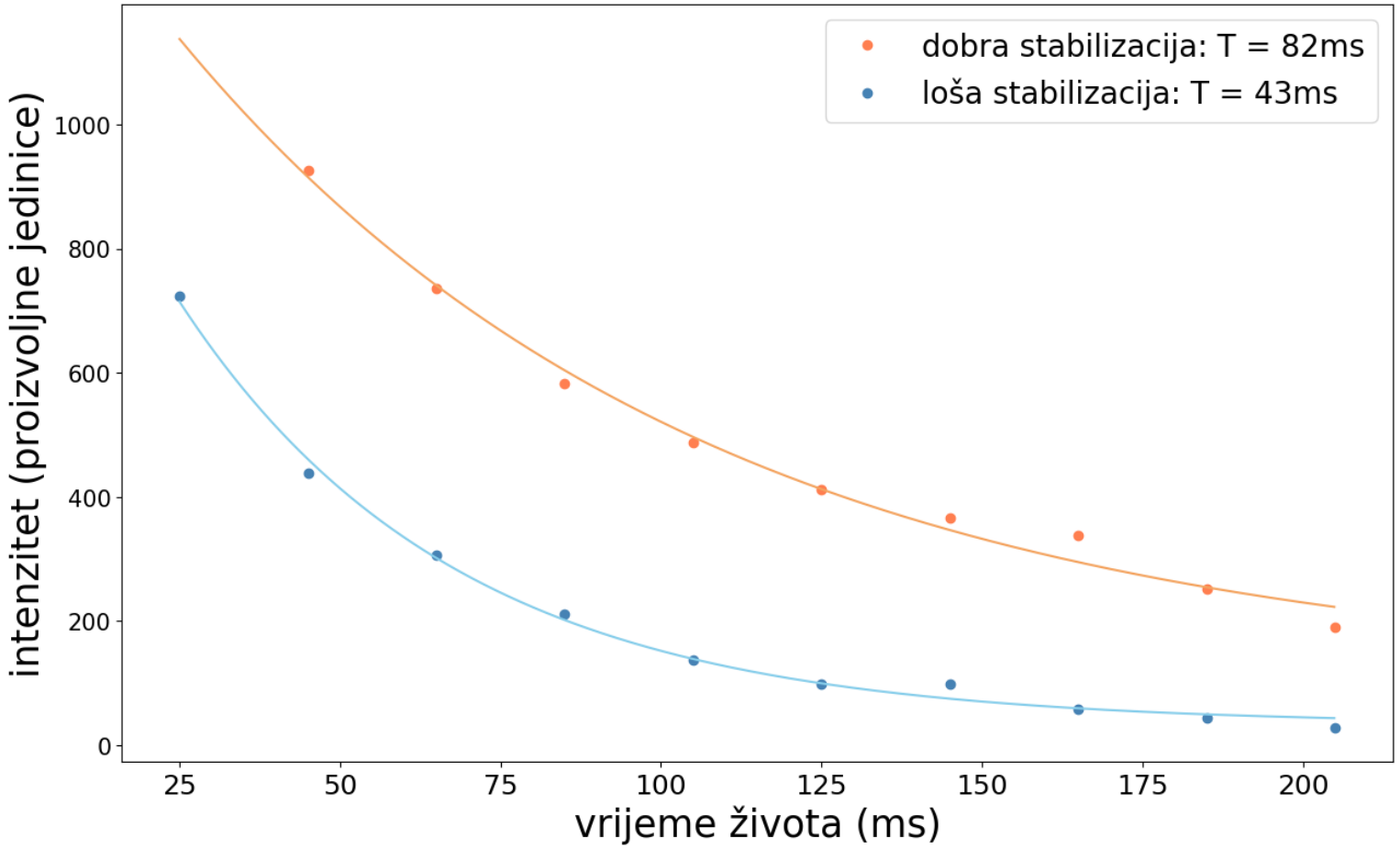

tof = 20ms


tof = 60ms


tof = 100ms


tof = 140ms

Vrijeme života



$$T_d = 82 \pm 13\ ms$$

$$T_l = 43 \pm 2\ ms$$

Hvala na pažnji!