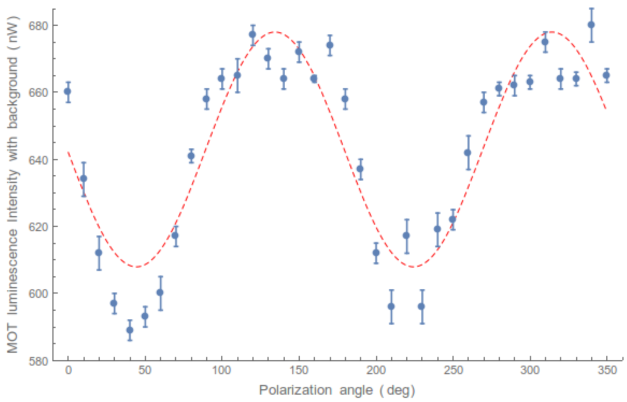

Figure 1: MOT luminescence intensity with background as a function of the polarization angle before the first MOT pass-through of one beam.

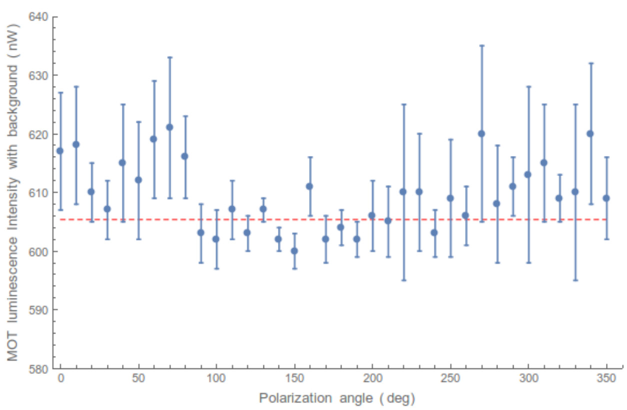

Figure 2: MOT luminescence intensity with background as a function of the polarization angle before the second MOT pass-through of one beam.

1 new things

1.1 Polarization direction dependence

As it is visible on Figure 1, the MOT luminosity changes periodically, following a π periodic dependence; the fitted function

$$f(x) = A\cos\left(\frac{\pi x}{180^\circ} - \varphi\right) + B$$

serves the purpose of confirming the periodicity, as the fitting is otherwise distorted by the abundance of near-maximum points compared to those near the minimum. Figure 2 shows the unadjusted luminosity as a function of the polarization angle of the beam changed before the second passing through the sample. Here, the strong fluctuations make it impossible to notice fine angle-dependent changes. The underlying function is likely a constant function, shown as the red dashed fitted line.

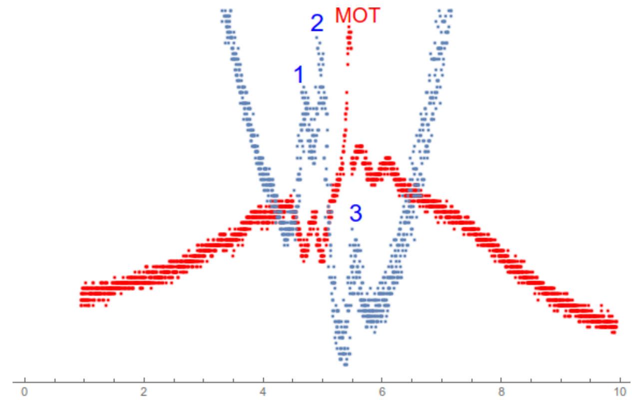

Figure 3: MOT luminescence intensity with background as a function of the polarization angle before the second MOT pass-through of one beam.

1.2 Detuning of the cooling laser

To quantify the ideal detuning of the cooling laser, we used a slow periodic signal to scan through the spectrum slow enough that the changes in the MOT can be recorded on an oscilloscope. The detected peaks (F $\rightarrow$ F1 and MOT fluorescence peak):

$$\begin{aligned}
3 \rightarrow 2,\, 4 &: \quad (4.708 \pm 0.024)\,\mathrm{s} \\
3 \rightarrow 3,\, 4 &: \quad (4.956 \pm 0.024)\,\mathrm{s} \\
3 \rightarrow 4 \quad &: \quad (5.556 \pm 0.016)\,\mathrm{s} \\
MOT \quad &: \quad (5.456 \pm 0.008)\,\mathrm{s}
\end{aligned}$$

By matching the difference of peaks 1, 2 and peaks 2, 3 with the frequencies of the transitions, averaging the results yields a frequency scale of

$$C = (114.161 \pm 11.163)\,\frac{\mathrm{MHz}}{\mathrm{s}}$$

The optimal detuning is the difference between the MOT and the $3 \rightarrow 4$ peaks:

$$\Delta\nu = C \cdot (0.100 \pm 0.008)\,\mathrm{s} = (11.4161 \pm 1.4423)\,\mathrm{MHz} \tag{1}$$

1.3 Detuning of the pumping laser

We found the following peaks:

$$\begin{aligned}
3 \rightarrow 2,\, 4 &: \quad (4.708 \pm 0.024)\,\mathrm{s} \\
3 \rightarrow 3,\, 4 &: \quad (4.956 \pm 0.024)\,\mathrm{s} \\
3 \rightarrow 4 \quad &: \quad (5.556 \pm 0.016)\,\mathrm{s} \\
MOT \quad &: \quad (5.456 \pm 0.008)\,\mathrm{s}
\end{aligned}$$

1.4 Population of MOT

$$R = \frac{\Gamma}{2}\frac{\frac{I}{I_{\mathrm{sat}}}}{1 + \frac{I}{I_{\mathrm{sat}}} + \left(\frac{2\Delta\nu}{\Gamma}\right)^2} = (18.4915 \pm 0.0434)\,\mathrm{MHz}, \tag{2}$$

where $\Gamma = 2\pi \cdot (6.0666 \pm 0.0018)$ MHz is the natural linewidth of the transition, $I_{\mathrm{sat}} = (1.66932 \pm 0.00035)\,\frac{\mathrm{mW}}{\mathrm{cm}^2}$, $I = \frac{2P}{\pi w^2} = (73.9409\ pm 3.00633)\frac{\mathrm{mW}}{\mathrm{cm}^2}$ the total cooling laser intensity ($P = 10.60 \pm 0.05$ mW is the total power), and $\Delta\nu$ is the detuning of the cooling laser (eqn. 1).
The total intercepted power at a distance ρ from the MOT by a lens with radius r, when the MOT has a radiation power P_{MOT}, is

$$P = \frac{P_{\mathrm{MOT}}}{4\pi\rho^2} \cdot \pi r^2,$$

from which ($\rho = (10.5 \pm 1.0)\,\mathrm{cm}$, $2r = (2.5 \pm 0.1)\,\mathrm{cm}$)

$$P_{\mathrm{MOT}} = 47.4 \pm 9.8\,\mu\mathrm{W} \tag{3}$$

The main error source is the distance measurement, but the lens diameter also has a significant uncertainty. The number of trapped atoms can be calculated now, as

$$P_{\mathrm{MOT}} = NRh\nu,$$

giving

$$N = 1.00687 \cdot 10^7 \pm 2.0811 \cdot 10^6 \tag{4}$$

for the population size.

References

[1] Unspecified Author, *FP Experiment: Rubidium MOT* (University of Bonn, 2014).

[2] D. A. Steck, *Rubidium 85 D Line Data*, `http://steck.us/alkalidata/rubidium85numbers.pdf`