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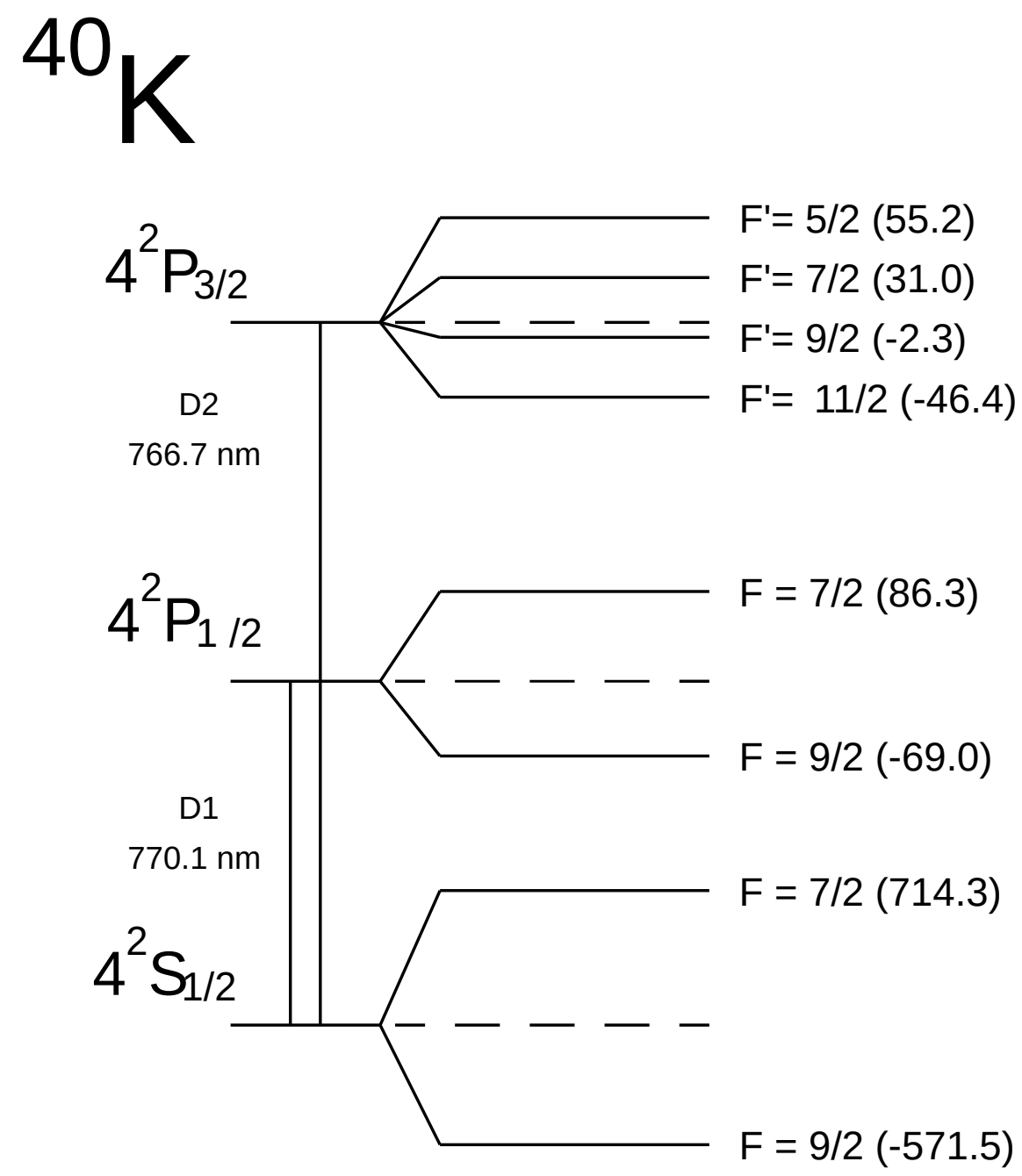
Towards laser locking in the telecom range by spectroscopy of molecular gases

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Motivation

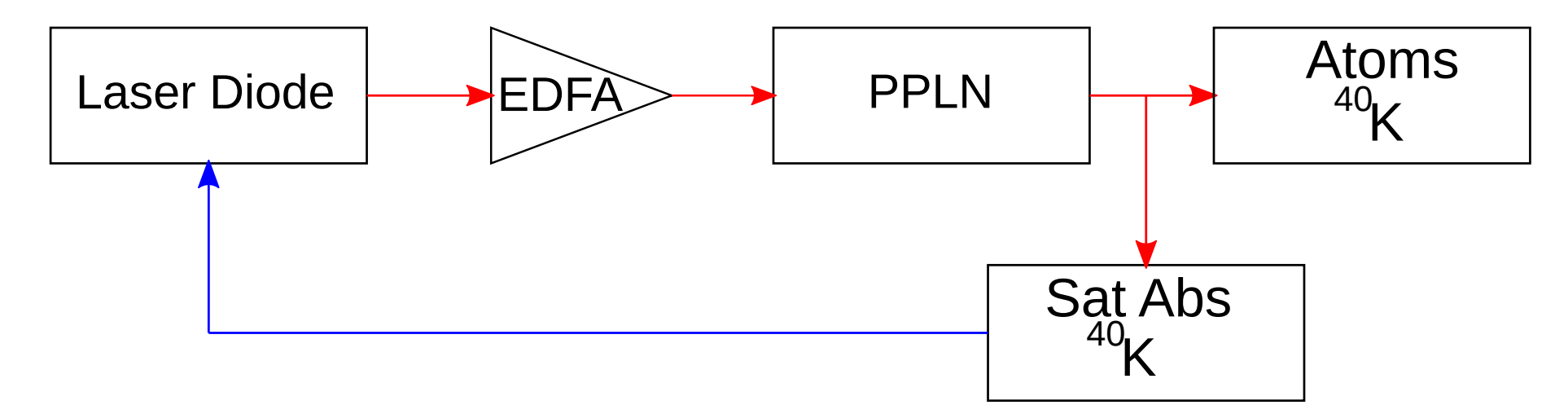
The AUFRONS (Ultra cold atoms in nanostructured optical potential) project aims at building near field optics / Ultra cold atoms hybrid systems to achieve stronger interaction between solid state and cold atoms physics. One of our goals is to manipulate cold fermionic species at the vicinity of a surface.



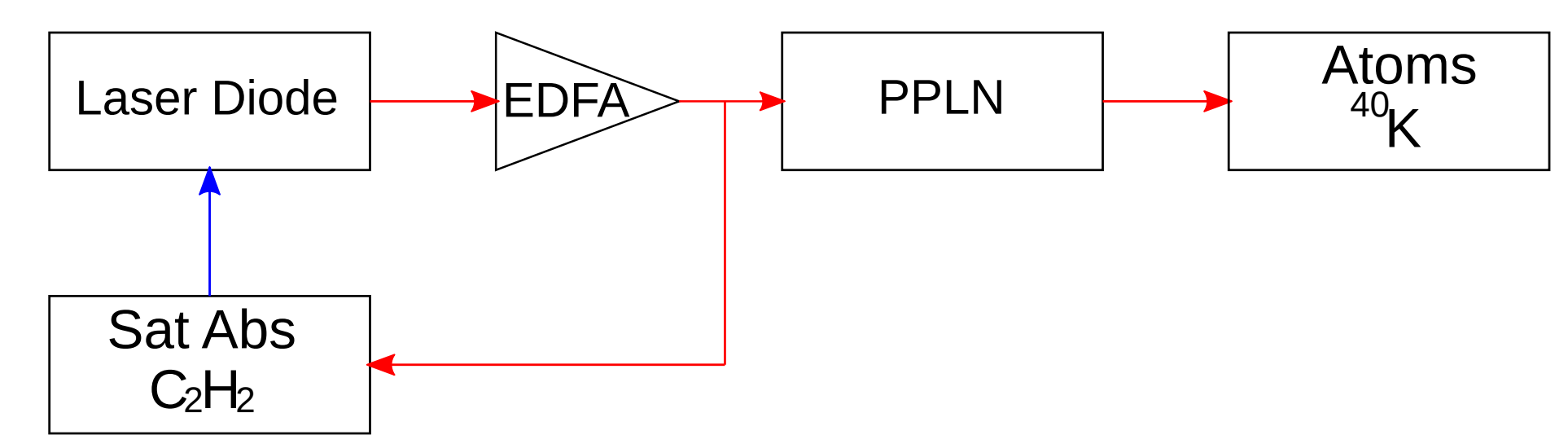
- ^{40}K : + transition frequency close to ^{87}Rb \rightarrow doubled telecom laser diodes
 + sympathetic cooling with ^{87}Rb
 [1] + low field Feshbach resonances
 - isotopic ratio (0,012 %)
 - hyperfine lines are close, difficult to lock onto

- C_2H_2 as rovibrational lines close to half the ^{40}K transition frequency
 + metrological transitions
 [2] + narrow lines
 + can work at room temperature
 - no need for a second doubling stage
 - low absorption

Potassium setup:

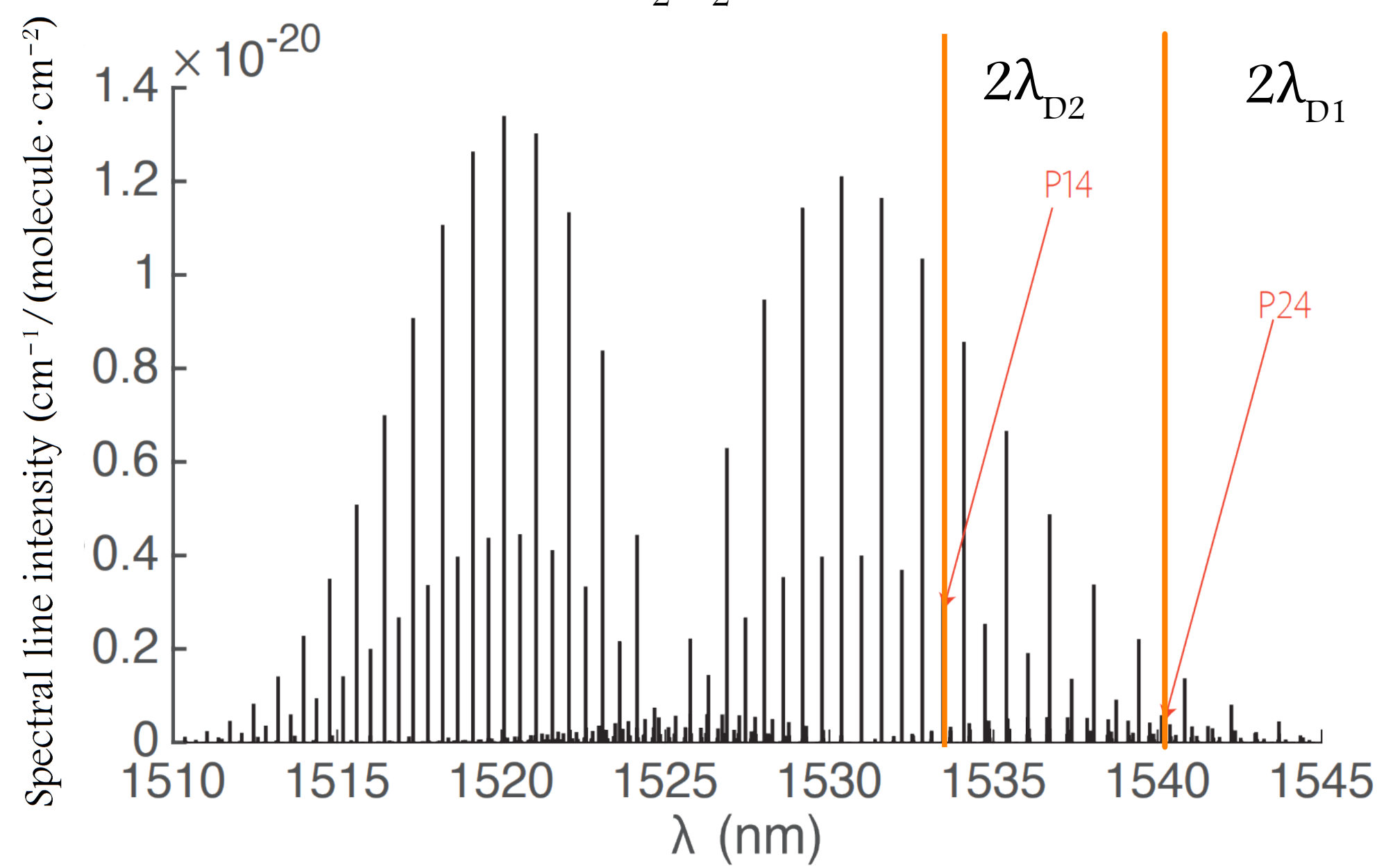


Acetylene setup:



Molecular Gases: Acetylene

Lines of interest for Potassium cooling (D1 and D2) using acetylene (C_2H_2) [2]



| | $2\lambda_{D1,D2}$ (nm) | $\lambda_{C2H2,P24/P14}$ (nm) | Frequency Gap (GHz) |
|-------------------|-------------------------|-------------------------------|---------------------|
| D1/P24 Transition | 1540.216 | 1540.125 | 11.456 |
| D2/P14 Transition | 1533.402 | 1533.461 | 7.522 |

Acetylene Spectroscopic Parameters

- S = Spectral line intensity ($\text{cm}^{-1}/(\text{molecules} \cdot \text{cm}^{-2})$) [2]

$$S = \underbrace{\text{wavenumber}} \times \underbrace{\text{Column density}}$$

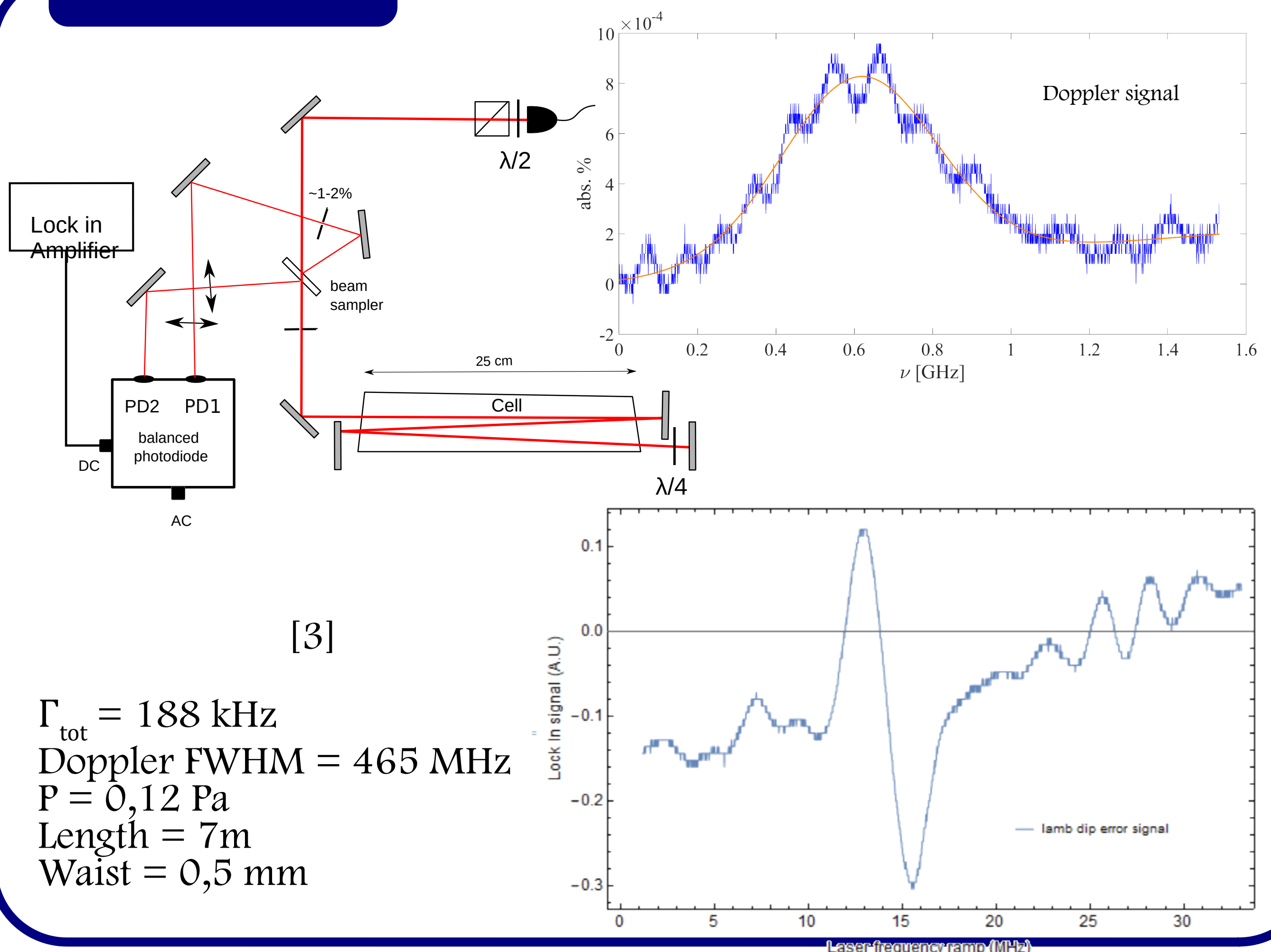
- Optical Density is given by $OD = S \times \text{line profile} \times \frac{P}{k_B T} L$ Doppler FWHM ≈ 472 MHz

$$\Gamma_{\text{tot}} = \Gamma_{\text{nat}} + \Gamma_{\text{pressure}} + \Gamma_{\text{transit}}$$

$$I_{\text{sat}} \propto \Gamma_{\text{tot}}^2$$

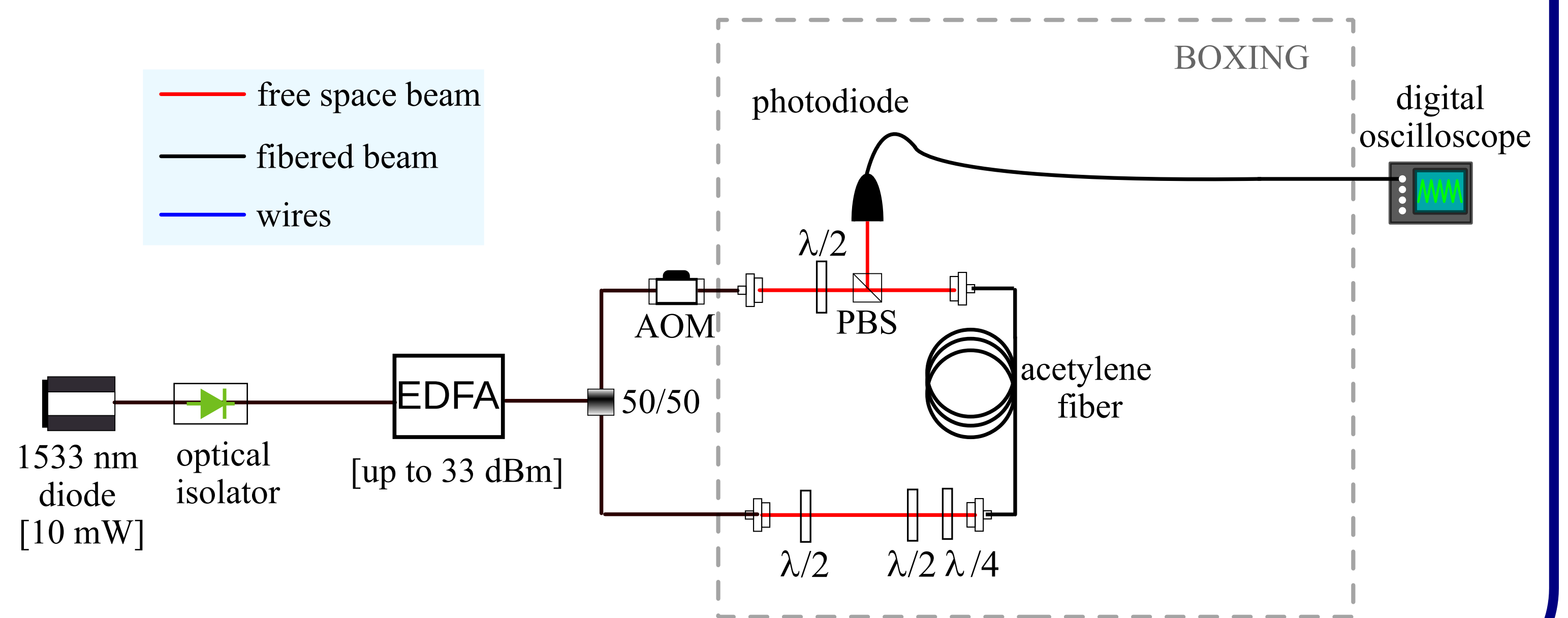
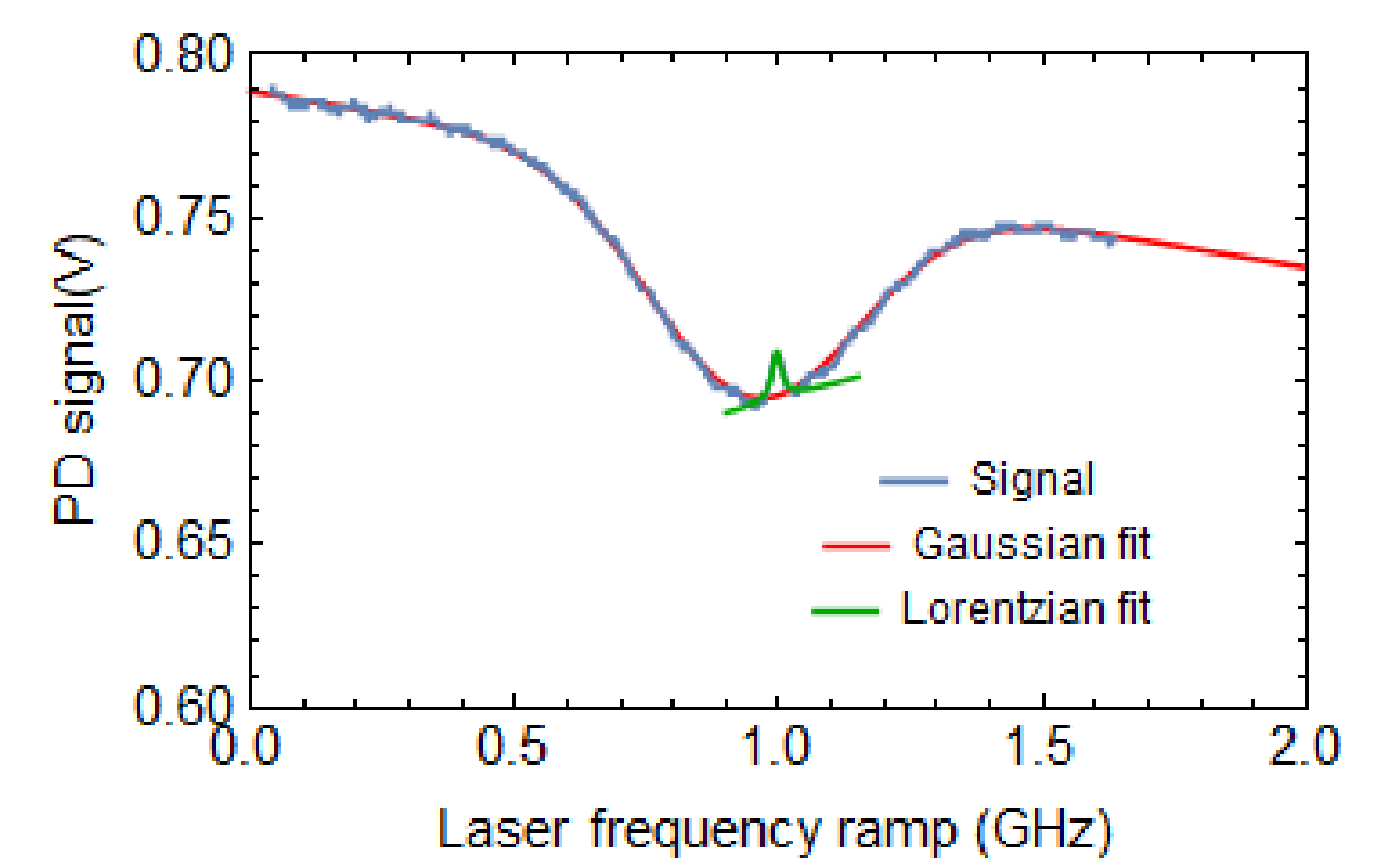
$$\begin{aligned} \Gamma_{\text{nat}} &= 5 \text{ Hz} \\ \Gamma_{\text{pressure}} &= (234 \text{ kHz/Pa}) \times P \\ \Gamma_{\text{transit}} &= \frac{0,19}{w_0} \sqrt{\frac{2k_B T}{m_{C_2H_2}}}, w_0 \text{ waist radius} \end{aligned}$$

Bulk Cell



Fiber Cell [4]

- Length = 7m
- MFD = 22 μm
- $P = 6$ Pa
- $\Gamma_{\text{tot}} = 6$ MHz
- $\Gamma_{\text{meas}} = 22$ MHz
- Sat Abs Amplitude: 16% of Doppler
- $P_{\text{sat}} \approx 20$ mW [5]



References

- [1] T. Tiecke. Properties of Potassium. <http://www.tobiastiecke.nl/archive/PotassiumProperties.pdf>, (2011).
- [2] HITRAN. Data base spectroscopy
- [3] J. Hald et al, Opt. Lett. **19**(3), 2052–2063 (2011)
- [4] M.Triches et al, Opt. Lett. **23**(9), 11227–11241 (2015)
- [5] J. Henningsen et al, Opt. Exp. **13**(26), 10475–10482 (2005)

Collaborations

Xlim:
 Fetah Benabid, Benoît Debord, Thomas Billotte

Perspectives

Experiment :

- Comparing bulk and fiber cells
- Herriott Cell
- Comparing the setups with ^{87}Rb reference via frequency comb
- Application for Potassium cooling

