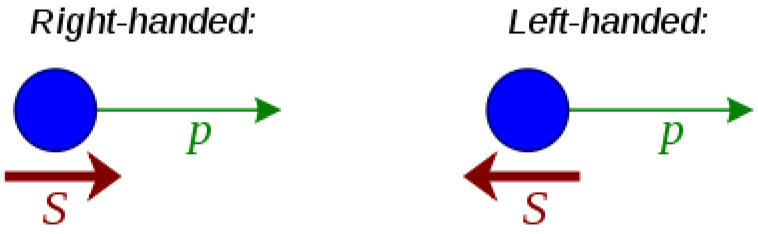
Measure polarization in potassium isotopes

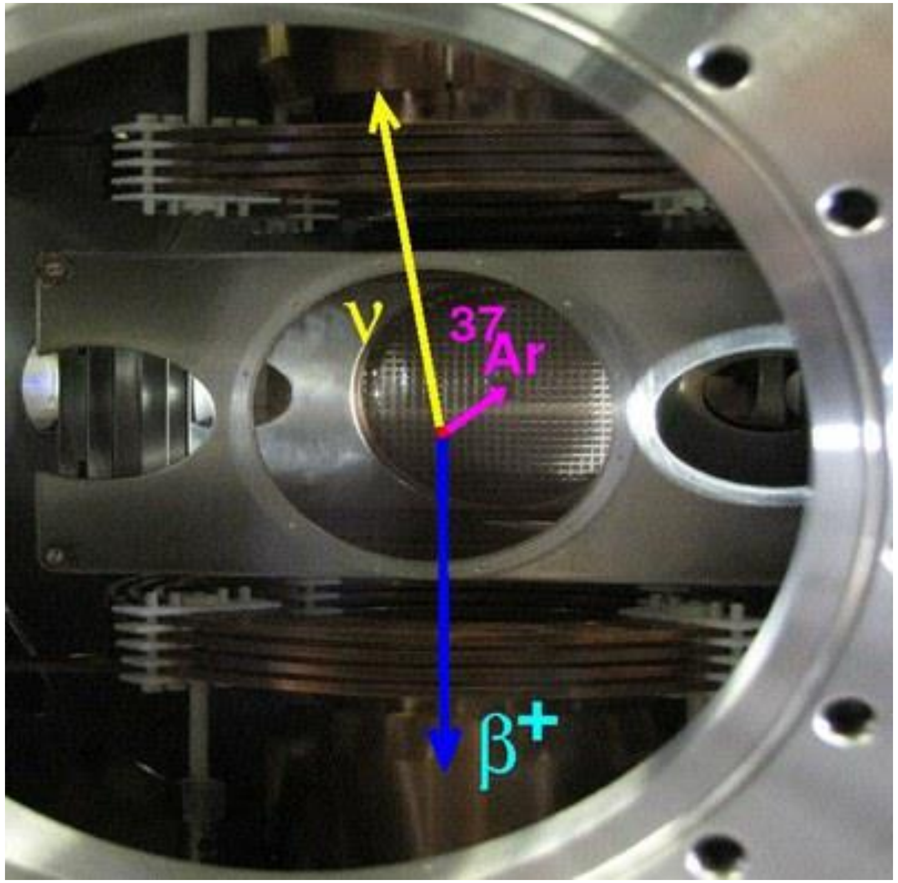
Dante Prins

Potassium 37 beta decay asymmetry experiment

Beta decay is known to violate parity symmetry, having a chirality dependance and a bias for left handedness. Our experiment polarized the parent atom and measures beta emission direction.



$$\mathbf{P} : \begin{pmatrix} x \\ y \\ z \end{pmatrix} \mapsto \begin{pmatrix} -x \\ -y \\ -z \end{pmatrix}.$$



0nm

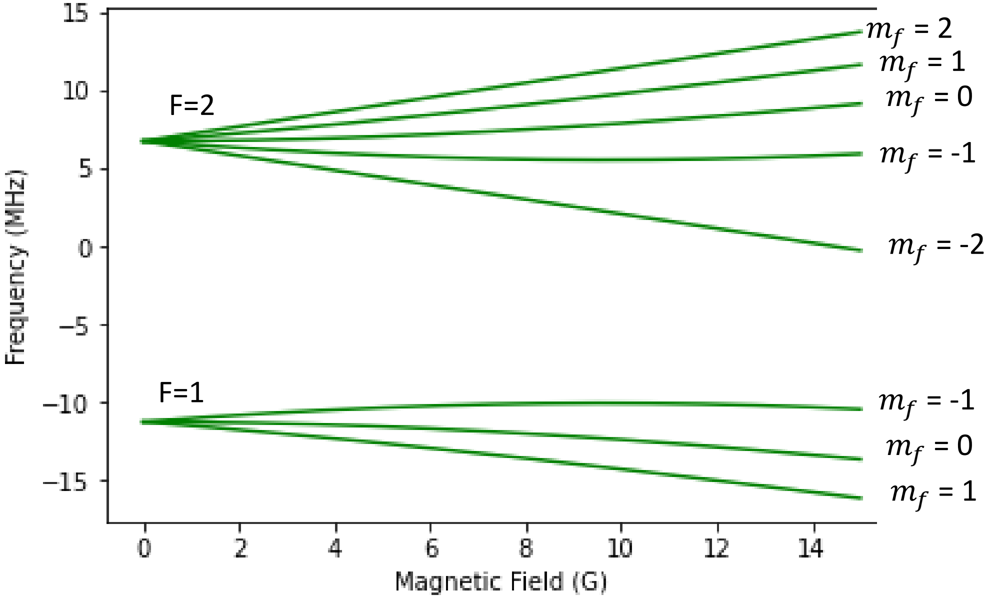
Polarization measurement

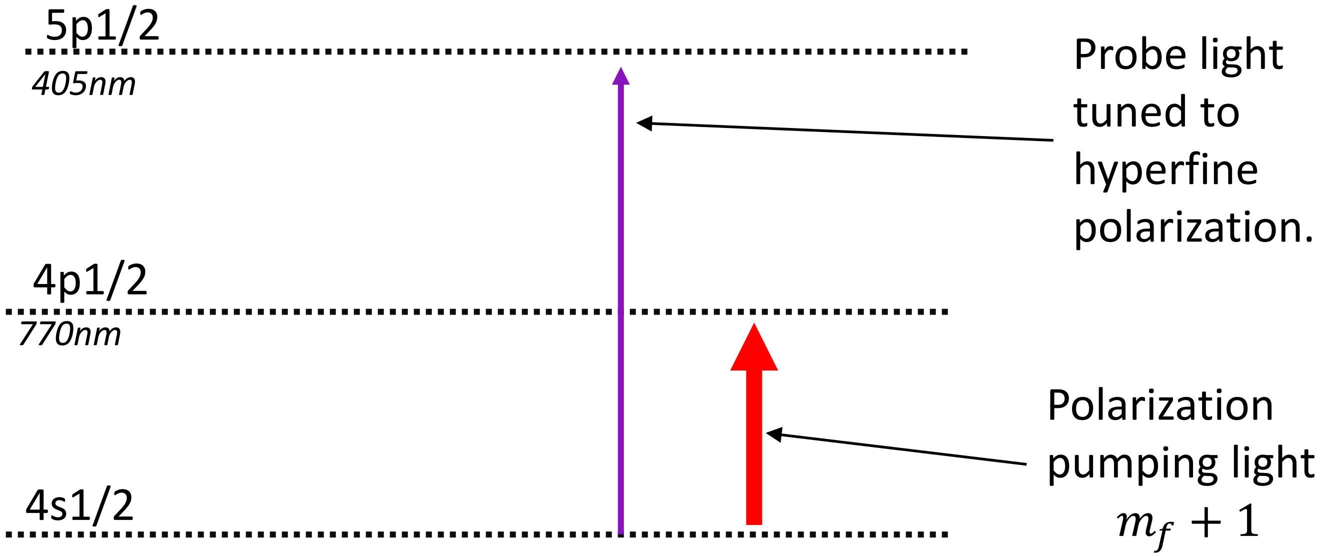
Zeeman effect at medium magnetic fields

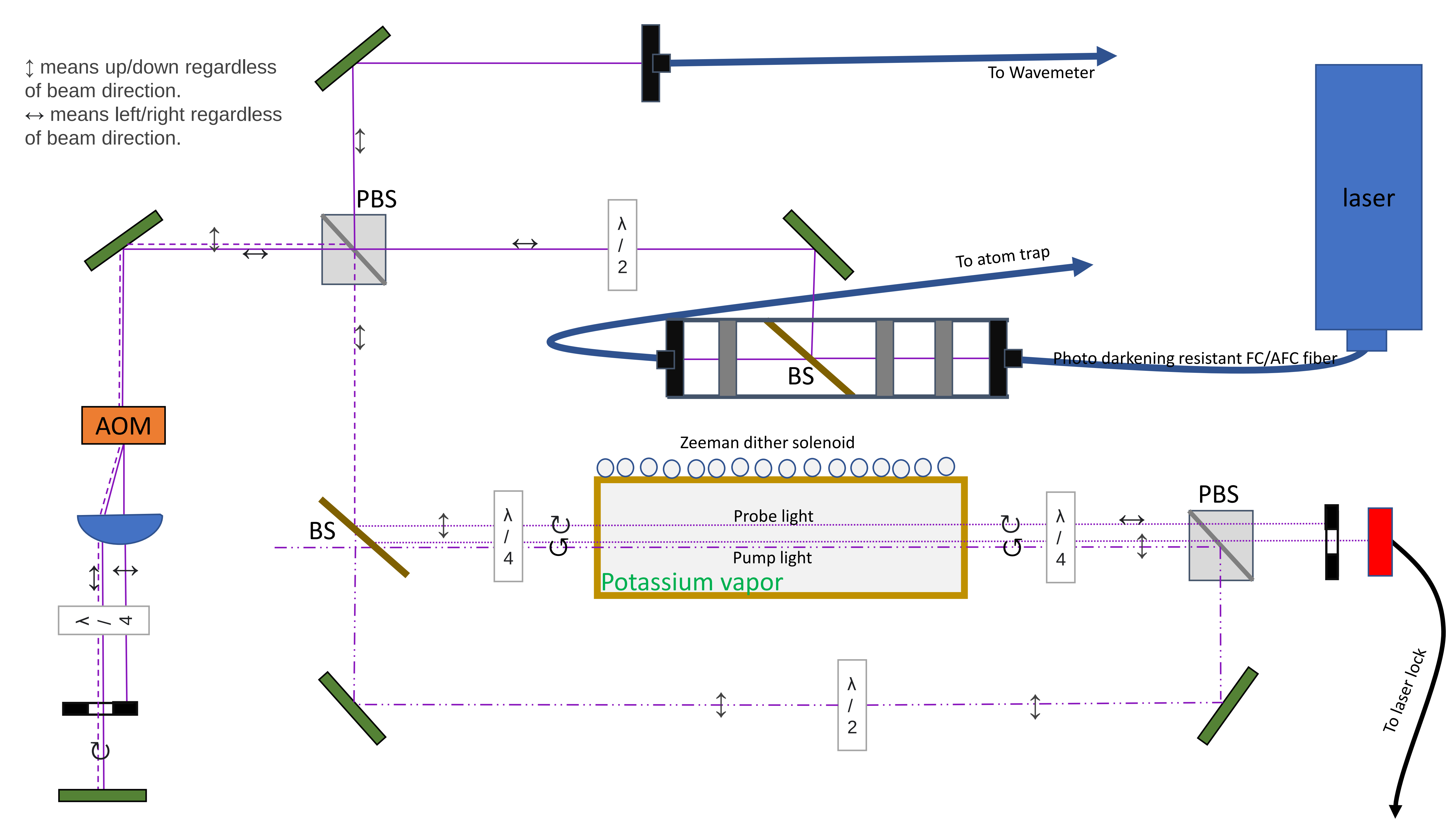
$$H = hAI_zJ_z + \frac{hA}{2}(J_+I_- + J_-I_+) + \mu_B B g_J J_z + \mu_N B g_I I_z$$

In the presence of a magnetic field energies will shift allowing us to probe individual polarizations.

Zeeman effect splitting for 5p1/2 K41







↕ means up/down regardless of beam direction.
↔ means left/right regardless of beam direction.
To Wavemeter
laser
PBS
λ / 2
To atom trap
BS
Photo darkening resistant FC/AFC fiber
AOM
Zeeman dither solenoid
BS
λ / 4
Probe light
Pump light
Potassium vapor
λ / 4
PBS
λ / 4
λ / 2
To laser lock

Hyperfine structure splitting varies by isotope

Isotope	Abundance
K37	1.23s half life
K39	93%
K41	7%

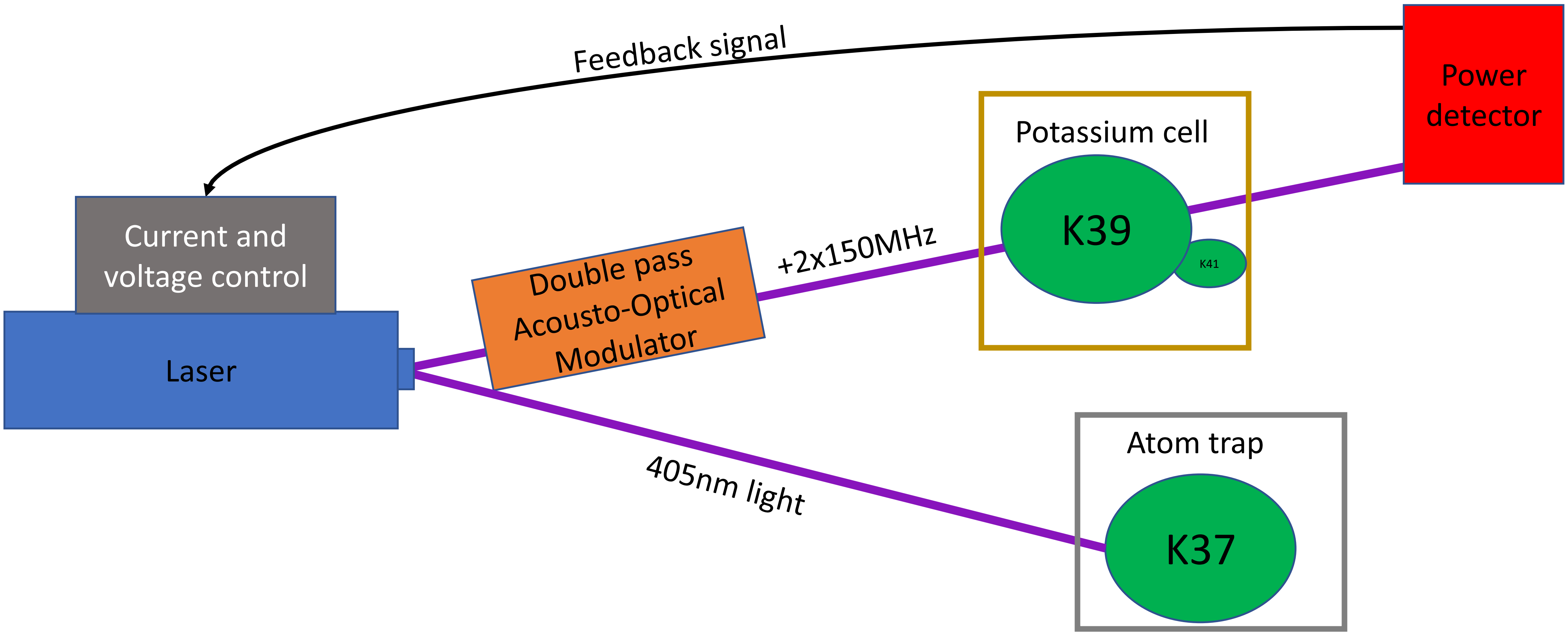
$$H_{HFS} = A\,\mathbf{I}\cdot\mathbf{J}$$

$$K37\ A_{4s_{1/2}} = 240.3\text{MHz}$$
$$K39\ A_{4s_{1/2}} = 461.7\text{MHz}$$
$$K41\ A_{4s_{1/2}} = 254.0\text{MHz}$$

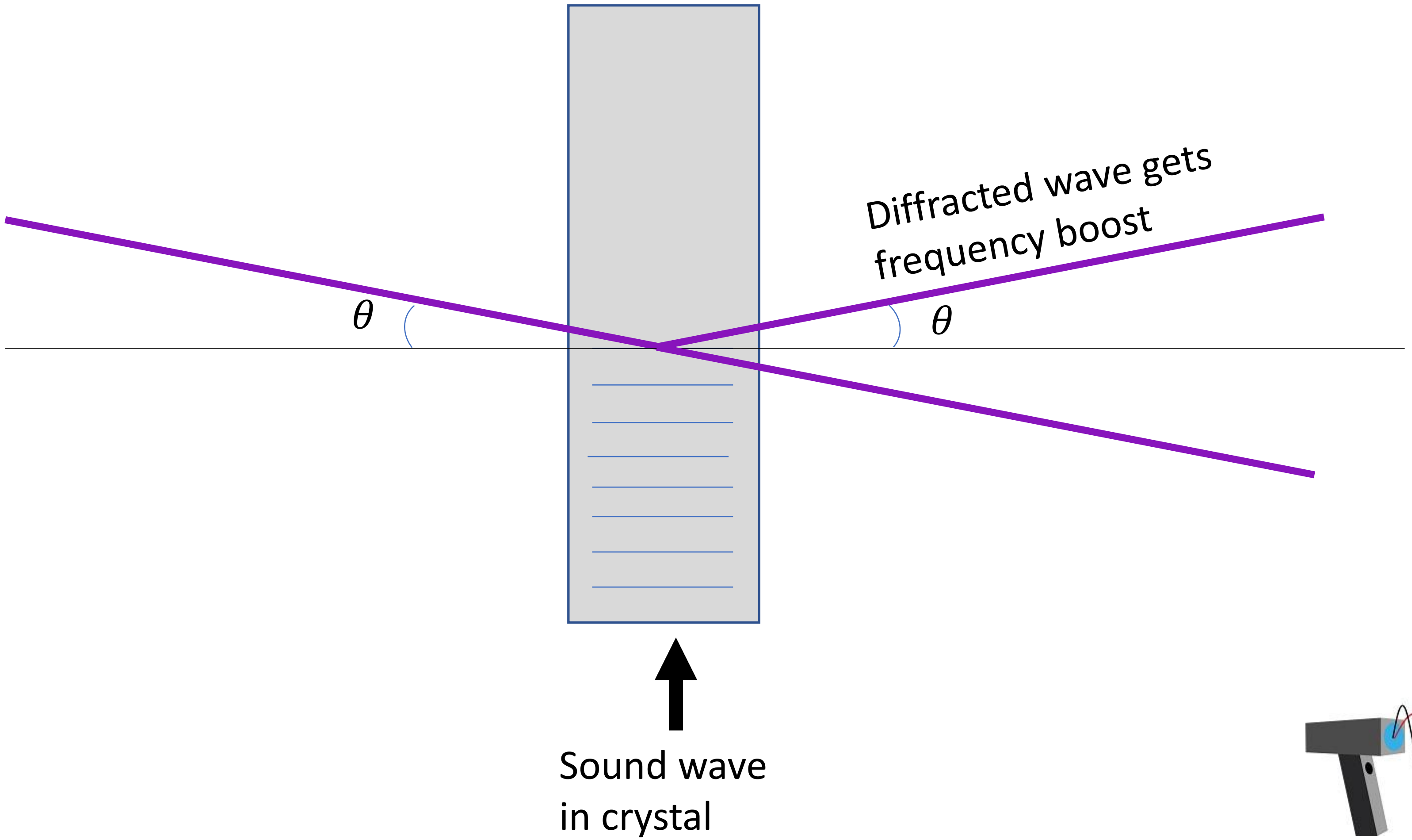
How do we lock the trap to K39 spectra but scan K37?

Isotope frequency shift is corrected by Acousto-Optical Modulator

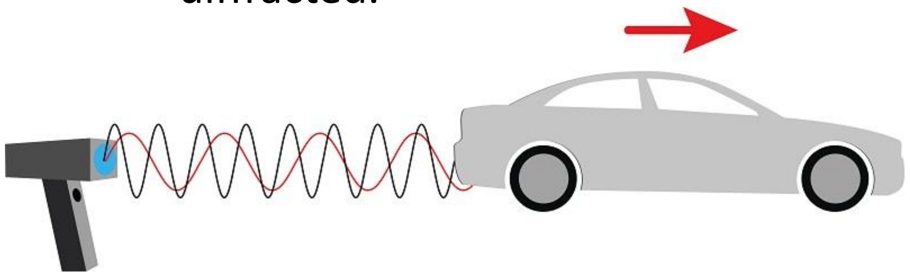
Picture of aom module



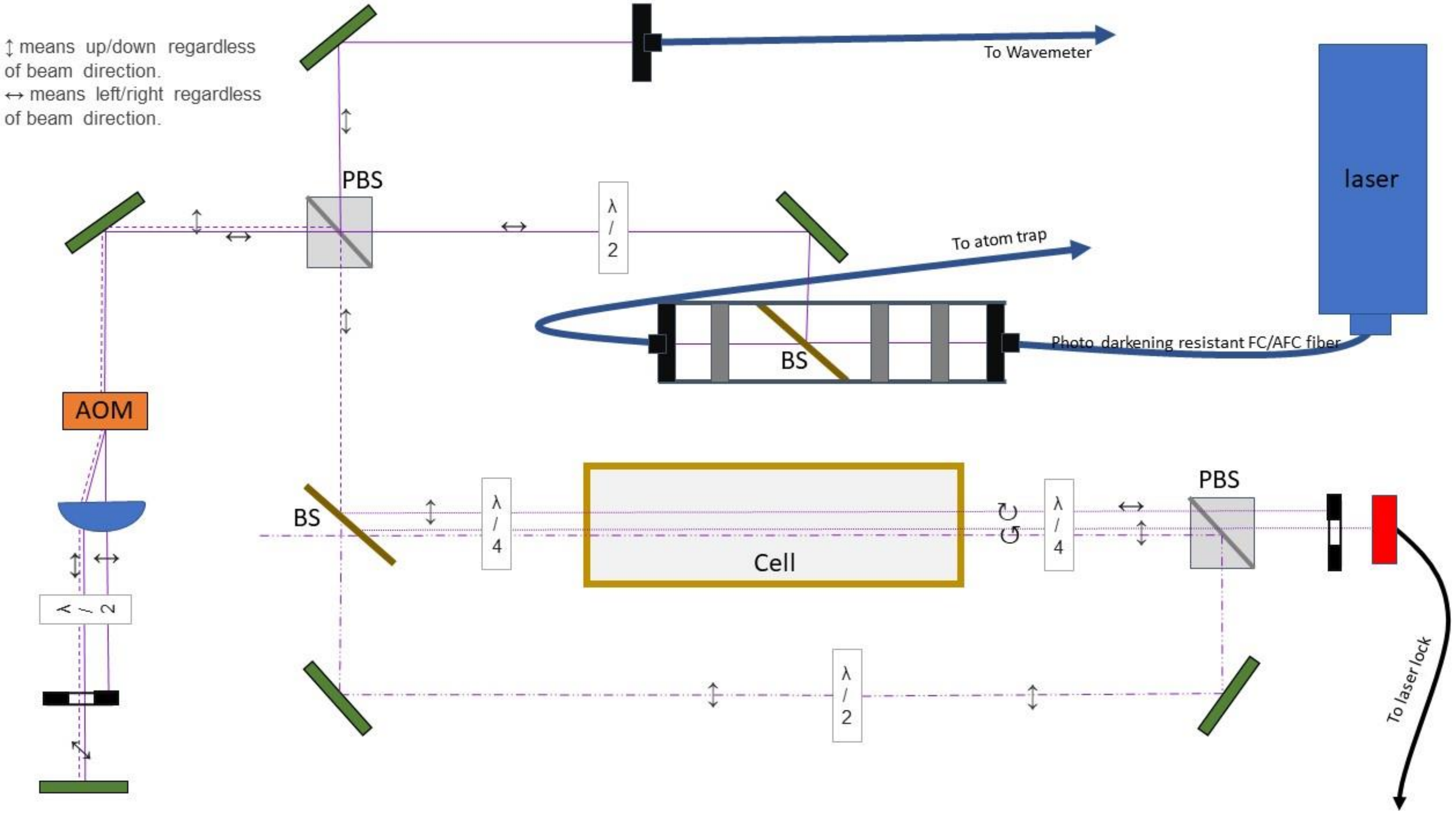
Acousto-Optical Modulator physics



The incoming light is Doppler shifted to a higher frequency in the reference frame of the moving Bragg plane before being diffracted.

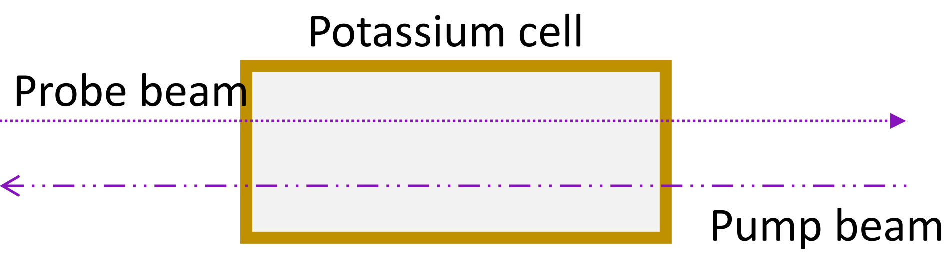


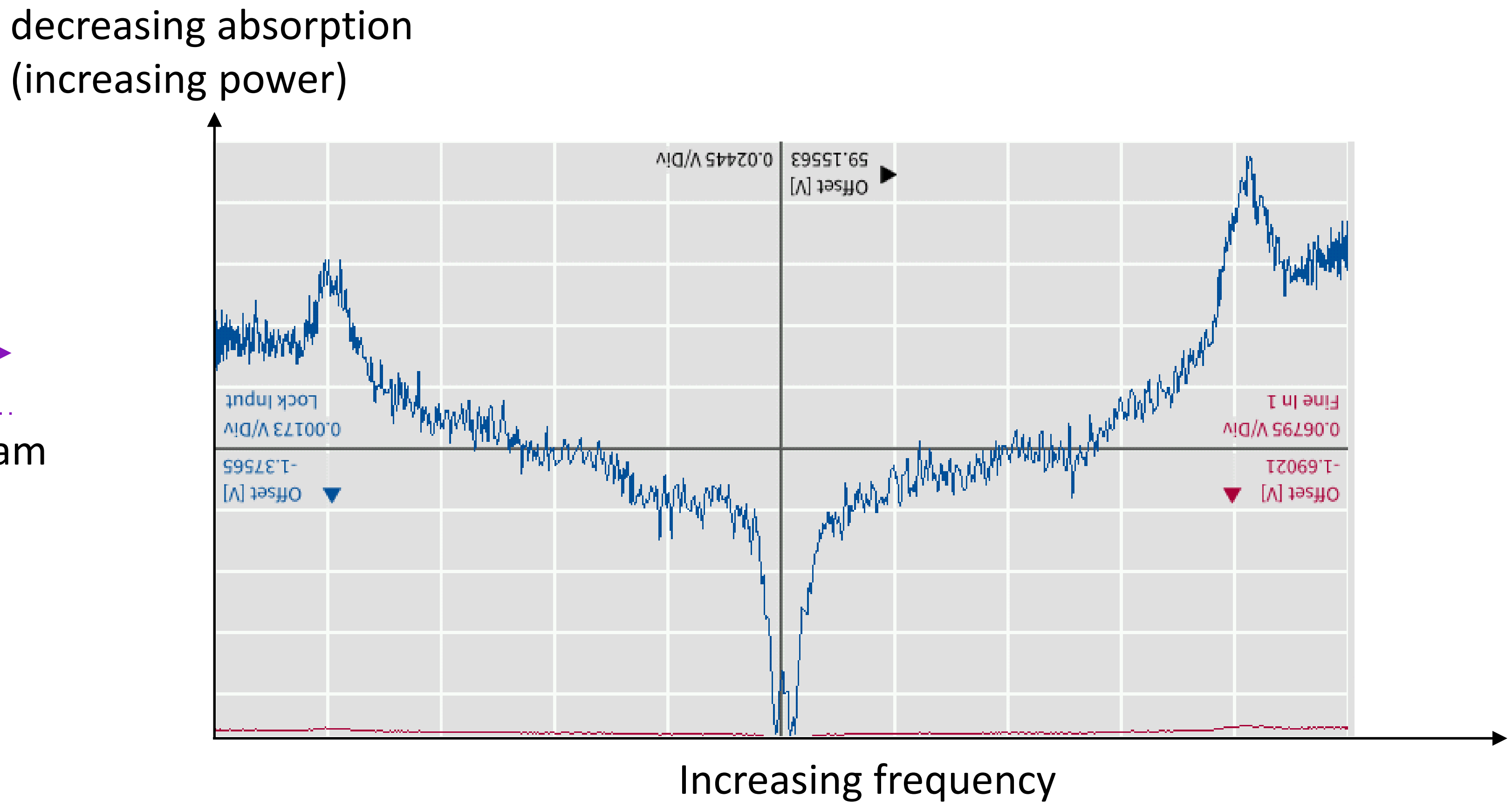
Beam polarization



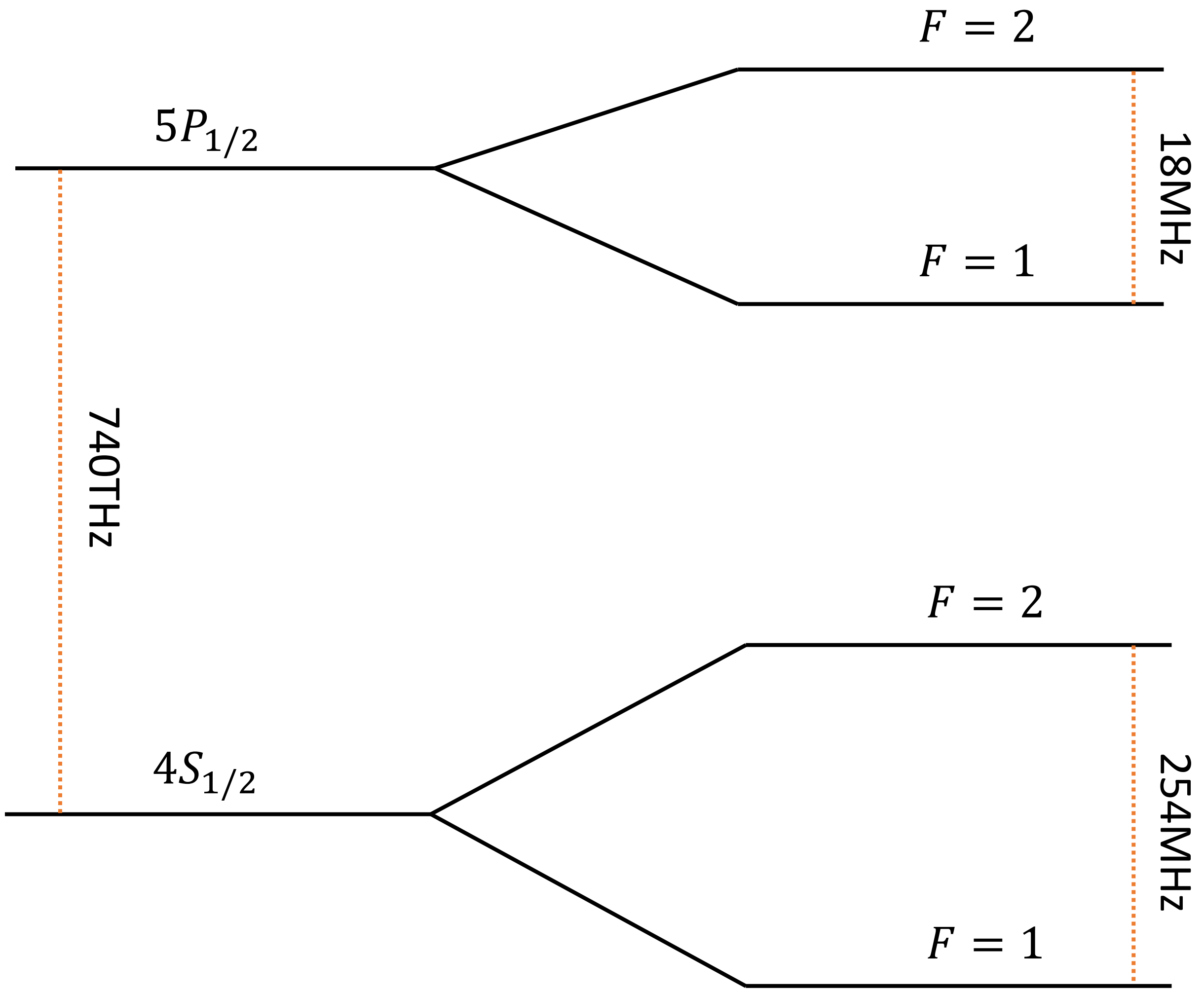
K cell sat spectroscopy

We know the cell will absorb light at transitions frequencies, how do we arrive at the actual absorption signal?





Hyperfine structure frequencies for K39



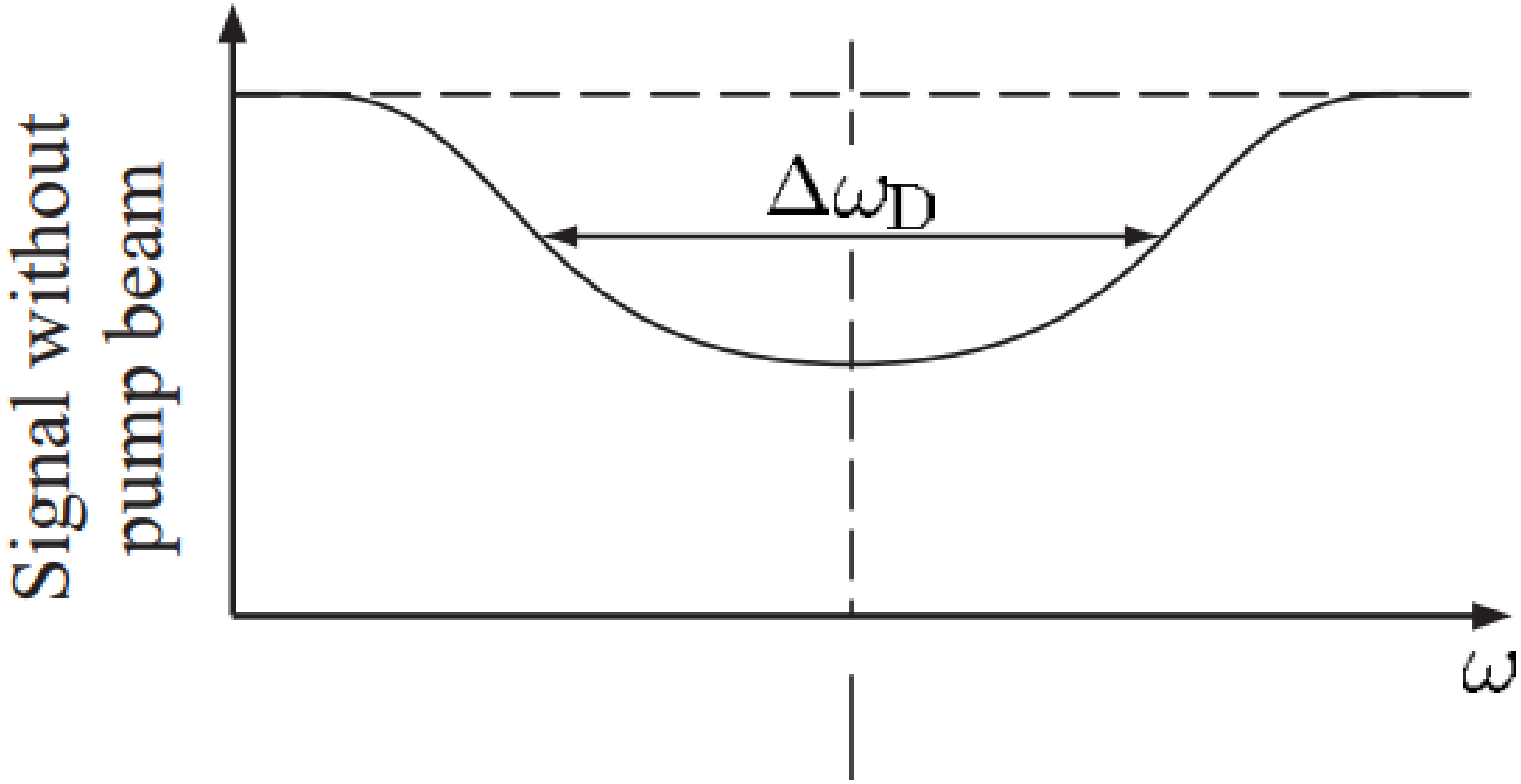
Hyperfine transition $\left\|4S_{\frac{1}{2}}\, F_I\right\rangle$ to $\left\|5P_{\frac{1}{2}}\, F_{II}\right\rangle$	Shift from $\mathbf{24701.382cm^{-1}}$
$F_I = 1$ $F_{II} = 2$	295MHz
$F_I = 1$ $F_{II} = 1$	277MHz
$F_I = 2$ $F_{II} = 2$	-166MHz
$F_I = 2$ $F_{II} = 1$	-184MHz

$$H_{HFS} = A\,\mathbf{I}\cdot\mathbf{J}$$

$$A_{4S_{1/2}} = 126.9\text{MHz}$$
$$A_{5P_{1/2}} = 8.99\text{MHz}$$

Doppler shift broadened absorption

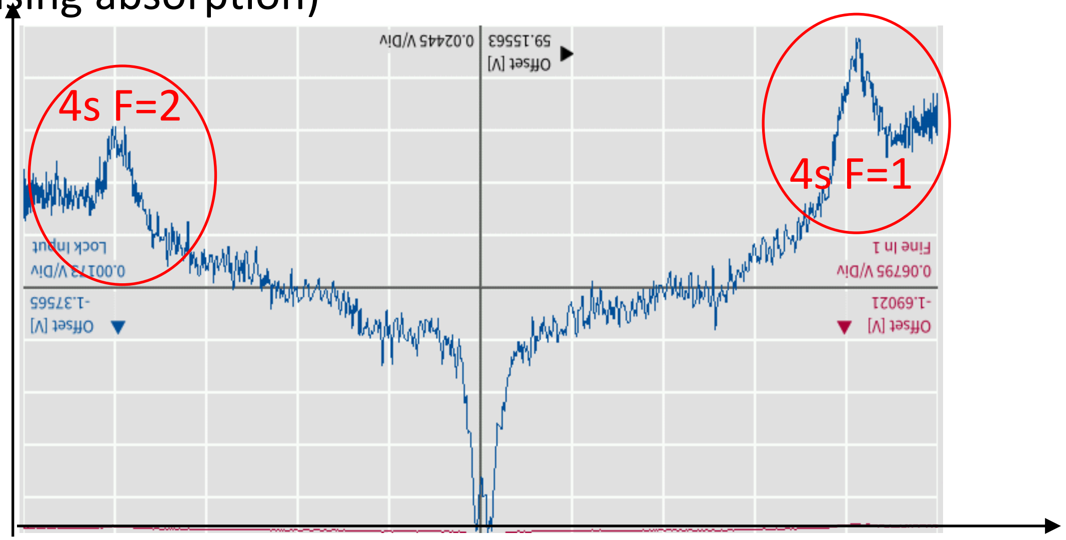
Decreasing absorption
(increasing power)

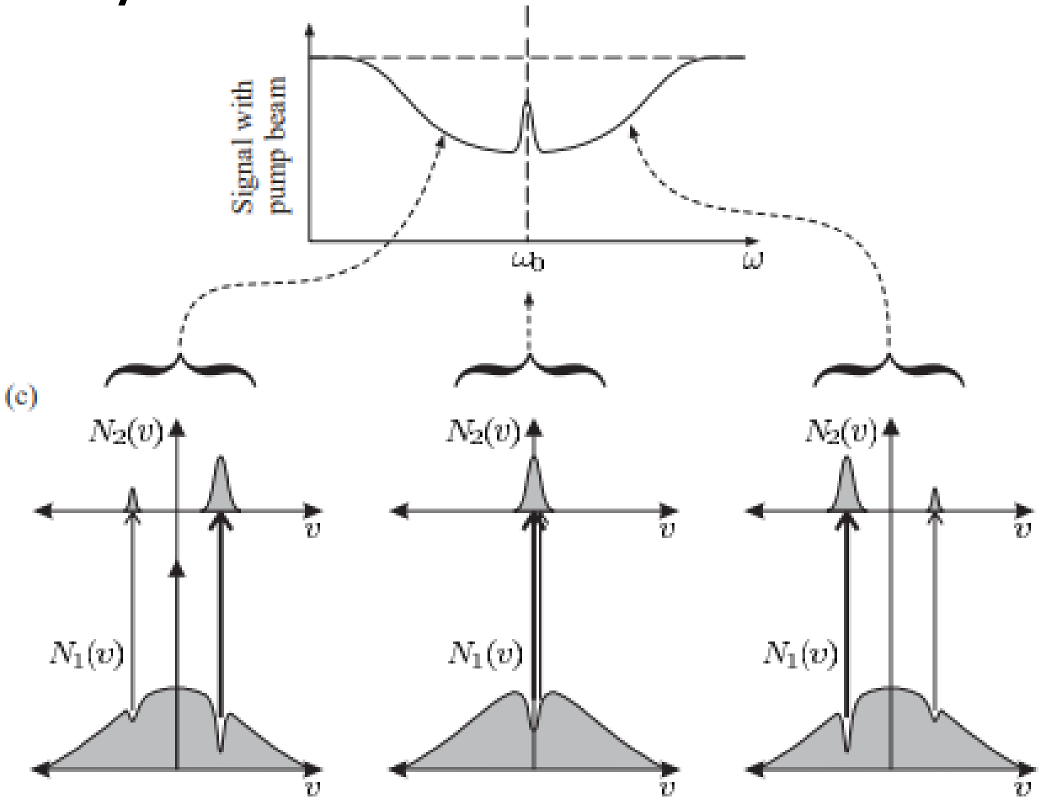


'Atomic Physics' by Foot.

Pump beam hole burning

Now that our absorptions are Doppler smeared, we use the pump beam to select atoms with zero velocity.

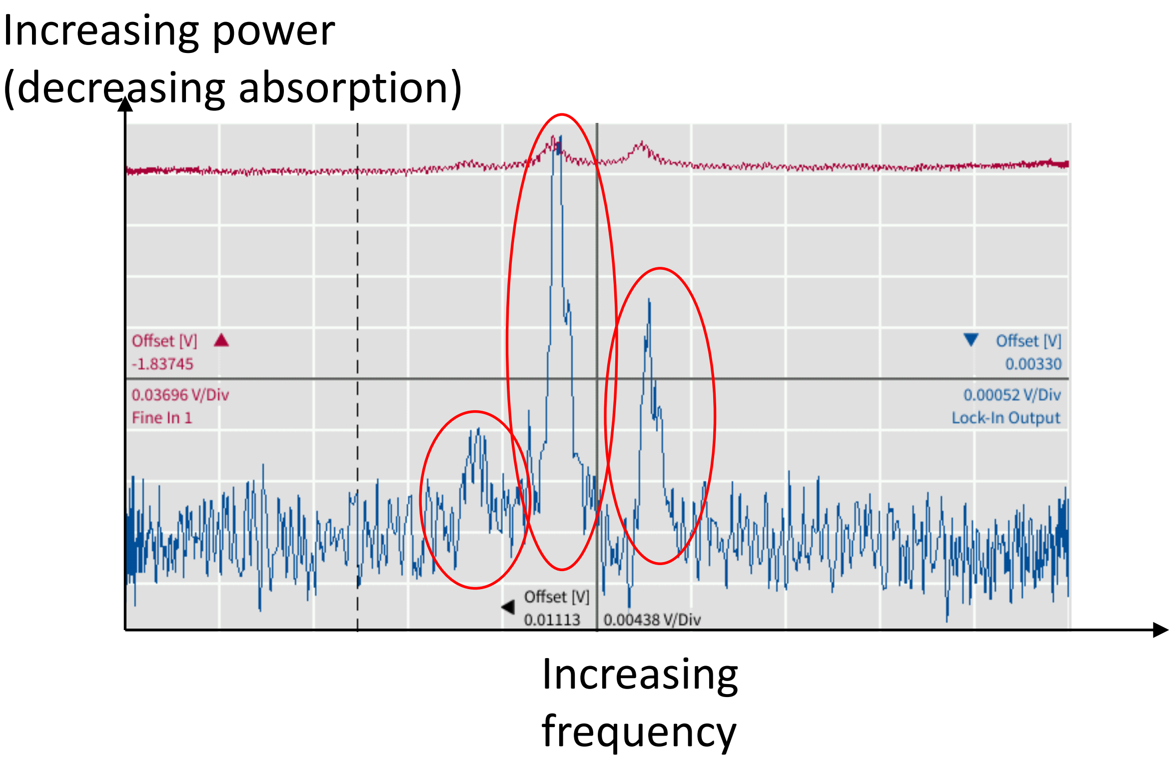


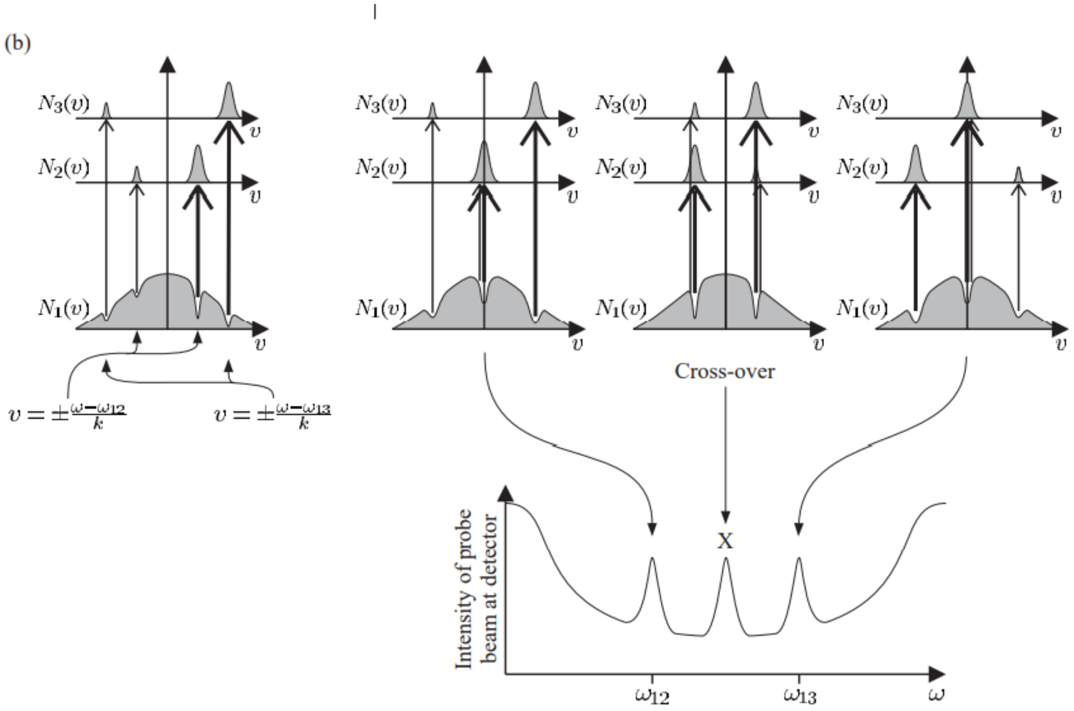


'Atomic Physics' by Foot.

Crossover effect

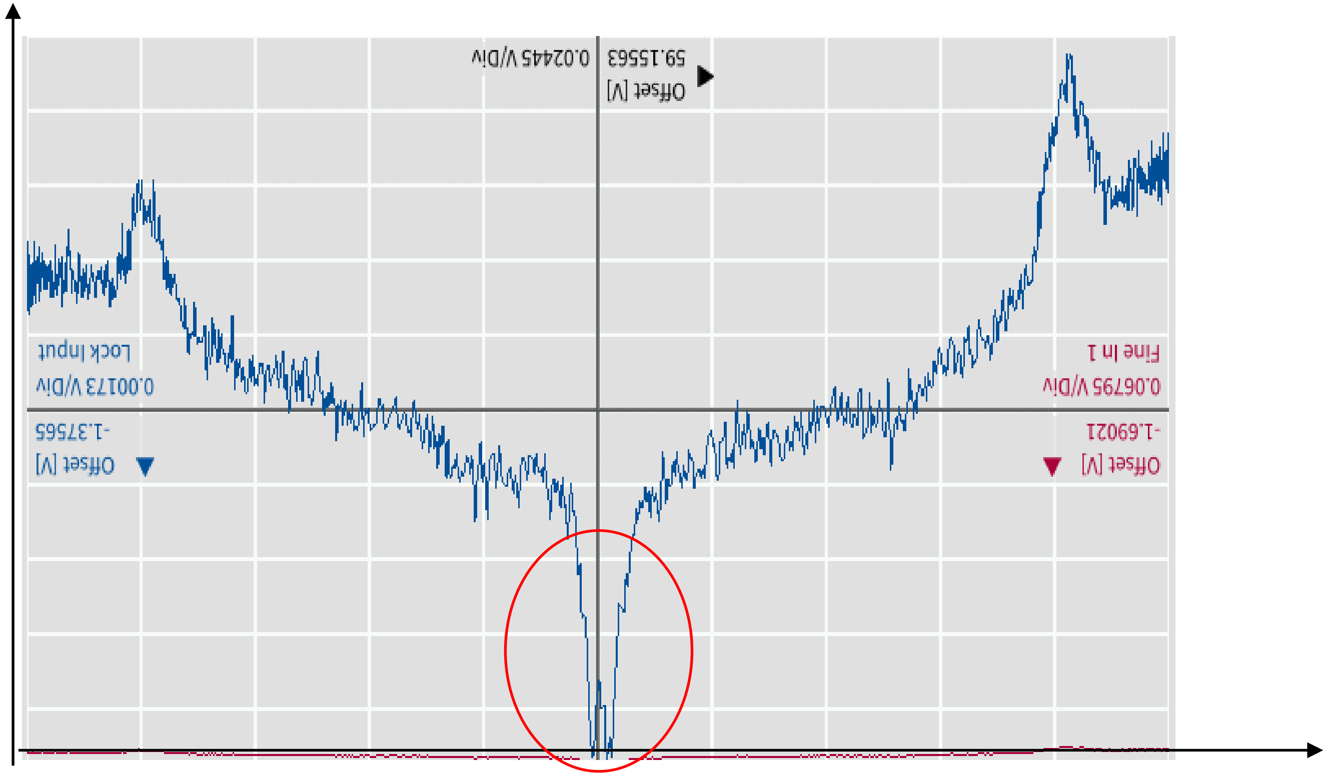
Every pair of peaks has a composite peak halfway in between from the doppler shifts of the two side peaks.



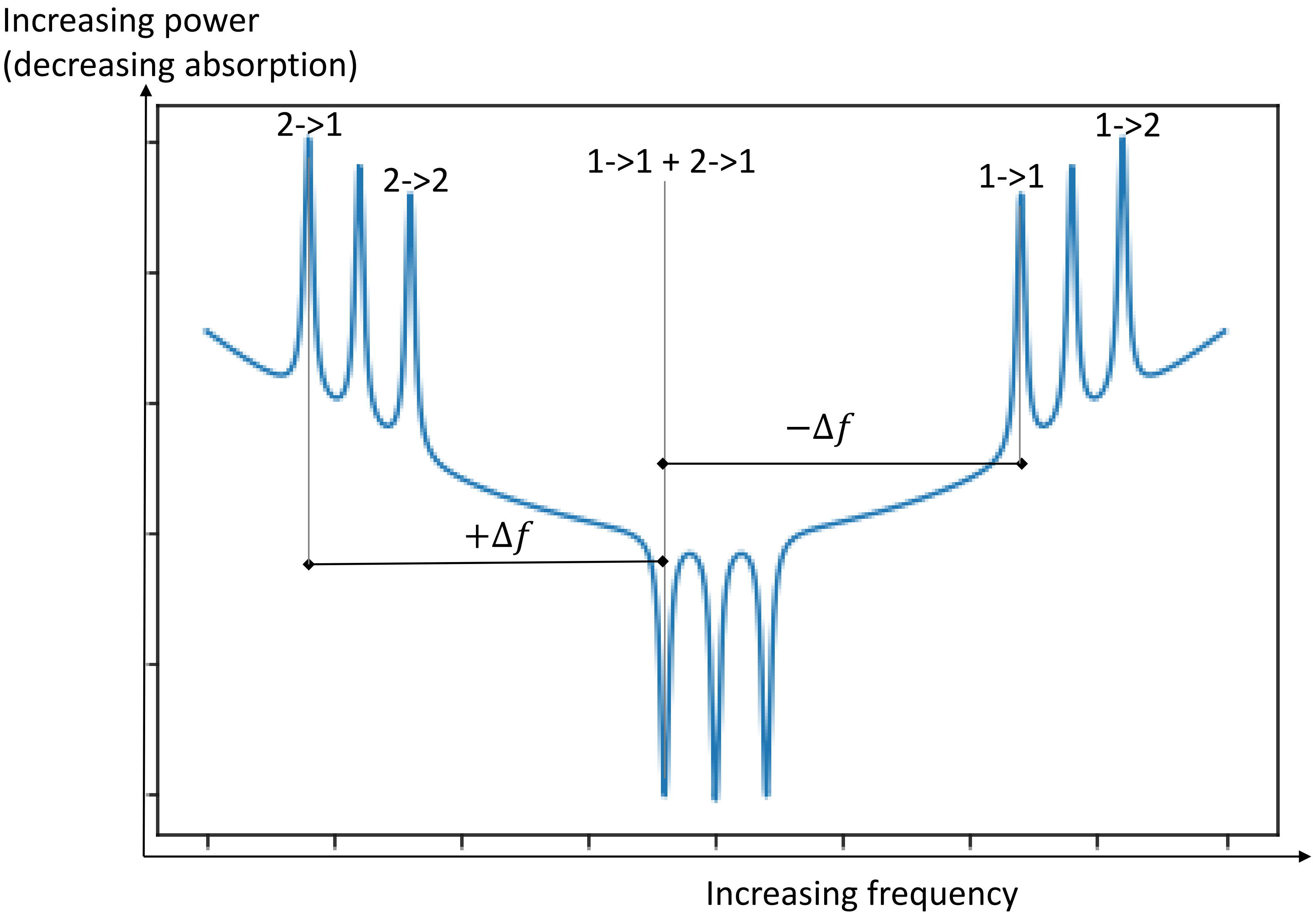


'Atomic Physics' by Foot.

Enhanced absorption



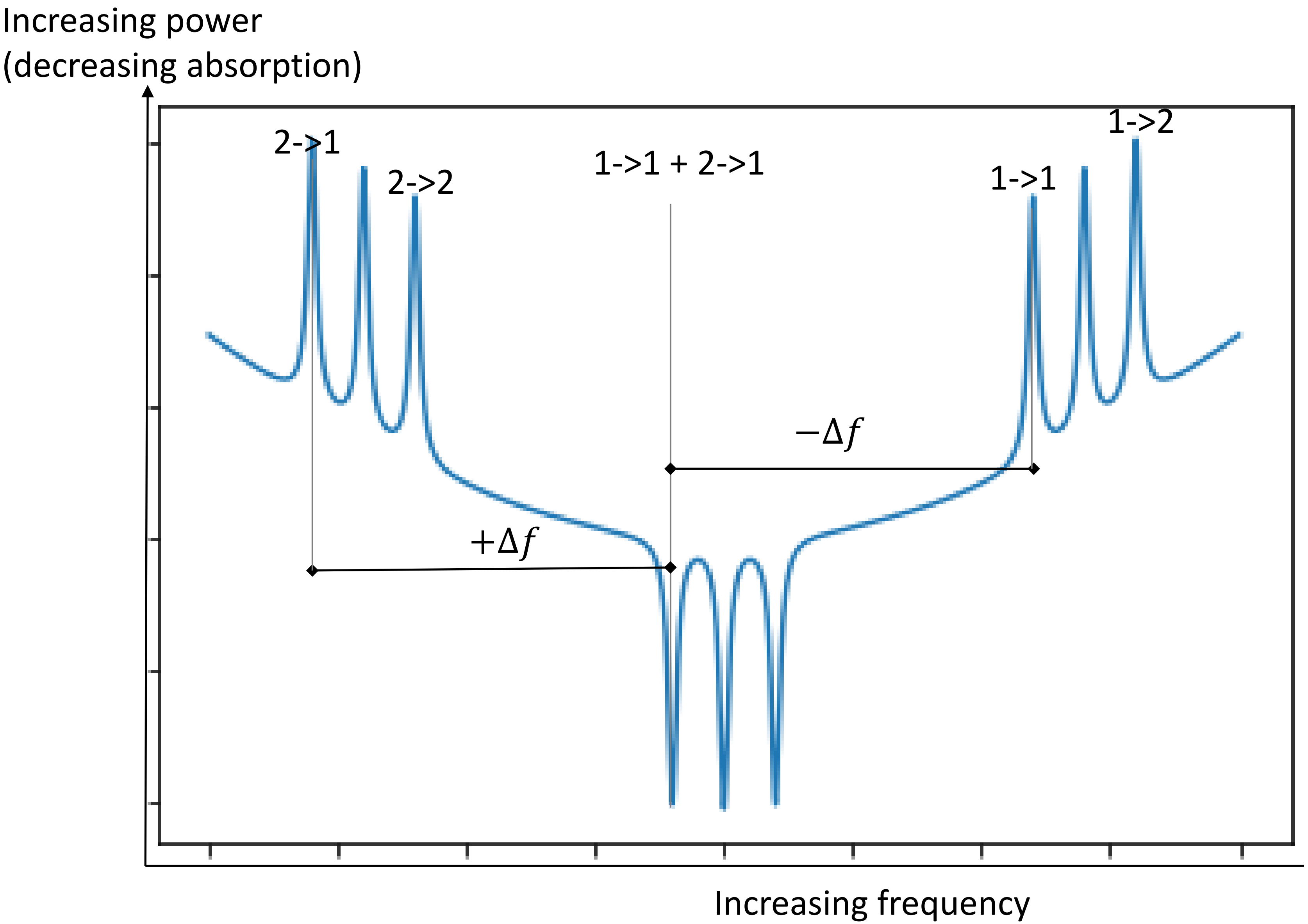
Enhanced absorption



Because the two Doppler crossed frequencies start from different hyperfine ground states the pump does not steal from the probe.

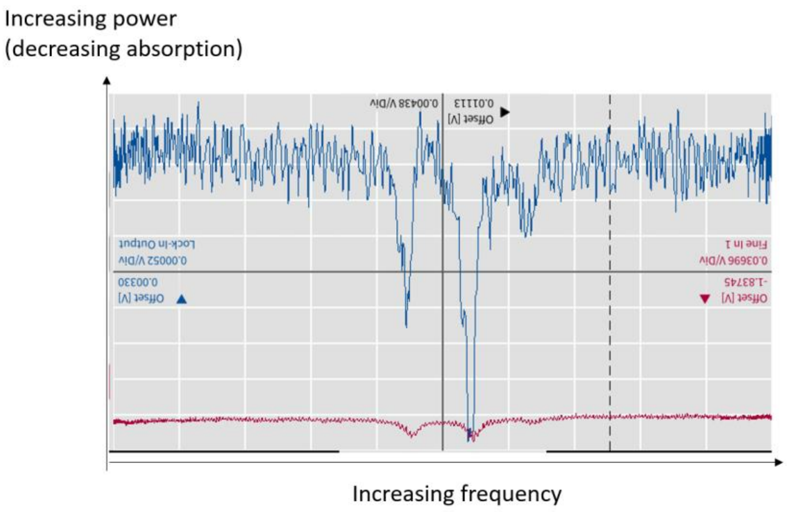
Instead, the pump beam states randomly decay towards the opposing hyperfine, increasing the population the probe sees.

Enhanced absorption



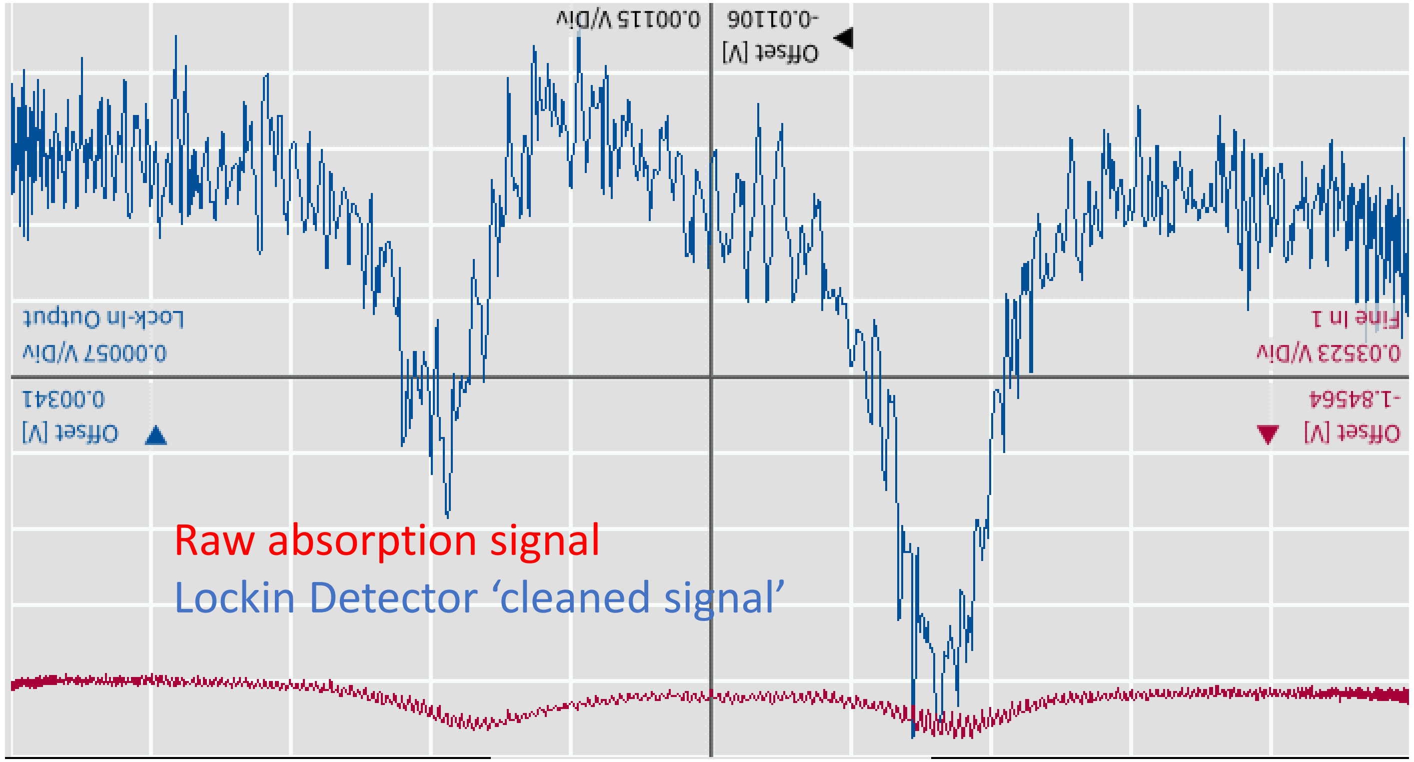
Atoms moving towards the probe beam absorb the pump beam in the 1->1 transition, which randomly decays, populating the F=2 ground state for the probe beam which is absorbed in the 2->1 transition.

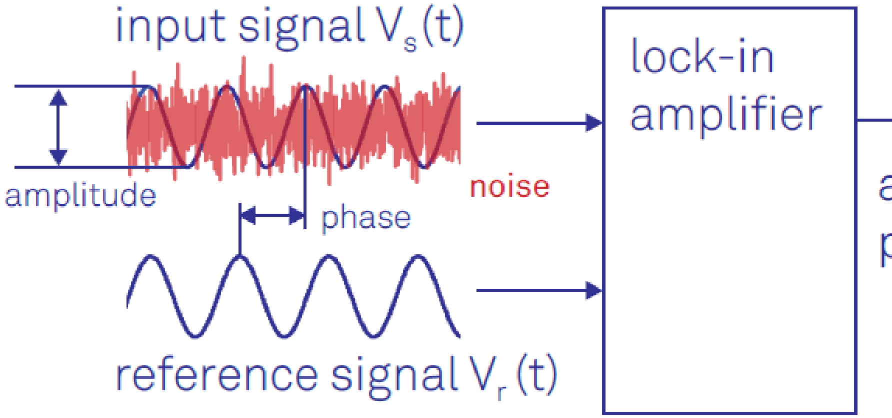
Atoms moving away from the probe beam absorb the pump beam in the 2->1 transition, which randomly decays, populating the F=1 ground state for the probe beam which is absorbed in the 1->2 transition.



Locking the laser frequency using absorption peaks

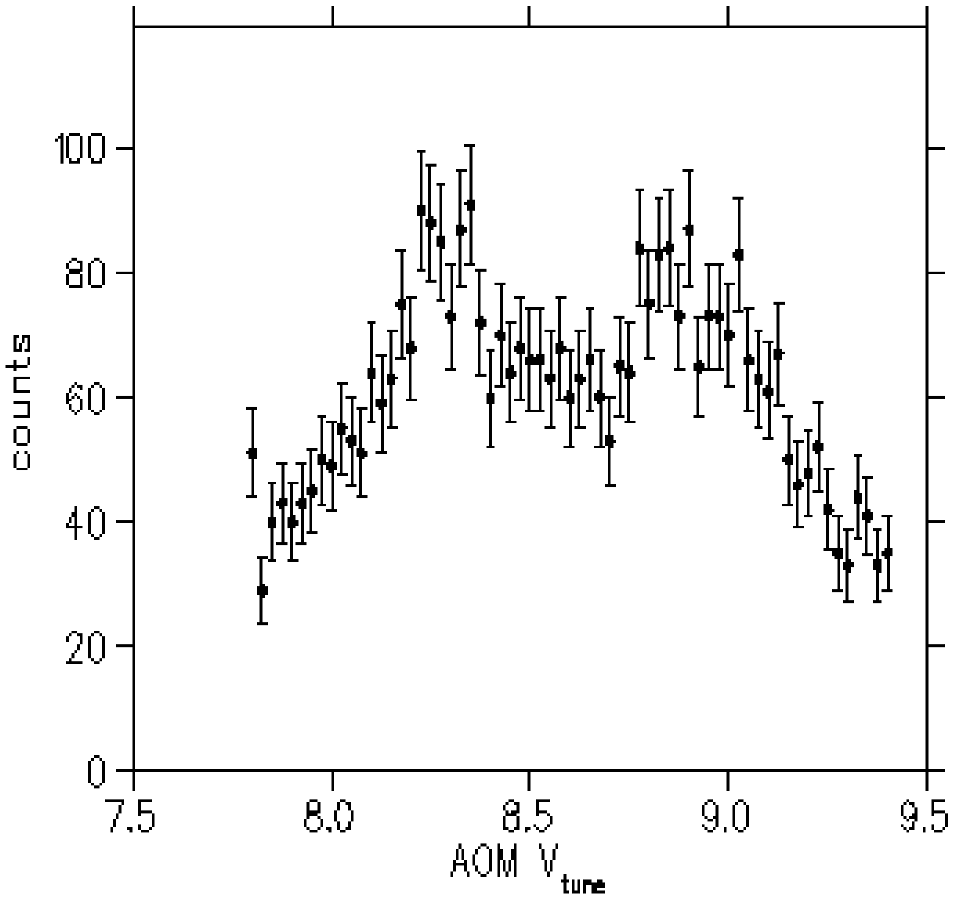
Using a solenoid and the Zeeman effect to produce slight high-frequency energy oscillations in the cell, correlating absorption peaks to our magnetic scan we can produce a cleaner signal and lock to the peak with a Proportional Integral Derivative control loop.



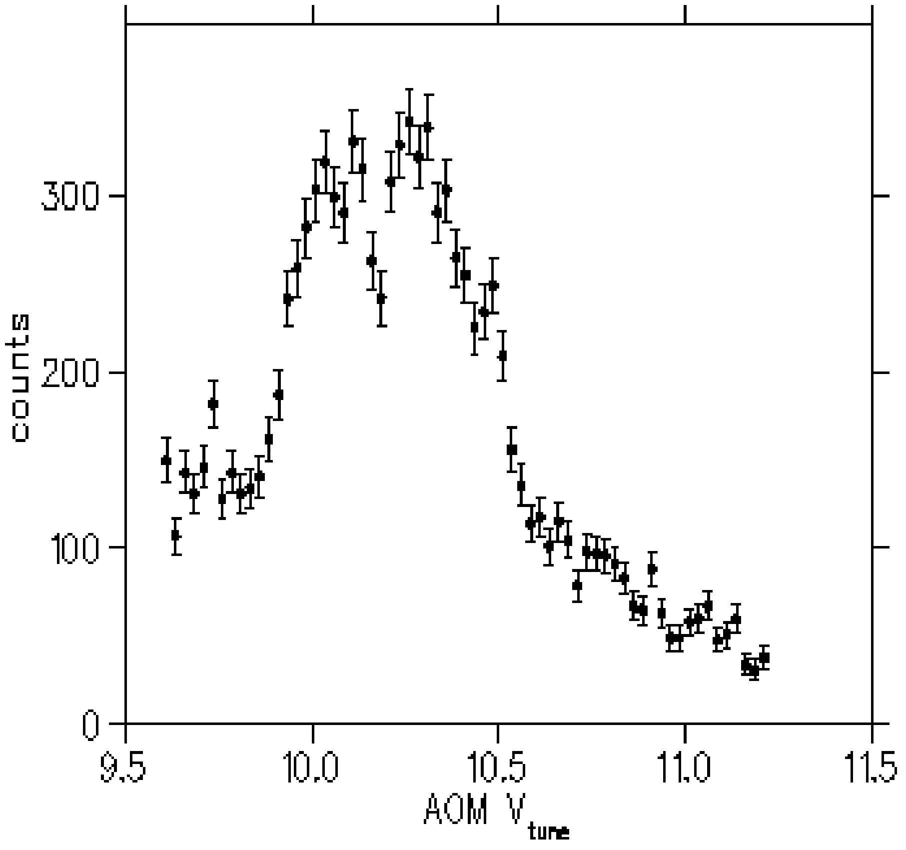


Very early data

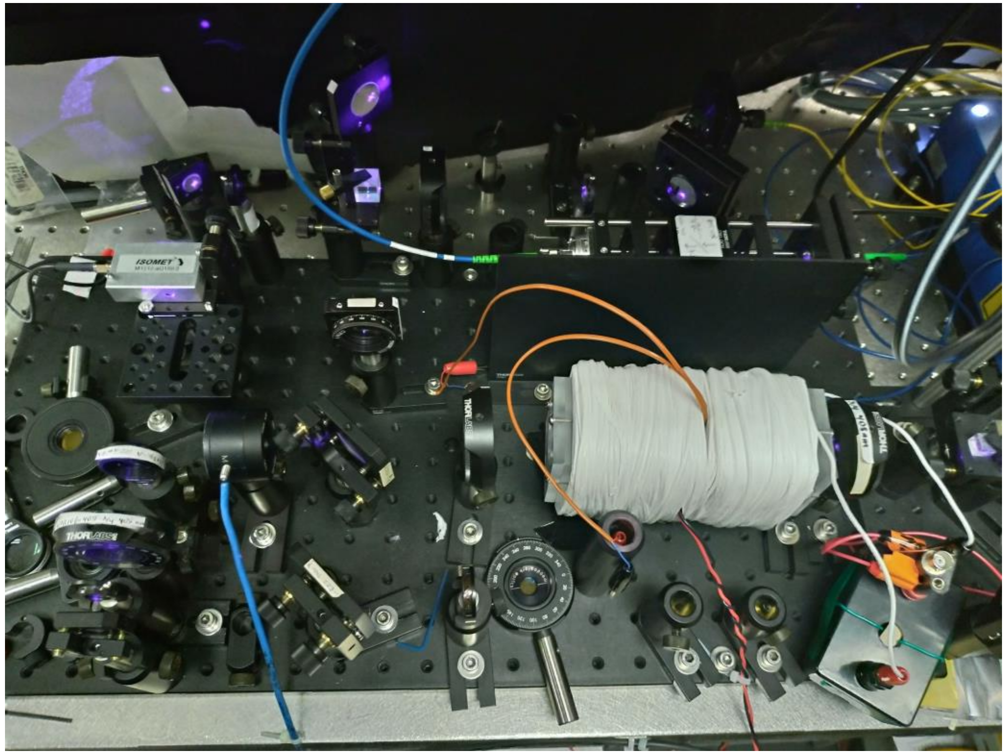
K41 2->1 and 2->2 absorptions

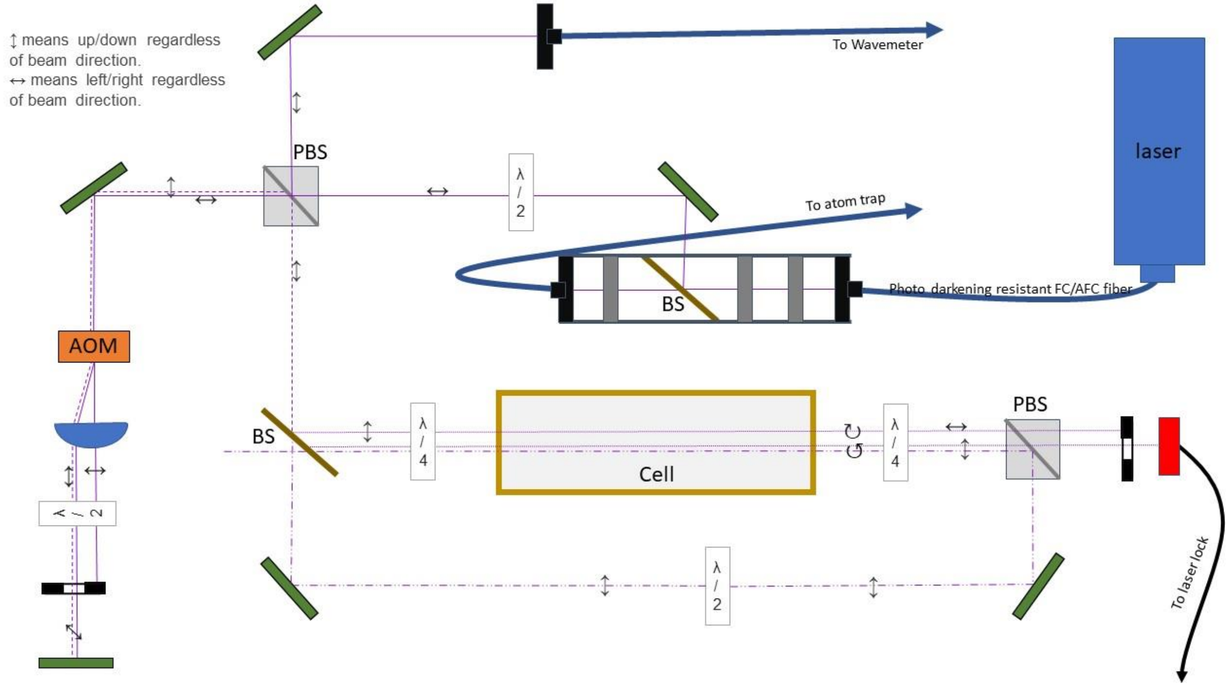


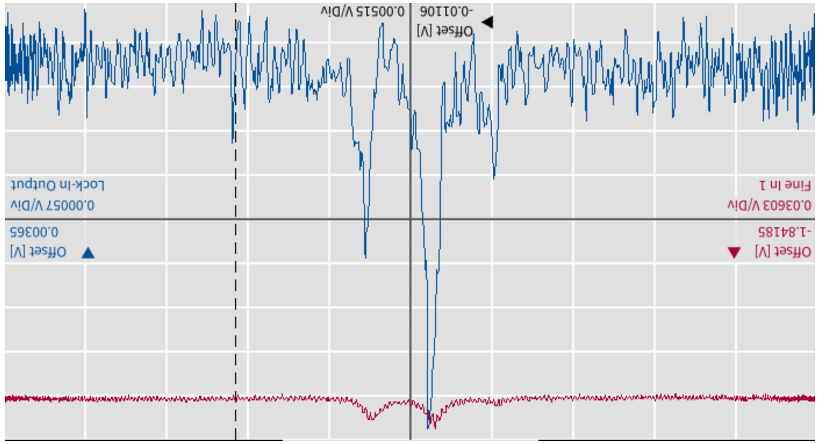
K41 1->1 and 1->2 absorptions



Thank you!




↕ means up/down regardless of beam direction.
↔ means left/right regardless of beam direction.
To Wavemeter
PBS
λ/2
To atom trap
laser
Photo darkening resistant FC/AFC fiber
BS
AOM
BS
λ/4
Cell
λ/4
PBS
λ/2
To laser lock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0.00515 V/Div
Lock-In Output
0.00057 V/Div
Offset [V]
0.00365
Fine In 1
0.03603 V/Div
Offset [V]
-1.84185