Phase transfer by a frequency comb for three photon coherent population trapping

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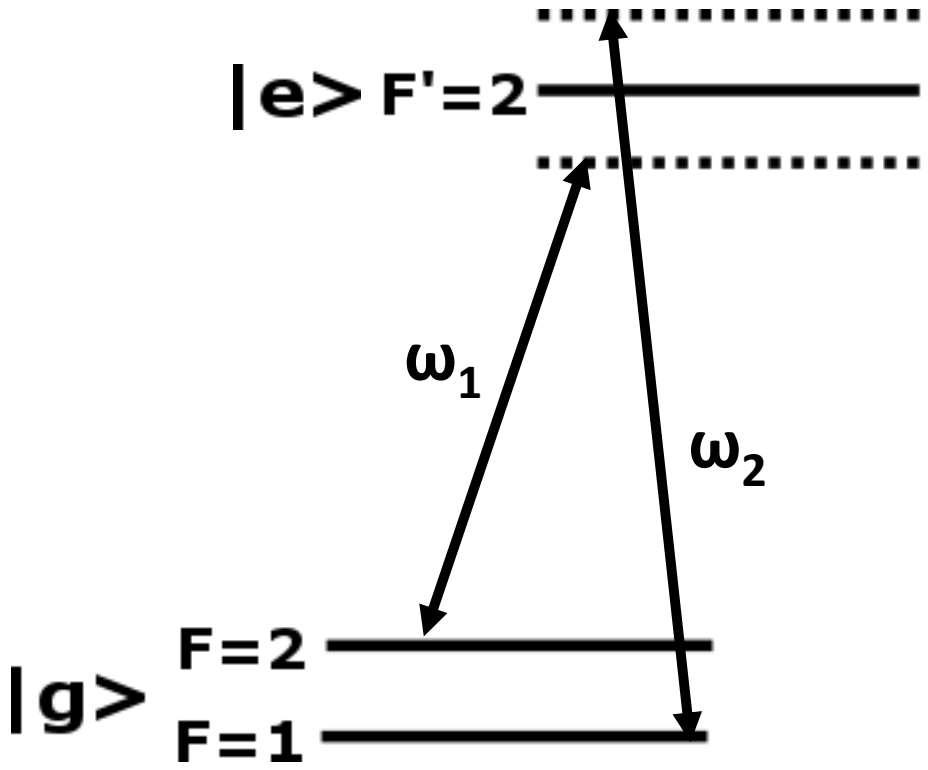
- Coherent population trapping
- Frequency comb
- First Results
- Prospect

Two photon coherent population trapping

Rubidium example :



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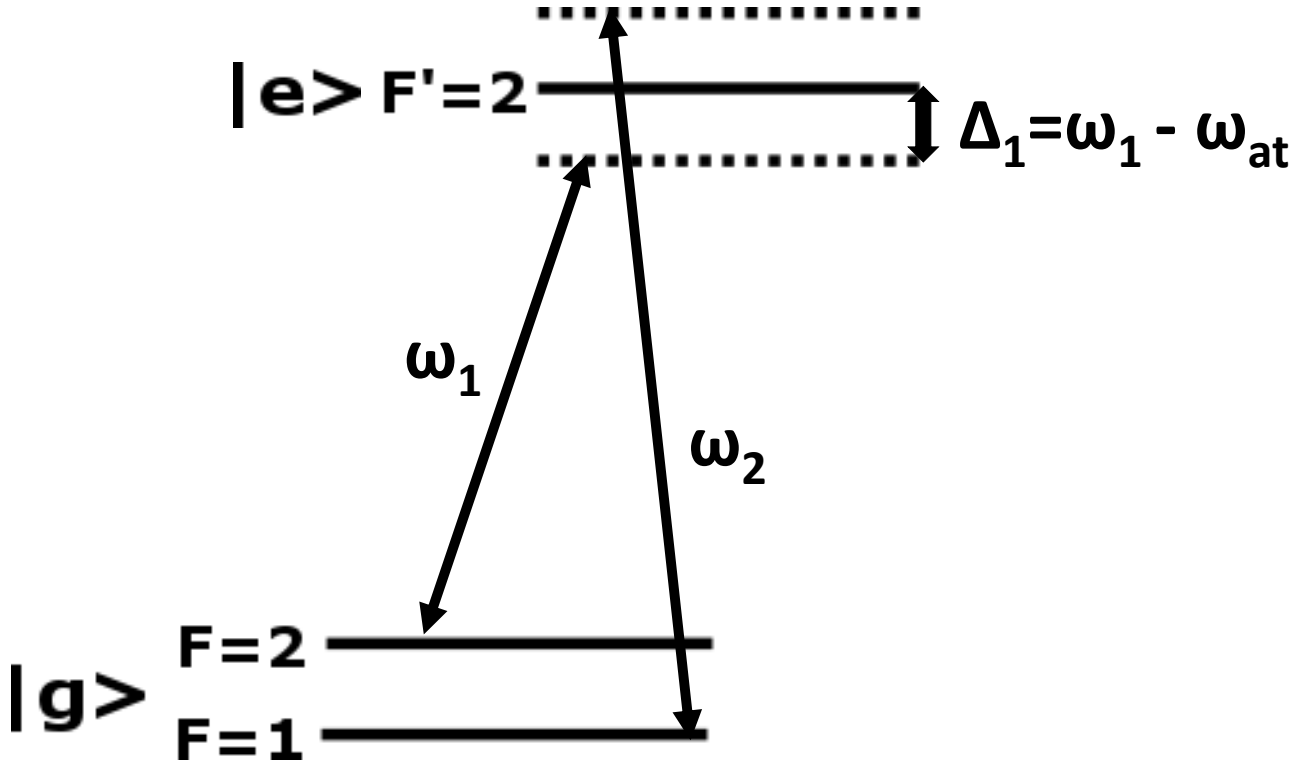

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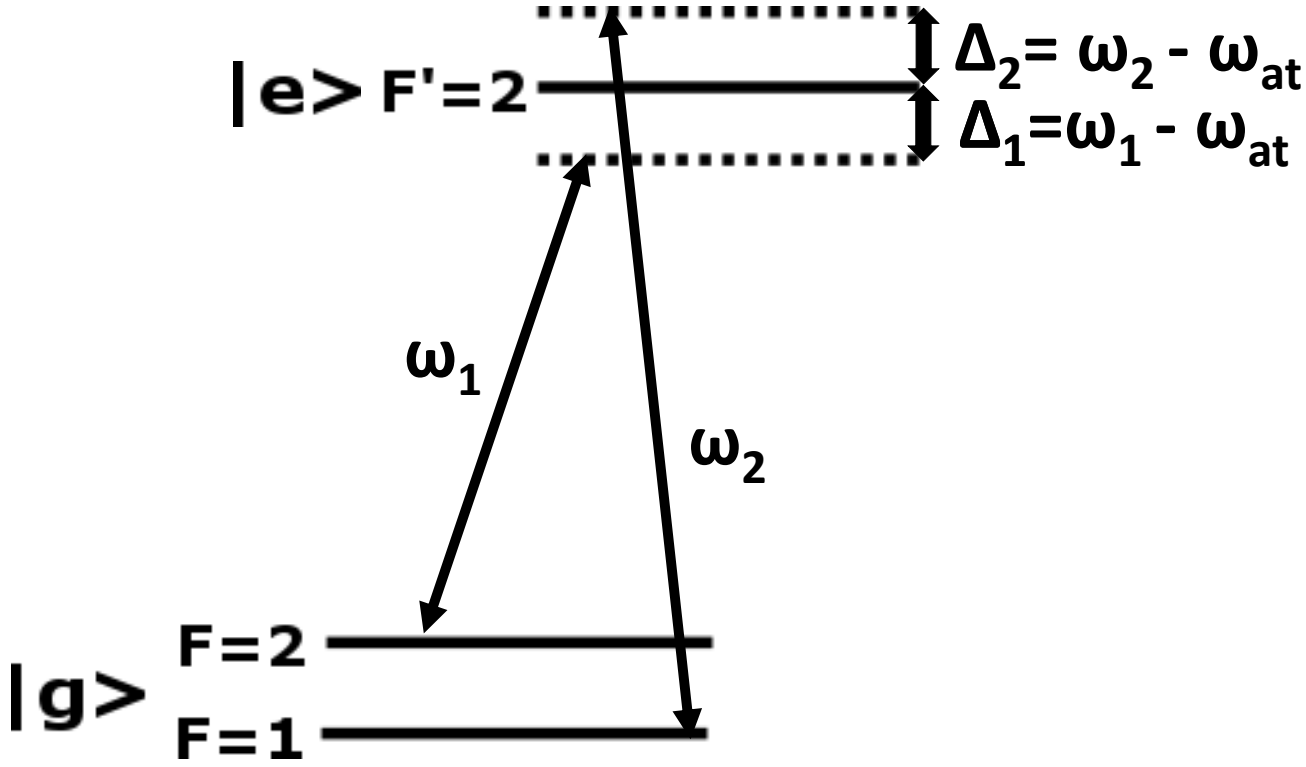

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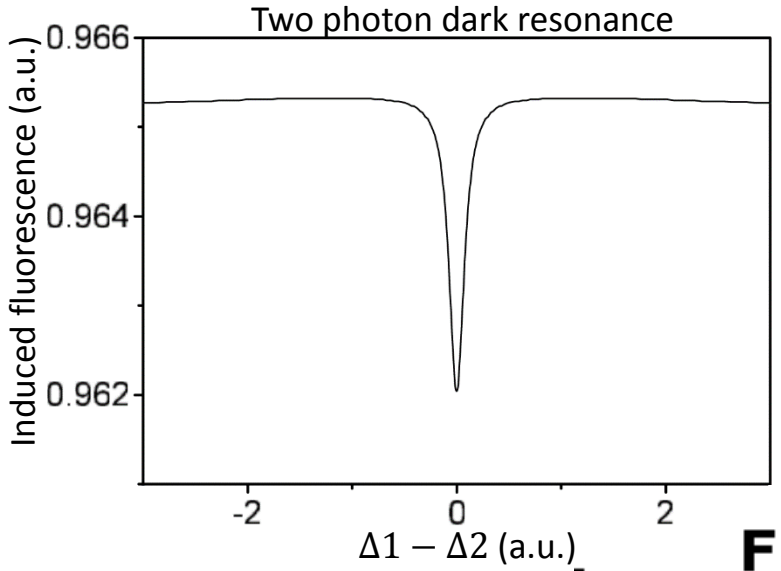

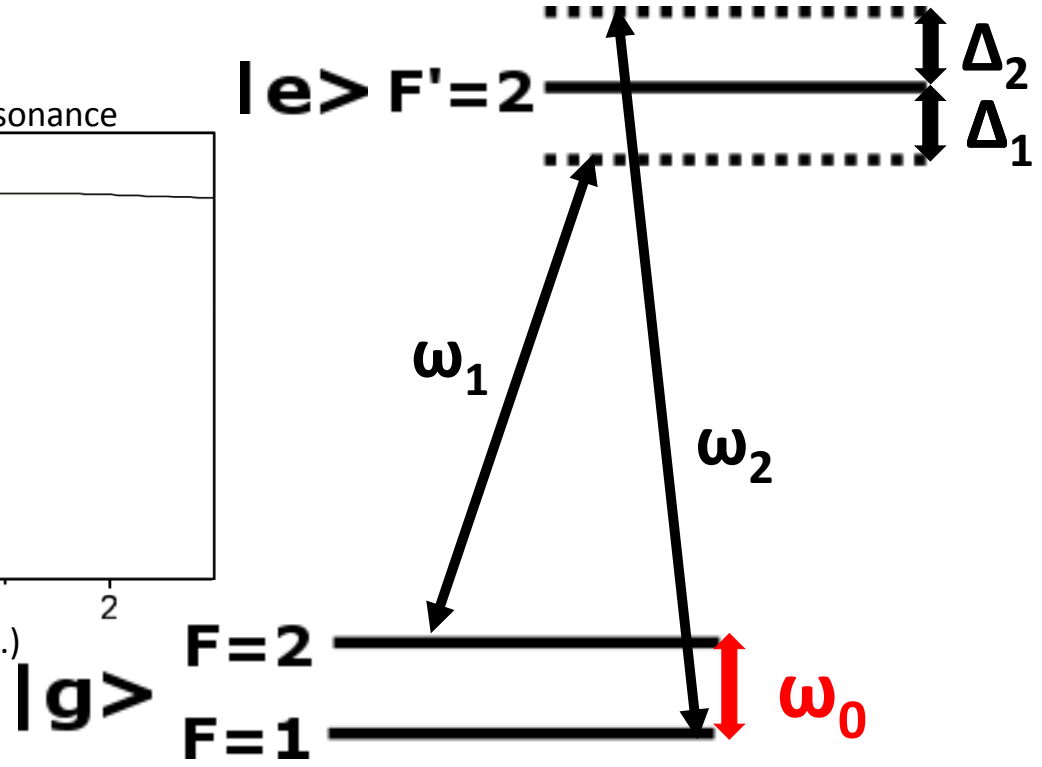

Frequency condition of 2 photons dark resonance is fulfilled when :

$$\Delta 1 = \Delta 2$$

Then,

$$\omega 2 - \omega 1 = \omega 0$$

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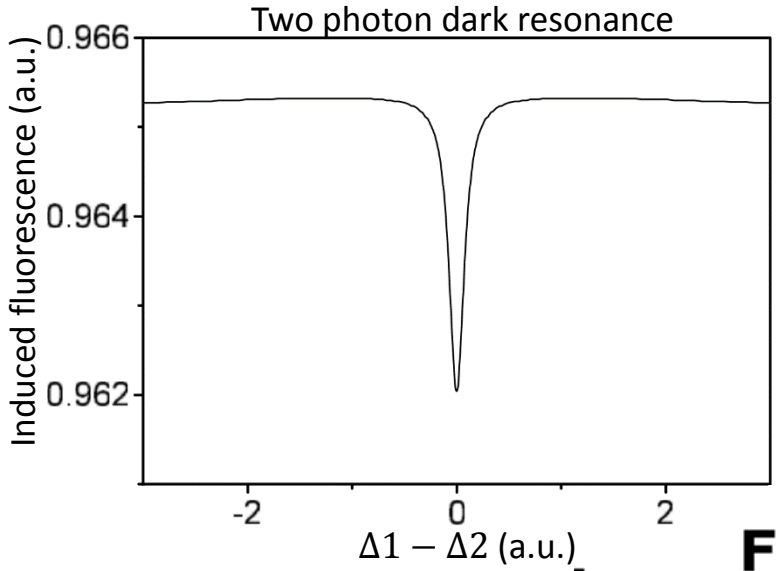

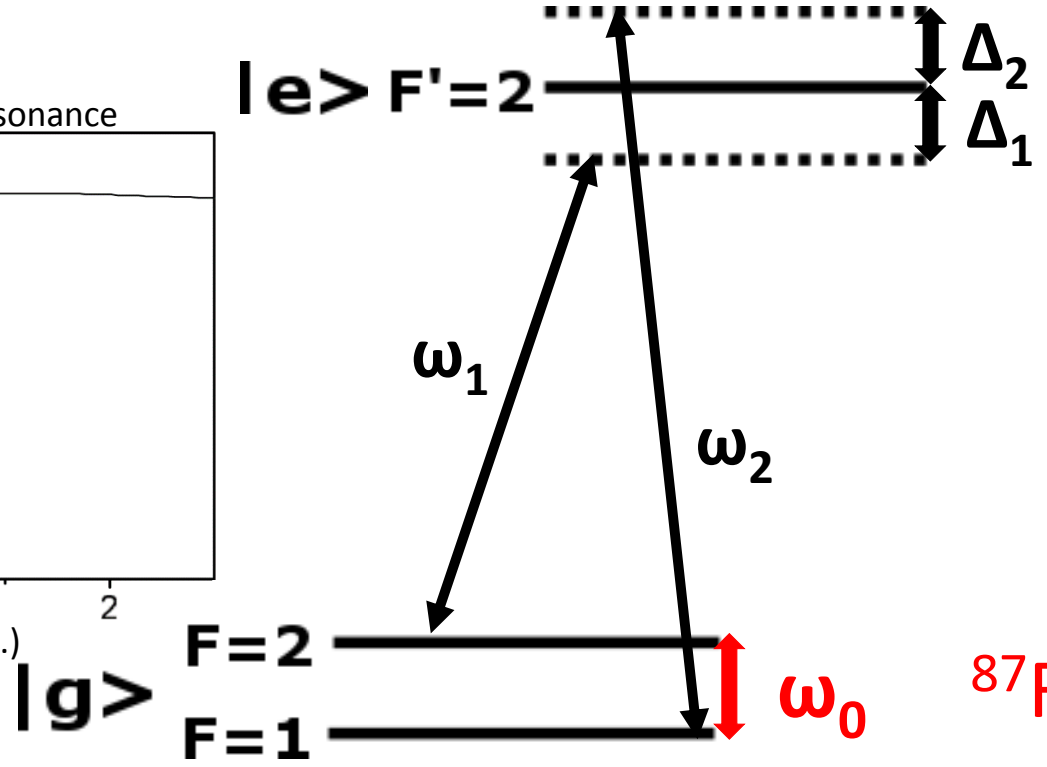

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^{87}Rb : 6,835 GHz

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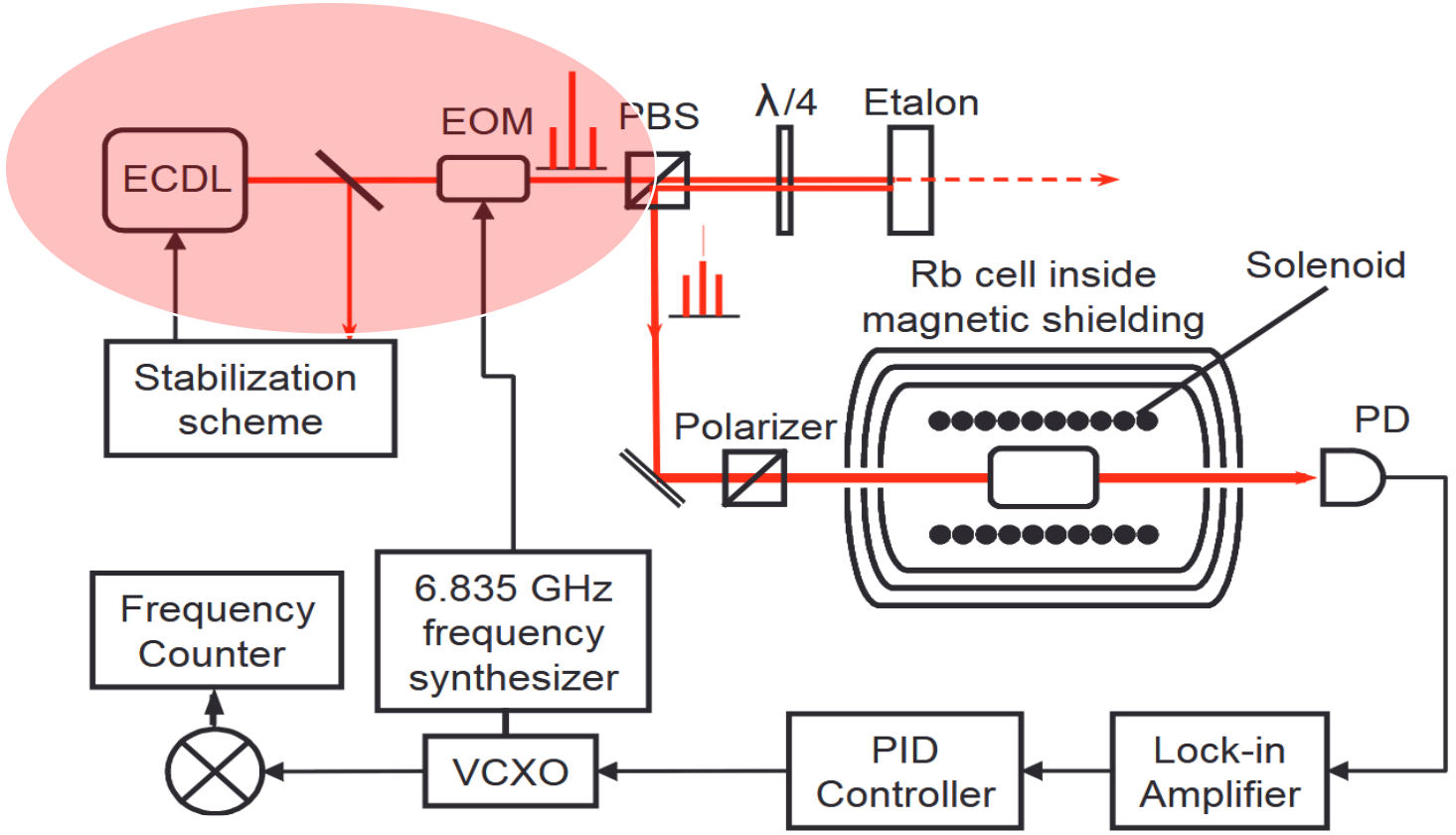

« Coherent population trapping resonances with linearly polarized light for all –optical miniature atomic clocks », S. A. Zibrov, Physical Review A (2010).

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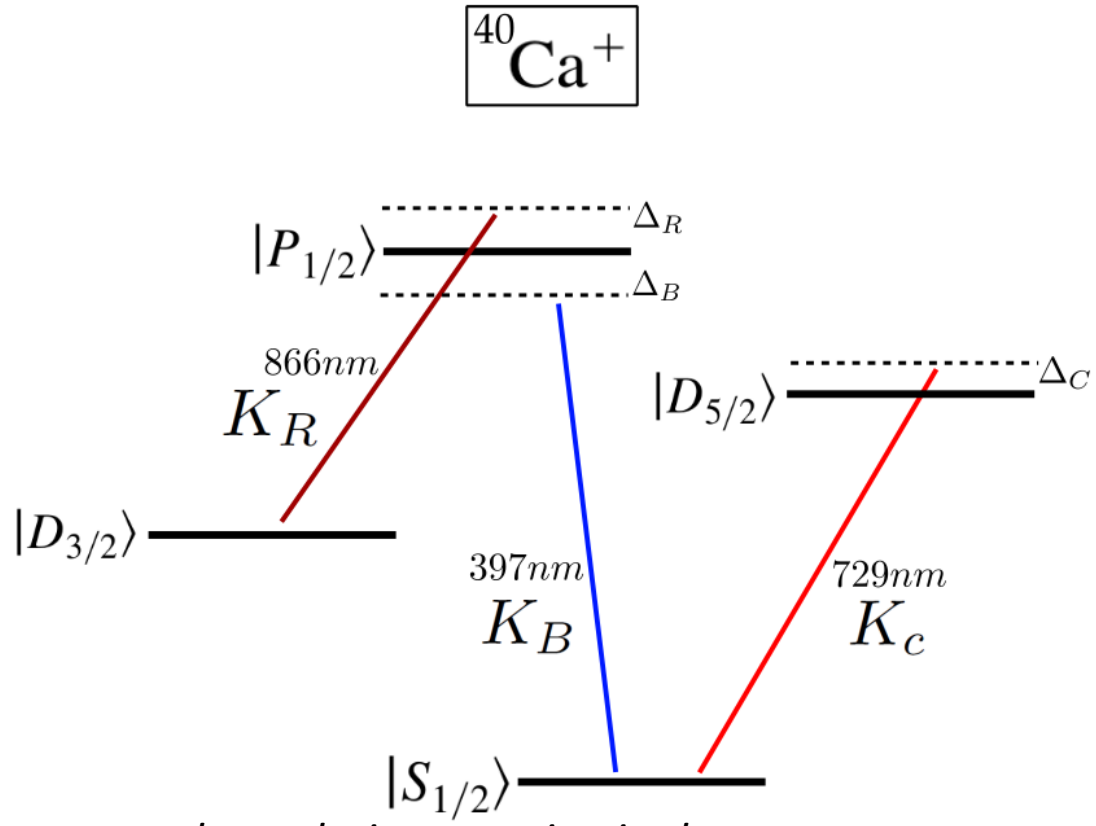
Coherent population trapping : Extension to three photons



« Quantum coherence and population trapping in three-photon processes », C. Champenois, G. Morigi and J. Eschner, Physical Review A (2006).

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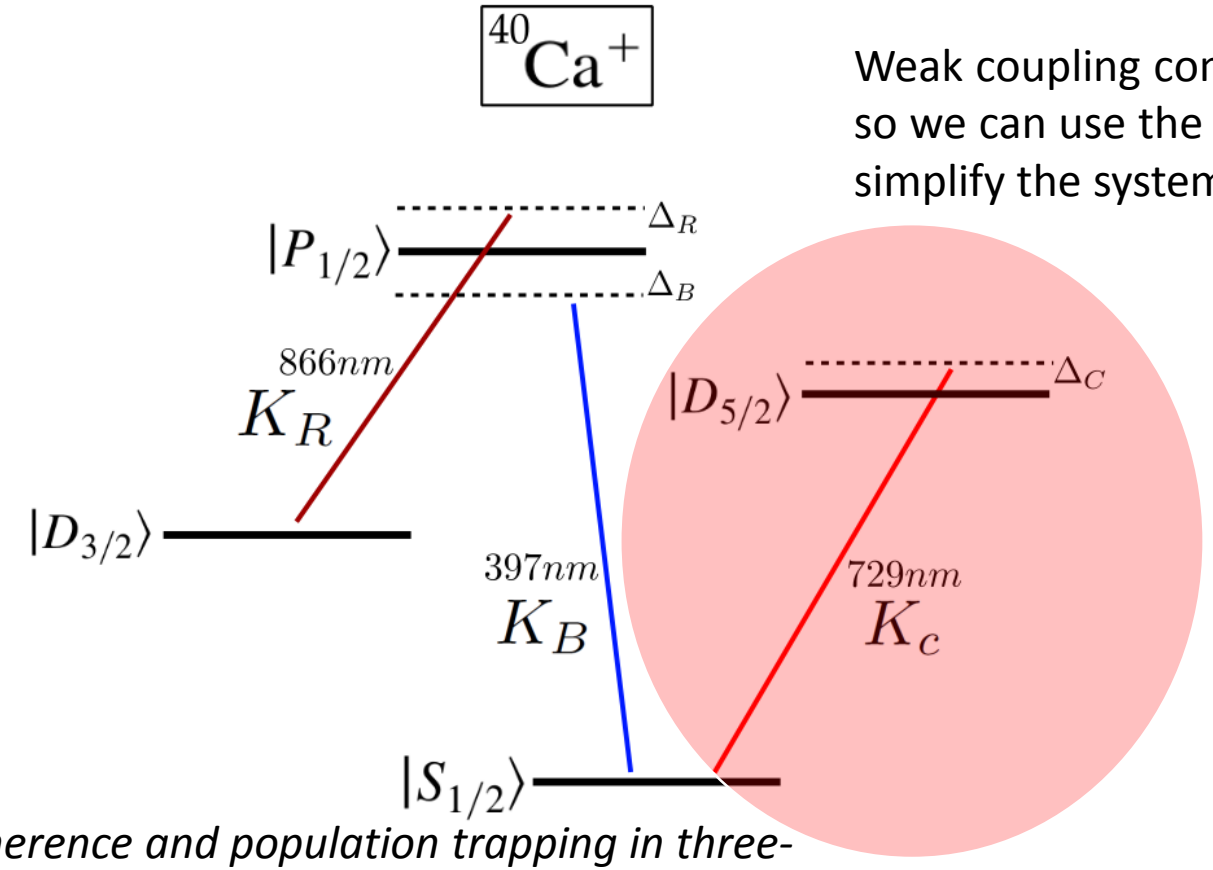

Weak coupling compared to others transitions, so we can use the small perturbation theory to simplify the system.

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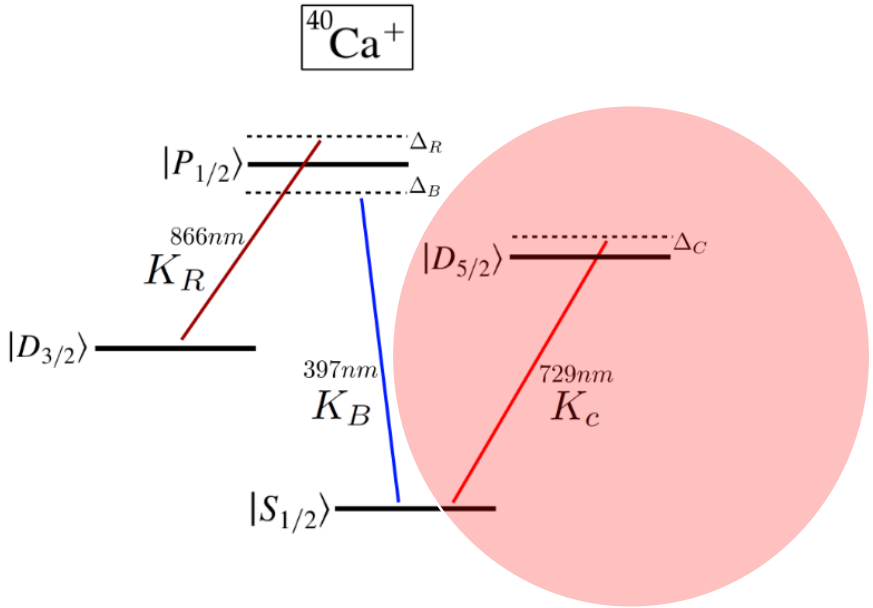

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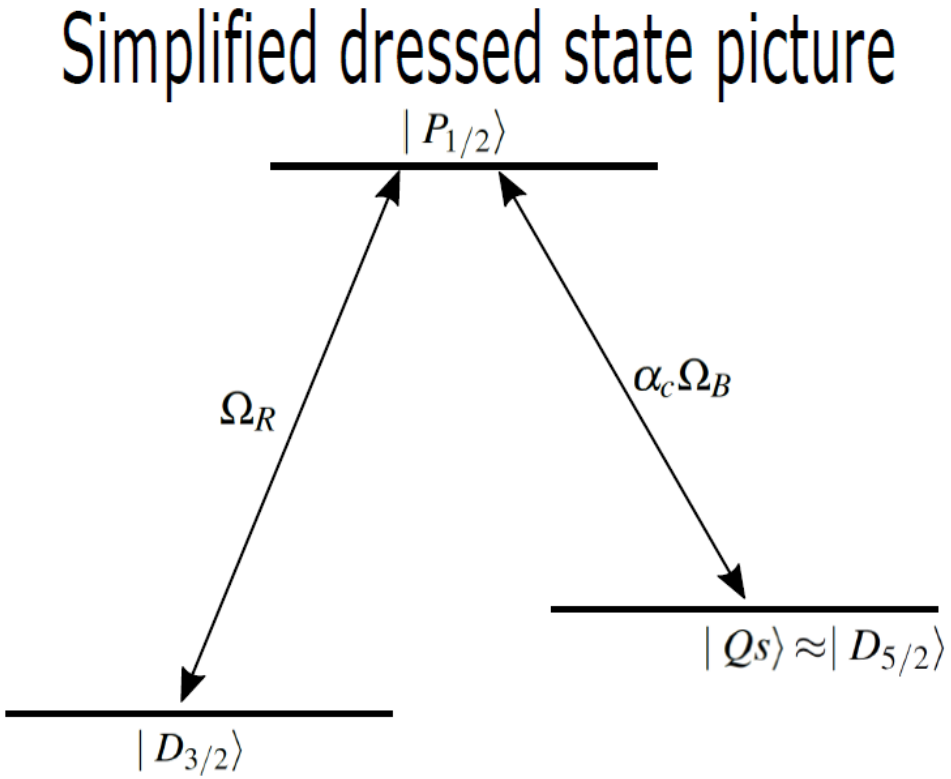
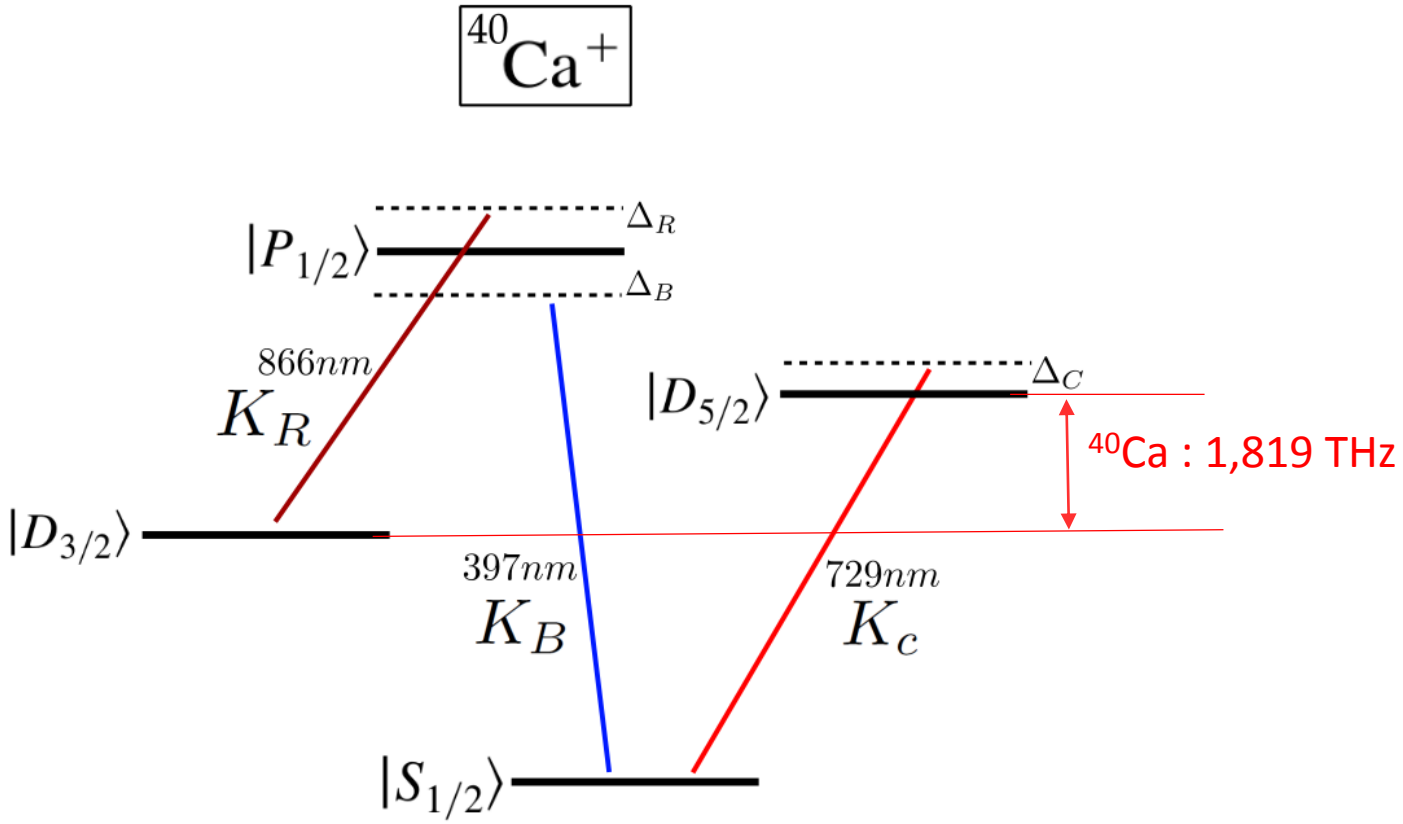


Coupling coefficient : $\alpha_c = \frac{\Omega_c}{2*\Delta_c}$

Interest to extend at three photon



Three-photon resonance condition :

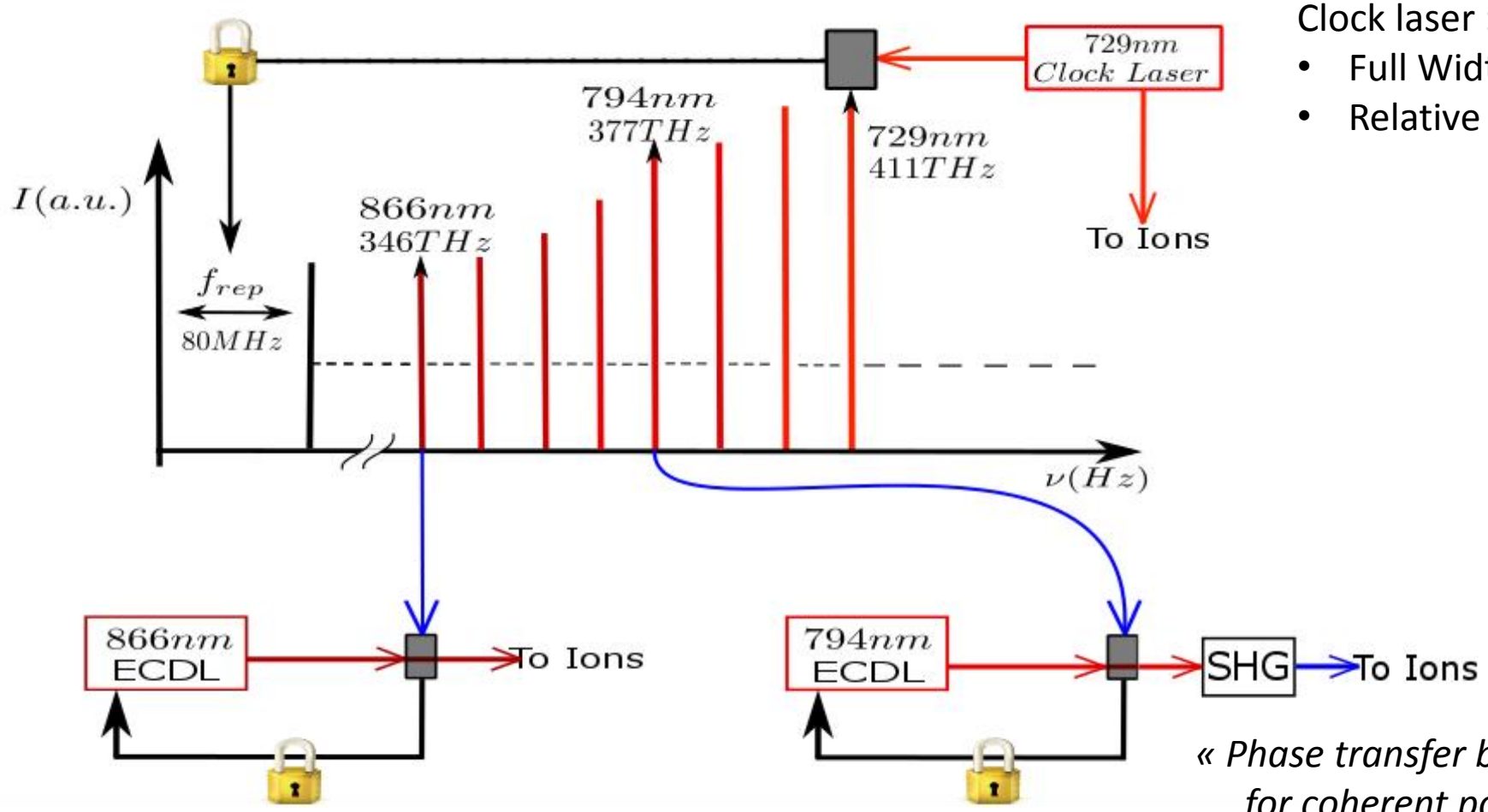
$\Delta_R + \Delta_C - \Delta_B = 0$

The frequency combination is then referenced to the magnetique-dipole transition :

$\omega_R + \omega_C - \omega_B = 1{,}819$ THz

« Terahertz Frequency Standart Based on Three-Photon Coherent Population Trapping », C. Champenois and all, Physical Review Letters (2007).

Phase transfer by a frequency comb

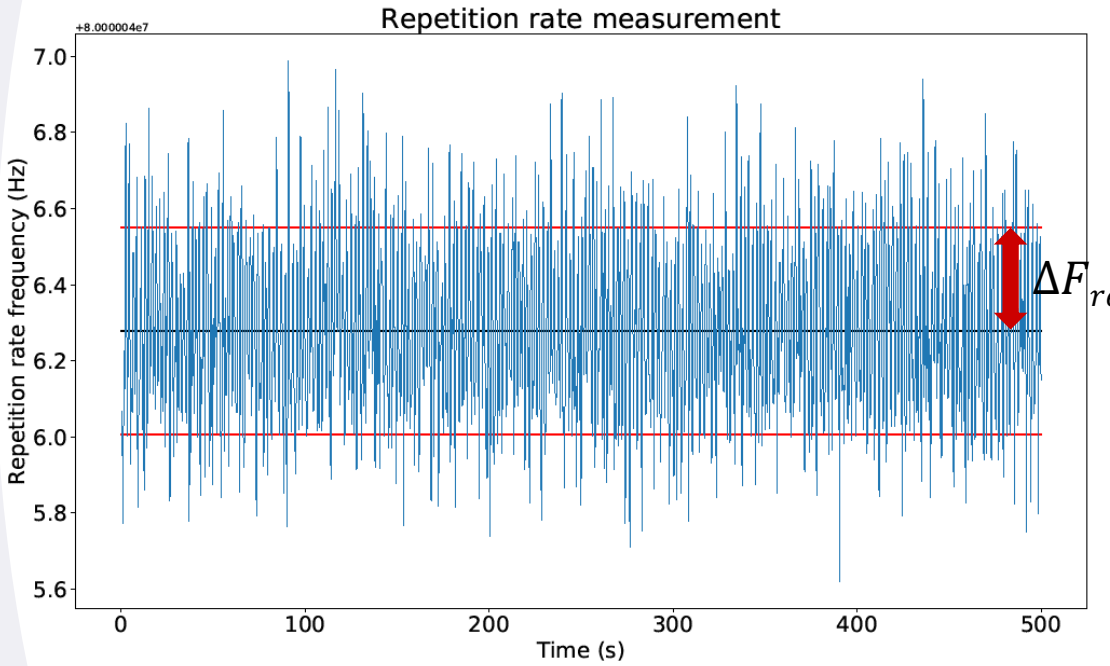


Clock laser :

- Full Width Half Maximum ≈ 3 Hz
- Relative stability at 1s : 6.10^{-15}

« Phase transfer between three visible lasers for coherent population trapping », M. Collombon and all, Optics Letters (2019).

Frequency computing



- Laser frequency :

  $\nu = N * F_{rep} + F_{beat}$

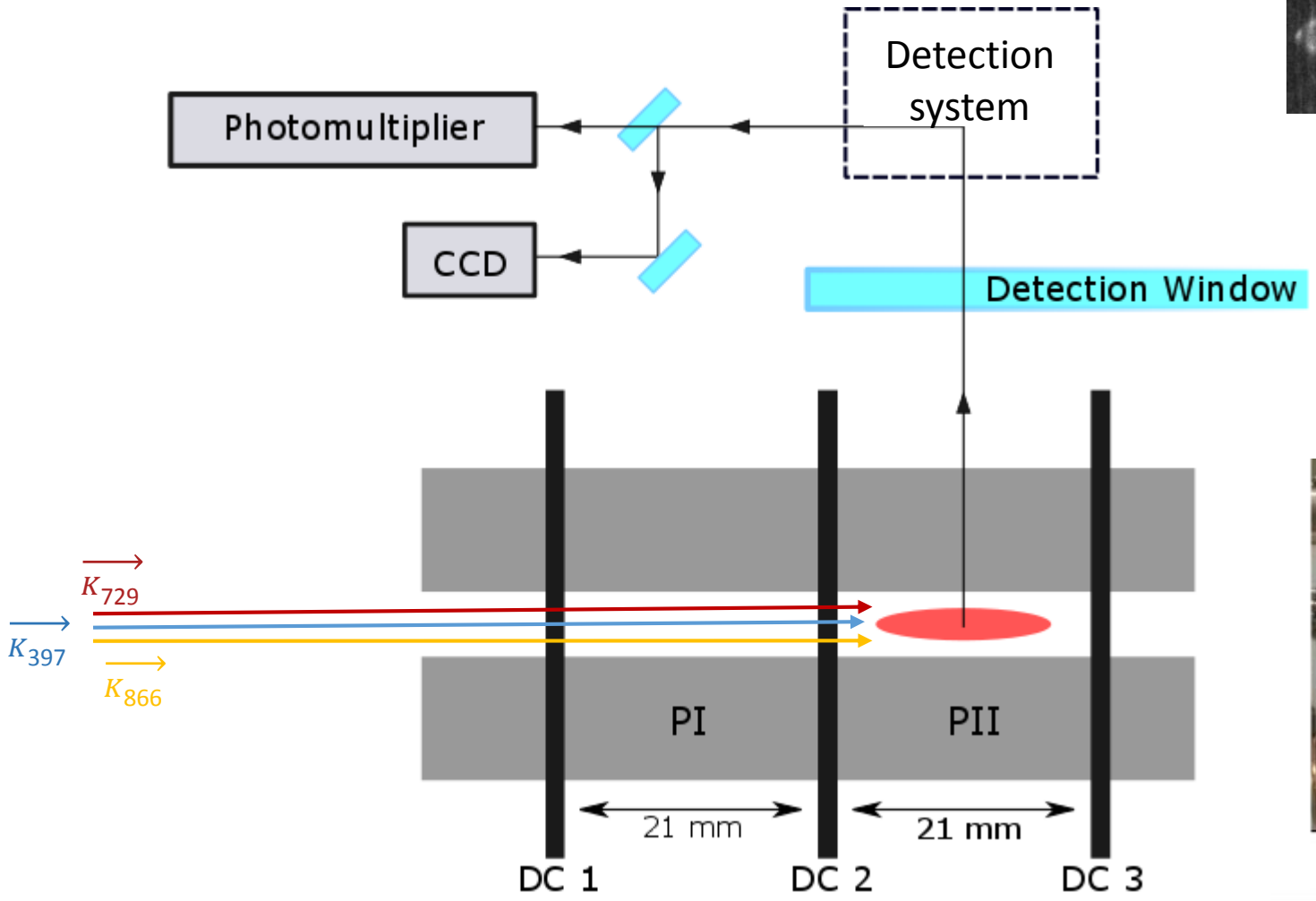
  $\Delta\nu = N * \Delta F_{rep}$, uncertainty of the order of 10 kHz.

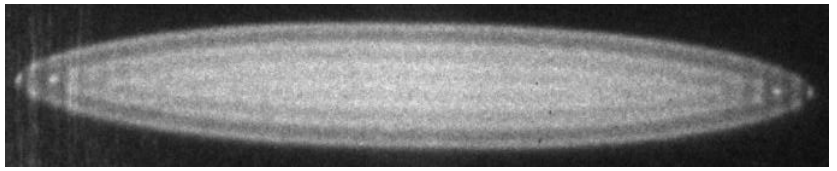
- THz frequency : ($\omega_R + \omega_C - \omega_B$ = 1,819 THz)

  $\nu_{THz} = (N_{866} + N_{729} - 2 * N_{794}) * F_{rep} + \Sigma F_{beat}$

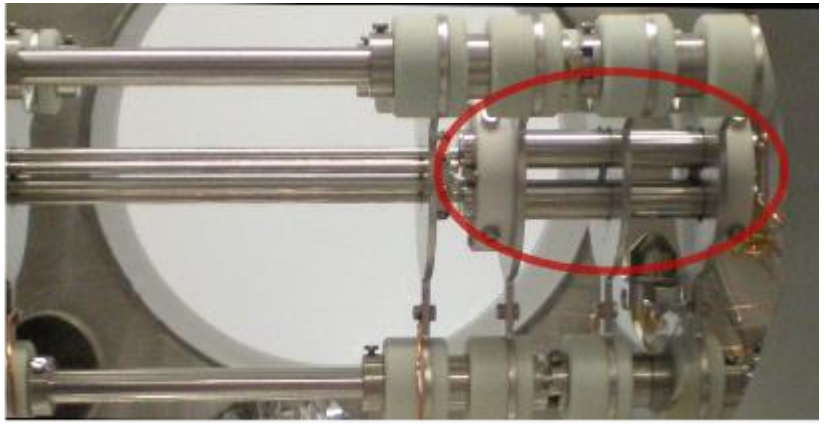
  $\Delta\nu_{THz} = (N_{866} + N_{729} - 2 * N_{794}) * \Delta F_{rep}$, uncertainty of the order of 10 Hz.

Experimental setup



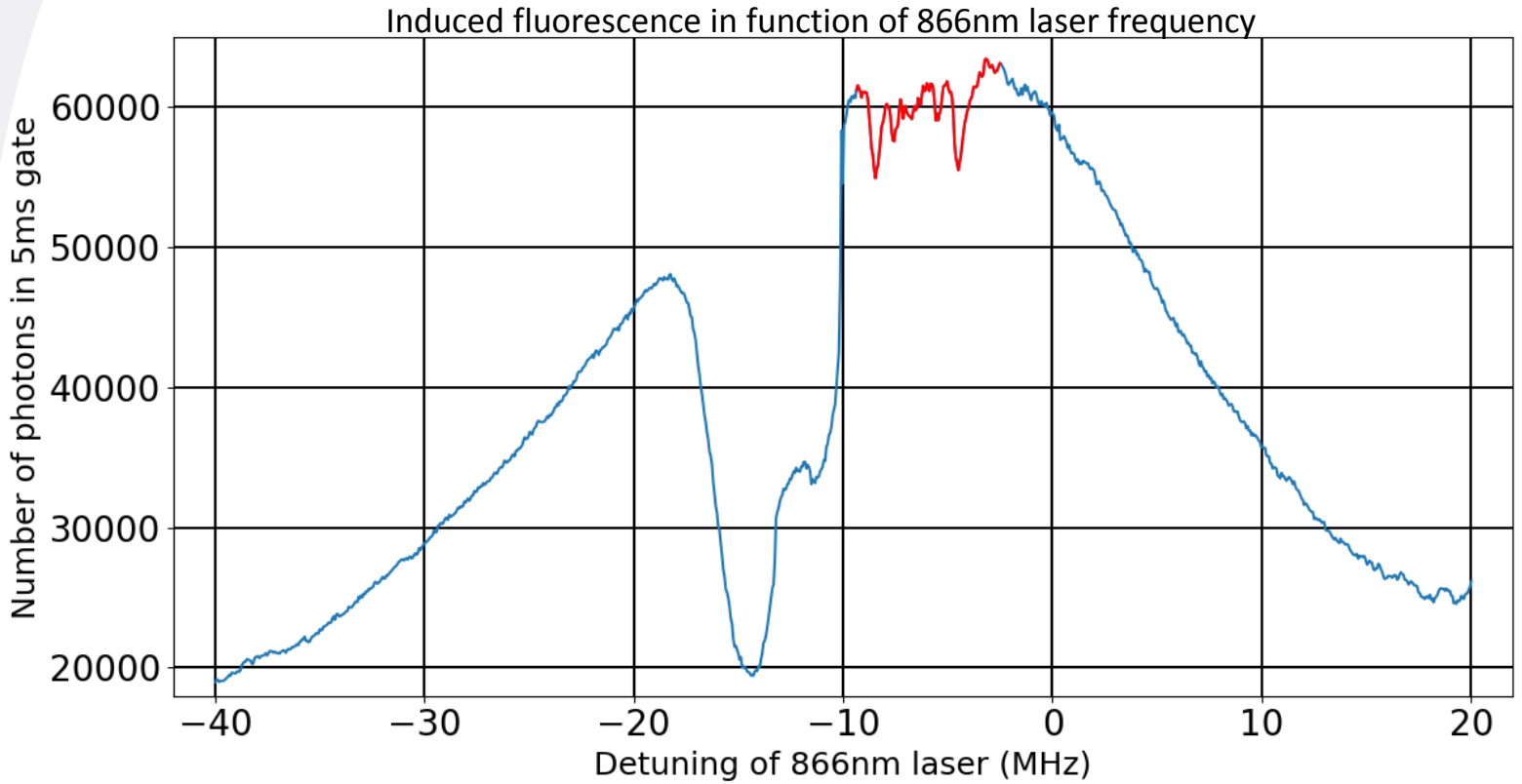


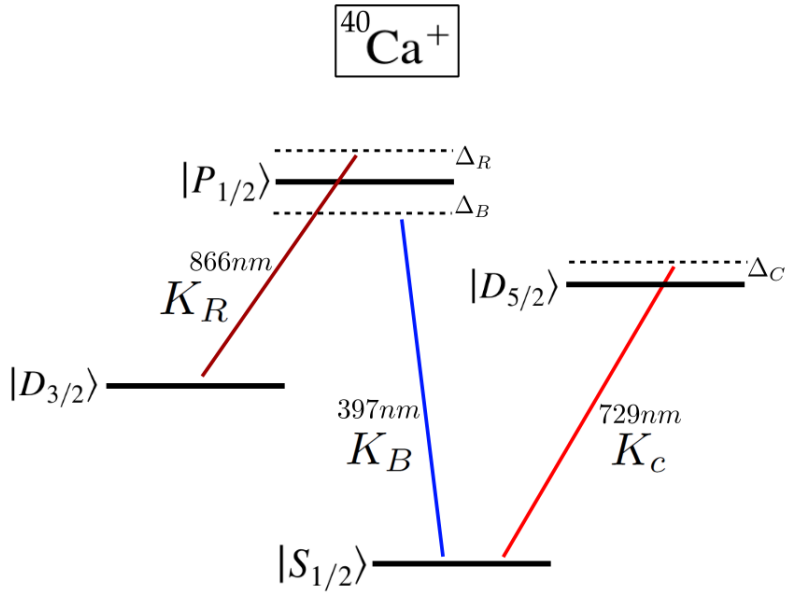
CCD Picture of a cloud with a thousand ions at 10 mK



The ion trap

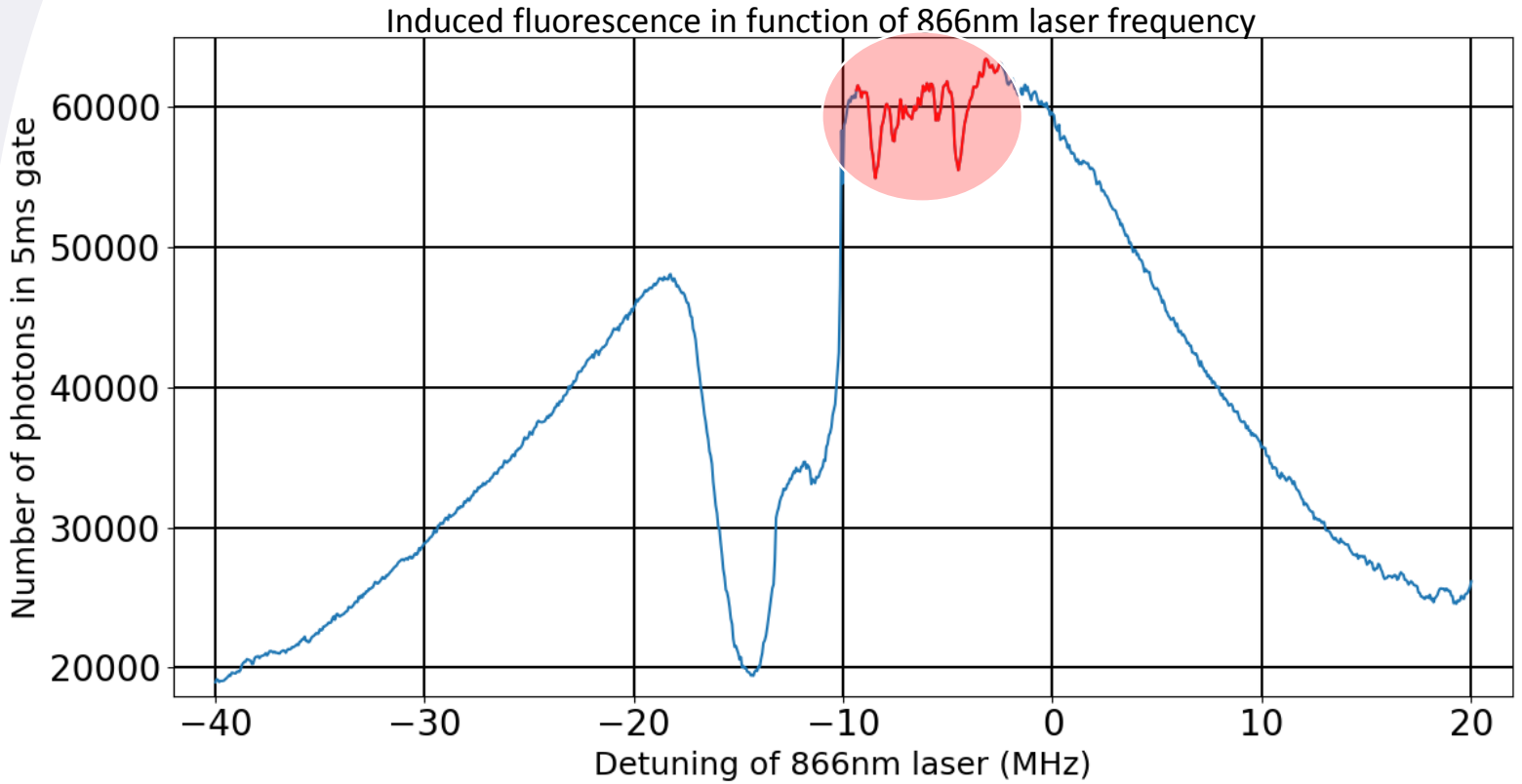
Interrogation method

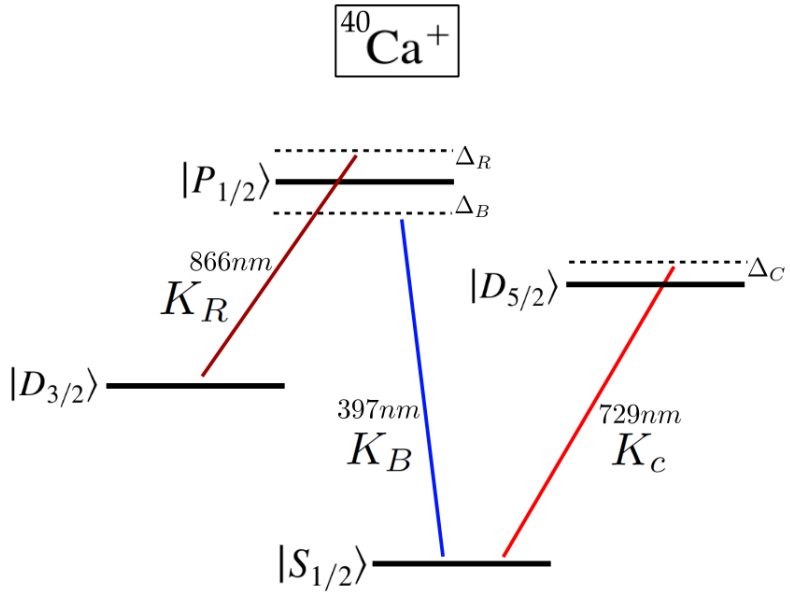




Once each laser is locked on the comb, we sweep 866nm laser frequency by sweeping frequency reference of the phase-lock.

Interrogation method





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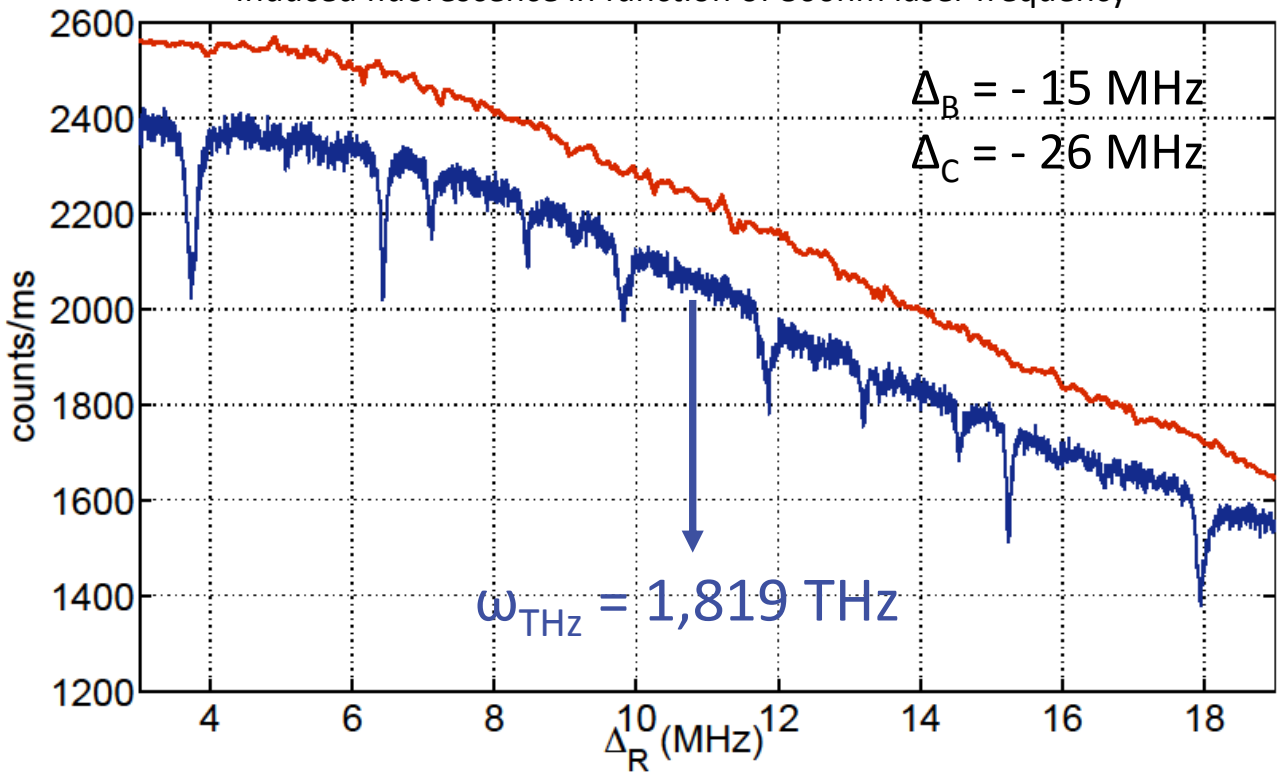
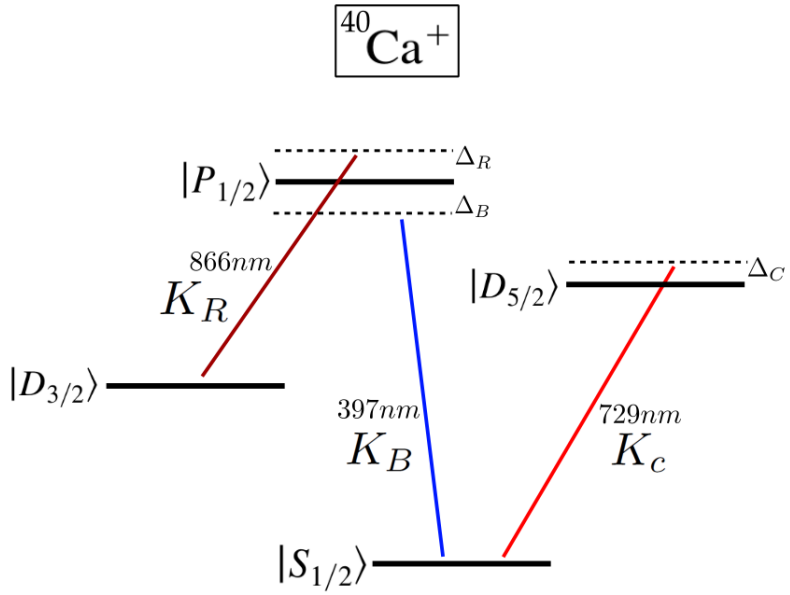
Induced fluorescence in function of 866nm laser frequency





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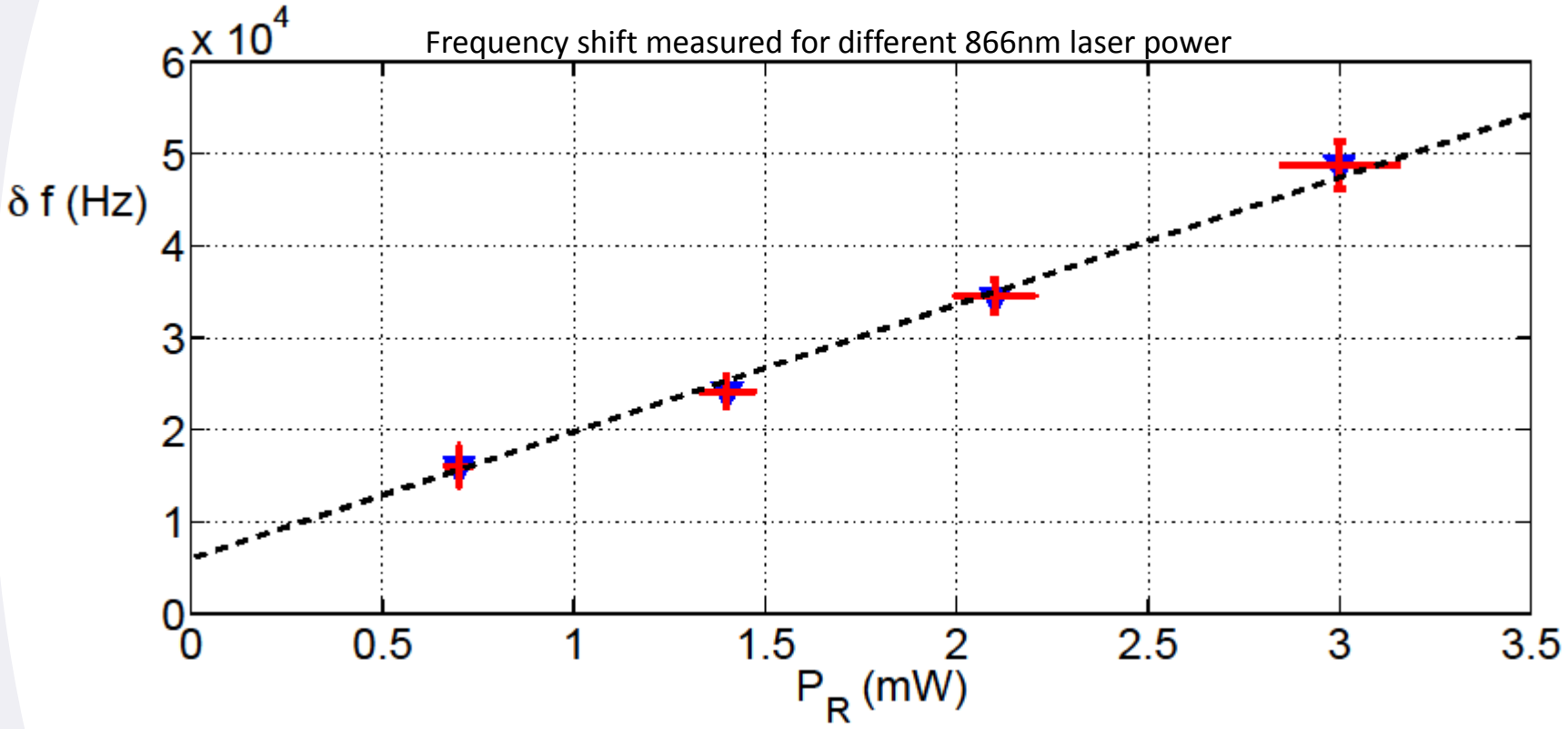
866nm laser intensity influence



The dark line is a linear fit of this plots, with slope 13,8 ± 1,8 kHz/mW.

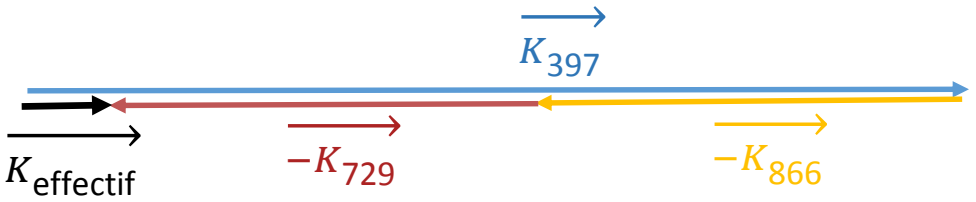
The limit shift for null power is equal to 4,8 ± 3,4 kHz.

« Experimental Demonstration of a Terahertz Frequency Reference based on Coherent Population Trapping», M. Collombon and all, arXiv (2019).

Other source of broadening

One of the source of broadening is the 1st Doppler effect,

$$(\vec{K}_{397} - \vec{K}_{866} - \vec{K}_{729}) * \vec{v} = \Delta_R + \Delta_C - \Delta_B$$



$$\vec{K}_{\text{effectif}} = \vec{K}_{397} - \vec{K}_{729} - \vec{K}_{866}$$

The broadening comming from the first order doppler effect is estimated at 20 kHz in our experiment.

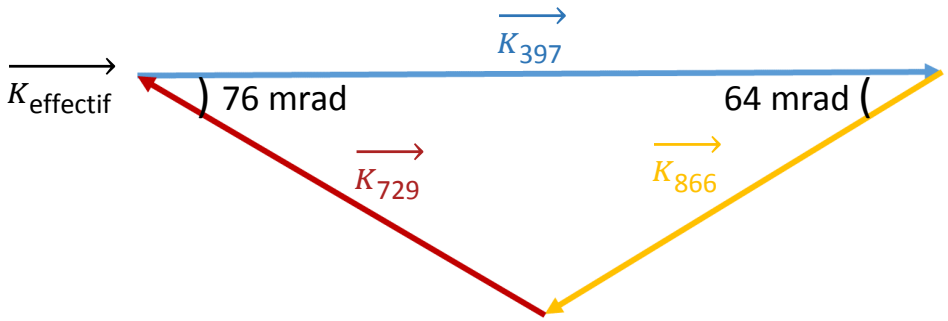
An other source of broadening is the fluctuation of the local magnetic field, estimated at 15 kHz in our experiment.

Prospect

Set the compensation of temporel fluctuation of magnetic field.

Implement 1st order Doppler effect free configuration.

Evaluate every source of shift.



Confinement d’Ions et Manipulation Laser team

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Mathieu Collombon