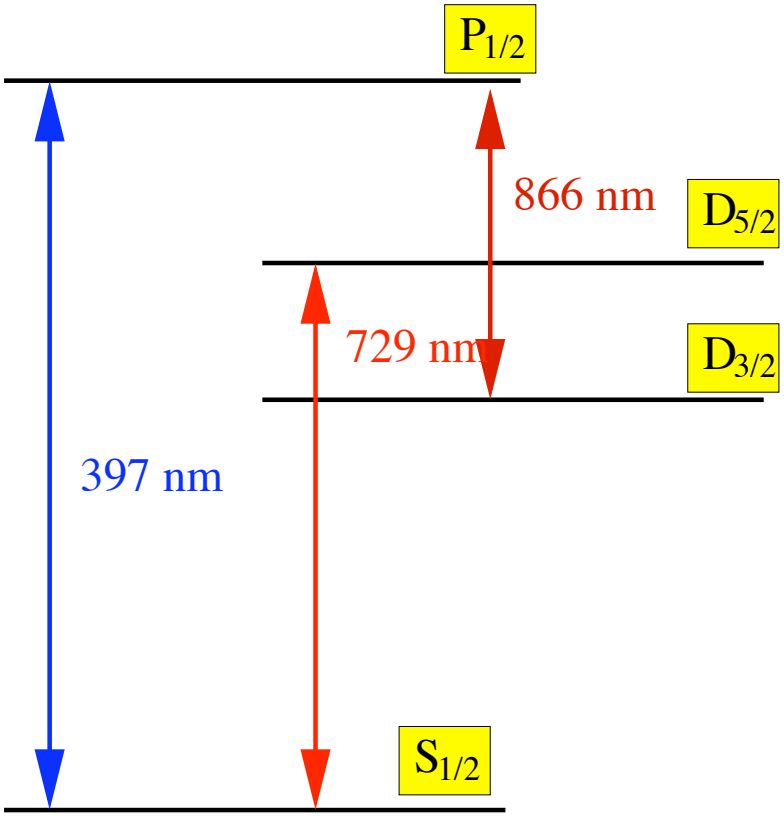
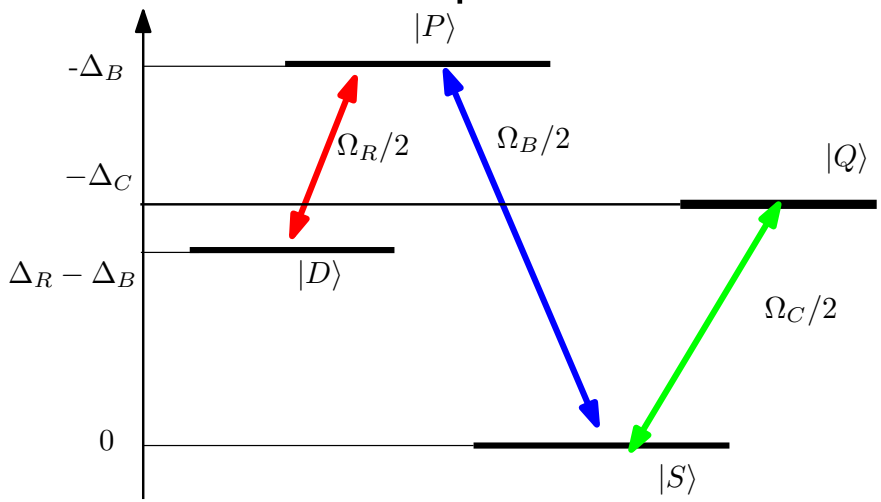
Coherent Population Trapping involving three photons



Ca+ involved transitions

in the dressed state picture



Champenois *et. al* P.R.A **74** (2006) 053404
Champenois *et. al* P.R.L **99** (2007) 013001
Kamsap *et. al* J. Phys B 46 (2013) 145502

In the dressed state picture

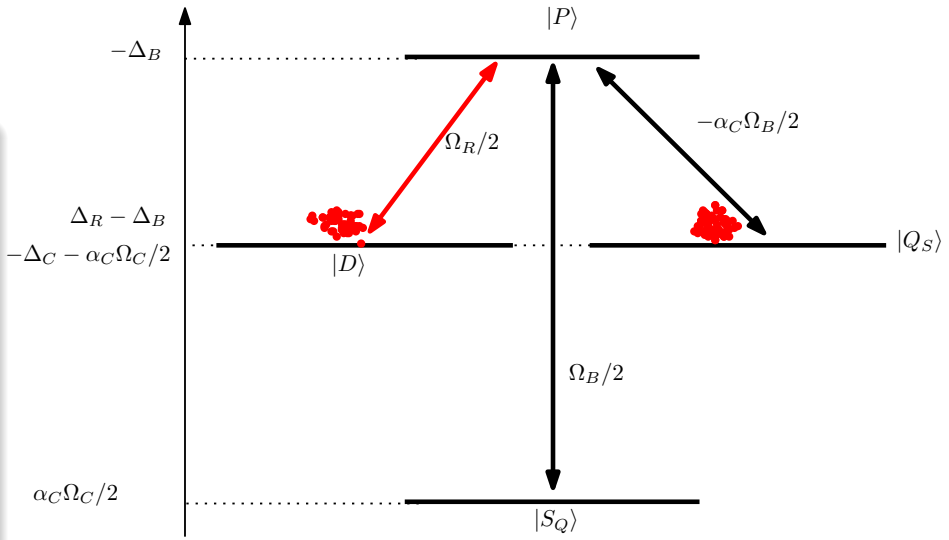
the Q-S coupling is diagonalized

- the $|Q\rangle$ state is mixed with $|S\rangle$ and light-shifted : $|Q_S\rangle$
- $|Q_S\rangle$ and $|D\rangle$ are degenerated if

$$\Delta_C + \alpha_C \Omega_C/2 = \Delta_B - \Delta_R$$

with

$$\alpha_C = \Omega_C/2\Delta_C$$



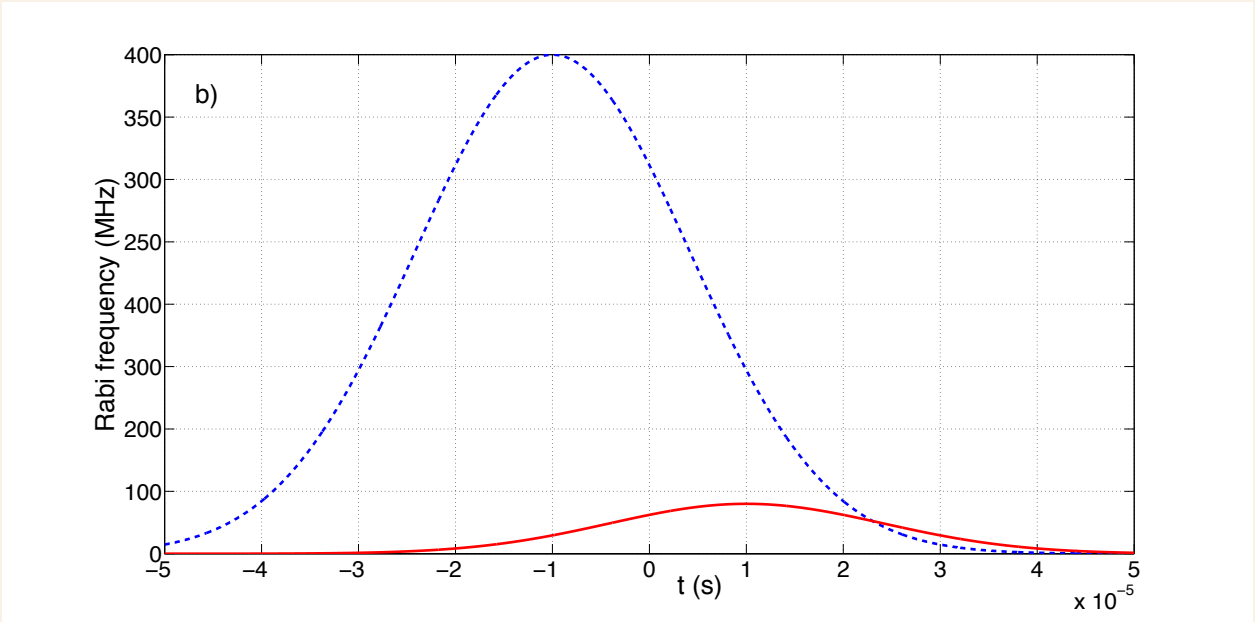
then, the atom is in the dark state

$$|\Psi_D\rangle = \mathcal{N}'\left(\mathcal{E}|D\rangle + |Q_S\rangle\right)$$

with $\mathcal{E} = \alpha_C \Omega_B/\Omega_R$

three-photon CPT for a STIRAP-like process

Transfer of population from $|D\rangle$ to $|Q_S\rangle$

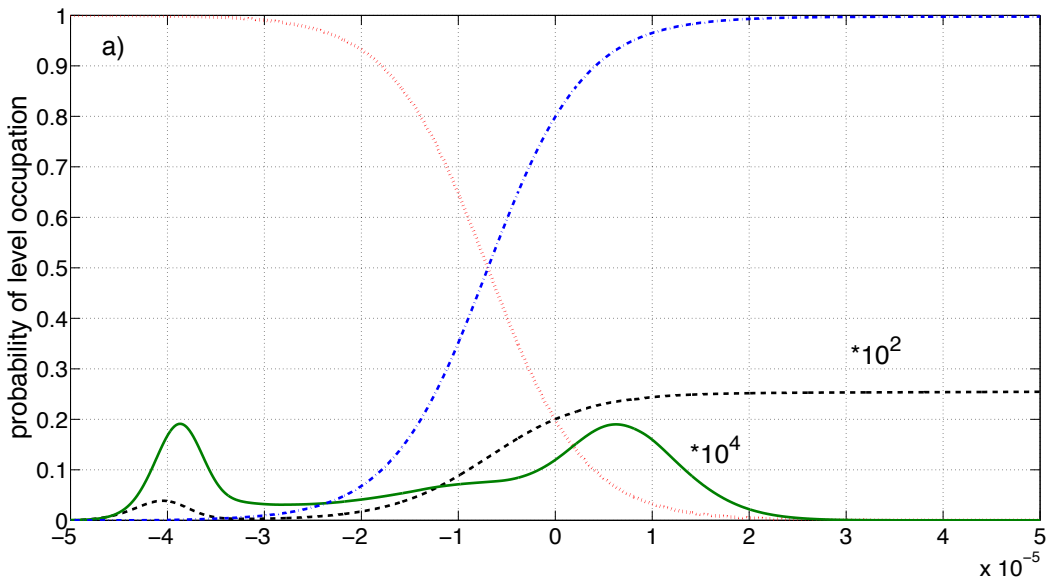


$\Omega_B(t)$
$\Omega_R(t)$

- typical value of α_C : 0.05
- Ω_B must be large enough such that $\alpha_C \Omega_B \simeq \Omega_R$
- the pulse order is the well-known STIRAP order
- then, the C-laser is switched off to end up in $|D_{5/2}\rangle$.

three-photon CPT for a STIRAP-like process

Transfer of population from $|D\rangle$ to $|Q_S\rangle$



$Pop_D(t)$
$Pop_Q(t)$
$Pop_S(t)$
$Pop_P(t)$

- a fidelity of $(1 - 8.10^{-5})$ can be reached with long transfer (100 μs)
- if $\mathbf{k_R} + \mathbf{k_C} - \mathbf{k_B} = \mathbf{0}$, the Doppler effect is canceled

CPT THz clock with first order Doppler effect cancellation

A 1.82 THz frequency reference (Ca^+)

- the dark resonance : $\Delta_C + \alpha_C \Omega_C/2 = \Delta_B - \Delta_R$ translates into

$$\omega_R + \omega_C - \omega_B = \omega_{QD} - \alpha_C \Omega_C/2$$

- $|D\rangle \rightarrow |Q\rangle$ = magnetic dipolar transition $D_{3/2} \rightarrow D_{5/2}$
- The Doppler free geometry : $\Delta \mathbf{k} = \mathbf{k_R} - \mathbf{k_B} + \mathbf{k_W} = \mathbf{0}$ allows CPT on an **ion cloud** to increase signal over noise ratio.
- A signal/ linewidth trade-off results in a reachable stability of $8 \times 10^{-14}/\sqrt{\tau}$ and a precision of 10^{-11} (limited by saturation and second order Doppler effect)
- The THz reference can be spread by the three optical signals.

Champenois *et. al* P.R.L **99**, 013001 (2007)