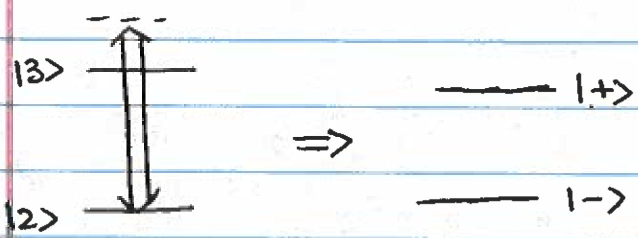
Physical interpretation of two-photon resonances

1: Dressed-state picture for the atom + control field

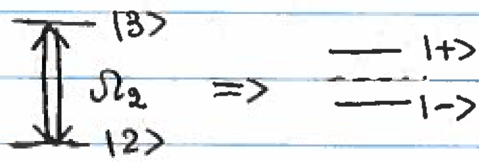


$$E_\pm = \hbar\left(-\frac{\Delta_2}{2} \pm \sqrt{\frac{\Delta_2^2}{2} + |\Omega_2|^2}\right)$$

Resonant case $\Delta_2 = 0$

$$E_\pm = \pm \hbar |\Omega_2|$$

$$|\pm\rangle = \frac{1}{\sqrt{2}}\left(\frac{|\Omega_2|}{\Omega_2}|2\rangle \pm |3\rangle\right)$$



Far-detuned case $\Delta_2 \gg |\Omega_2|$

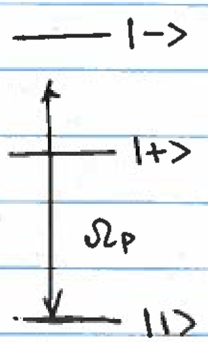
$$E_- \simeq -\hbar\Delta_2 - \hbar\frac{|\Omega_2|^2}{\Delta_2}$$

$$|-\rangle \approx |3\rangle + \underbrace{\Omega_2^*/\Delta_2}_{\ll 1}|2\rangle$$

$$E_+ \simeq \hbar\frac{|\Omega_2|^2}{\Delta_2}$$

$$|+\rangle \approx |2\rangle - \underbrace{\frac{\Omega_2}{\Delta_2}}_{\ll 1}|3\rangle$$

① Off-resonant control field + probe



$|-\rangle \approx |3\rangle$ — strongly decaying, width $\sim \gamma_{31}$

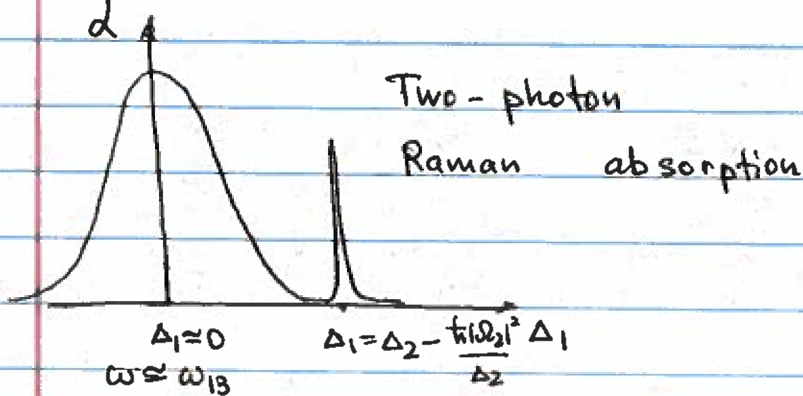
$|+\rangle \approx |2\rangle$ — no/small decay, width $\sim \gamma_{21}$

Two absorption resonances

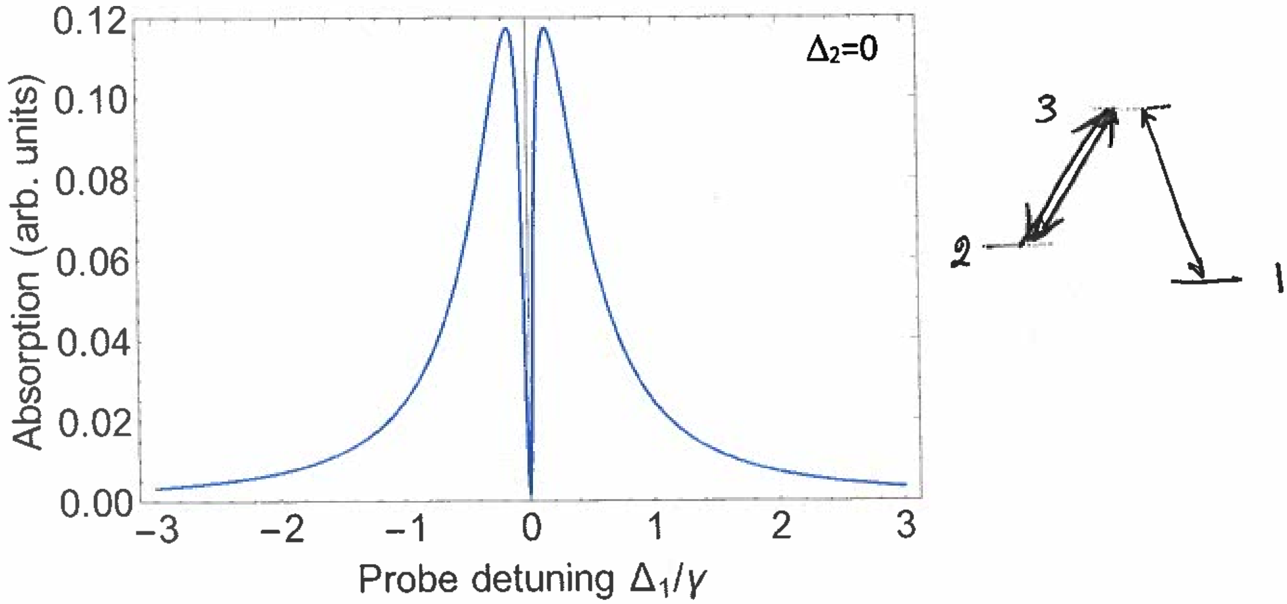
$|1\rangle \to |+\rangle$ => almost like $|1\rangle \to |3\rangle$, "normal" one-photon absorption

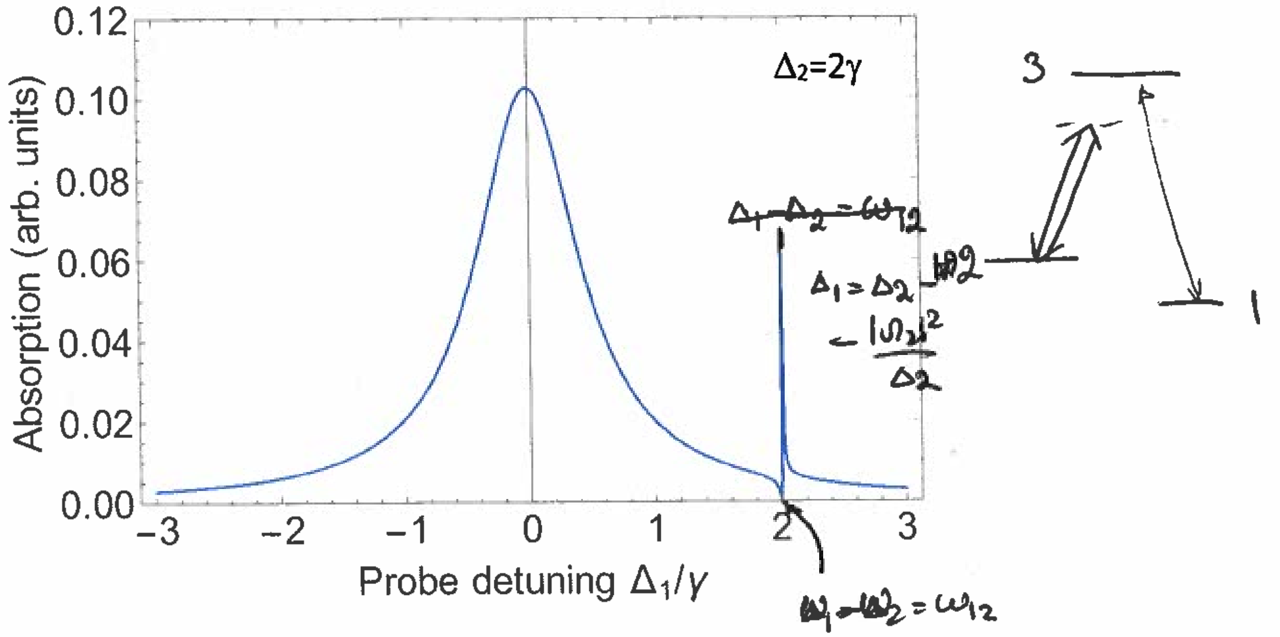
~~$|1\rangle \to |3\rangle$~~

$|1\rangle \to |+\rangle \Rightarrow$ almost $|1\rangle - |2\rangle$ coupling via a two-photon transition

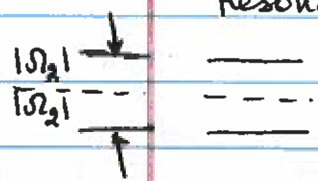


Two-photon process enables transitions b/w two ground states with minimum involvement of the excited state (~~no~~ virtually zero population of the excited state, thus the properties of the probe field susceptibility determined by the parameters of the two ground states $|1\rangle$ & $|2\rangle$.


Δ2=0
Absorption (arb. units)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
−3
−2
−1
0
1
2
3
Probe detuning Δ1/γ
3
2
1


Δ2=2γ
Absorption (arb. units)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
−3
−2
−1
0
1
2
3
Probe detuning Δ1/γ
3
2
1

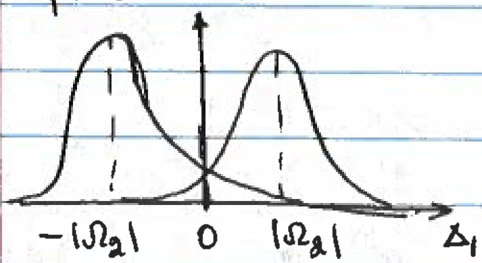
Resonant case $\Delta_2 = 0$ (Ω_2 - real)



$|+\rangle = \frac{1}{\sqrt{2}}(|2\rangle + |3\rangle)$

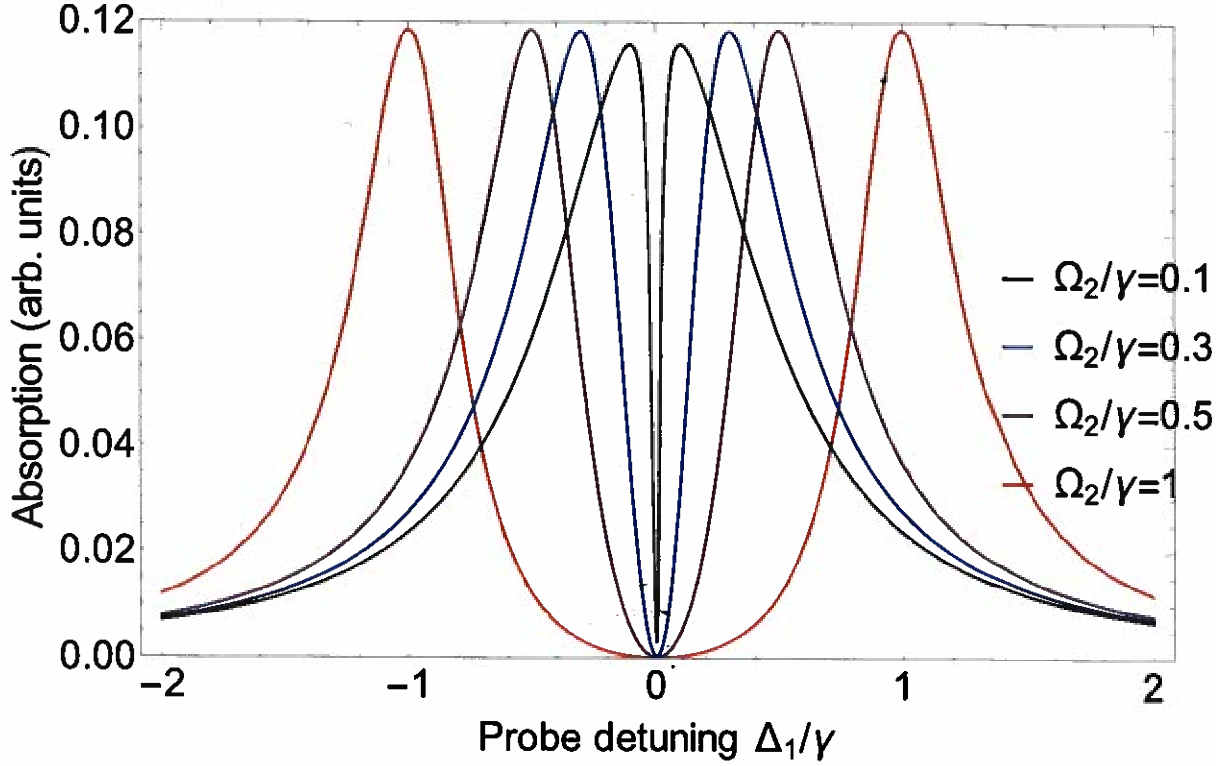
$|-\rangle = \frac{1}{\sqrt{2}}(|2\rangle - |3\rangle)$

Naively, we would expect observing two overlapping absorption peaks for the probe field



Autler - Towns splitting
Observed for low/no ground-state coherence

However, ~~if one can the [illegible]~~ if the two-photon interaction is coherent, the probe interactions with the two symmetric transitions ($\Delta_2 = \Delta_1 = 0$) destructively interfere, eliminating possibility of excitation to the state $|3\rangle$ and absorption. (Actually, such destructive interference exists for any Δ_2, but it is less intuitive)



Absorption (arb. units)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
−2
−1
0
1
2
Probe detuning Δ1/γ
Ω2/γ=0.1
Ω2/γ=0.3
Ω2/γ=0.5
Ω2/γ=1