

5/1/2013

DRESSED ATOMS

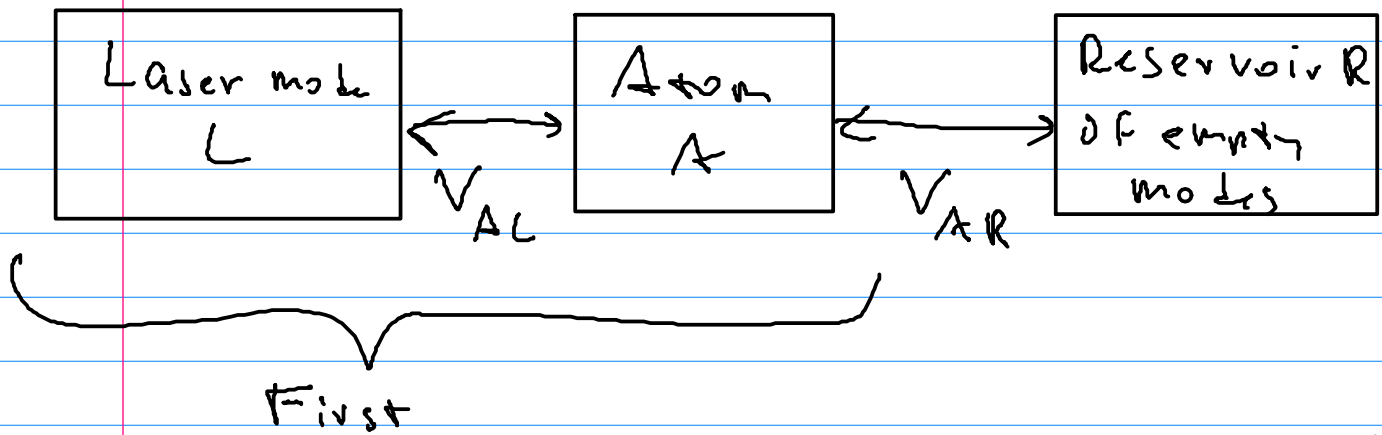
API, Ch. VI

= an atom + ONE mode of the e.m. field

"Nothing new" beyond OBE, BUT: new insight

"Difference" to the OBE

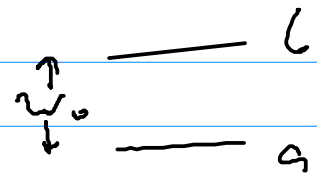
- combined state of atom + em field
- Change of basis: dressed basis
- Laser field NOT treated as a classical field



$$H_L = \hbar \omega_L (a^\dagger a + \frac{1}{2})$$

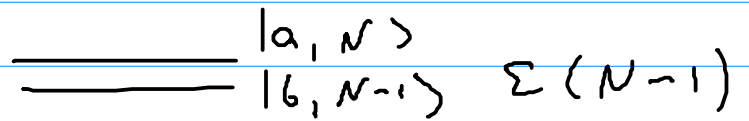
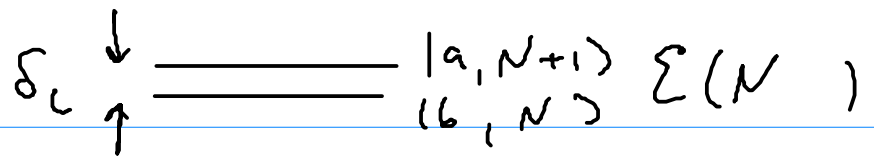
$$H_A = \hbar \omega_0 (|b\rangle\langle b|)$$

eigenstates of H_A and H_L



N photons
 $|a\rangle, |b\rangle$

$$\delta_L \ll \omega_0 \quad \left\{ |a, N+1\rangle, |b, N\rangle \right\} = \Sigma(N) \text{ manifold}$$



Atom-Laser Coupling

$$V_{AL} = -\vec{d} \cdot \vec{E}_\perp(\vec{R})$$

Laser Field operator

$$\vec{E}_\perp(\vec{R}) = \sqrt{\frac{\hbar \omega_L}{2 \epsilon_0 V}} \hat{\epsilon}_L (a + a^\dagger)$$

$$\vec{d} = \vec{d}_{ab} (|b\rangle\langle a| + |a\rangle\langle b|)$$

coupling constant $g = -\hat{\epsilon}_L \vec{d}_{ab} \sqrt{\quad}$

Coupling within each manifold $\Sigma(N)$

$$\langle b, N | V_{AL} | a, N+1 \rangle = g \sqrt{N+1}$$

$a, N+1$ also couples to $b, N+2$
 b, N also couples to $a, N-1$

nonresonant

neglected within the RWA

N is large, then $\Delta N \sim \sqrt{N} \ll N$

$$\Rightarrow \nu_N \approx g \sqrt{\langle N \rangle} \quad \text{independent of } N$$

$$\vec{\Sigma}_0 = 2 \bar{\Sigma}_L \sqrt{\frac{\hbar \omega_L}{2 \epsilon_0 v}} \sqrt{\langle N \rangle}$$

$$\hbar \Omega_1 := -\vec{d}_{AB} \cdot \vec{\Sigma}_0 \Rightarrow \nu_N = \hbar \Omega_1 / 2$$

Rabi Frequency Ω_1

Hamiltonian for each $\Sigma(N)$

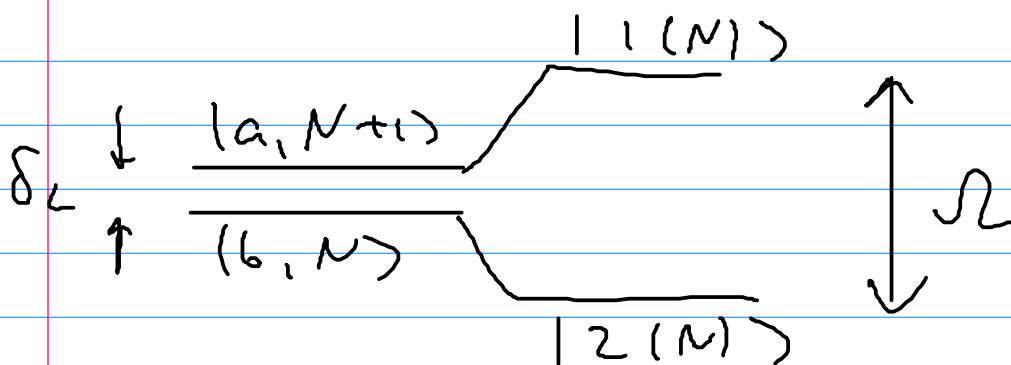
$$\frac{\hbar}{2} \begin{pmatrix} -\delta_L & \Omega_1 \\ \Omega_1 & \delta_L \end{pmatrix}$$

coupled pendulum Hamiltonian

Solution

$$\hbar \Omega = \hbar \sqrt{\delta_L^2 + \Omega_1^2}$$

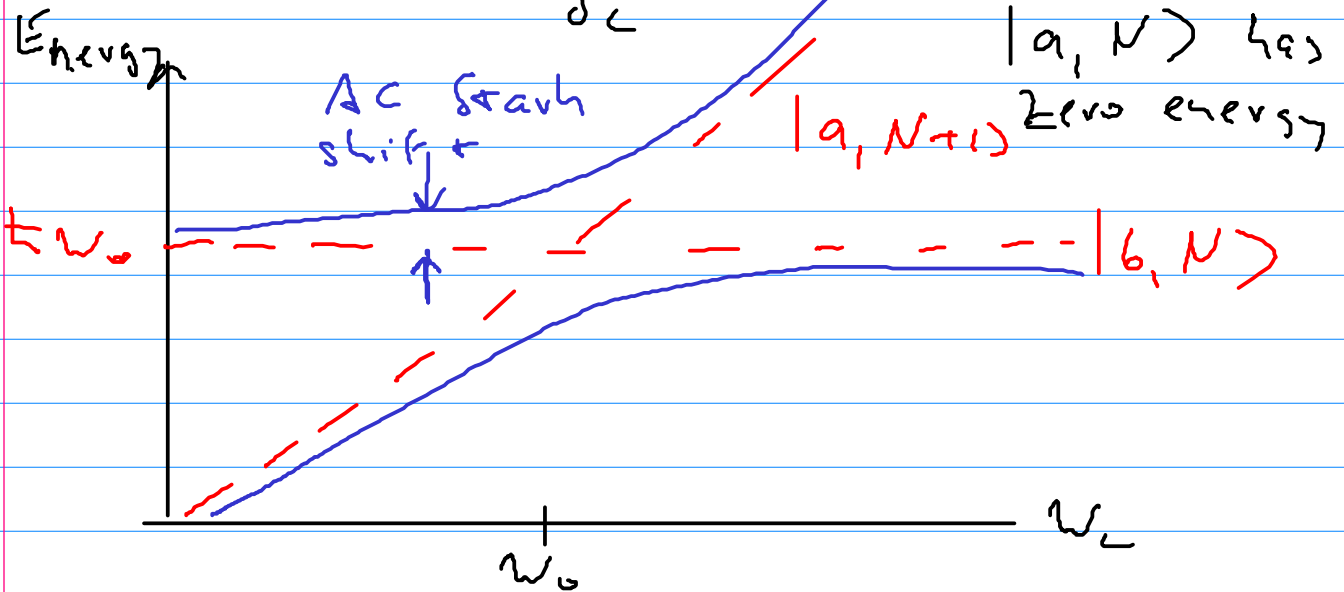
generalized Rabi Frequency



$$|1(N)\rangle = \sin\theta |a, N+1\rangle + \cos\theta |b, N\rangle$$

$$|2(N)\rangle = \cos\theta |a, N+1\rangle - \sin\theta |b, N\rangle$$

$$\tan 2\theta = -\frac{\Omega_c}{\delta_c}$$



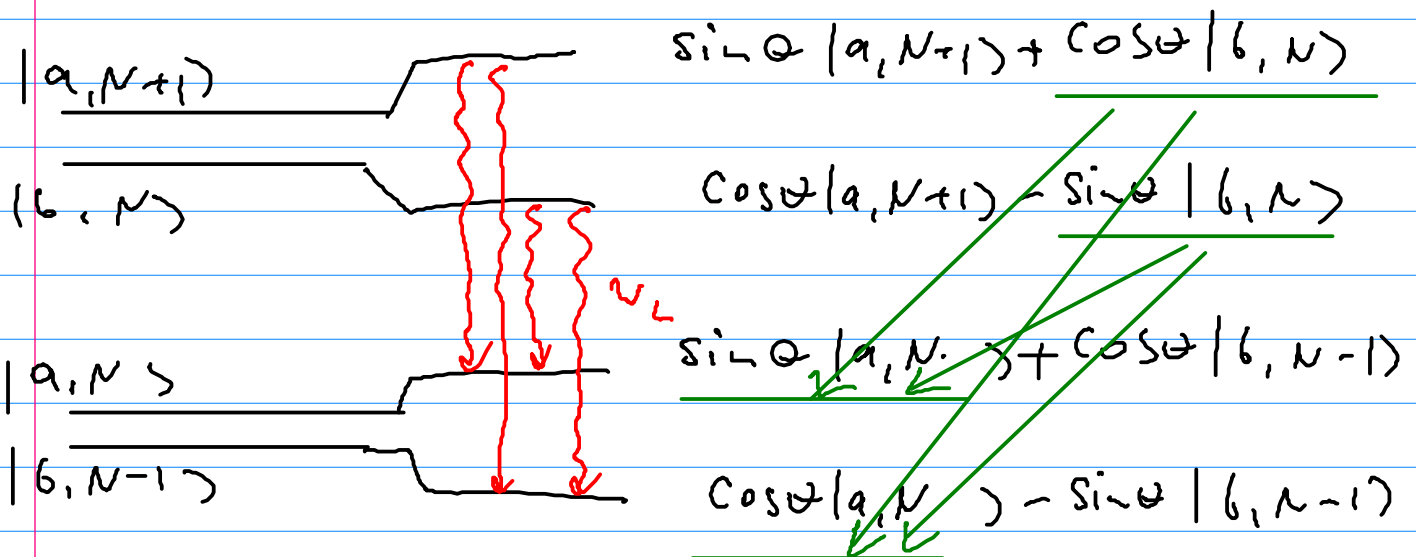
Spectrum of the emitted light

Dressed atom



Carrier + two sidebands

MOLLOW triplet



Fluorescence triplet

ω	Rate
$\omega_L + \Omega$	$\Gamma_{1 \rightarrow 2} \approx \Gamma \cos^4 \theta$
$\omega_L - \Omega$	$\Gamma_{2 \rightarrow 1} = \Gamma \sin^4 \theta$
ω_L	$2 \Gamma \cos^2 \theta \sin^2 \theta$

Population (Intensity = population \times rate)

Rate equation (Populations don't couple + coherences for $\Omega \gg \Gamma$)

$$\dot{\pi}_1 = -\pi_1 \Gamma_{1 \rightarrow 2} + \pi_2 \Gamma_{2 \rightarrow 1} \text{ etc}$$

$$= 0 \text{ in } \pi_i^{st} \text{ steady state}$$

$$\pi_1^{st} = \frac{\Gamma_{2 \rightarrow 1}}{\Gamma_{1 \rightarrow 2} + \Gamma_{2 \rightarrow 1}} = \frac{\sin^4 \theta}{\cos^4 \theta + \sin^4 \theta}$$

$$\theta = 45^\circ$$

$$\dot{\pi}_i = -\Gamma_{pop} (\pi_i - \pi_i^{st})$$

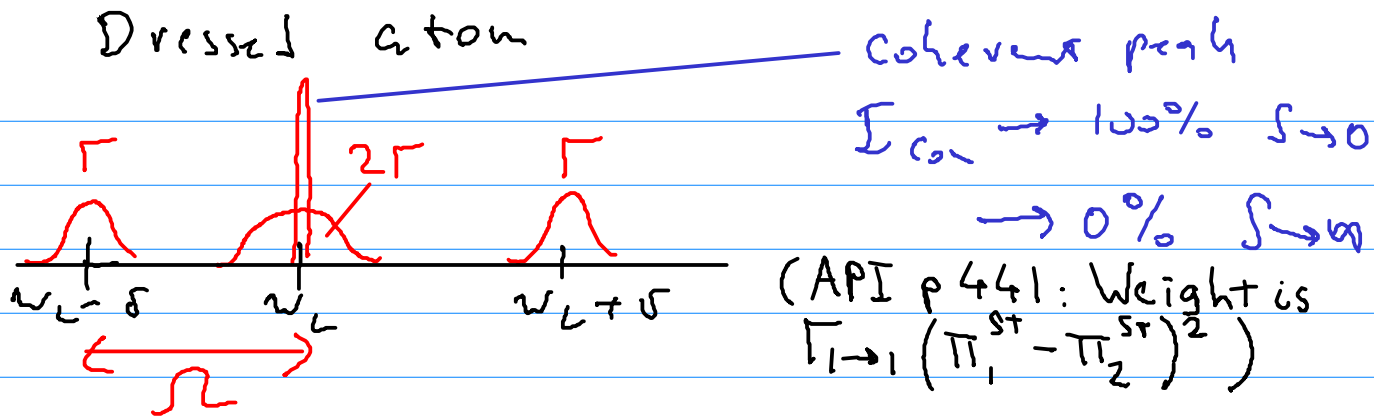
$$\Gamma_{pop} = \Gamma_{1 \rightarrow 2} + \Gamma_{2 \rightarrow 1} = \Gamma (\cos^4 \theta + \sin^4 \theta)$$

Relaxation rate for populations

Similar:

$$\Gamma_{col}$$

Relaxation rate for coherence between dressed states



Width of emission lines

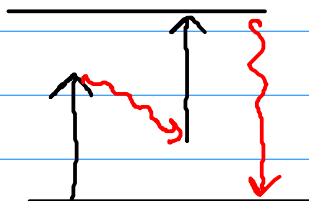
- central feature width Γ_{pop}
- sidebands Γ_{coh}

OBE - linear matrix equation, complex eigenvalues ν_i

	$\delta_L \gg \Omega, \Gamma$	$\omega_L = \omega_0$ $\Omega_i \ll \Gamma$	$\Omega_i \gg \Gamma, \omega_L = \omega_0$
ν_i	$i\delta_L + \Gamma/2$	$\Gamma/2$	$i\Omega_i + \frac{3}{4}\Gamma$
	$-i\delta_L + \Gamma/2$	$\Gamma/2$	$i\Omega_i + \frac{3}{4}\Gamma$
	Γ	Γ	$\Gamma/2$

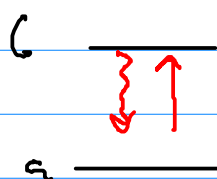
⇓ ν_i

Diagrams



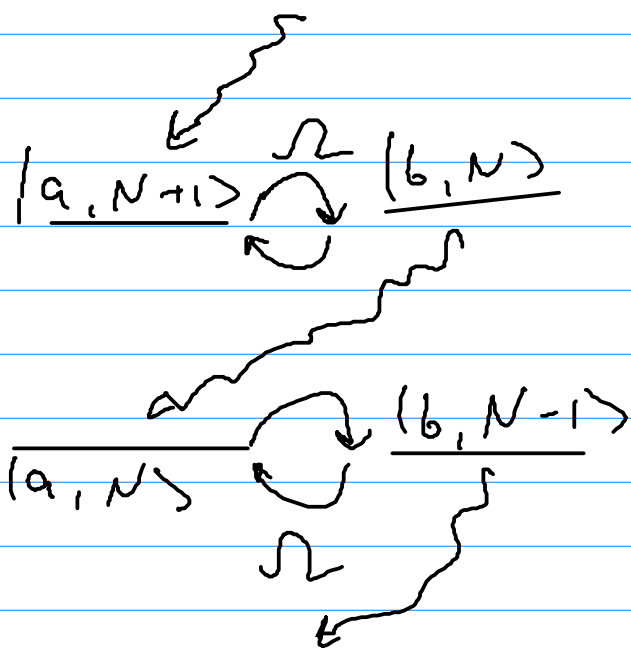
lower and upper sideband

inelastic component of the central peak

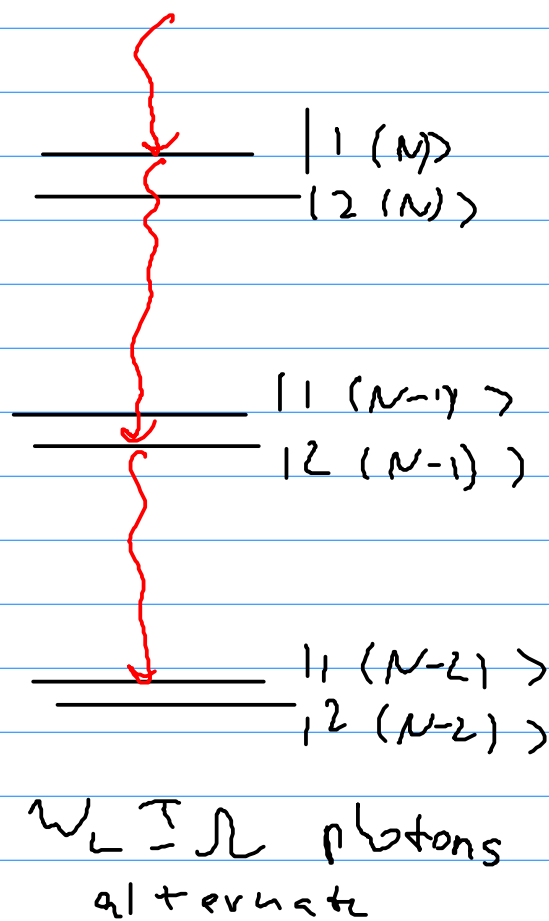


inverse scattering of the excited state (b)

Radiative cascade in the uncoupled and dressed state basis



antibunching
 temporal resolution better
 $\Omega^{-1} \Rightarrow$ can't see
 side bands



$\omega_L \approx \Omega$ photons
 alternate