Saturation broadening and Autler-Townes splitting

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Solution: *a. The eigenvalues of the effective Hamiltonian (1.38) excited in resonance,*

$$E = -\frac{\imath}{4}\Gamma \pm \frac{\imath}{4}\sqrt{\Gamma^2 - 4\Omega^2} \ ,$$

describe possible effects of line broadening and/or shift due to the coupling. Two cases are interesting: In the case $\Gamma > 4\Omega$ we get,

$$E = \mathfrak{Re}\ E = 0 \qquad , \qquad \Gamma_{eff} = -2\mathfrak{Im}\ E = \frac{1}{2}\Gamma \mp \frac{1}{2}\sqrt{\Gamma^2 - 4\Omega^2} \ .$$

That is, the resonance is not shifted or split, but undergoes a line broadening, as already shown in (2.76).
In the case $\Gamma < 4\Omega$,

$$E = \mathfrak{Re}\ E = \pm\frac{1}{2}\sqrt{\Omega^2 - \frac{1}{4}\Gamma^2} \qquad , \qquad \Gamma_{eff} = -2\mathfrak{Im}\ E = \frac{1}{2}\Gamma \ .$$

we observe an splitting of the line called Autler-Townes splitting. When saturation is strong, the two new lines are separated by Ω, each having the natural width Γ. Figs. 2.15(a,b) show the bifurcation of the spectrum at the point $\Omega_{12} = \frac{1}{2}\Gamma$.
b. The Liouville matrix can be found in the numerical MATLAB code in given in the file 'LM_Bloch_AutlerTownes.m'.
c. Fig. 2.15(c) shows the results of the simulations. The laser Ω_{23} probes the population ρ_{22} by excitation to a higher level, that is, the fluorescence emitted by the population ρ_{33} is representative for the population ρ_{22}.

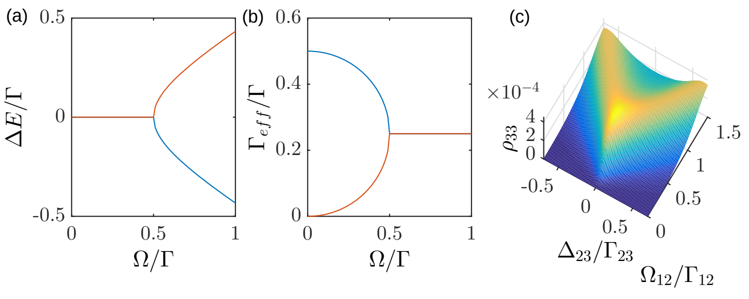

Figure 2.15: (code for download) (a) Autler-Townes splitting and (b) linewidths as a function of the Rabi frequency. (c) Population of the excited state in a three-level system in cascade configuration, as shown in Fig. 2.3(c) in a function of the Rabi frequencies Ω_{23} and Ω_{12}. The parameters are, $\Gamma_{23} = 0.5\Gamma_{12}$, $\Gamma_{13} = 0.01\Gamma_{12}$, $\Omega_{23} = 0.1\Gamma_{12}$.