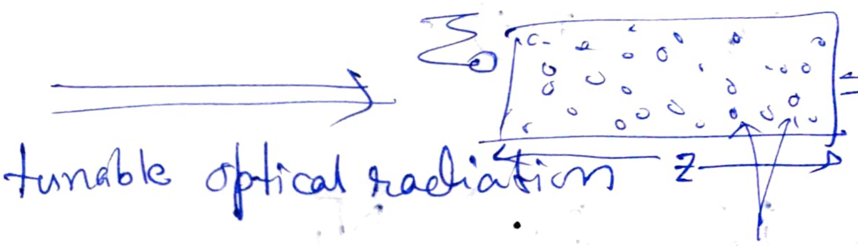
3. Laser amplification

field

$$\mathcal{E}(z) = \mathcal{E}_0 e^{-\alpha(\omega) z}$$



$$\boxed{I \propto |\mathcal{E}|^2}$$

intensity

E_2 — N_2 no (per unit volume) atoms are excited to E_2

E_1 — N_1 no. of atoms (per volume) are not excited.

For the medium to be absorbing

$$N_1 > N_2$$

$$\mathcal{E}(z) = \mathcal{E}_0 e^{-\alpha(\omega) z}$$

ω is freq. of incident radiation.

$\alpha(\omega)$ is amplitude attenuation coefficient

This can be derived (Not in your syllabus)

$$\alpha(\omega) = \frac{\lambda^2}{4\pi} \frac{\gamma_{rad}}{\Delta\omega_a} \frac{N_1 - N_2}{1 + \left[2(\omega - \omega_{21})/\Delta\omega_a\right]^2}$$

where $E_2 - E_1 = \omega_{21} \pm \Delta\omega_a$

linewidth

λ = transition wavelength in the laser material

$$I(z) = |\mathcal{E}(z)|^2 = I_0 \exp(-2\alpha(\omega) z)$$

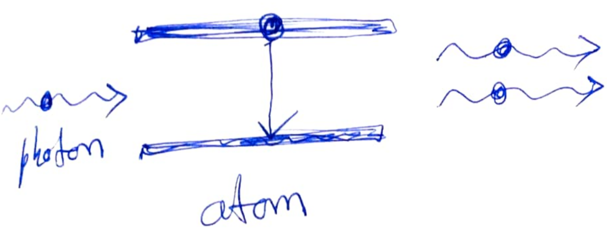
In case of population inversion

$$N_2 > N_1$$

$$-\alpha(\omega) \equiv \alpha_m(\omega) = \frac{\lambda^2}{4\pi}\,\frac{\gamma_{rad}}{\Delta\omega_a}\,\frac{N_2 - N_1}{1 + [2(\omega - \omega_a)/\Delta\omega_a]^2}$$

$$I(z) = I_0 \exp[+2\alpha_m(\omega) z]$$

The intensity will be coherently amplified.



4. Laser pumping and population inversion

See next page →

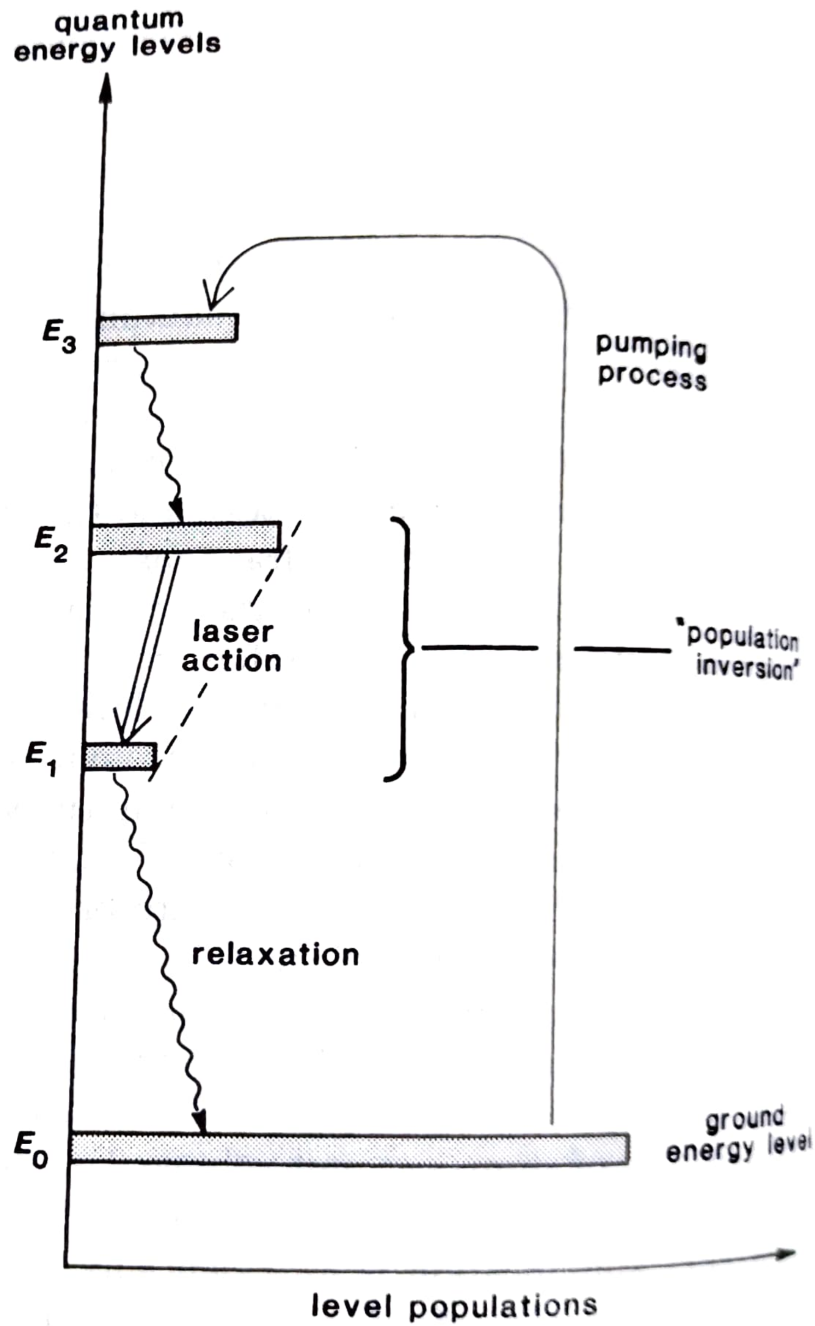


FIGURE 1.29
A four-level laser pumping system.

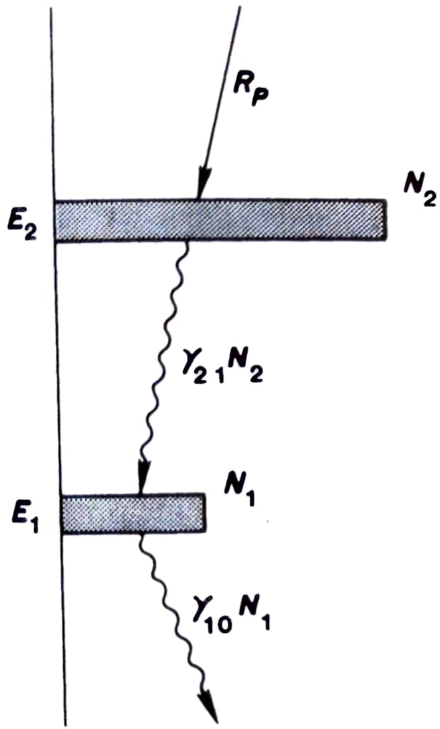


FIGURE 1.30
Rates of flow between atomic energy levels in an ideal four-level laser system.

[Four-level pumping model]

pumping rate R_{p0} (atoms/second) from E_0 to E_3.

Certain ~~from~~ fraction η_p of the atoms excited upward (to E_3) will relax down to intended upper level of laser action (E_2 for this case).

So η_p is pumping efficiency for the laser system. $\therefore$ Effective pumping (to E_2) rate $\boxed{R_p = \eta_p R_{p0}}$

$$\frac{dN_2}{dt} \approx R_p - \gamma_{21} N_2$$

(Let us not consider laser action for the moment)

$$\frac{dN_1}{dt} \approx \gamma_{21} N_2 - \gamma_{10} N_1$$

Let us assume, a continuous pumping is applied and steady state is achieved

at steady state $\frac{dN_1}{dt} = 0$ $\frac{dN_2}{dt} = 0$

$$N_{2,ss} = \frac{R_p}{\gamma_{21}} \qquad N_{1ss} = \frac{\gamma_{21}}{\gamma_{10}} N_{2,ss}$$

$$(N_2 - N_1)_{ss} = \frac{R_p(\gamma_{10} - \gamma_{21})}{\gamma_{10}\gamma_{21}} = R_p \tau_{21}\left(1 - \frac{\tau_{10}}{\tau_{21}}\right)$$

required $\boxed{\tau_{10} < \tau_{21}}$