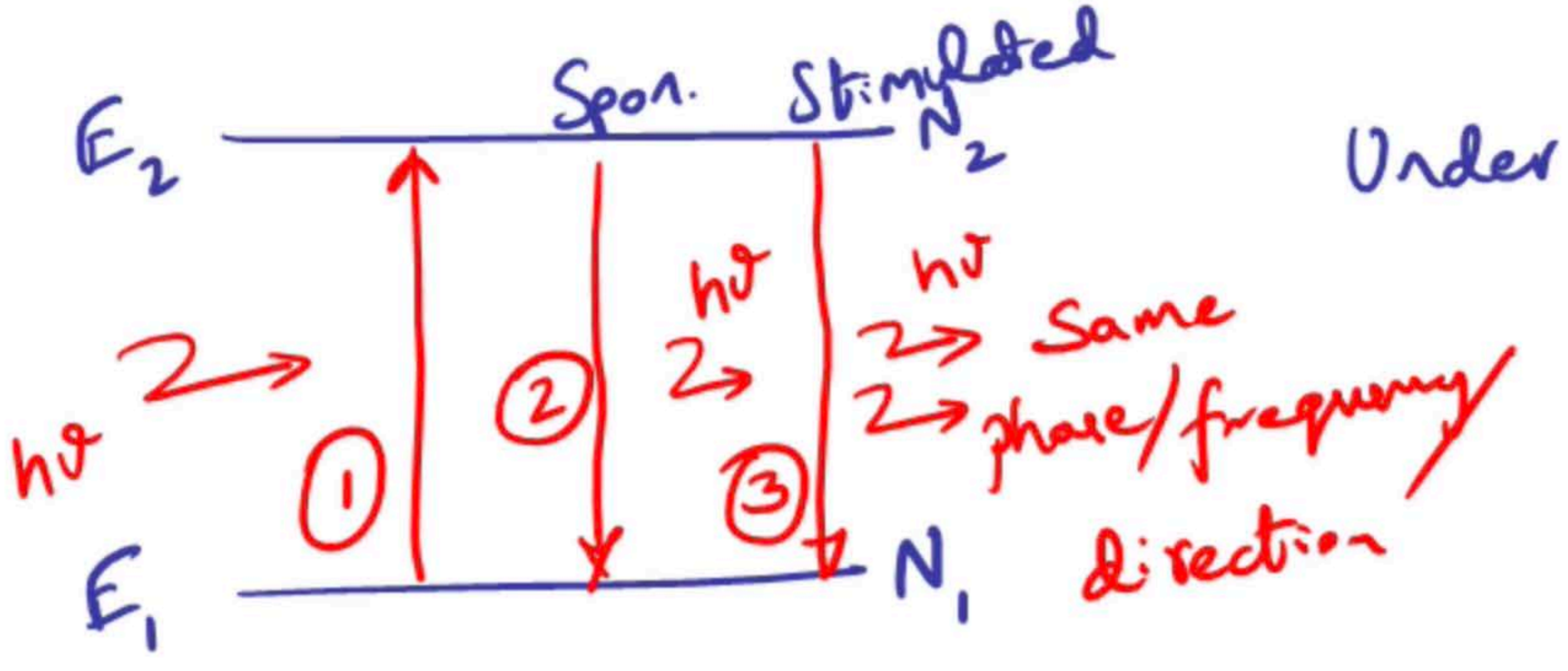
Learning Objective: Identify the fundamental principles of photon interaction w/ atoms

Analyze light generation and amplification



Under steady state conditions,

$$R_{abs} = R_{spon} + R_{stim}$$

$$B' N_1 \rho_{abs} = A N_2 + B N_2 \rho_{em}$$

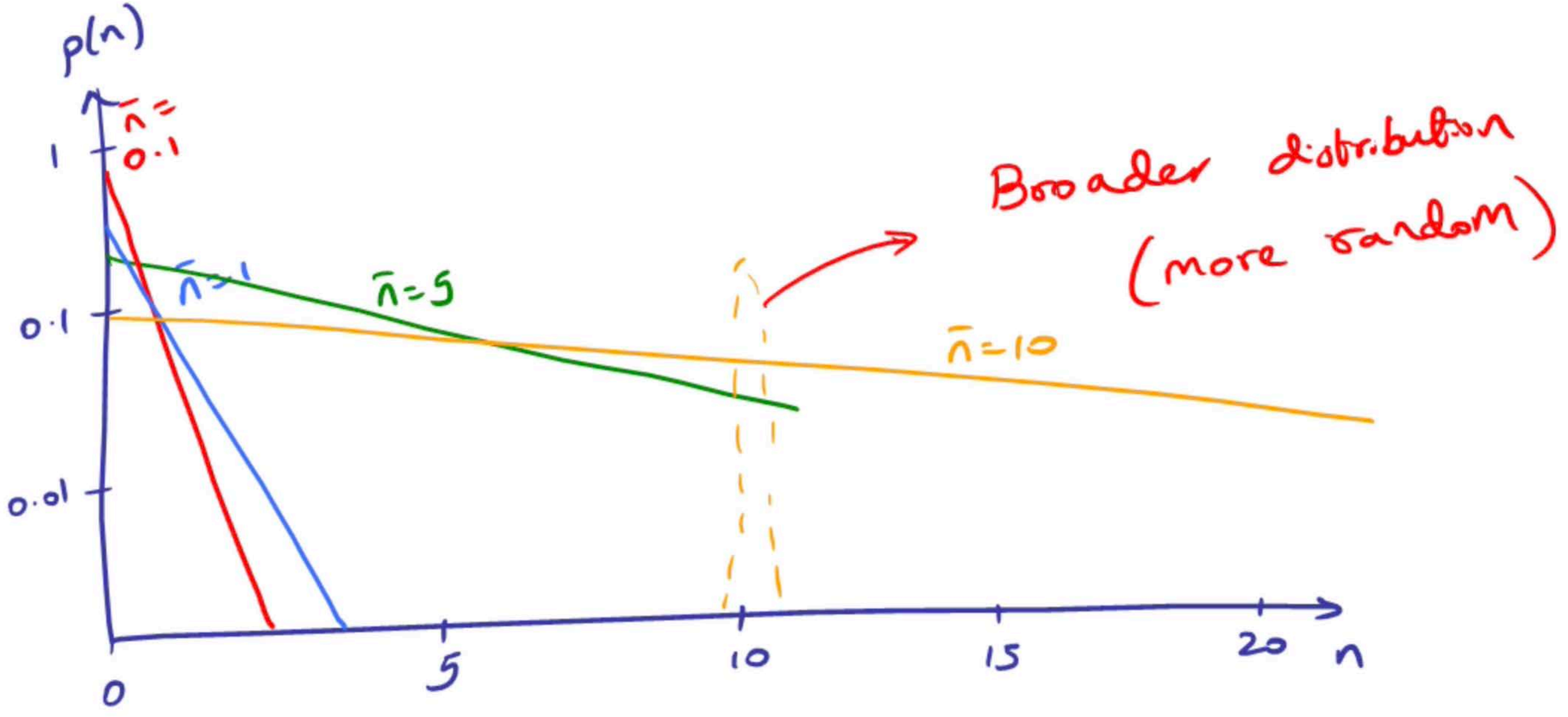
If $\rho_{em} = \rho_{abs}$,

$$\rho_{em} = \frac{A N_2}{B' N_1 - B N_2} = \frac{A/B}{\frac{B'}{B} \cdot N_1/N_2 - 1}$$

$\Rightarrow$ Similar to Planck's ρ_{em} for blackbody radiation

$$\boxed{p(n) = \frac{1}{\bar{n}+1}\left(\frac{\bar{n}}{\bar{n}+1}\right)^n}$$

where $\bar{n} = \dfrac{1}{\exp\left(\frac{h\nu}{k_B T}\right) - 1}$

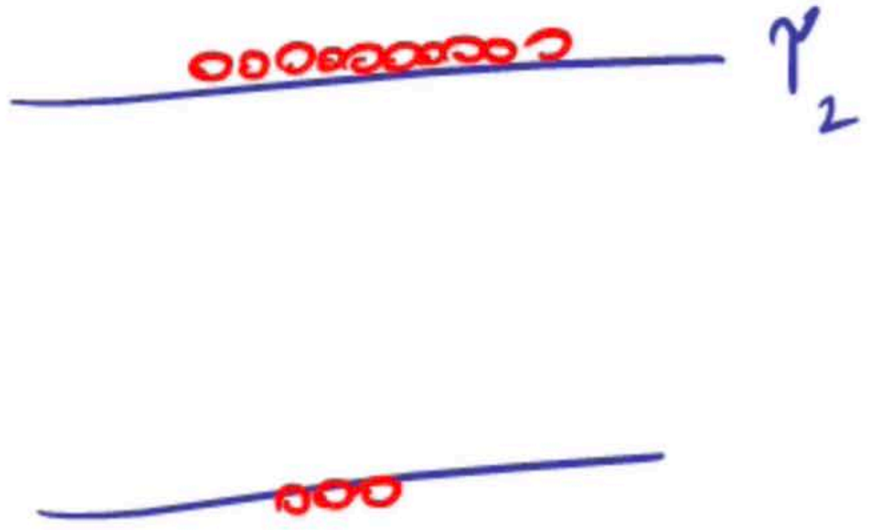


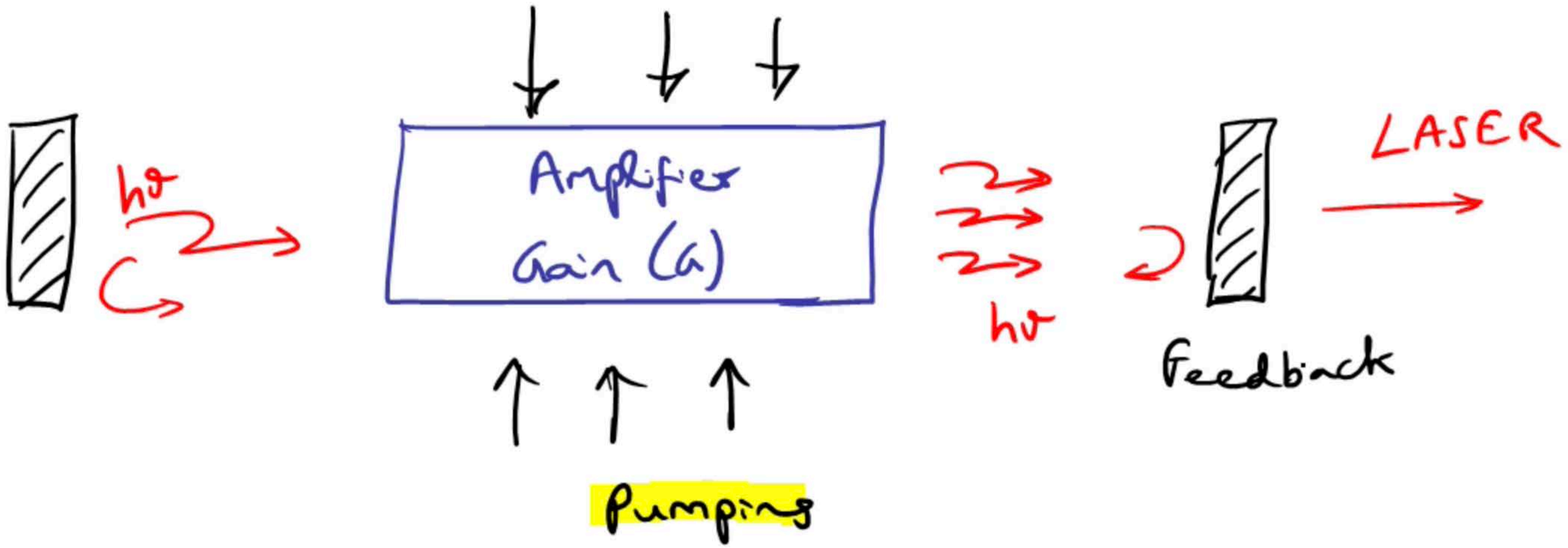
Observation #3

For $R_{stim} > R_{spon}$

$N_2 > N_1$ (population inversion)

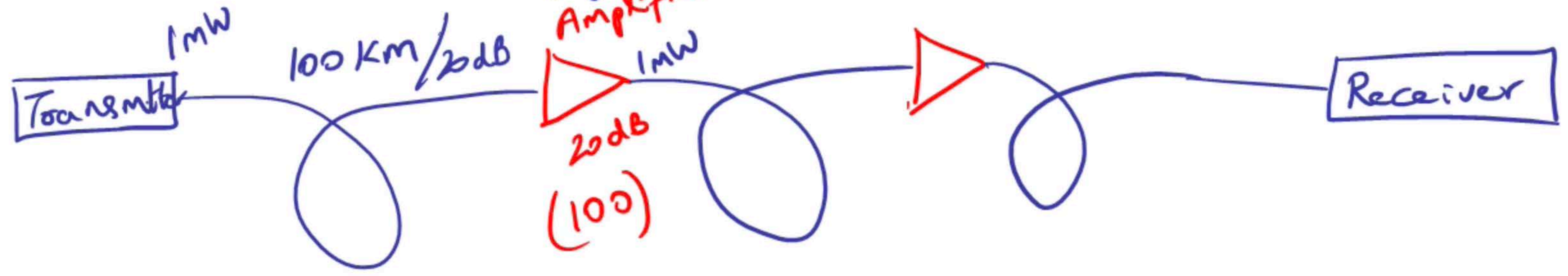
$\Rightarrow$ external pumping/excitation





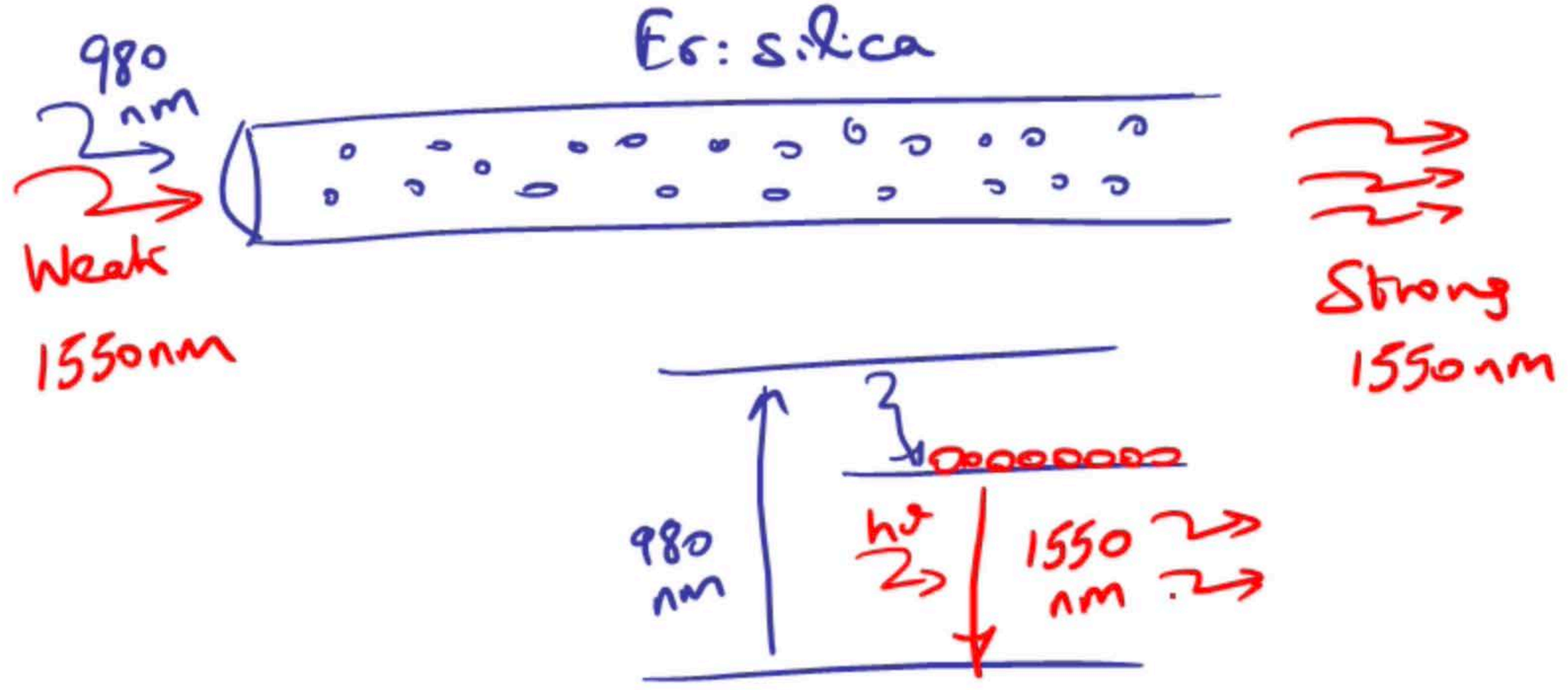
Example: Optical fiber Communication System

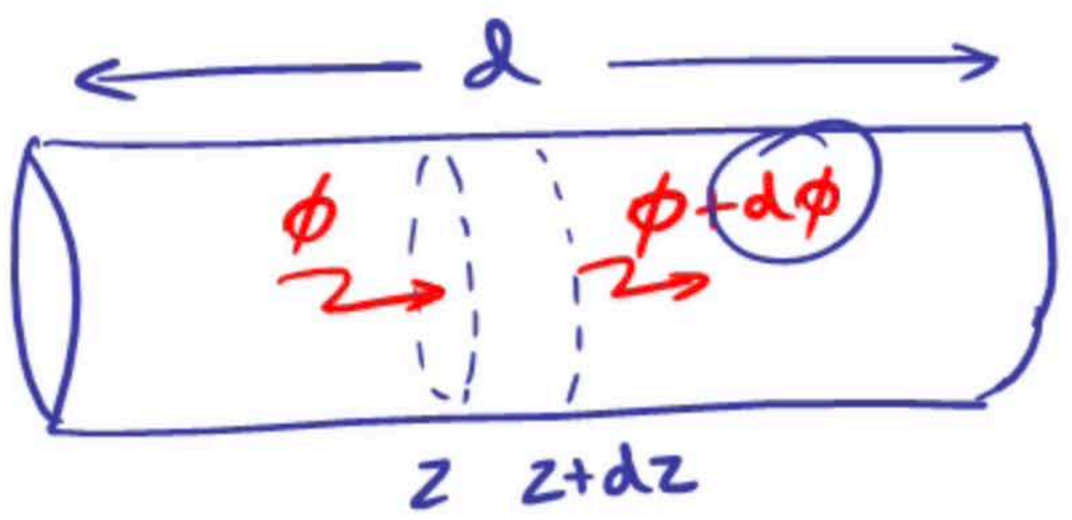
Noise figure $= \dfrac{(SNR)_{IN}}{(SNR)_{OUT}}$

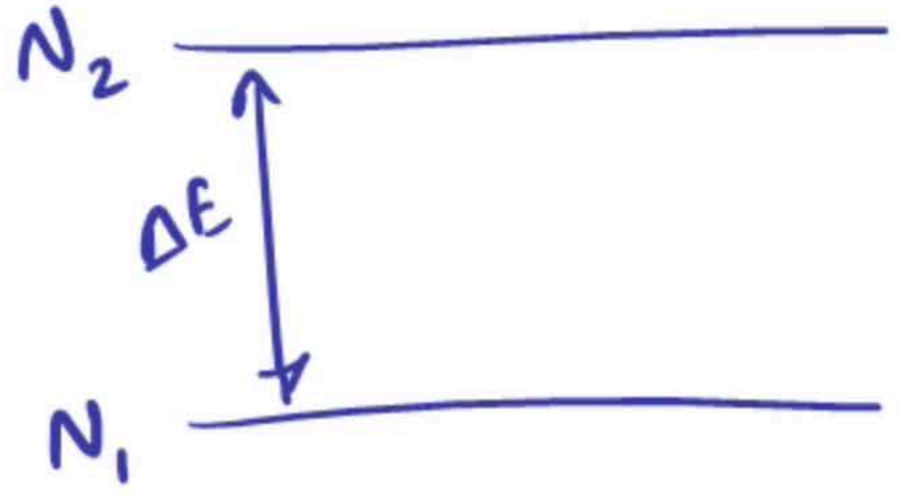


Attenuation 0.2 dB/km

@ $\lambda = 1550$ nm







Assume spontaneous emission is negligible

Absorption @ rate $N_1 W_i$ where $W_i = \phi\,\sigma(\nu)$

Transition cross-section

$$\sigma(\nu) = \frac{\lambda^2}{8\pi t_{sp}} g(\nu)$$

Stimulated emission @ rate $N_2 W_i$

Net Flux, $d\phi = N . W_i \, dz$ where $N = N_2 - N_1$ $\quad N\sigma$

$$\frac{d\phi}{dz} = N . \phi(z) . \sigma(\nu) \Rightarrow \phi(z) = \phi(0) . \exp\left[\gamma(\nu) . z\right]$$

$$\boxed{\text{Gain} = \frac{\phi(d)}{\phi(0)} = \exp\left[\gamma(\nu) . d\right]}$$