4.2 Essentials for the amplification of electromagnetic radiation

We now investigate a system of atoms in a cavity.
Question: At which conditions do we find an amplification of radiation?
Answer: When the number of emissions is larger than the number of absorption's! i.e.

$$\frac{N_2 B_{21}\varrho(\omega) + N_2 A_{21}}{N_1 B_{12}\varrho(\omega)} = \frac{N_2}{N_1}\left(1 + \frac{A_{21}}{B_{12}\varrho(\omega)}\right) > 1 \qquad . \tag{4.19}$$

Independent of $\varrho(\omega)$ we get this condition if

$$N_2 > N_1 \qquad . \tag{4.20}$$

This is a direct consequence of

$$B_{12} = B_{21} \qquad . \tag{4.21}$$

For thermodynamic equilibrium we find at room temperature with $\hbar\omega \approx 2\text{eV}$

$$\frac{N_2}{N_1} = \exp\left(-\frac{\hbar\omega}{kT}\right) \approx 10^{-34} \tag{4.22}$$

- The condition $N_2 > N_1$ is called inversion.
- Only for systems far from thermodynamic equilibrium this inversion state can exist.
- $N_2 > N_1$ corresponds to a negative temperature.