Semester S1 – Fundamentals of coherent optics

Fiber amplifiers, tutorial #3

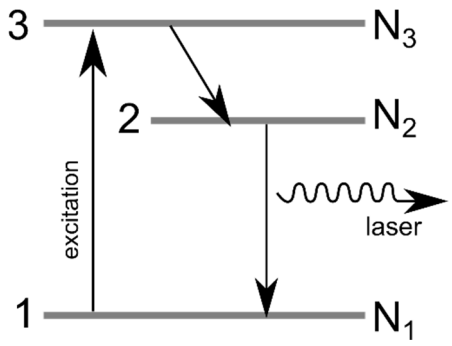
I Two-level laser system

1. Considering both stimulated transitions and spontaneous relaxation, establish the rate equations for a two-level laser system.

2. Show that, at steady state, population inversion cannot be achieved.

3. Saturation of the population difference
   a. Show that, at steady state, $\Delta N/N$ saturates when the signal intensity increases. Define W_{sat}, the value of the stimulated transition probability at which the population difference is driven down to exactly half its initial value.
   b. Draw $\Delta N(W_{12})$ for a medium doped with atoms with τ = 1 ms in concentration N = 10^{25} m^{-3}.

II Three-level laser system

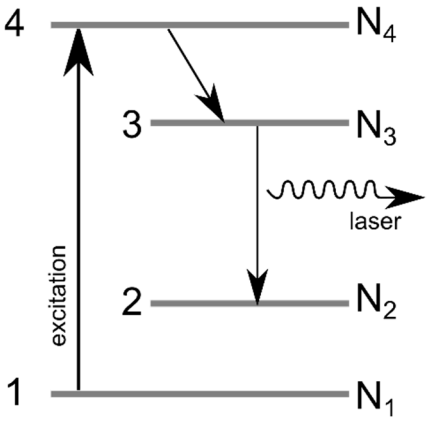


1. Establish the rate equations for a three-level laser system.

2. Show that, at steady state, population inversion occurs for a pumping rate W_{13} higher than a threshold value W_{pt} to be determined.

3. Establish a relation for $\Delta N(W_{13})$ for a medium doped with atoms with τ = 1 ms in concentration N = 10^{25} m^{-3}. Plot on the same figure $\Delta N(W_{1j})$ for the two-level system (j = 2) and the three-level system (j = 3).

III Four-level laser system



1. Establish the rate equations for a four-level laser system.

2. Show that, at steady state, population inversion occurs as soon as pumping is supplied.

3. Establish a relation for $\Delta N(W_{14})$ for a medium doped with atoms with $\tau = 1$ ms in concentration $N = 10^{25}$ m^{-3}. Plot on the same figure $\Delta N(W_{1j})$ for the two-level system ($j = 2$), the three-level system ($j = 3$) and the four-level system ($j = 4$).