SIMPLE RATE EQUATIONS IN A TWO - LEVEL LASER SYSTEM

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Introduction

"LASER" is an acronym for "**L**ight **A**mplification by **S**timulated **E**mission of **R**adiation." The laser is a light source that exhibits unique properties such as directionality, monochromaticity and coherence [Eleccion, 1972]. These properties easily distinguish the laser from any other source of light hence has found a wide variety of applications in modern technology. Lasers have become a subject of research to date. In this essay the writer is going to discuss rate equations in a simple two - level laser.

Quantum theory in a two - level laser system

Consider a molecule with two quantised states represented with Ψ_1 and Ψ_2 and energy of the states E_1 and E_2 where $E_2 > E_1$.

Figure 1: Atom irradiated by white light with N_2 atoms in level 2 and N_1 atoms in level 1.

In order for a laser to produce an output, more light must be producedby stimulated emission than is lost through absorption. For this process to occur, more atoms must be in energy level E_2 than in level E_1 which does not occur under normal circumstances, this process is called "*population inversion.*"

Under the action of the incident electromagnetic field, the atoms at upper level have a certain possibility to jump to the corresponding lower levels, emitting photons with the same frequency, direction and phase with the incident waves. This process is called "*stimulated emission*"[Svelto, 1998].

Another process which occurs in a laser is *absorption.* A photon strikes an atom in energy state E_1 and is absorbed by that atom. The photon ceases to exist and its energy appears as increased energy in the atom, which moves to the E_2 energy level.

Spontaneous emission - is a random process, atoms emit light spontaneously independent of any external influence.

The transition rates of the three processes are:
Spontaneous emission($2 \rightarrow 1$)

$$\frac{dN_2}{dt} = -AN_2$$

where A is the decay rate $= \frac{1}{\tau}$

Stimulated emission ($2 \rightarrow 1$)

$$\frac{dN_2}{dt} = -B_{21}N_2u(\nu)$$

where B_{21} is a constant.
$u(\nu)$ is the energy density.

Absorption ($1 \rightarrow 2$)

$$\frac{dN_2}{dt} = B_{12}N_2u(\nu)$$

where B_{12} is a constant.
$u(\nu)$ is the energy density.

Adding them up:

$$\frac{dN_2}{dt} = B_{12}N_2u(\nu) - B_{21}N_1u(\nu) - AN_2 = -\frac{dN_1}{dt}$$

since absorption and stimulated emission are inverse processes therefore:

$$B_{12} = B_{21} = B$$

The above equation can be written as:

$$\frac{dN_2}{dt} = -\frac{dN_1}{dt} = B(N_1 - N_2)u(\nu) - AN_2$$

To predict the behaviour of a laser we should understand the dynamics of evolution of population between quantum levels $(N_1, N_2, N_3, ...)$.

References

M. Eleccion. The family of lasers. *IEEE Spectrum*, March 1972.

Svelto. *Principles of Lasers*. McGraw Hill, 1998.