

Objectives: Understanding how a laser works and explaining its main properties.

I. Introduction

Watch the French CNRS video "les 50 ans du laser" (<http://www.maniplaser.com/>) and answer the following questions:

1. What does LASER mean?
2. What did Einstein discover in 1905 concerning light?
3. What principle, proposed by Einstein, is at the root of laser?
4. When was the first laser carried out?
5. Quote a few examples of laser.
6. Quote a few examples of applications of laser.
7. What is the principle of laser?



- What is pumping? How can the emitted light be amplified? Why is the optical amplifier placed between two mirrors?
8. What are the main properties of the light emitted by a laser?

II. Understanding how a laser works

Open the following animation: <http://phet.colorado.edu/en/simulation/lasers>.

1. How can an atom emit a radiation?

In this part, you will work with a single atom, two energy levels and you won't activate the mirrors.

The parameters that you can change are: the incident photon flow (Lamp Control), the wavelength of the photons, the lifetime of an atom in the excited state, the energy level E_2 of the excited state of the atom.

Remark:

In the simulation we can use a single step mode by clicking on the pause button.

a. Absorption and spontaneous emission

Adjust the parameters settings to get absorption of photons and spontaneous emissions of photons.

Absorption

- Under which condition is a photon absorbed by the atom?
- Illustrate this condition with a diagram showing the two energy levels of the atom: E_1 (ground level = lowest level of energy of the atom) and E_2 (excited state = upper level of energy).
- Show the transition by using an arrow and draw the absorbed photon.

Spontaneous emission

- What can be said about the frequency of the emitted photon? What can be said about its wavelength?
- Draw a diagram including the two energy levels of the atom E_1 and E_2 .
- Show the transition by using an arrow and draw the emitted photon.

b. Stimulated emission

Change the parameters settings to get a stimulated emission.

- Draw another diagram showing the two energy levels of the atom E_1 and E_2 .
- Indicate the transition by using an arrow. Draw the photon that causes the stimulated emission and the one that is emitted.
- What are the common properties of these photons?

2. How does a laser work?

a. Optical pumping and population inversion

In order to further a stimulated emission, it is necessary to maintain more atoms in a same excited level than in the ground one. This is called: population inversion.

In this part, you will work with several atoms, three energy levels and you won't activate the mirrors.

Adjust the settings to get a population inversion between the levels 1 and 2.

- Draw a diagram representing the three energy levels of the atom: E_1 , E_2 and E_3 .
- Show the transitions by using arrows.

b. Amplification

Select the mirrors.

Adjust the parameters to create a functional laser.

- What is the function of the two mirrors?
- Why do they allow the amplification of the laser beam?

c. Properties of the beam

- What are the main properties of the light beam?

Studying a ruby laser

In a ruby laser, chromium ions Cr^{3+} are excited to the E_3 level. A fast transition takes place to the E_2 level. Finally a photon stimulates the transition from this E_2 level to the ground one.

- Calculate the wavelength of the light radiation emitted by this laser.

- In which area of the light spectrum is it located?

Data: $1\text{eV} = 1.60 \cdot 10^{-19}\text{ J}$; $h = 6.63 \cdot 10^{-34}\text{ J}\cdot\text{s}$; $c = 3.00 \cdot 10^8\text{ m}\cdot\text{s}^{-1}$;

Energy levels: $E_1 = 0\text{ eV}$ and $E_2 = 1.79\text{ eV}$