

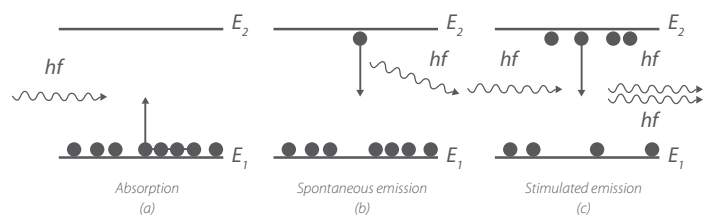
# Lasers – what are they and how do they work?

The name 'LASER' is an acronym for 'Light Amplification by Stimulated Emission of Radiation'. Let's look into the different words separately:

Light is an electromagnetic wave travelling at a speed of  $3.0 \times 10^8$  m/s. The wave model of light is, however, inadequate to describe the interaction with atoms and molecules. For this we describe light as a flux of photons. Each photon propagates at the speed of light and contains the energy  $E = hf$ , where  $f$  is the frequency and  $h$  is Planck's constant. So the higher a photon's energy, the higher the wave frequency will be.

Amplification is well known to all of us since it occurs in all electronics. A signal with a small amplitude, which is guided into an amplifier, shows up with several times higher amplitude at the output. Optical signals can be amplified by the process called stimulated emission, first described in 1916 and 1922 by Albert Einstein.

**Stimulated emission:** Irradiation of molecules or atoms may cause absorption of the light beam and we observe a decrease in the intensity of the beam. Say we have an atom with a ground state energy level  $E_1$  and excited state energy level  $E_2$  (see figure below). The energy of an absorbed photon excites an electron to jump from level  $E_1$  to  $E_2$  (a). The atom is unstable when in an excited state, so after a short while it loses the energy in the form of a photon, as the electron returns to energy level  $E_1$ . This photon is transmitted in any random direction (b). This process is called Spontaneous Emission. If we now have an already excited atom, and irradiate it with more photons of the right energy, it stimulates one of the electrons in energy level  $E_2$  to jump to  $E_1$  and emit its energy as a photon. This emitted photon is like a twin of the incoming photon. Both photons have the same propagation direction, energy (therefore frequency) and phase. This is called Stimulated Emission (c). The net effect is that we observe an increase in light intensity as the beam moves through the sample. The segment where this amplification takes place is called the optical amplifier.



For a laser to work, we need certain components: an optical amplifier, energy input and a resonator. A resonator is formed by two mirrors that are aligned to reflect light back and forth along the same path (the optical axis). One of these mirrors are, however, partially transmissive, to allow energy to escape out of the resonator in the form of a laser beam. Figure 2 (right) shows how the process starts. First you charge your optical amplifier with energy. Spontaneous emission gives off photons in all random directions. Eventually a photon will be emitted exactly along the optical axis of the resonator. Stimulated Emission increases the intensity, and the resonator makes this process repeat many times over, since it bounces back and forth along the optical axis. When photons reach the partially transmissive mirror, some of them exits the resonator as a laser beam.

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## Principle of laser startup

