Properties of Lasers

Modern Physics, Spring 2015


Background

I have chosen to write this report on the topic of lasers. Throughout the course I have learned about light by understanding its interaction with matter and behavior at the atomic level. I wanted to use this approach to learn about lasers.

Initial questions

- What are lasers?
- How are lasers different from other light sources?
- What are the practical uses of lasers?

Selected problem

I have narrowed down my question to "What properties of lasers make them different from other light sources in that they can be used in laser cutting and lithography?"

Own explanation (original hypothesis)

Lasers are light beams that are concentrated on one point. This precision as well as the focused energy is what gives lasers the ability to cut through material.

Critical evaluation

My hypothesis comes from observations from laser pointers or from what I’ve seen on TV. I want to understand what gives lasers the ability to cut through material unlike with other light sources.

Search results

A laser is defined to be “a device that projects a highly concentrated narrow beam of light which is amplified to great brightness using stimulated radiation”.

Sunlight is made up of different wavelengths, or colors, of light. Laser light however contains only one wavelength. This property makes lasers monochromatic, meaning of one color. Another property of lasers is that all the wavelengths are in phase, meaning they wave together. This property is called coherency. Laser light travels in the same direction, parallel to one another. This is what makes laser light beams very narrow and concentrated on one spot rather than spread out like with other light. This property makes lasers collimated.

**Stimulated Emission**

When an electron is excited from a lower to a higher energy level, it will eventually want to drop back to its lower energy state. When it does this, it will emit a photon. This process is called spontaneous emission. Stimulated emission is the process by which an incoming photon can interact with an excited atomic electron. This interaction creates a new photon of the same energy with identical phase, frequency, polarization and direction.

![Figure 1. Stimulated emission](image1)

This process however is exceeded by absorption, in which the energy of an absorbed photon causes an identical but opposite atomic transition. This is so because there are more electrons with lower energy states than in higher energy states. When population inversion is present, meaning there are more electrons in excited states than in lower energy states, the rate of stimulated emission exceeds that of absorption and optical amplification is possible. This is the precondition for light amplification in lasers. This is what gives lasers the property of coherence and the ability to continuously emit light.

![Figure 2. Light coherency](image2)

A laser makes many of atoms release trillions of photons all at once so they can line up to form a concentrated light beam. When a photon hits an already excited atom, the excited atom gives off two photons of light. This is called stimulated emission which amplifies the photon.

**Collimation**
The light from a laser is released as a thin beam concentrated on one spot. We say that the beam is highly collimated. This occurs because the cavity of the laser has two nearly parallel mirrors on the front and the back from which the atoms bounce back and forth. The back mirror is nearly perfectly reflected, while the front mirror is about 99% reflecting, letting out 1% of the beam. This 1% is the beam that we see. While the light is bouncing back and forth between the mirrors, it is gaining being amplified due to stimulated emission. This is displayed in the figure below.

Figure 3. Reflection of atoms in beam

Summary (New explanation)

A laser is a device that projects a highly concentrated narrow beam of light which is amplified using stimulated radiation. Lasers have three properties: coherency, collimation and monochromatic properties. These three properties of lasers produce a small focus point of intense power. This focused power is what makes laser light useful for cutting and welding. It is also possible to control laser light very precisely which is why it is useful for performing eye surgery.

Compared to other sources of light such as flashlights, electrical energy is converted into visible light. The light from lasers however is created by exciting electrons to higher states (light amplification). A flashlight will emit light by spontaneous emission, which is the process by which electrons emit photons when transitioning from a higher level state to a lower level state. Lasers emit light via stimulated emission which emits photons that are in phase with each other giving lasers the property of coherence. Light coming from a flashlight is not coherent. The coherent property of lasers is what allows it to travel long distances. Laser light can be beamed to the moon. Lasers also do not spread like the light from a flashlight would which makes it concentrated to one point.

Additional questions

What new questions raised based on your search?

- I looked mostly into the coherent and collimated property of lasers. I would like to figure out what gives lasers the monochromatic property.

References


