

Lasers and LEDs

Observations about Lasers and LEDs

- Lasers and LEDs often have pure colors
- Lasers produce narrow beams of intense light
- Lasers are dangerous to eyes
- Reflected laser light has a funny speckled look

3 Questions about Lasers and LEDs

- How does laser light differ from regular light?
- How does a laser produce coherent light?
- How does an LED produce its light?

Question 1

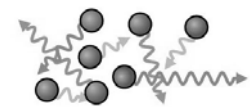
- How does laser light differ from regular light?

Light: Photons and Waves

- Electrons obey the Pauli exclusion principle
 - Each wave mode can have only one unique electron.
 - That result gives structure to atoms and materials
- Photons don't obey the Pauli exclusion principle
 - Each wave mode can have many photons
 - A radio wave has many photons in a single wave
- Most light sources produce photons randomly
 - Each photon usually has its own wave mode
 - But laser light is an exception!

Spontaneous Emission

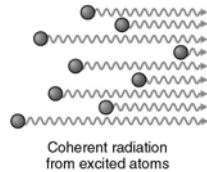
- Excited atoms normally emit light spontaneously
- These photons are uncorrelated and independent
- Each photon has its own wave mode
- These independent waves are incoherent light



Incoherent radiation from excited atoms

Stimulated Emission

- Excited atoms can be stimulated into duplicating passing light
- These photons are correlated and identical
- The photons all have the same wave mode
- This single, giant wave is coherent light

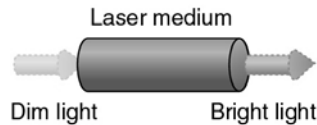


Question 2

- How does a laser produce coherent light?

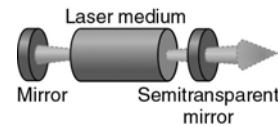
Laser Amplification

- Light can be amplified using stimulated emission
 - Excited atom-like systems can act as a laser medium
 - That medium will duplicate any photons that have the right wavelength, polarization, and orientation
 - This duplication is perfect: the photons are true clones
- This light amplification is the basis for lasers



Laser Oscillation

- A laser medium can amplify its own light
 - A laser medium in a resonator acts as an oscillator
 - It duplicates its one of its own spontaneous photons
 - Duplicated photons leak from semitransparent mirror
- The photons from this oscillator are identical



Properties of Laser Light

- Coherent – identical photons
- Controllable wavelength/frequency – colors
- Controllable spatial structure – narrow beams
- Controllable temporal structure – short pulses
- Energy storage and retrieval – intense pulses
- Giant interference effects
- But apart from all this, laser light is still just light

Examples of Lasers

- Gas lasers (powered by discharges)
 - Helium-neon lasers (red, green, yellow)
 - Carbon dioxide lasers (infrared)
- Solid state lasers (powered by current or light)
 - Diode lasers (red, blue, infrared)
 - Ruby lasers (red)
 - Nd:YAG lasers (infrared)
 - Ti:Sapphire lasers (infrared)

Question 3

- How does an LED produce its light?

Light-Emitting Diodes

- LEDs are Light-Emitting Diodes
 - They conduct current only in one direction
 - Each charge releases energy on crossing pn-junction
 - That energy is often emitted as a photon of light
- For LEDs to emit higher-energy photons,
 - they must be designed to have larger band gaps
 - they must be supplied with larger voltage drops
- Laser diodes are LEDs that can amplify light.

Summary about Lasers and LEDs

- Lasers produce coherent light by amplification
- Coherent light contains many identical photons
- Laser amplifiers and oscillators are common
- LEDs are incoherent, light-emitting diodes