Lasers and LEDs

Introductory Question

- In movies, laser beams are always shown as bright pencils of light streaking through the air or space. If you were to look from the side at a beam from a powerful laser, would you be able to see that laser beam as it travels past you?

A. Yes
B. No
C. Yes in air, No in space

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

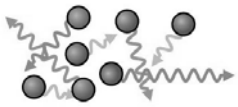
- How does laser light differ from regular light?

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 photons has its own wave mode
- These independent waves are incoherent light



Incoherent radiation from excited atoms

Clicker Question

- If you split the beam from a flashlight into two beams and overlap those beams on a white screen, can you see interference effects?

A. Yes, because the beams contain light waves
B. No, because there are too many independent light waves
C. No, because the beams don't contain waves.

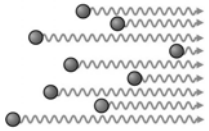
Clicker Question

- Atomic orbitals are electron standing waves and don't change with time. When a light wave passes an atom, its electrons

A. remain in their atomic orbitals and the atom is unchanged by the passing wave.
B. move into mixtures of orbitals, allowing the atom to polarize with the wave's electric field.

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



Coherent radiation from excited atoms

Clicker Question

- If you split the beam from a laser pointer into two beams and overlap those beams on a white screen, can you see interference effects?

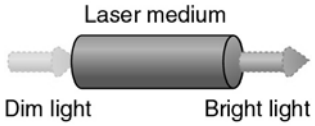
A. Yes, because the beams contain light waves
B. No, because there are too many independent light waves
C. No, because the beams don't contain waves.

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



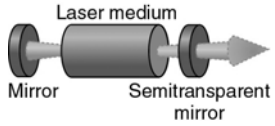
Clicker Question

- If you place mirrors around a laser medium,

A. nothing will happen because the mirrors will prevent light from reaching the laser medium.
B. a photon emitted spontaneously by the laser medium will be duplicated endlessly.

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

Introductory Question (revisited)

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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?

Clicker Question

- When electrons cross a diode's pn-junction from n-side to p-side, they are in the conduction band. They leave the p-side in the valence band. Shortly after crossing the junction, each electron

A. releases energy by dropping from the conduction band to the valence band.
B. absorbs energy by rising from the conduction band to the valence band.

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