Advanced LED and LASER Structures Including Quantum Well Structures, and Applications

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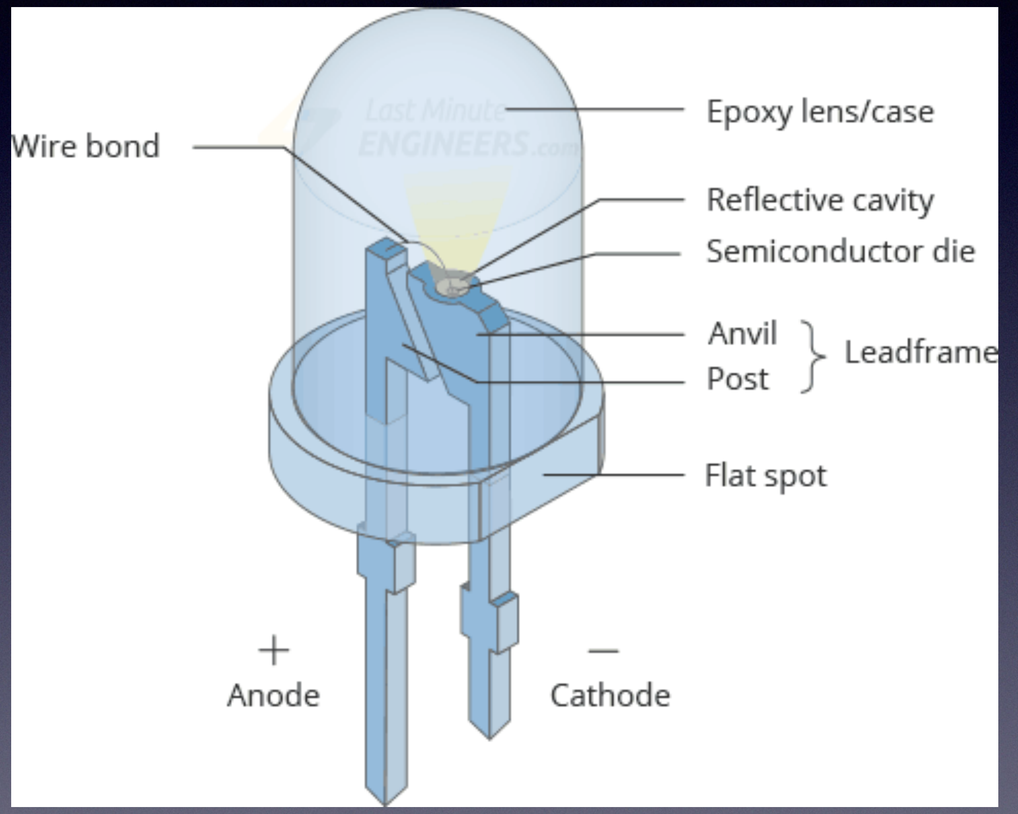
Abstract: This presentation discusses LED and Laser diodes, some of their main structures, and their advantages and disadvantages.

Outline

- Definition and specifications of LED and LASER
- Quantum wells structure
- Edge and Surface emissions
- 4 main structures
- Advantages, disadvantages, applications
- Summary
- References
- 5 Key topics

LEDs

- Light emitting diode : a semiconductor light source that emits light when current flows through it
- Consists of P-n junction diode: emits light when forward biased
- Emits incoherent light over wide spectral range
- LED are mostly monochromatic
- Significantly divergent
- LED can be manufactured to emit all wavelength of visible spectrum
- Spontaneous emission



LED Categories

- Low current
- Standard
- Ultra high output

LED

Advantages

- Small in size and light in weight
- Long lifetime
- Low power consumption
- Energy efficiency because they consume low energy

Disadvantages

- Sensitive to temperature
- High initial cost
- Potential color shift

Uses and applications of LED

- Used in most lighting devices
- Can be used in aviation lighting
- Used in car headlamps
- All smartphones and cameras and most electronic devices have LED
- Used in major appliances like TVs

LASER

- Light amplification by simulated emission of radiation
- Stimulated emission which occurs when a photon at a certain frequency interacts with an excited electron and drops to a lower energy level
- Semiconductor diodes that are pumped with current at the p-n junction
- Consist of single wavelength
- Highly coherent
- Also produce monochromatic light

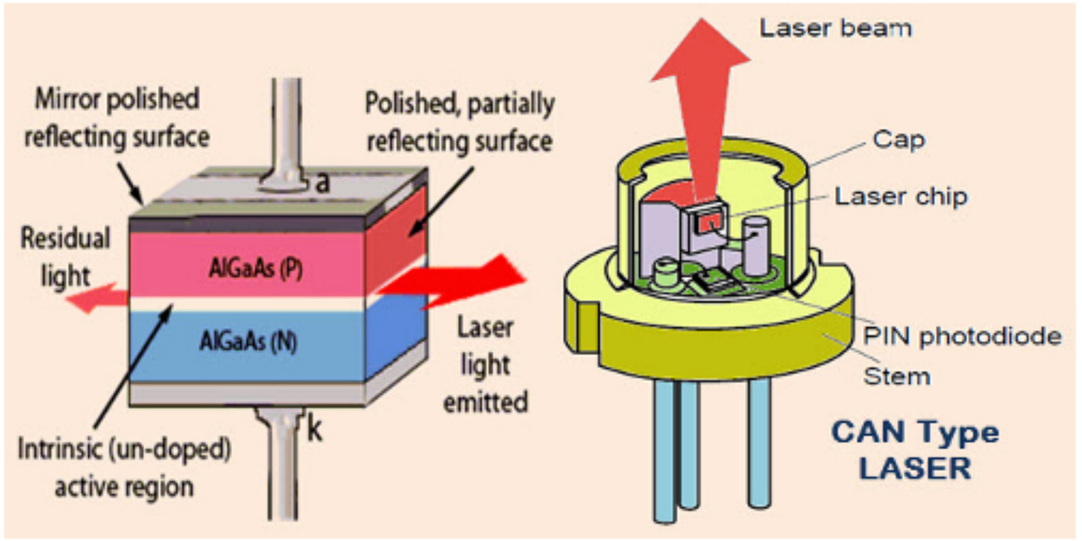


Image is from www.elprocus.com

LASER

Advantages

- High coupling efficiency
- Can be used in high temperatures
- Produces high optical power

Disadvantages

- Expensive
- Have overheating problems
- Produce divergent beam

Uses and Applications of laser diode

- Good for distance measuring due to high coherence
- Used in telecommunications due to narrow spectral qualities
- Used for Laser printers, DVD readers, and DNA sequencing technology

4 main structures

- Homostructure
- Heterostructure
- Double heterostructure
- Quantum Wells

Homostructure

- Consist of P-n homojunction
- P and n junctions are both doped heavily
- Thickness of the active region is a few micrometers

*Active region is where electrons and holes coexist

Heterostructure

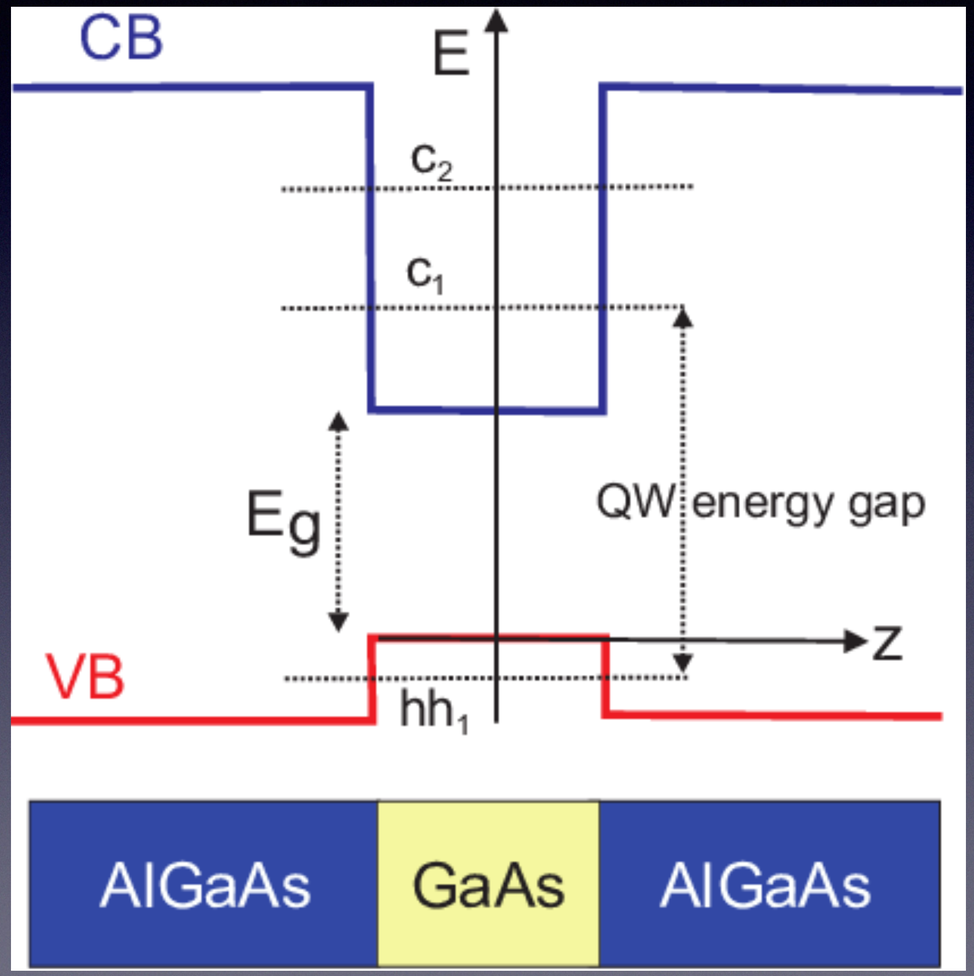
- P-p heterojunction replaces p region in order to restrict diffusion
- That results in a P-p-n junction
- Causes a defined active layer in p region

Double heterostructure

- Could be P-p-N or P-n-N
- Creates a heterojenction on each side of the active region
- Has an active region of 100-300 nm
- High efficiency and high optical gain

Quantum Well

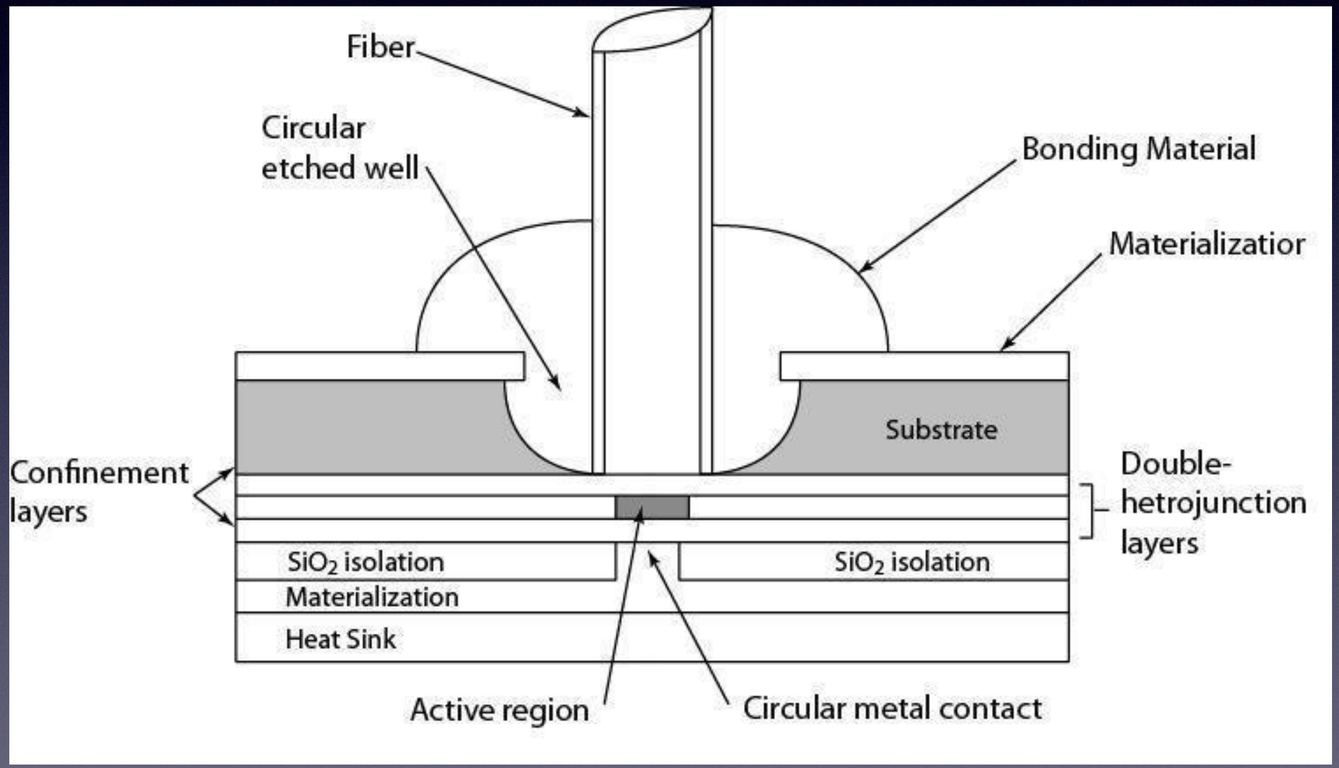
- Potential well with different energy levels
- Thin layer confining electrons and holes
- A type of heterostructure that have smaller active region and are important in designing laser diodes
- Formed by embedding a material (example: Gallium Arsenide) between semiconductor layers of larger band gap(example: Aluminum Gallium Arsenide)
- Usually 5-20 nm thick
- Used as waveguides in laser diodes
- Can be used for high optical gain
- The emission wavelength depends on material
- Difficult to generate more than one color per laser



Surface emitting LED (SLED)

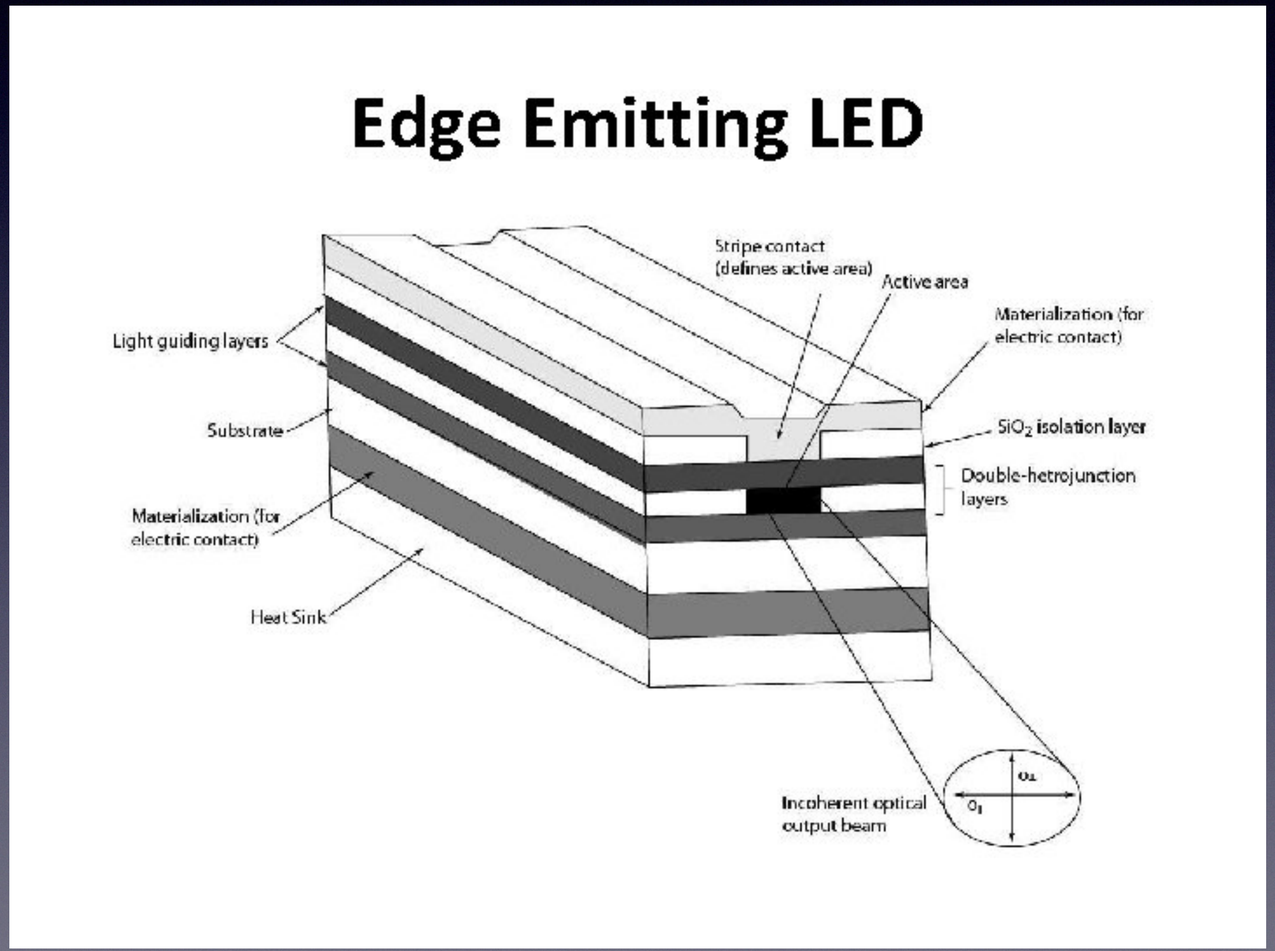
- Light emitting perpendicular to the junction plane
- Light is emitted over a wide angle
- The primary active region where photons are emitted has a diameter of 20-50 um
- Low thermal impedance in the active region allows for high radians emission into the optical fiber

*Active region is where electrons and holes coexist



Edge emitting LED (ELED)

- Light emitted parallel to junction plane
- Has high radiance
- Used in Optical communications
- Can be used for single mode and multimode fiber systems
- ELED can couple more power than SLED but have a smaller spectral range
- Light emits through the front facet while the back facet is highly reflective



Summary

- Light emission can either be from the edge or surface of the diode
- Light is usually emitted from the P-n junction
- Quantum well is a type of heterostructure
- 3 main categories for LED, Low current, standard and high output
- LED and LASER are usually monochromatic
- 4 main structures are Homostructure, Heterostructure, Double Heterostructure, and Quantum well

Sources

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5 Key points

- Stimulated emission occurs when a photon at a certain frequency interacts with an excited electron and drops to a lower energy level.
- In Quantum well structures, it is difficult to generate low wavelength, i.e colors in the mid to far infrared region.
- Edge emitting diodes emit light perpendicular to the junction plane and produce high output power.
- Surface emitting diodes emit light parallel to the junction plane and have a high range of wavelength
- Quantum wells structure are double heterostructure with a smaller active region