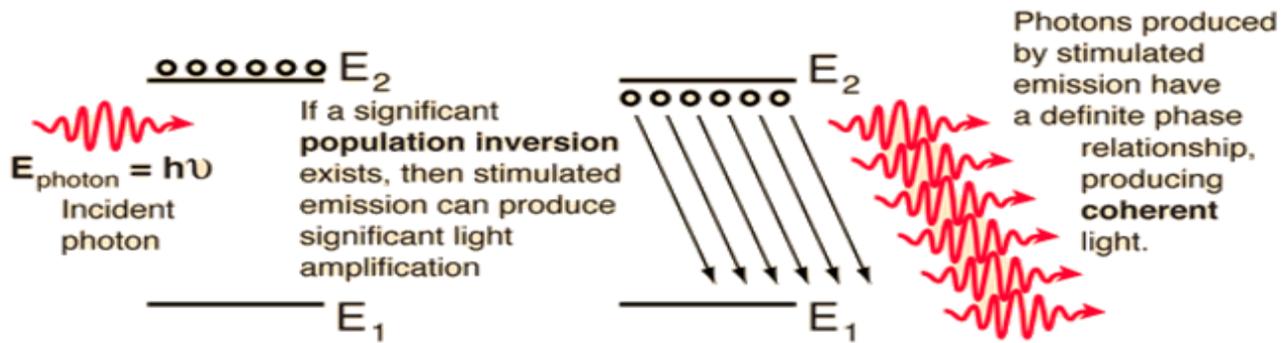
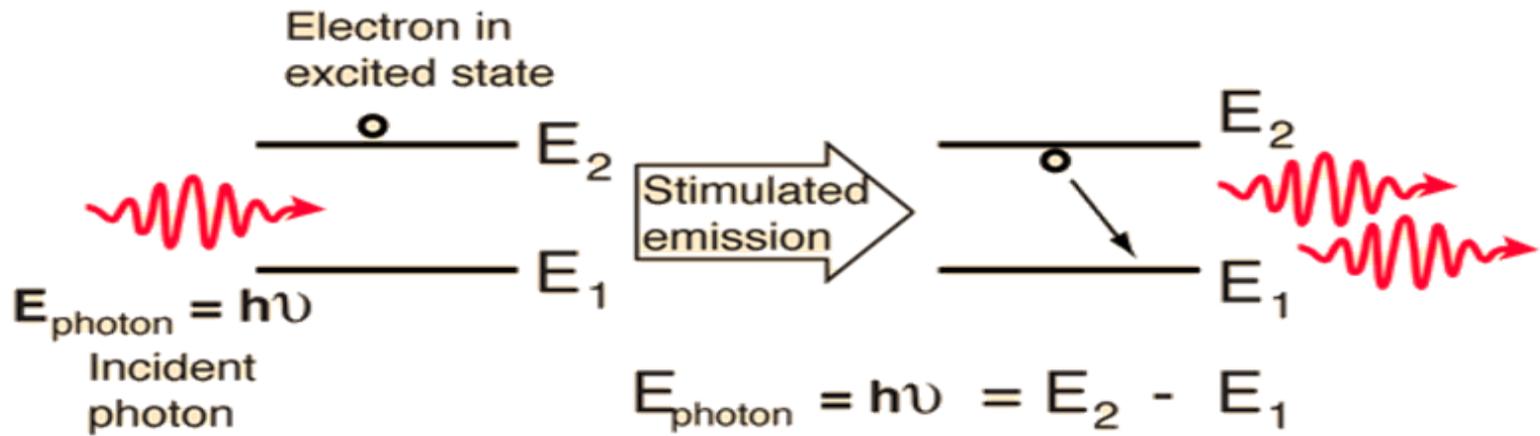


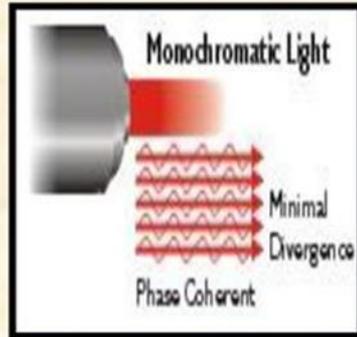
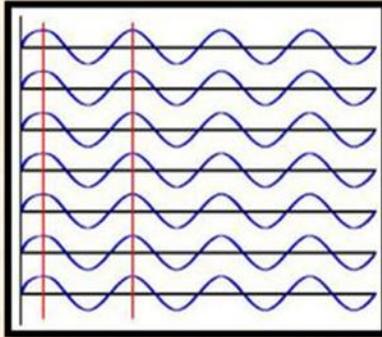
Optical Sources





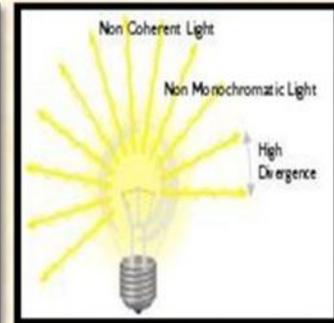
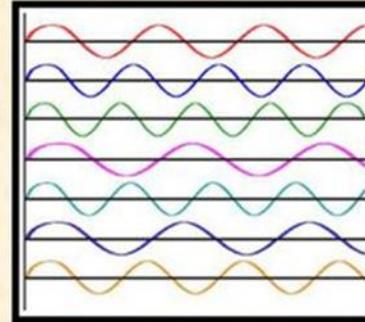
DIFFERENCE

LASER LIGHT



1. **Coherent** : in phase (in harmony)
2. **Collimated**: parallel
very narrow beam
no divergence
3. **Monochromatic**: single wavelength
single color
4. **Directional**: unidirectional
5. **Brightness** : extremely very high
power density

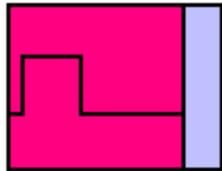
ORDINARY LIGHT



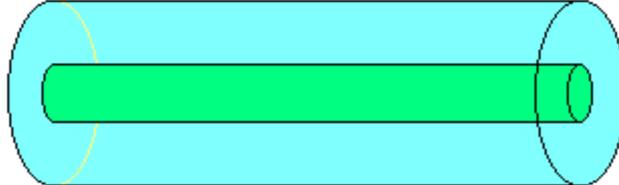
1. **Incoherent** : random phase
2. **Not collimated**: unparallel
very wide beam
high divergence
3. **Many wavelength**
Many color
4. **Multi directional**
5. **Brightness** : very low power density

OPTICAL FIBER Communication

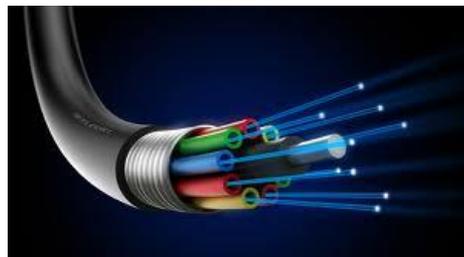
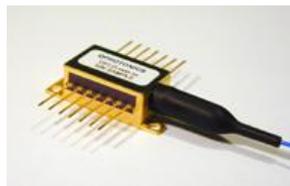
Optical Fiber



Tx optical Source



Rx optical detector



Types of Optical Fiber compatible Sources

- LED (Light Emitting Diodes)



- LASER

(Light Amplification by Stimulated Emission of Radiation)



LEDs

Emits incoherent light through spontaneous emission.

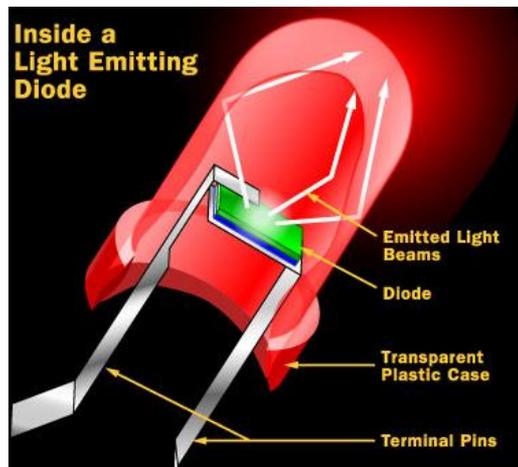
Used for Multimode systems with 100-200 Mb/s rates.

Broad spectral width and wide output pattern.

850nm region: GaAs and AlGaAs

1300–1550nm region: InGaAsP and InP

Two commonly used types: ELEDs and SLEDs



Optical Sources suited to Fiber Optic Communication:

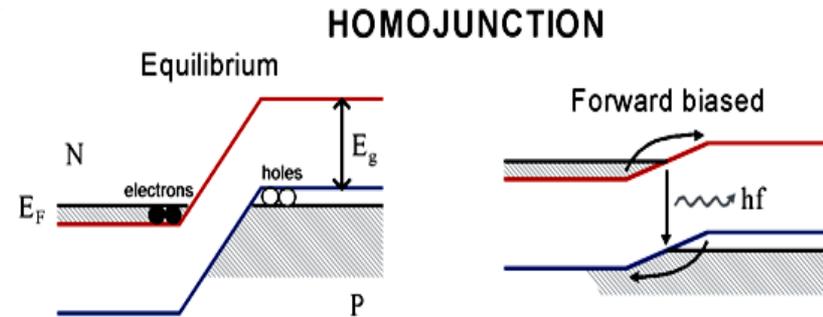
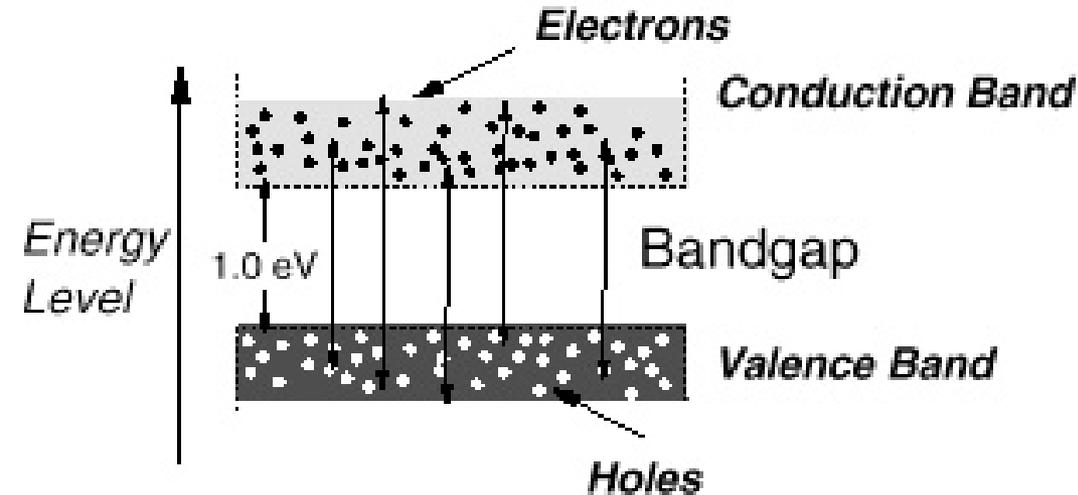
- **Light Emitting Diode (SLED, ELED, SLD)**
- **Semiconductor Laser (DFB, DBR, Vertical-Cavity Surface-Emitting Laser(VCSEL) , Multi Quantum Well , In-Fiber Lasers, Fiber Ring Lasers)**

Optical Source Requirements:

- **Dimensions to suit the optical fiber geometry**
- **Narrow radiation pattern (beam width)**
- **Ability to be directly modulated by varying driving current**
- **Fast response time**
- **Adequate output power to couple into the optical fiber**
- **Narrow spectral width**
- **Driving circuit issues**
- **Stability, Efficiency, Reliability and cost**

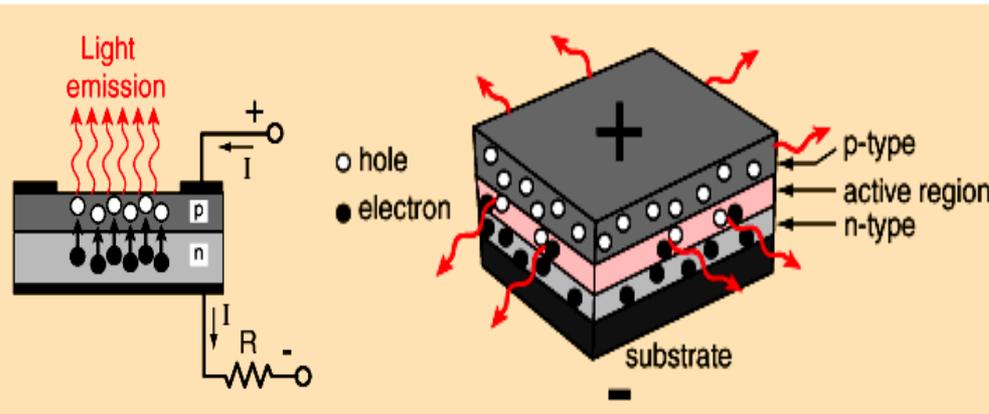
LED Basic operation

- A PN junction acts as the active or recombination region.
- When PN junction is forward biased, electrons and holes recombine either radiatively (emitting photons) or non-radiatively (emitting heat). This is simple LED operation.



- Emitted wavelength depends on bandgap energy
- Transitions take place from any energy state in either band to any state in other band. Results in a range of wavelengths produced (spontaneous emission). Typically the wavelength range is more than 80 nm.

Light Emitting Semiconductors



Material	Wavelength Range (μm)	Bandgap Energy (eV)
AlGaInP	0.61 - 0.68	1.82 - 1.94
GaAs	0.9	1.4
AlGaAs	0.8 - 0.9	1.4 - 1.55
InGaAs	1.0 - 1.3	0.95 - 1.24
InGaAsP	0.9 - 1.7	0.73 - 1.35

- Light is emitted at the site of carrier recombination which is primarily close to the junction.
- The amount of radiative recombination and the emission area within the structure is dependent upon the semiconductor materials used and the fabrication of the device.

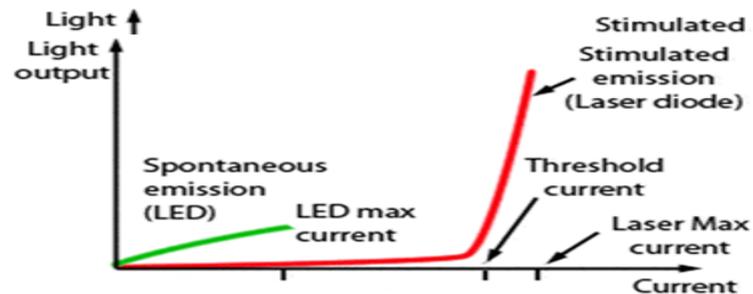
TYPES of LEDs

- Edge Emitting LED's
- Surface Emitting LED's

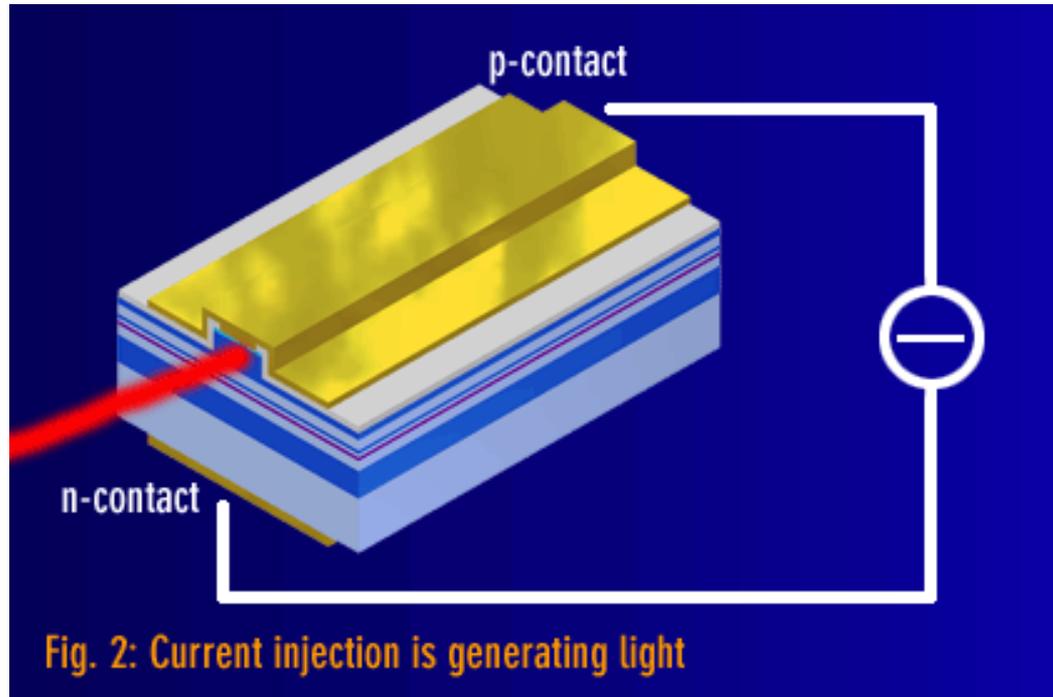
- Direct Band gap-

III V compounds like GaAlAs , GaAsP, InGaAsP

LED - Light emitting diode	LASER - Light amplification by stimulated emission of radiation
It is polychromatic	Highly monochromatic
It is not coherent	It is coherent
Spontaneous emission is responsible for it.	Stimulated emission is responsible for it.
Not directional	Highly directional
Feedback is not required in LED.	Proper feedback is essential in LASER to be treated as an optical source.

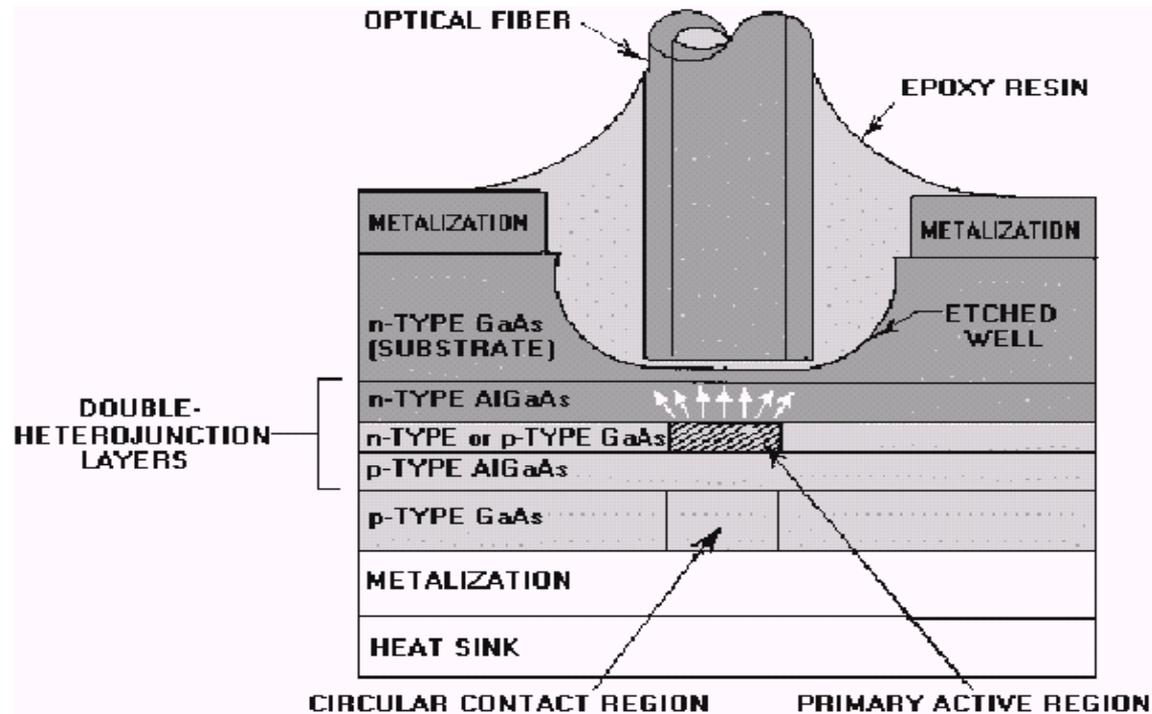


LEDs for FO Communication



- Coupling lens used to increase efficiency.
- Short optical Links with Large NA fibers.
- Data rates less than 20 Mbps.

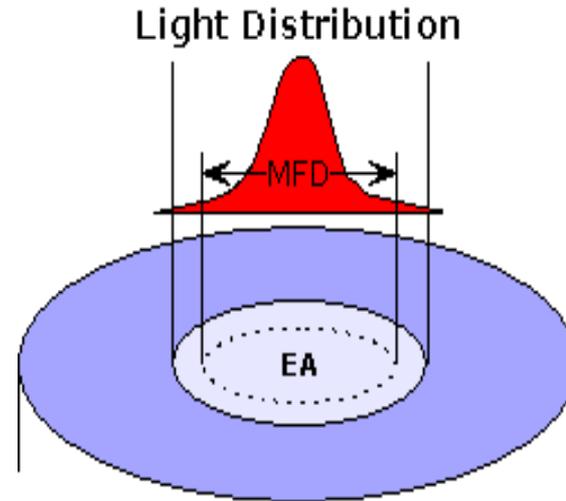
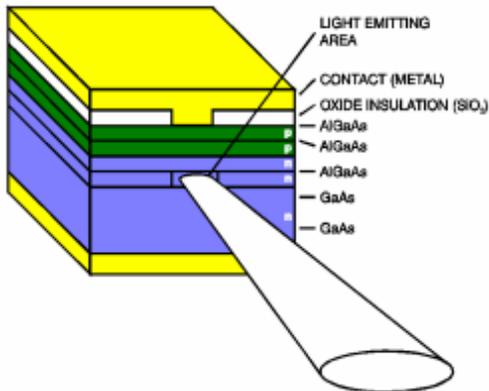
SURFACE EMITTING LED'S



- Coupling lens used to increase efficiency.
- Short optical Links with Large NA fibers.
- Data rates less than 20 Mbps.

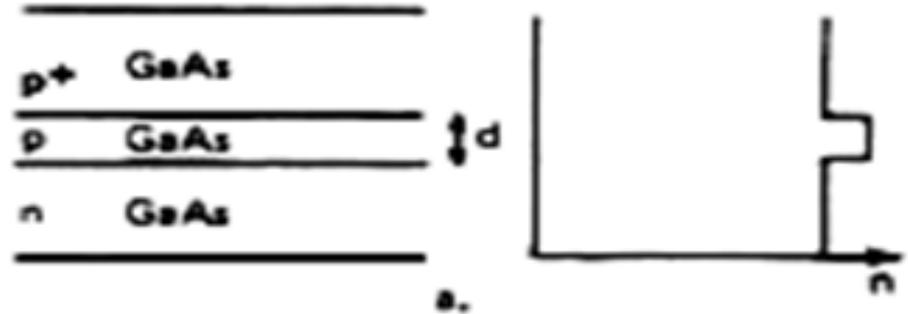
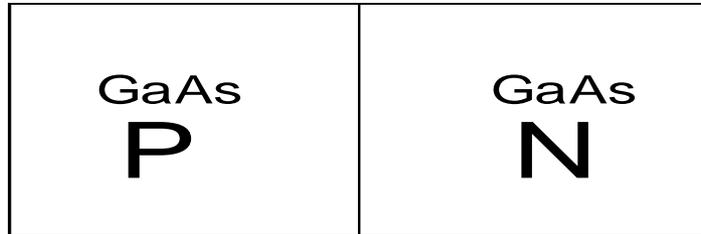
Edge Emitting LED's

Edge-emitting Diode: An LED that emits light from its edge, producing more directional output than surface-emitting LED's that emit from their top surface.



Effective Area: Light is not distributed in the fiber core uniformly. Rather, it follows a distribution that typically peaks in the center of the core and then tails off near the core-cladding interface. It usually extends some short distance into the cladding as well.

- **Homojunctions:** P- type and N-type from **same material**



- **Carriers are not confined**
- **Light is not confined**

Structure and index of refraction in gallium arsenide with a junction width d

- LED should have a high radiance (light intensity), fast response time and a high quantum efficiency for Fiber Optic Communication system

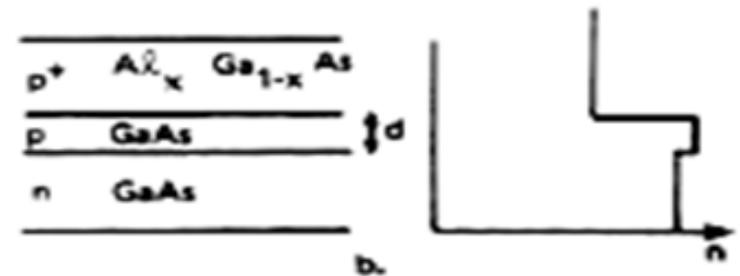
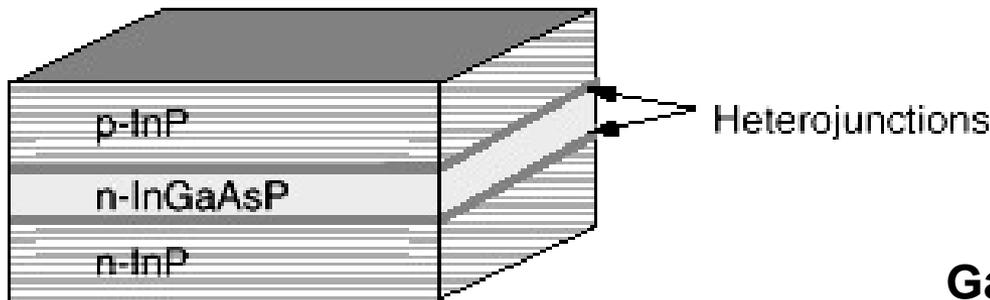
Heterojunction

- Heterojunction is the advanced junction design to reduce diffraction loss in the optical cavity.
- This is accomplished by modification in the material to control the index of refraction of the cavity and the width of the junction.
- The index of refraction of the material depends upon the impurity used and the doping level.
- The Heterojunction region is actually lightly doped with p-type material and has the highest index of refraction.
- The n-type material and the more heavily doped p-type material both have lower indices of refraction.
- This produces a light pipe effect that helps to confine the light to the active junction region. In the homojunction, this index difference is low and much light is lost.
- Double or single hetero-structure junction with better light output

Heterojunctions: Different p- and n- materials

- Carriers are confined
- Light is also confined
- Single Heterojunction, Double Heterojunction.

- A heterojunction is a junction between two different semiconductors with different bandgap energies.
- The difference in bandgap energies creates a one-way barrier. Charge carriers (electrons or holes) are attracted over the barrier from the material of higher bandgap energy to the one of lower bandgap energy.



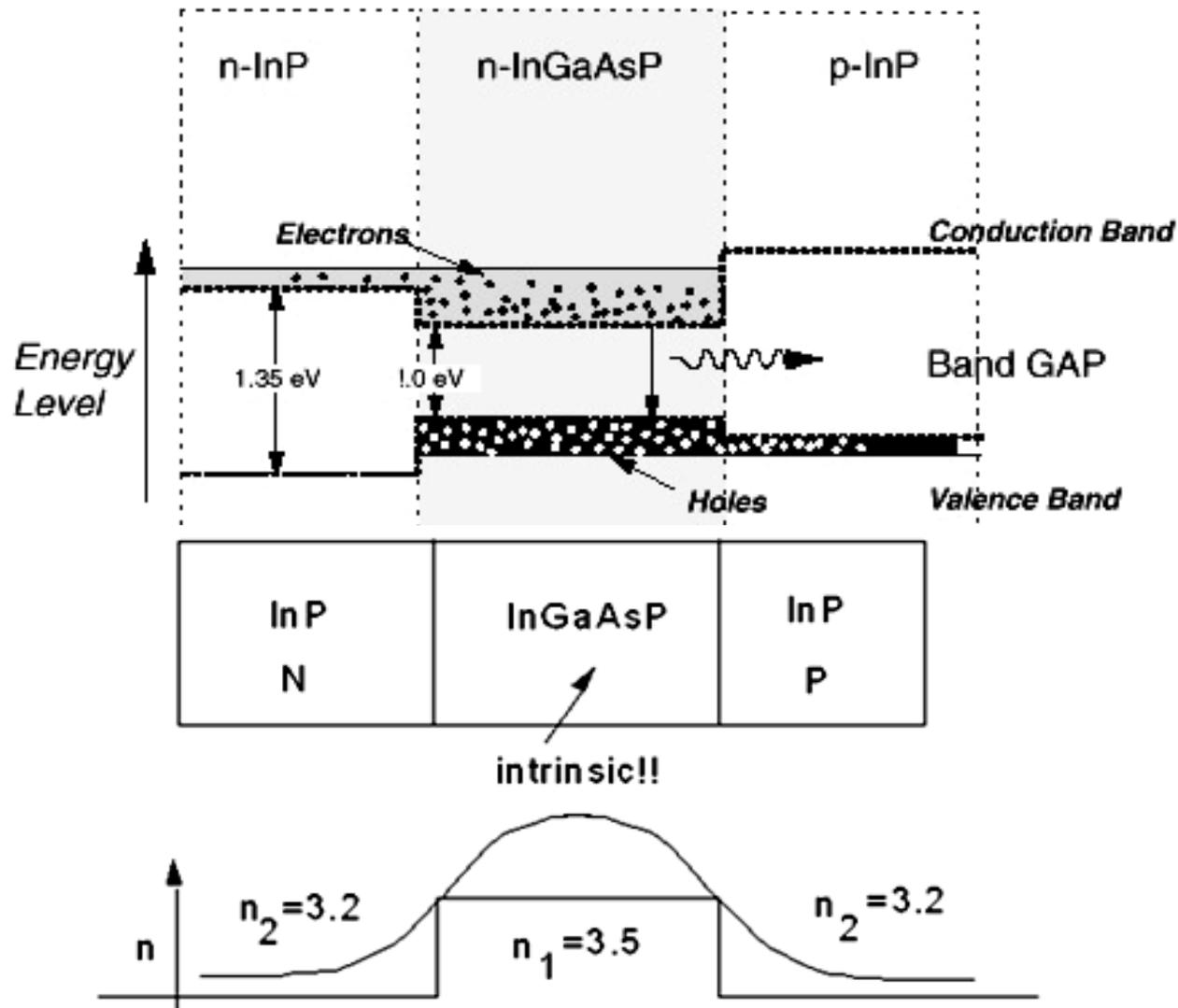
Gallium Arsenide-Aluminum Gallium Arsenide single heterojunction

Double Heterojunction

- When a layer of material with a lower bandgap energy is sandwiched between layers of material with a higher energy bandgap a *double heterojunction* is formed. This is called a double heterojunction because there are two heterojunctions present - one on each side of the active material.
- The double heterojunction forms a barrier which restricts the region of electron-hole recombination to the lower bandgap material. This region is then called the “active” region

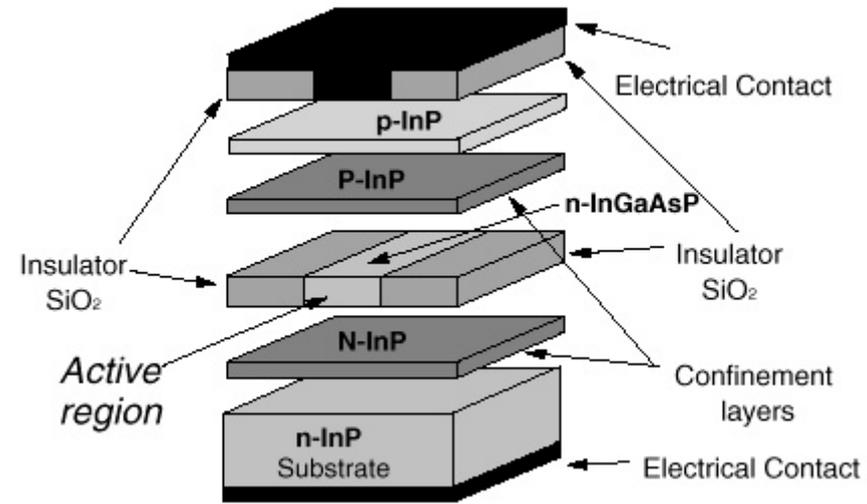
Double Heterojunction

- The valence band of n-InGaAsP is at a higher energy than the valence band of the adjacent n-InP. The conduction band is at a lower energy level.
- p-InP has higher energy levels than n-InP but the bandgap is the same



➤ Electrons are attracted across the left-hand junction from the n-InP to the n-InGaAsP.

➤ Holes are attracted across the right-hand junction from the p-InP into the n-InGaAsP.



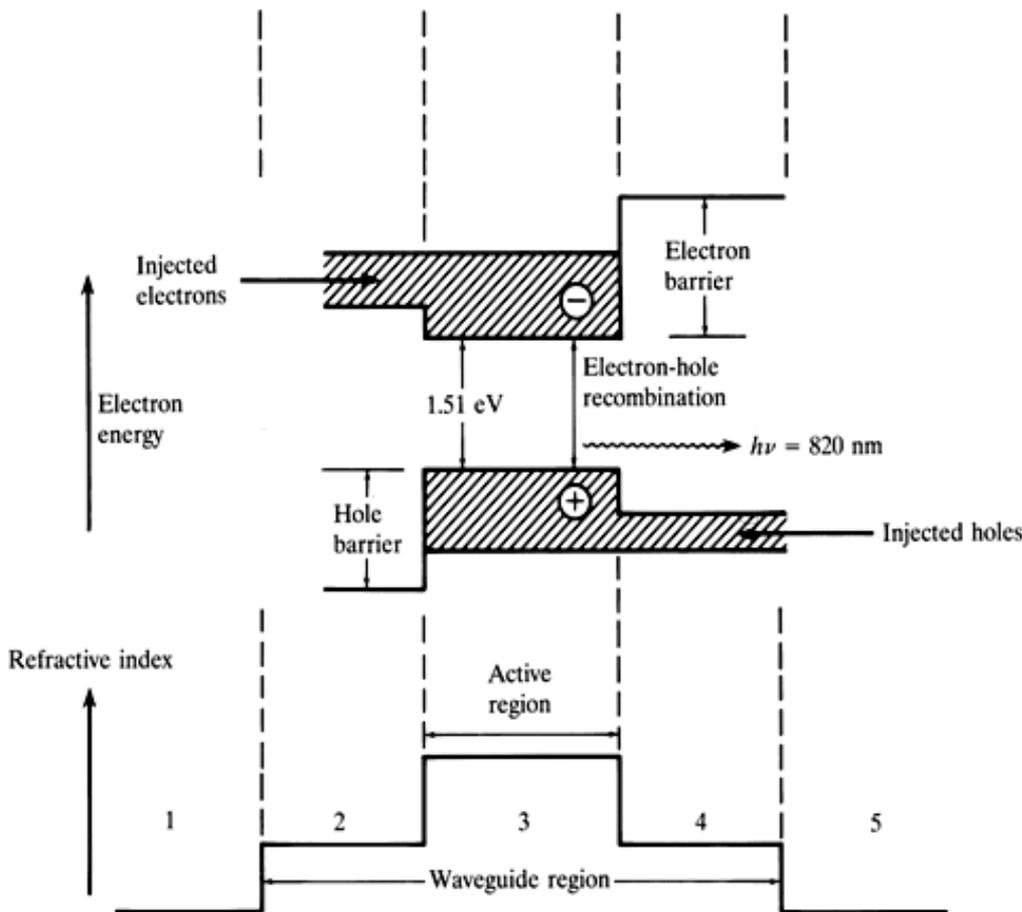
➤ Recombination takes place in the n-InGaAsP and spontaneous emission (or lasing) occurs.

➤ The heterojunction allows to have a small active region where the light is produced.

➤ The material in the active region has a higher refractive index than that of the material surrounding it. This means that a mirror surface effect is created at the junction which helps to confine and direct the light emitted.

Double Heterojunction

Metal contact	<i>n</i> -type GaAs substrate	<i>n</i> -type Ga _{1-x} Al _x As	<i>n</i> -type Ga _{1-y} Al _y As	<i>p</i> -type Ga _{1-x} Al _x As	<i>p</i> -type GaAs	Metal contact
		Light guiding and carrier confinement	Recombination region	Light guiding and carrier confinement	Metal contact improvement layer	
		~ 1 μm	~ 0.3 μm	~ 1 μm	~ 1 μm	



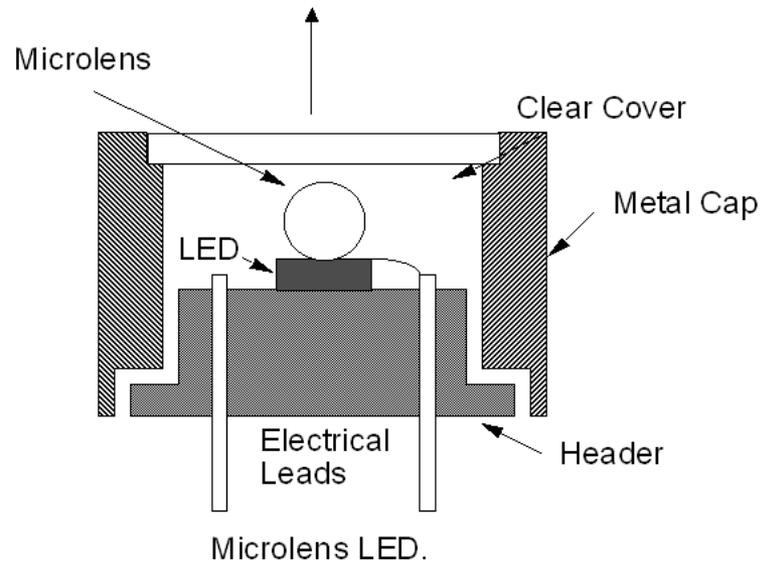
Confining and Guiding the Light within the Device

- Within the device the light must be confined and directed to the exit aperture so that it can be directed into the fibre which is done using insulating materials SiO₂ to confine the active region and the current path.
- The active region in a heterostructure has a higher refractive index.
- This junction forms a mirror layer and helps to confine the light to the active layer. For this reason, the outer layers are often called “confinement layers”

LED : Specifications of importance

- Optical Output Power
- Output Spectrum
- Light coupling into Fiber
- Modulation Bandwidth

Packaging – Microlensed LED



Thank you