(MPM-202) Optoelectronics and Optical Communication System

UNIT-II (Optical Sources and Detectors)

Lecture-1

by

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SYLLABUS

MPC-202 OPTOELECTRONICS AND OPTICAL COMMUNICATION SYSTEM Credits 4 (3-1-0)

UNIT I: Optical process in semiconductors

Optoelectronic properties of semiconductor: effect of temperature and pressure on bandgap, carrier scattering phenomena, conductance processes in semiconductor, bulk and surface recombination phenomena, optical properties of semiconductor, EHP formation and recombination, absorption in semiconductors, effect of electric field on absorption.

UNIT II: Optical sources and detectors

An overview of optical sources (Semiconductor Laser and LEDs), Optical Detectors: Type of photo detectors, characteristics of photo detectors, noise in photo detectors, photo transistors and photo conductors.

UNIT III: Optical fiber

Structure of optical wave guide, light propagation in optical fiber, ray and wave theory, modes of optical fiber, step and graded index fibers, transmission characteristics of optical fibers, signal degradation in optical fibers; attenuation, dispersion and pulse broadening in different types of optical fibres.

UNIT IV: Fiber components and optoelectronic modulation

Fiber components: Fibre alignments and joint loss, fiber splices, fiber connectors, optical fiber communication, components of an optical fiber communication system, modulation formats, digital and analog optical communication systems, analysis and performance of optical receivers, optoelectronic modulation.

Optical Sources : Introduction

- The optical sources are often considered to be the **active component** in an optical fiber communication system.

- Its fundamental function is to **convert electrical energy of a current into optical energy (light)** in an effective manner which allows the light output to be effectively launched or coupled into the optical fiber.

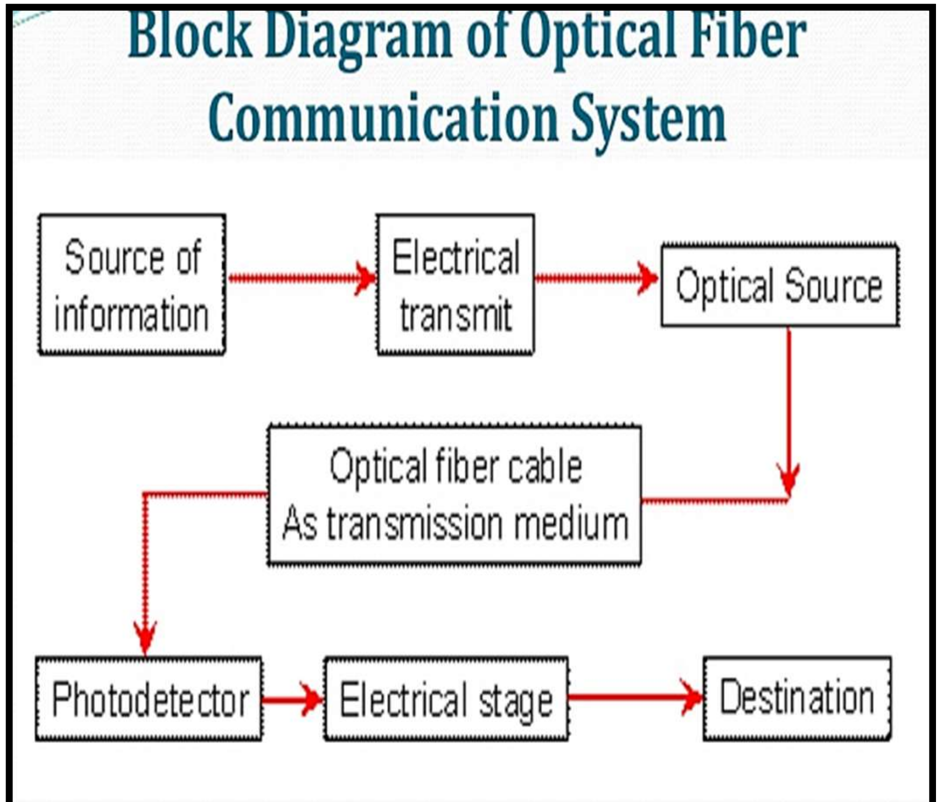


Figure: Basic Block Diagram of Optical Communication System

Optical Sources

- There are many light sources that are available in nature but all the light sources can not be used as optical sources because they have their own limitation-

- For example they **can not be switched on or off** so we can not modulate them.

- Also light sources are available with **large spectral width** therefore we can not use them in optical communication.

- The two major optical sources that are used in optical communication are **LASERs and LEDs.**

Source Characteristics

➢ Critical Parameters

- Emission wavelength
- Spectral width
- Modulation speed, amplitude and phase modulation capability
- Divergence/ability to couple into a fiber
- Power/energy consumption/efficiency
- Compactness, reliability, cost-effectiveness
- Possible sources : LEDs / Laser diodes

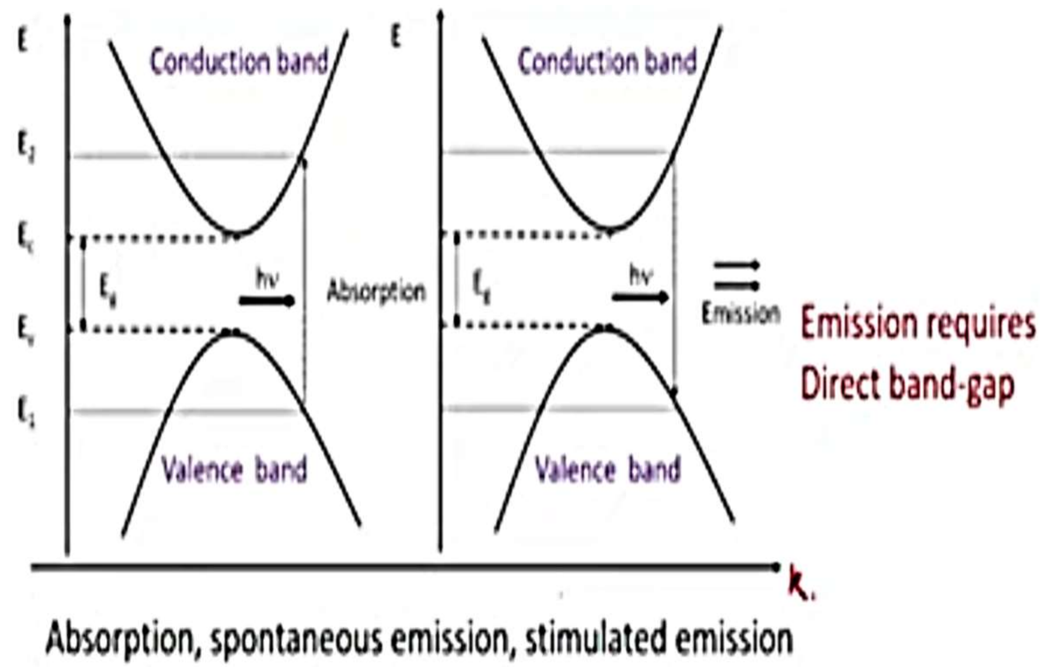
Light Matter Interaction in Semiconductor

- Energy and momentum is conserved.

- **Photo detectors : Absorption,**
  LEDs : spontaneous emission,
  Laser Diodes: Stimulated emission.

- Emission requires population inversion (electrons in conduction band, holes in valance band)

- Carriers (electrons) injected in the active layer
  - Carrier occupy C.B. leaving hole in V.B. & population inversion is created.



- No phase relation between emitted photon in spontaneous emission.

Efficiency of Carrier Recombination

- **Radiative Recombination**
  - Electrons and holes recombine to emit photons.
  - Recombination life time : τ_r , Recombination rate $R_r = {}^{n}/{\tau_r}$

- **Non-radiative Recombination**
  - Electrons and holes recombine to emit phonons.
  - Defect states, Auger Recombination
  - Recombination life time : τ_{nr} , Recombination rate $R_{nr} = {}^{n}/{\tau_{nr}}$

- **Nonradiative Recombination reduces the efficiency of photon generation.**

- **Internal Quantum Efficiency :**

$$\eta_{ext} = \frac{R_r}{R_r + R_{nr}} = \frac{\tau_{nr}}{\tau_r + \tau_{nr}}$$

Optical Sources

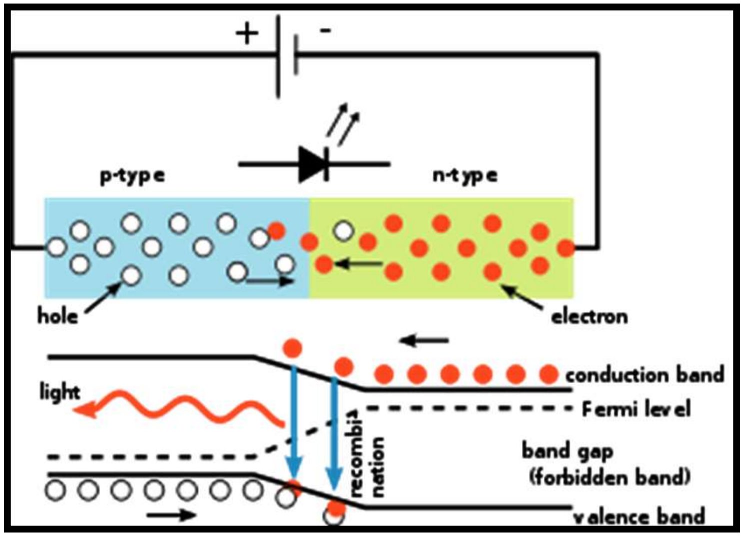
- The sources generally used in optical communication are-

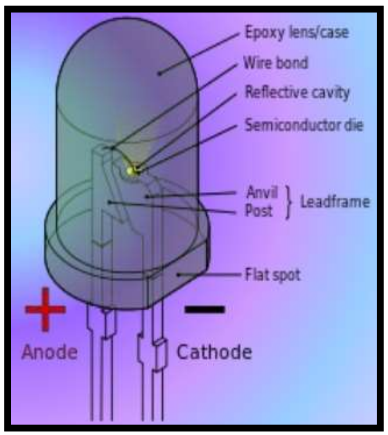
- **Light Emitting Diodes (LEDs)**
  - Simple, inexpensive
  - Incoherent, limited directionality
  - Large wavelength content

- **LASER Diodes**
  - High power
  - Highly coherent, highly directional
  - Small wavelength content
  - Complex structure
  - costly

Light Emitting Diodes

- A light-emitting diode (LED) is a semiconductor light source that **emits light when current flows through it**.
- Electrons in the semiconductor recombine with holes releasing energy in the form of photons.
- The **color of the light** (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the band gap of the semiconductor.
- **White light** is obtained by using multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device.

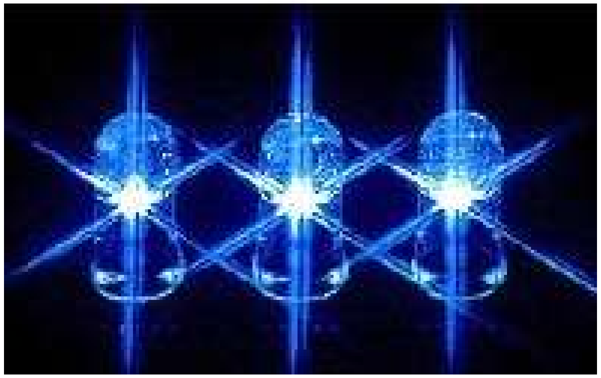




Advantages

Some important and beneficial feature of LEDs has been listed below-

- **Small size**
- **Low voltage**
- **Long life and robust**
- **Available in different colours**
- **Efficient**
- **Easily dimmable**
- **Environment friendly: no mercury**
- **Quick response/ instant start**



Semiconductor LASER

- **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation **(LASER).**
- **LASER** light is **monochromatic, coherent and moves in the same direction.**
- A **semiconductor laser** is a laser in which a **semiconductor serves as a photon source.**
- The most common semiconductor material that has been used in lasers is **Gallium Arsenide**.
- **Stimulated, organized photon emission** occurs when two electrons with the same energy and phase meet. The two photons leave with **the same frequency and direction.**
- Mainly there are two types in semiconductor laser:

1. **Homojunction laser**
2. **Heterojunction laser**

Homojunction and Heterojunction Laser

- **Homojunction Laser**

  It is simply a laser diode where the active medium is a semiconductor similar to that found in a light-emitting diode. The most common and practical type of laser diode is formed from a p-n junction and powered by injected electric current.

- **Heterojunction Laser**

  A heterojunction is an interface that occurs between two laser or regions of dissimillar crystalline semiconductors. These semiconducting materials have unequal band gaps as opposed to a homo junction.

Use of heterojunctions in lasers was first proposed in 1963 in Herbert Kroemer.

Semiconductor LASER

- In semiconductor diode lasers conduction band plays the role of excited level and valance band play the role of ground level.

- **Population inversion** requires the presence of large concentration of holes in the valance band.

- A simple way to achieve population inversion is to make a semiconductor in the form of a PN-junction diode from heavily doped P and N type semiconductors.

- When PN-junction diode is forward biased, the electrons from ‘n’ region and holes from ‘p’ region recombine with each other at a junction.

- During the recombination process light radiations (photons) is released from certain specified direct band gap semiconductor like GaAs.


THANK YOU