# Fibre Optics and Laser

# Lecture 1

**Unit: 9**

Physics

KAS 201

B.Tech (1st Sem.)

Assistant Professor

Applied Sciences

# Content

| Name of Topic | Duration (Hrs.) | % of Coverage in Exams |
|---|---|---|
| Fibre Optics | 04 | 10 |
| Laser | 05 | 10 |

# Unit Objective

- To provide the basic knowledge for the design of optical transmission system .
- To understand and how to minimized the attenuation loss during transmission of data through optical fibre cable .
- To develop skills for the design of LASER system.
- To provide basic physics knowledge of gaseous and solid state LASER.

# Course Objective

CO1: To provide the knowledge of Relativistic Mechanics and their uses to engineering applications.

CO2: To provide the knowledge of Quantum Mechanics and to explore possible engineering utilization

CO3: To provide the knowledge of interference, diffraction.

CO4: To provide the knowledge of the limitation of classical physics and ideas in solving the problems in their parent streams.

# Course Outcome

After completion of course students are;

CO1 Able to solve the relativistic mechanics problems

CO2 Able to apply the concept of quantum mechanics

CO3 Able to develop the understanding of laws of optics and their application in various processes

CO4 Able to aware of limits of classical physics & to apply the ideas in solving the problems in their parent streams

# CO-PO and PSO Mapping

| CO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 | PO-7 | PO-8 | PO-9 | PO-10 | PO-11 | PO-12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | - | 2 | 2 | 2 | - | - | - | - | 2 |
| CO2 | 3 | 2 | 1 | - | 1 | 2 | 2 | - | - | - | - | 2 |
| CO3 | 3 | 3 | 1 | - | 2 | 2 | 2 | - | - | - | - | 2 |
| CO4 | 3 | 2 | 2 | - | 2 | 3 | 2 | - | - | - | - | 2 |
| Mean | 3.0 | 2.25 | 1.3 | - | 1.8 | 2.3 | 2.0 | - | - | - | - | 2.0 |

# Fibre Optics Content

| Name of Topic | Duration (Hrs.) | % of Coverage in Exams |
|---|---|---|
| Fundamental Ideas about optical fiber, Propagation mechanism | 01 | 2% |
| Acceptance Angle and cone, Numerical aperture | 01 | 2% |
| Classification of OFC | 01 | 4% |
| Dispersion and Attenuation | 01 | 2% |

# Content

- Introduction
- Fundamental ideas about optical fibers
- Propagation Mechanism
- Acceptance angle and cone, Numerical aperture
- Single and Multimode fibers
- Dispersion and attenuation

# Topic Objective

- To provide the fundamental idea about optical fiber.
- To provide the knowledge of propagation mechanism.

# Topic Outcome

After completion of course students are;

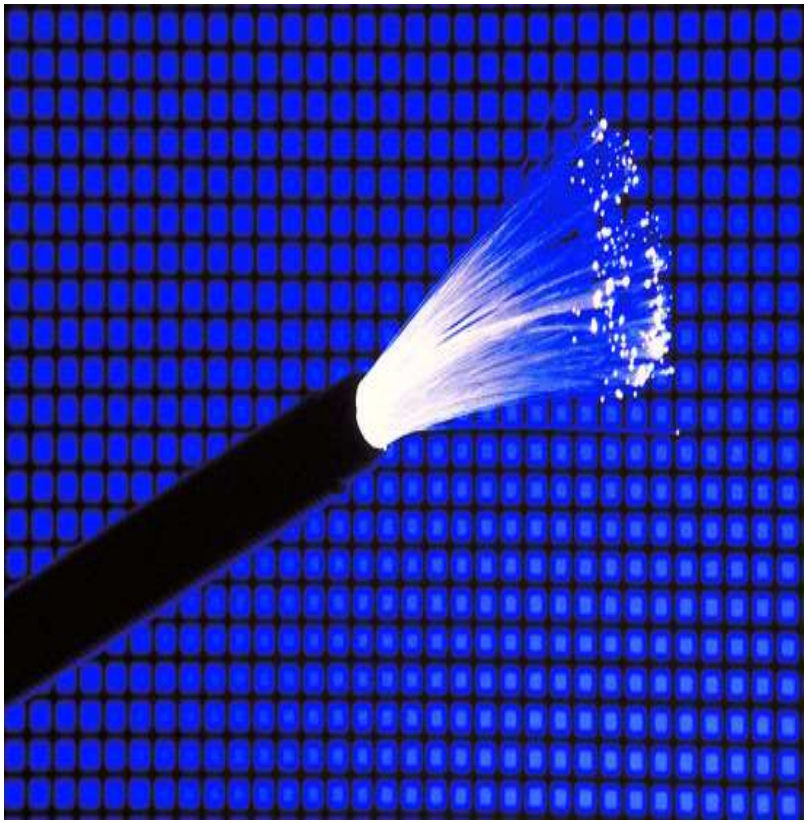
- Able to define basic idea of optical fiber.
- Able to explain propagation mechanism of optical fiber.

# Today's Lecture

- Fundamental ideas about optical fibers
- Propagation Mechanism

# Optical Fibre

- A optical fiber is a hair thin cylindrical fiber of glass or any transparent medium.
- Information carried in the form of light rays
- Hundreds of thousands arranged in bundles to form optical cables



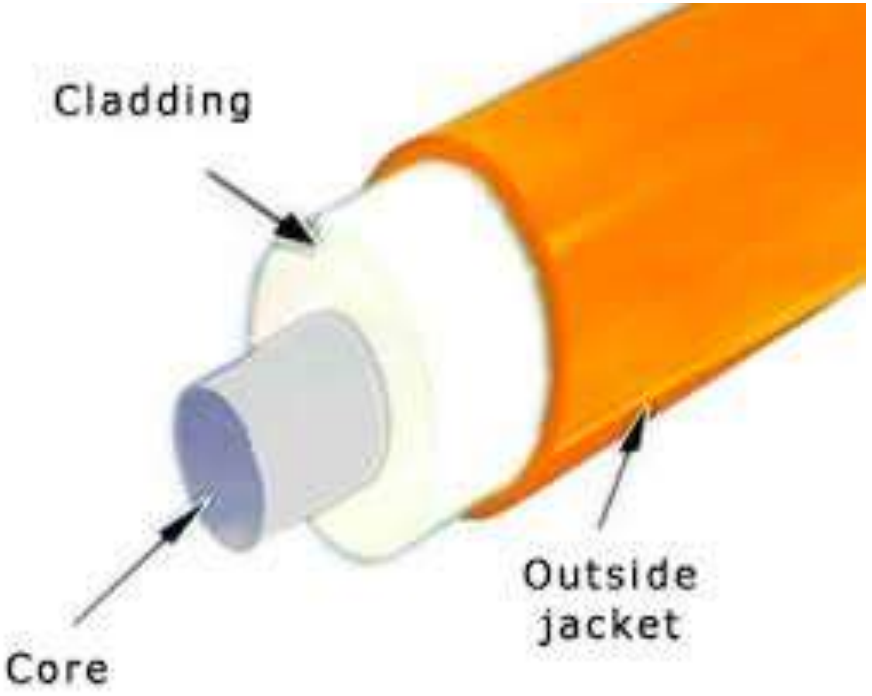
# Fabrication of OFC

## Materials

- Glass( e.g.SiO2)
- Plastic( e.g. polystyrene)
- Doping products(e.g. germanium)

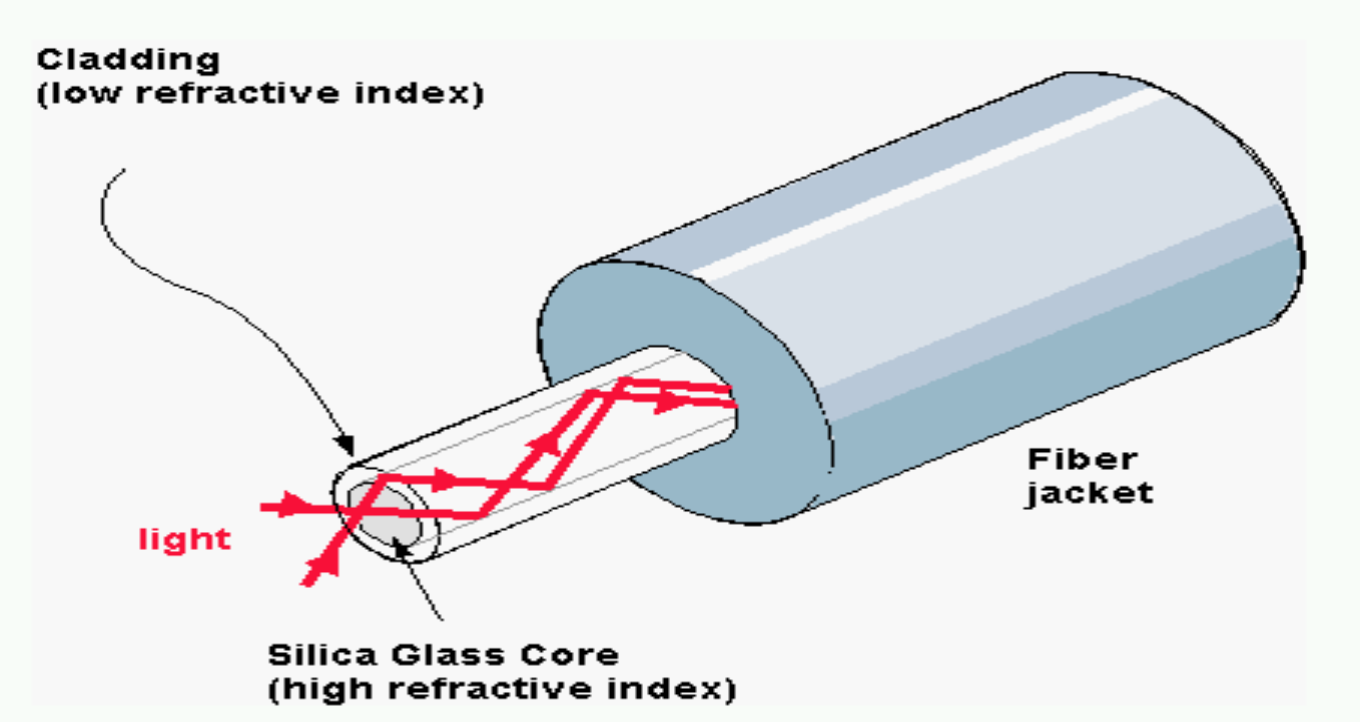
# Fundamental idea about Optical Fibre

- Core - Glass or plastic with higher refractive index where light travel
- Cladding – Glass or plastic with lower refractive index than core
- Jacket- protect the fiber from damage and moisture



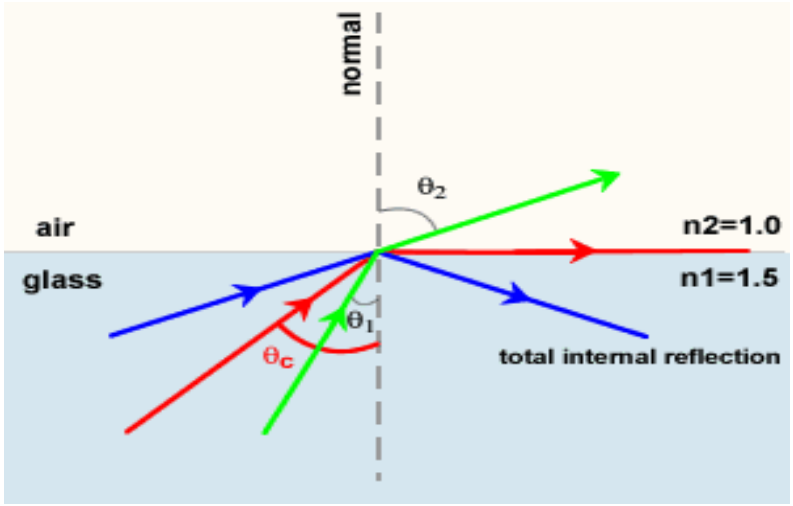
# Propagation mechanism

**For light propagation through the fiber, the conditions for total internal** reflection (TIR) **should be met at the core-cladding interface**

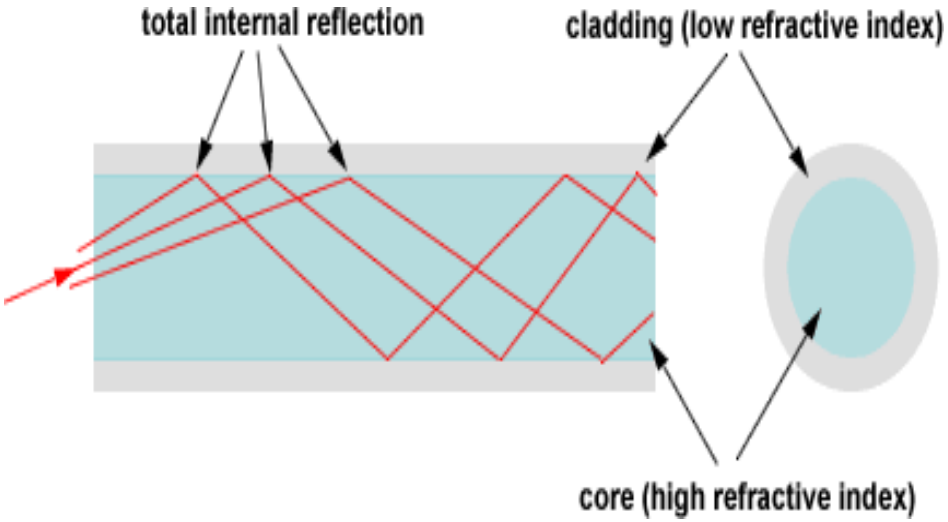


# TIR

- At critical angle θc ,light travelling from denser to rarer will be refracted along boundary




- At angle of incidence larger than critical angle, the total internal reflection(TIR)



# Daily Quiz

1. The core of a fiber optic cable is made of

   (a) air (b) Glass

   (c) Diamond (d) Quartz

2. The core of a fiber optic is surrounded by

   (a) wire braid shield (b) Kevlar

   (c) cladding (c) plastic insulation

3. Which of the following is not a major benefit of fiber-optic cable?

   (a) immunity from interference (b) no electrical safety problems

   (c) Excellent data security (d) lower cost

# Previous Year Questions

## Short answer type questions

1. What is critical angle?
2. How does the light propagate along a fiber?
3. What is the principle of operation of a fiber? **[2012,2013]**

## Long answer type questions

1. Explain basic principle of optical fiber. **[2009,2010,2013]**

2. Describe the propagation mechanism and communication in optical fibers. Also discuss about the signal loss in optical fibers. **[2012]**

# Fibre Optics and Laser

# Lecture 2

**Unit: 9**

Physics

KAS 201

B.Tech (2nd Sem.)

Assistant Professor

Applied Sciences

# Topic Objective

- To provide the knowledge of acceptance angle, acceptance cone.
- To provide the knowledge of numerical aperture and relative refractive index.

# Topic Outcome

After completion of course students are;

- Able to define acceptance angle and acceptance cone of optical fiber.
- Able to calculate numerical aperture and relative refractive index of an optical fiber.

# Prerequisite and Recap

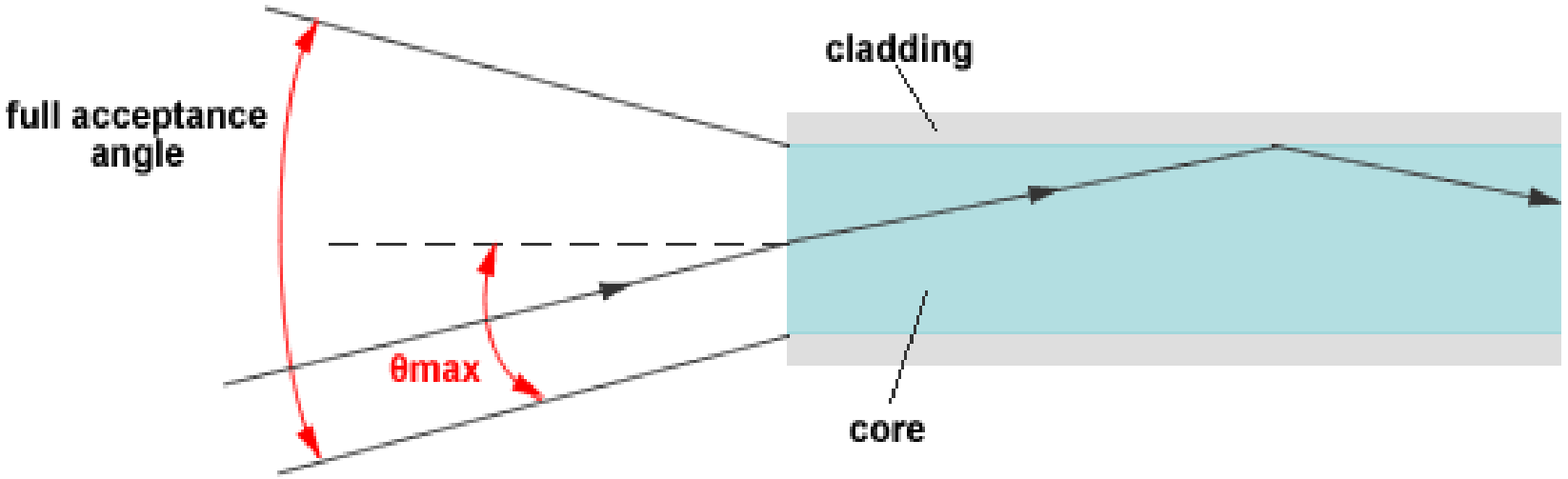
- Optical fibre has 3 main components : Core, Cladding and Buffer Jacket
- Light propagate through optical fibre by follow the process of **TIR**

# Today's Lecture

- Acceptance Angle
- Acceptance Cone
- Numerical Aperture (NA)
- Relative index difference

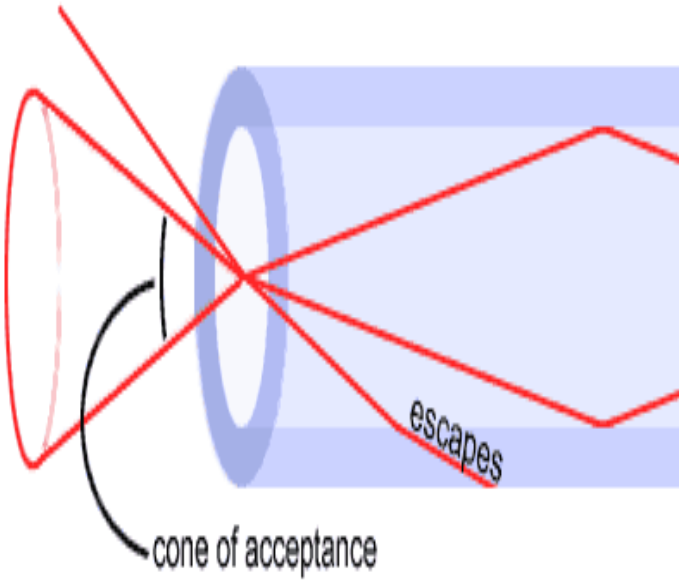
# Acceptance angle

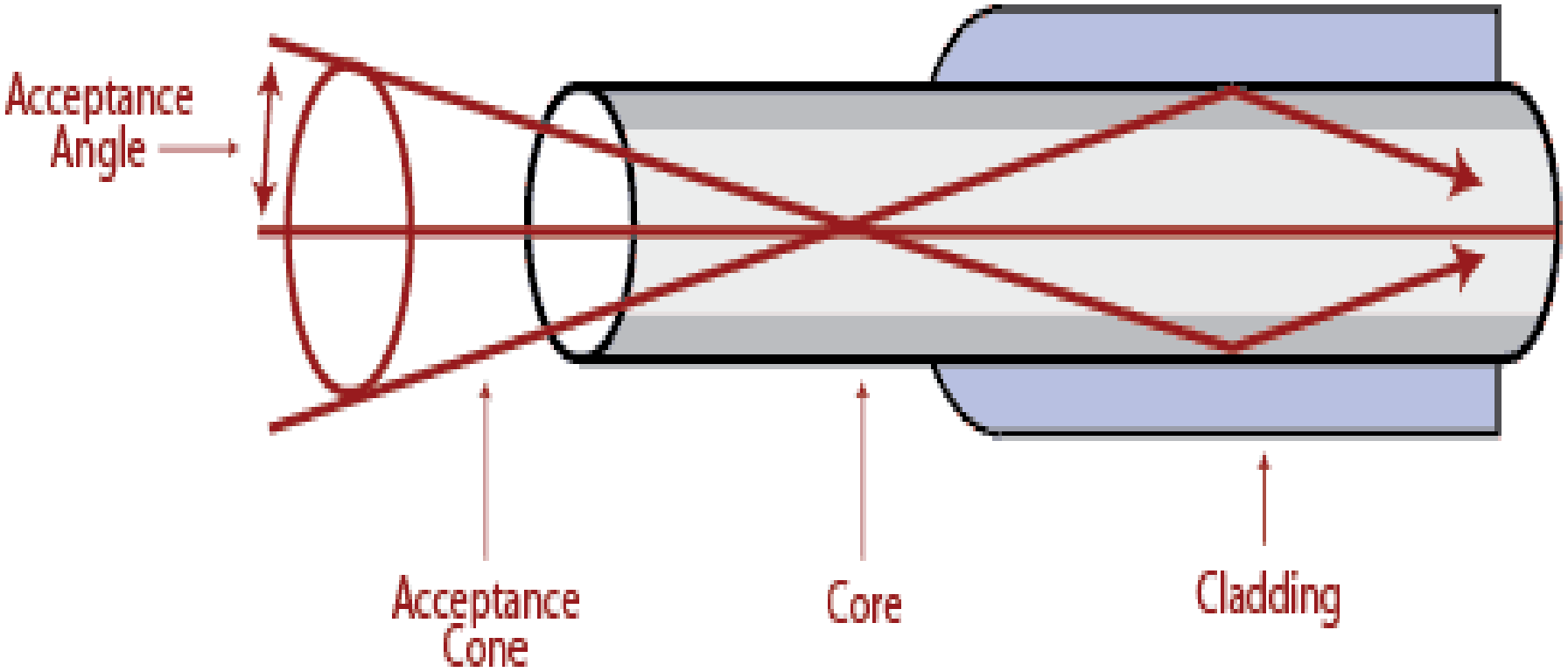
- Acceptance angle is maximum angle at which a light ray enters into core and propagate through it in zigzag path



# Acceptance Cone

- The cone associated with angle $2\boldsymbol{\theta}_{max}$ is called the acceptance cone
- The light that enters the fiber at angles within the acceptance cone are guided through core




Acceptance
Angle
Acceptance
Cone
Core
Cladding

# Numerical Aperture (NA)

Its a very useful parameter which Measure the light gathering ability of an fiber

Larger the magnitude of NA,greater amount of light accepted by fiber from the external source

$$NA = \mathrm{Sin}\theta_{max} = \sqrt{n_{core}^2 - n_{cladding}^2}$$

# NA and Δ(Relative refractive index difference)

- The relative refractive index difference shows the difference between the core and cladding refractive index

$$\Delta = \frac{\mu_{core} - \mu_{cladding}}{\mu_{core}}$$

$$NA = n_{core}(2\Delta)^{1/2}$$

# Daily Quiz

1. The maximum angle in which the external light rays may strike air/glass interface and still propagate down the fiber.

(a) Acceptance angle (b) Acceptance cone

(c) critical angle (c) none of above

2. It is the figure of merit used to measure the magnitude of the acceptance angle.

(a) acceptance angle (b) numerical aperture

( c) Index profile (d) refractive index

3. The effect of a large magnitude of the numerical aperture

(a) The amount of external light the fiber will accept is greater.

(b) The amount of external light the fiber will accept is less

(c) The amount of modal dispersion will be less.

(d) The amount of chromatic dispersion will be greater

# MCQ

1. When a beam of light travels through media of two different densities, if the angle of incidence is greater than the critical angle, _____ occurs

   (a) Total internal reflection (b) Refraction

   (c) incidence (d) none of above

2. The minimum angle of incidence at which the light ray may strike the interface of two media and result in an angle of refraction of 90 degrees or greater.

   (a) optimum angle (b) angle of refraction

   (c) critical angle (d) none of above

3. It is the angle at which the propagating ray strikes the interface with respect to the normal

   (a) refracted angle (b) incident angle

   (c) reflected angle (d) critical angle

# Previous Year Questions

## Short answer type questions

1. What do you mean by acceptance angle and acceptance cone of a fiber?
2. What is numerical aperture?
3. How numerical aperture is related with acceptance angle?

## Long answer type questions

1. Explain acceptance angle and acceptance cone of an optical fiber. What do you mean by numerical aperture? Derive expressions for them **[2010,2009]**
2. With reference to optical fibers, obtain an expression for the acceptance angle in terms of the refractive indices of the core material, cladding material and that of the medium outside of fiber. **[2013]**

# Fibre Optics and Laser

# Lecture 3

**Unit: 9**

Physics

KAS 201

B.Tech (2nd Sem.)

Assistant Professor

Applied Sciences

# Topic Objective

- To provide the knowledge of classification of optical fiber.

# Topic Outcome

After completion of course students are;

- Able to classify optical fiber.

# Prerequisite and Recap

- Acceptance angle
- Acceptance Cone
- Numerical Aperture

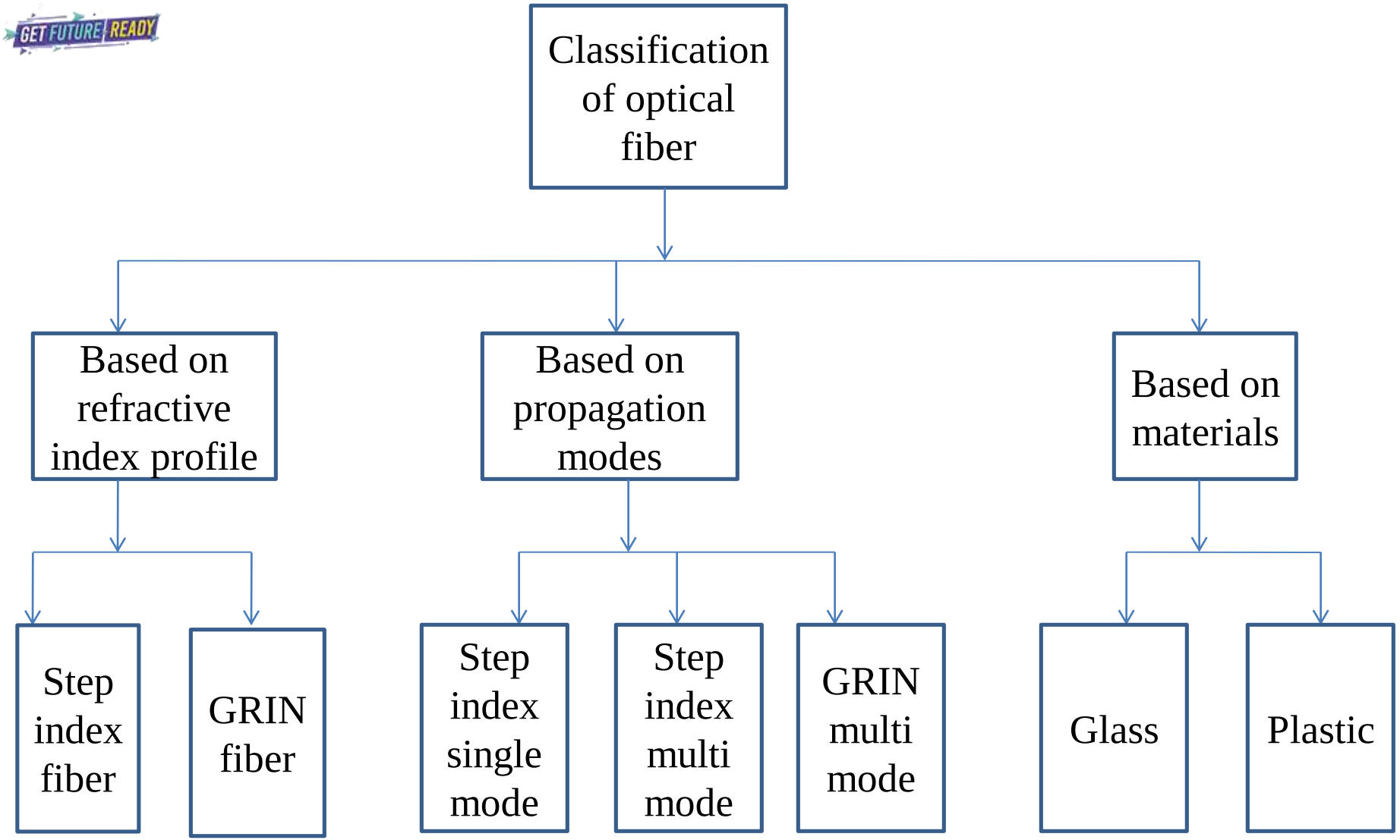
# Today's Lecture

- Classification of OFC
- Single and Multi-Mode Fibre
- Step-Index and Graded Index Fibre

# Classification of Optical fibre

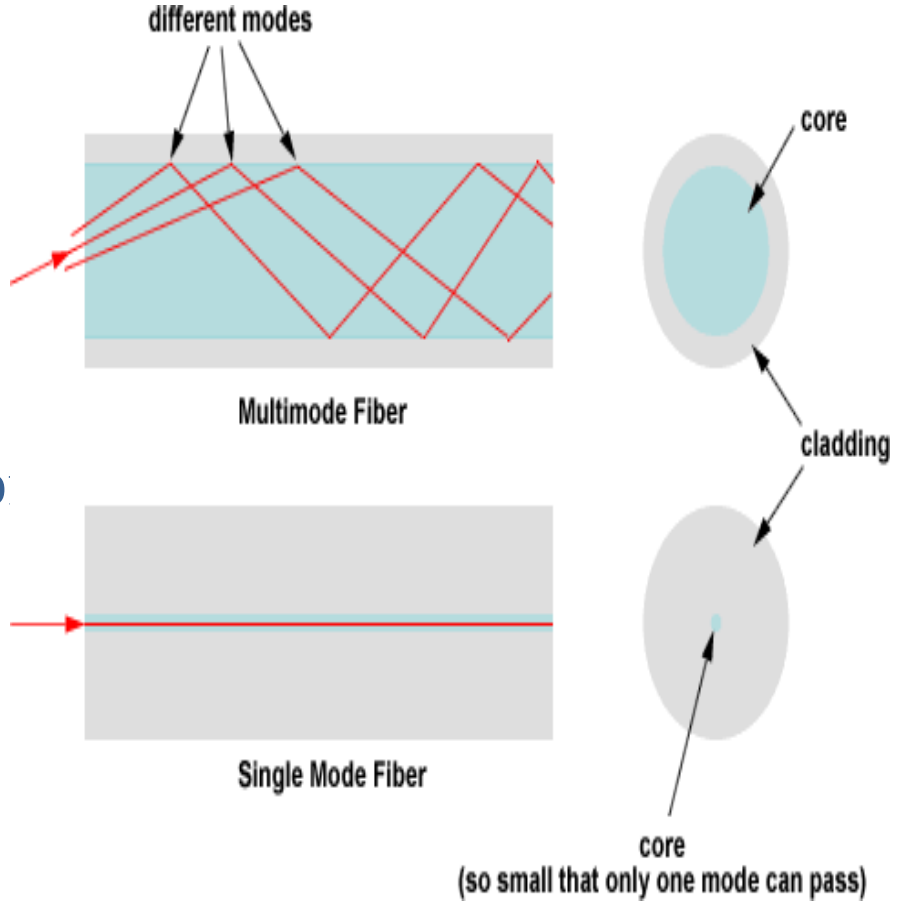
**Optical fibers are categorized into different types based on the**

- **mode of propagation**
- **refractive index of the core and cladding and**
- **the materials which are used to make the fiber**

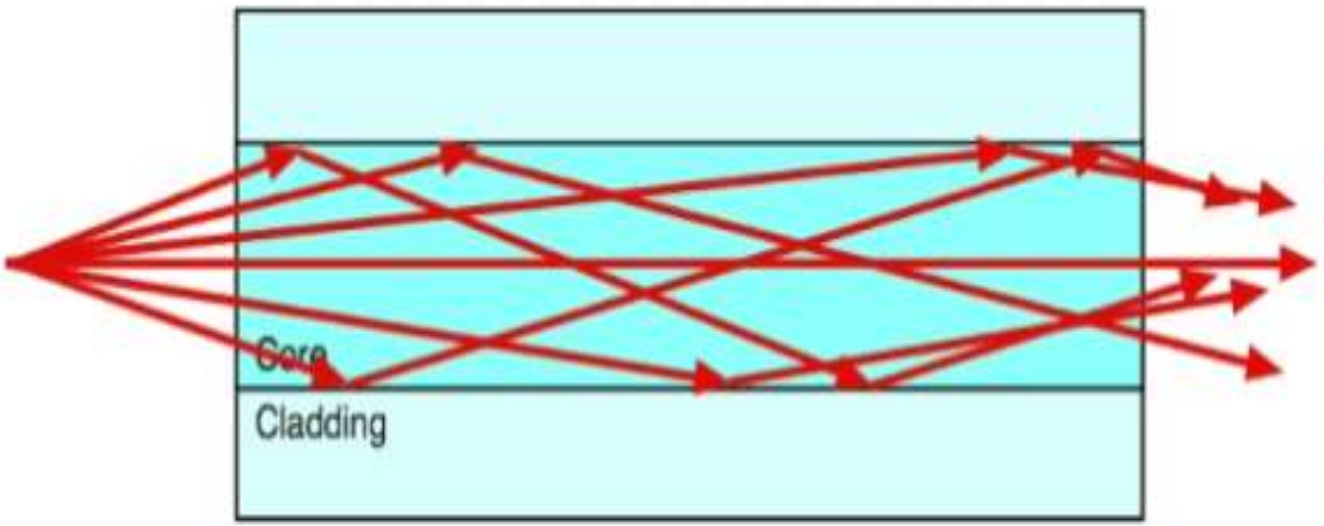

Classification of optical fiber
Based on refractive index profile
Based on propagation modes
Based on materials
Step index fiber
GRIN fiber
Step index single mode
Step index multi mode
GRIN multi mode
Glass
Plastic

# Single Mode (SMF)

- Only one mode propagate
- Small core and high cladding diameter
- Difference of refractive index o core and cladding is small
- No dispersion of signal



# Multi-Mode Fibre (MMF)

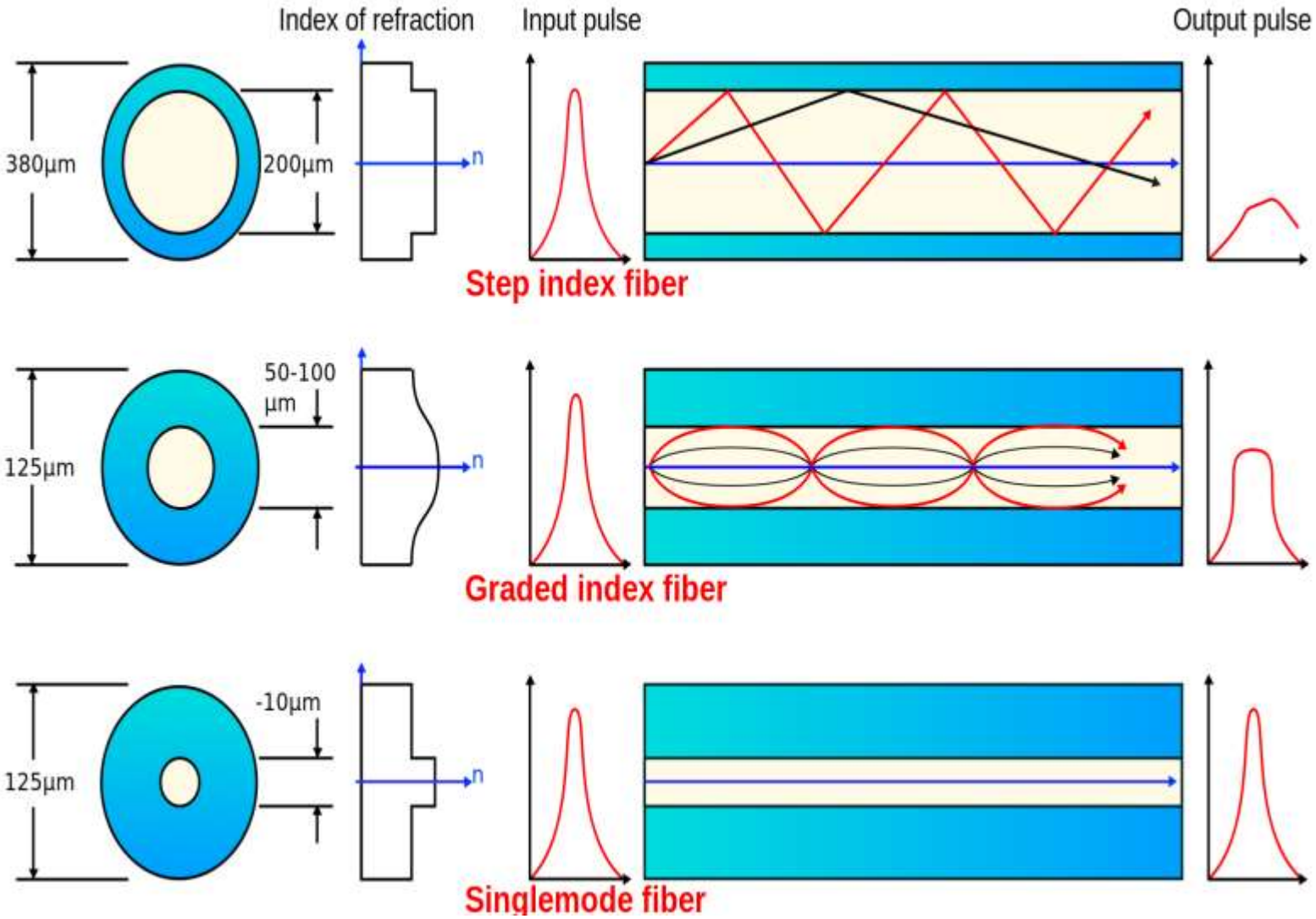



- Large number of modes for light ray
- Core diameter is (40μm) and that of cladding is (70μm)
- Relative refractive index larger than single mode fiber
- Large dispersion and attenuation

# On the basis of Refractive index

- **Step-index optical fiber**
  - ➢Refractive index of core and cladding is uniform or constant
  - ➢Light rays propagate in meridiognal rays
- **Graded- index optical fiber**
  - ➢ Core has non uniform refractive index
  - ➢Cladding has uniform refractive index
  - ➢Light rays propagate in helical form

# Geometry of Optical Fibre



# MCQ

1. Step index sustain only

   (a) single mode propagation (b) multimode propagation

   ( c) both (a) and (b) (d) None of these

2. Periodic self- focusing of optical rays occurs with the

   (a) Graded index optical fiber (b) Step index optical fiber

   (c) Single mode optical fiber (d) Multi-mode optical fiber

3. In graded index optical fiber the refractive index of core is

   (a) Non uniform (b) increase towards axis of core

   (c) same at core –cladding interface (d) All of above

# Previous Year Questions

## Short answer type questions

1. What is multimode step index fiber?
2. What is single mode step index fiber?
3. Define Graded index multimode fiber.

## Long answer type questions

1. Describe various type of optical fibers on modes and core refractive index? **[2012]**

2 . What do you understand by the modes of an optical fiber? Discuss the merits and demerits of mono mode fibers over multimode counterpart? **[2009]**

**3**. Explain single mode and multimode fiber. What are the advantages of optical fiber over copper wire? **[2010,2013]**

# Fibre Optics and Laser

# Lecture 4

**Unit: 9**

Physics

KAS 201

B.Tech (2nd Sem.)

Assistant Professor

Applied Sciences

# Topic Objective

- To provide the knowledge of losses in optical fiber.

# Topic Outcome

After completion of course students are;

- Able to calculate and define losses in optical fiber.

# Prerequisite and Recap

- On the basis of Refractive index: Step-Index and Graded Index Fibre
- On the basis of Mode: Single and Multi-Mode fibre
- On the basis of Material : Glass and Plastic

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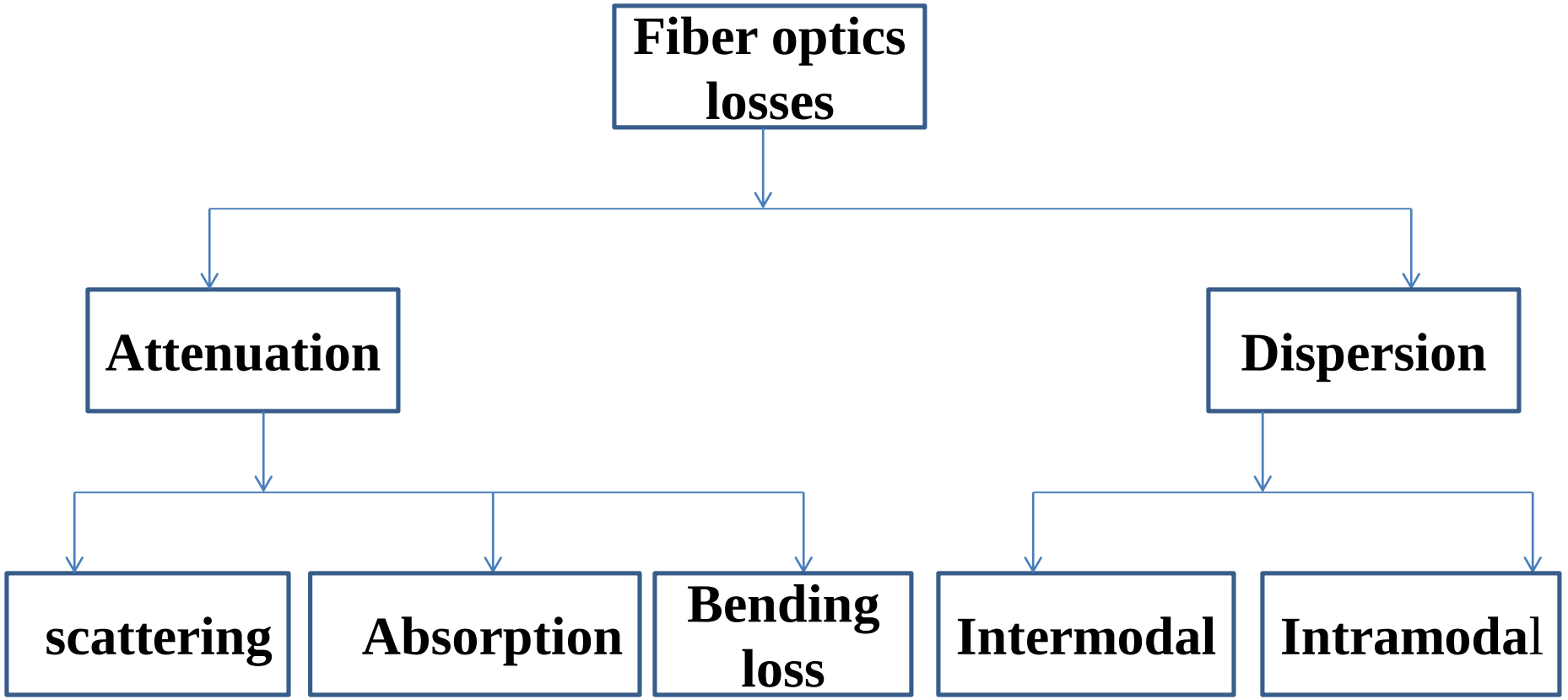
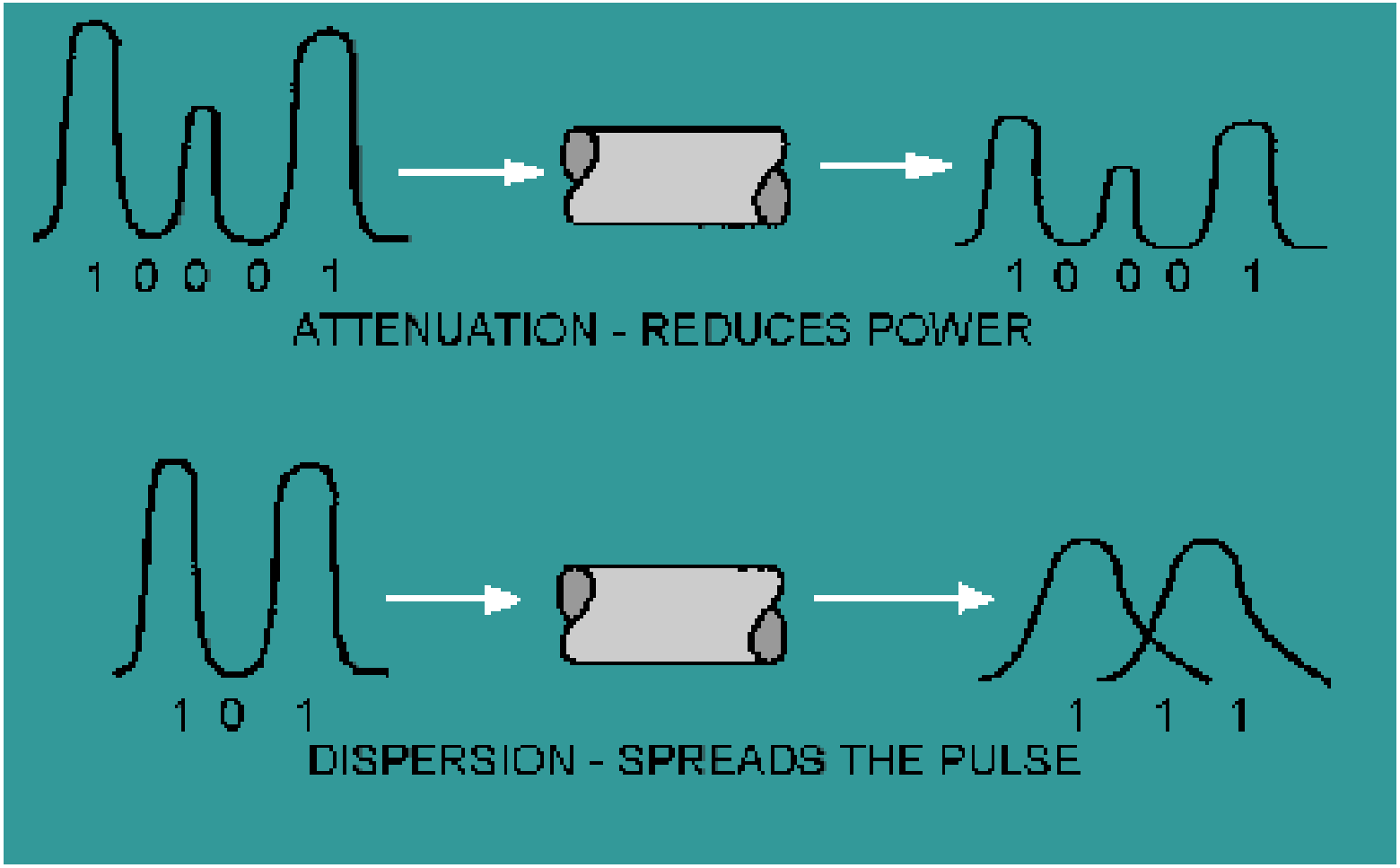
# Today's Lecture

- Type of Losses in Optical Fibre
- Attenuation
- Dispersion

# Types of Losses in Optical Fibre



# Attenuation and Dispersion



# Attenuation Loss

- It means loss of the light energy as the light pulse travels from one end of the fiber to other.
- The following relation defines signal attenuation

$P_{in}$ = input power

$P_{out}$ = output power

L is the length of fiber

$$\alpha = \frac{10}{\mathrm{L}} \log\left(\frac{P_{in}}{P_{out}}\right)$$

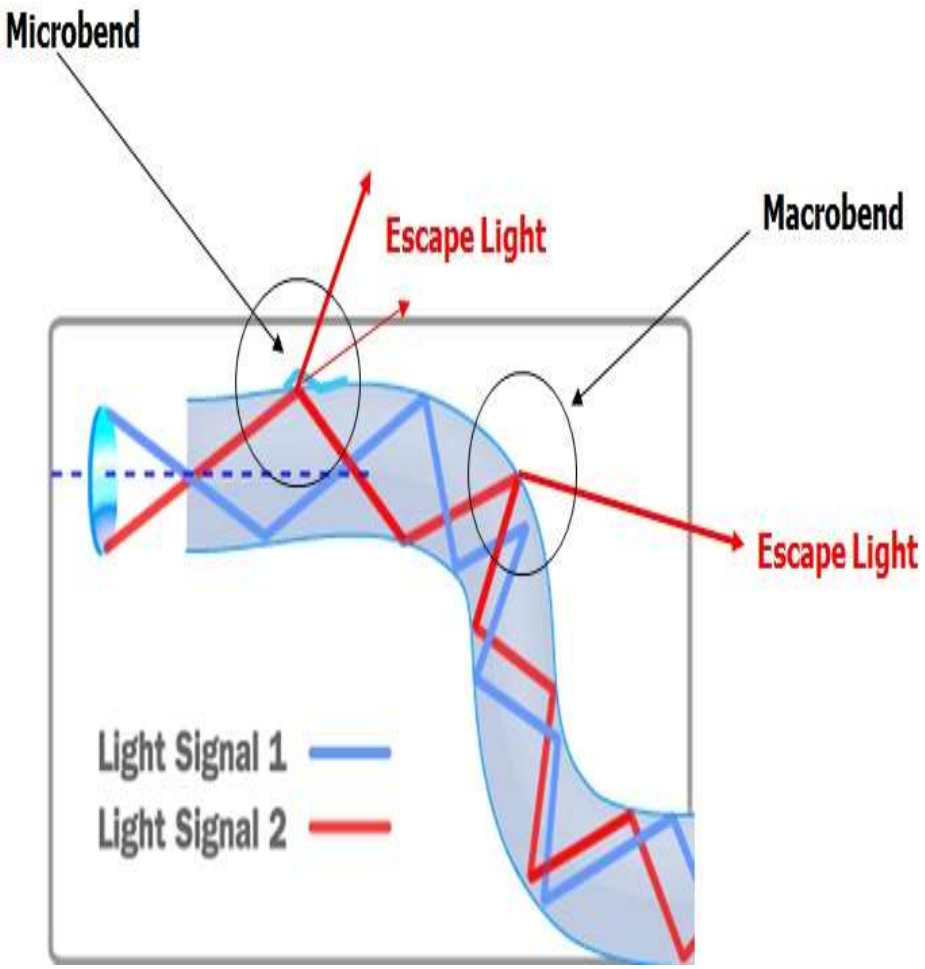
- The unit of attenuation is decibels/kilometer(db/km)

# Types of Attenuation

- Absorption losses : Caused by the fiber itself or by impurities in the fiber such as water and metal
- Scattering losses: Arise from microscopic variations in the material density and structural defects occurring during fiber manufacture.
- Bending losses-The loss which exists when an optical fiber undergoes bending. These are two types:
  - Macro bending
  - Micro bending

# Bending Loss

- Macro bending
  - Light lost from core due to tight bends in complete fiber
  - Poor reeling and mishandling during installation
- **Micro bending**
  - Microscopic deformations in core-cladding interface
  - Caused by poor cable design



# Dispersion Loss

A pulse of light sent into fiber broaden in time as it propagate through the fiber called **pulse dispersion**

- **Intermodal dispersion**
  - Different modes or light rays travel with different speed
  - Occur only in multimode fiber
- **Intramodal dispersion**
  - As a given source emits over a range of wavelengths and because of the intrinsic property of the material, different wavelengths take different amount of time.
  - Occur in all types of fibers

# Previous Year Questions

## Short answer questions

1. Describe scattering loss in optical fiber.

**[2012]**

1. Why modal dispersion is negligible in single mode fiber?

**[2011]**

## Long answer questions

1. Discuss the different types of pulse dispersion in optical fiber

**[2013]**

# You-tube Video Links

1. https://www.youtube.com/watch?v=aqazAcE19vw
2. https://www.youtube.com/watch?v=aqazAcE19vw
3. https://www.youtube.com/watch?v=evSgbe6sBv4
4. https://www.youtube.com/watch?v=pavBq7HIoIE

# Assignment

***One line:***

- Write the names of the structural parts of optical fiber.
- What is the difference between index profile of step index fiber and graded index fiber?
- How the chromatic dispersion can be eliminated?

***Short answer type:***

- Describe the basic principle of an optical fiber.
- Define acceptance angle, acceptance cone.
- What do you mean by numerical aperture?

# Assignment

***Long answer type:***.

- Describe the propagation mechanism and communication in optical fiber. Also discuss about the signal loss in optical fiber.
- Explain single mode and multimode fiber. What are the advantages of optical fiber over copper wire?
- What do you mean by pulse broadening? Discuss dispersion in optical fiber in detail.

# Previous Year Questions paper

Printed Page 1 of 2 Sub Code: AS102

Paper Id: 199232 Roll No:

**B. TECH**
**(SEM-I) THEORY EXAMINATION 2019-20**
**ENGINEERING PHYSICS I**

*Time: 3 Hours* *Total Marks: 100*

**Note:** Attempt all Sections. If require any missing data; then choose suitably.

**SECTION A**

**1. Attempt *all* questions in brief.** **2 x 10 = 20**

a. Define inertial and non-inertial frame of reference with example.
b. Define proper and improper time interval.
c. Write down Maxwell's equation for free space.
d. Define poynting vector and write down its dimension.
e. Why Newton's rings are circular?
f. What do you mean by dispersive power of grating?
g. State two difference between interference and diffraction.
h. Define optical activity.
i. Define population inversion and pumping.
j. Define acceptance angle and numerical aperture.

**SECTION B**

# Previous Year Questions paper



## SECTION B

**2. Attempt any *three* of the following: 10x3=30**

a. What was the objective of conducting the Michelson-Morley experiment? Describe the experiment. How is the negative result of the experiment interpreted?

b. State and Deduce Poynting theorem for the flow of energy in an electromagnetic field.

c. Discuss the phenomenon of interference of light in thin films and find the condition of maxima and minima. Show that the interference patterns of reflected and transmitted monochromatic source of light are complementary.

d. Derive an expression for the intensity distribution due to Fraunhofer's diffraction by single slit. Show that the intensity of the first subsidiary maximum is about 4.5% of that of the principal maximum,

e. Describe the construction and working of Nicol Prism. Explain how Nicol prism acts as a polarizer and analyzer.

## SECTION C

**3. Attempt any *one* part of the following: 10x1=10**

a. Derive an expression for variation of mass with velocity.

b. Calculate the amount of work to be done to increase the speed of a electron from $0.8c$ to $0.9c$. Given the rest energy of electron =0.5MeV where $c$ is the velocity of light.

**4. Attempt any *one* part of the following: 10x1=10**

a. Write down Maxwell's equations in free space and show that E, H and direction of propagation from a set of orthogonal vectors.

b. Assuming that all the energy from a 1000 watt lamp is radiated uniformly; calculate the values of the intensities of electric and magnetic fields of radiation at a distance of 2m from the lamp.

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# Previous Year Questions paper

**Printed Page 2 of 2** **Sub Code:EAS101**

**Paper Id:** 199221 **Roll No:**

**5. Attempt any *one* part of the following:** **10 x 1 = 10**

a. Define resolving power and dispersive power of grating. Derive an expression for the resolving power of a plane transmission grating.

b. What are Einstein's coefficients? Derive Einstein's relation.

**6. Attempt any *one* part of the following:** **10 x 1 = 10**

a. What is double refraction? Explain the construction and working of Nicol prism.

b. Explain why two level laser systems does not have any physical significance? Describe the principle and working of three-level and four-level laser systems.

**7. Attempt any *one* part of the following:** **10 x 1 = 10**

a. Explain the basic principle of optical fibre. Discuss the optical fibre classification.

b. What is basic principle of holography? Describe the principle of holography using the processes of construction and reconstruction of image. Give some applications also.

Physical Constants

| | | |
|---|---|---|
| Rest mass of electron | $m_e$ | $= 9.1 \times 10^{-31}$ kg |
| Rest mass of Proton | $m_p$ | $= 1.67 \times 10^{-27}$ kg |
| Speed of light | c | $= 3 \times 10^{8}$ m/s |
| Planck's Constant | h | $= 6.63 \times 10^{-34}$ J-s |
| Charge on electron | e | $= 1.6 \times 10^{-19}$ C |
| Boltzmann's Constant | k | $= 1.38 \times 10^{-23}$ J-K$^{-1}$ |

# Expected Questions for University Exam

1. What is optical fiber?
2. Why the refractive index of cladding is more than core?
3. What precautions are needed to minimize material dispersion**?**
4. What do you mean by acceptance angle?
5. What are the main sections of an optical fiber? Explain the function of each section.
6. Describe different types of losses in optical fiber.
7. What do you understand by modes of an optical fiber? Discuss propagation of light in single mode, multi-mode and graded index multimode fiber.
8. With reference to optical fibers, obtain an expression for the acceptance angle in terms of the refractive indices of the core material, cladding material and that of the medium outside of fiber.

# Summary

- Optical fiber is least expensive, most reliable method for high speed and long distance communications
- It has cylindrical structure having parts Core, Cladding and and outer Jacket
- The amount of light is bent by refraction is given by Snell's law and basic principle of operation of optical fiber is TIR
- Optical fiber will only propagate light that enters the fiber within a certain cone, called acceptance cone and half of acceptance cone called acceptance angle

# Summary

- In optics, the numerical aperture(NA) characterizes the range of angles over which the system can accept or emit light
- On the basis of Refractive Index: Step-Index and Graded index Fibre
- On the basis of Mode: Single and Multi-Mode Fibre
- On the basis of Material: Glass and Plastic
- Attenuation and dispersion  in optical fiber

# NPTEL video Links

1. https://nptel.ac.in/courses/108104113/

# References

1. Engineering Physics by SK Gupta

# Fibre Optics and Laser

# Lecture 5

**Unit: 9**

Physics

KAS 201

B.Tech (2nd Sem.)

Assistant Professor

Applied Sciences

# Content

| Name of Topic | Duration (Hrs.) | % of Coverage in Exams |
|---|---|---|
| Fibre Optics | 04 | 10 |
| Laser | 05 | 10 |

# Unit Objective

- To provide the basic knowledge for the design of optical transmission system .
- To understand and how to minimized the attenuation loss during transmission of data through optical fibre cable .
- To develop skills for the design of LASER system.
- To provide basic physics knowledge of gaseous and solid state LASER.

# Course Objective

CO1: To provide the knowledge of Relativistic Mechanics and their uses to engineering applications.

CO2: To provide the knowledge of Quantum Mechanics and to explore possible engineering utilization

CO3: To provide the knowledge of interference, diffraction.

CO4: To provide the knowledge of the limitation of classical physics and ideas in solving the problems in their parent streams.

# Course Outcome

After completion of course students are;

CO1 Able to solve the relativistic mechanics problems

CO2 Able to apply the concept of quantum mechanics

CO3 Able to develop the understanding of laws of optics and their application in various processes

CO4 Able to aware of limits of classical physics & to apply the ideas in solving the problems in their parent streams

# CO-PO and PSO Mapping

| CO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 | PO-7 | PO-8 | PO-9 | PO-10 | PO-11 | PO-12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | - | 2 | 2 | 2 | - | - | - | - | 2 |
| CO2 | 3 | 2 | 1 | - | 1 | 2 | 2 | - | - | - | - | 2 |
| CO3 | 3 | 3 | 1 | - | 2 | 2 | 2 | - | - | - | - | 2 |
| CO4 | 3 | 2 | 2 | - | 2 | 3 | 2 | - | - | - | - | 2 |
| Mean | 3.0 | 2.25 | 1.3 | - | 1.8 | 2.3 | 2.0 | - | - | - | - | 2.0 |

# Laser Content

| Name of Topic | Duration (Hrs.) | % of Coverage in Exams |
|---|---|---|
| Absorption, Spontaneous and stimulated emission of radiation | 01 | 3% |
| Einstein's Coefficients and Population inversion | 01 | 2% |
| Construction and working of ruby laser | 01 | 2% |
| Construction and working of He-Ne laser | 01 | 2% |
| Laser applications | 01 | 1% |

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# Content

- Introduction
- Absorption of Radiation
- Spontaneous and Stimulated Emission of Radiation
- Einstein Coefficient's
- Population Inversion
- Construction and Working of Ruby Laser
- Construction and Working of He - Ne Laser
- Laser Applications

# Topic Objective

- To provide the basic knowledge of laser.
- To provide the knowledge of absorption, spontaneous emission and stimulated emission.

# Topic Outcome

After completion of course students are;

- Able to define basics of laser
- Able to distinguish absorption, spontaneous emission and stimulated emission.

# Today's Lecture

- Introduction
- Absorption of Radiation
- Spontaneous and Stimulated Emission of Radiation

# LASER

**Light Amplification by Stimulated Emission of Radiation.**

**First laser made by T. H. Maiman**

Laser light beam is

- coherent
- Highly Intense
- Unidirectional
- Monochromatic

# Important Milestones

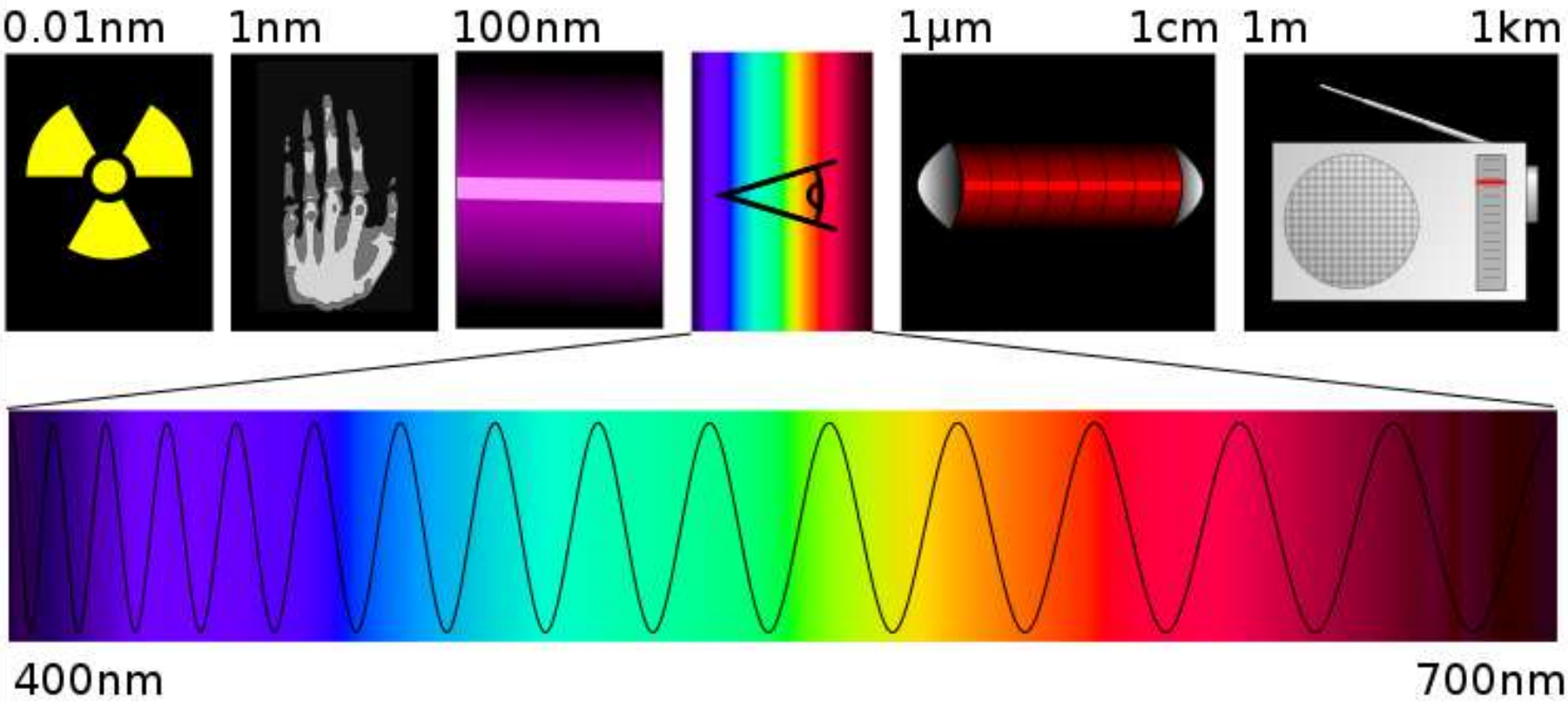
- **1917** :- The theory of stimulated emission was put forward by the Albert Einstein.
- **1954** :- Stimulated Emission used by Charles Townes in **MASER**.
- **1958**:- The MASER principle was extended to the optical frequencies by Townes et al and were awarded by **Novel prize in Physics in 1964.**
- **1960**:- The first successful demonstration of laser device by T. Maiman using Ruby Crystal

- **1961**:- Within a few months of the operation of the Ruby laser, Ali Javan and his associates constructed the first gas laser i.e. Helium-Neon Laser.
- **1962**:- Semiconductor laser was discovered.
- **1963**:- C. K. N. Patel discovered $CO_2$ laser.
- **1964**:- Ar–ion laser and Nd:YAG laser were discovered.

# LASER

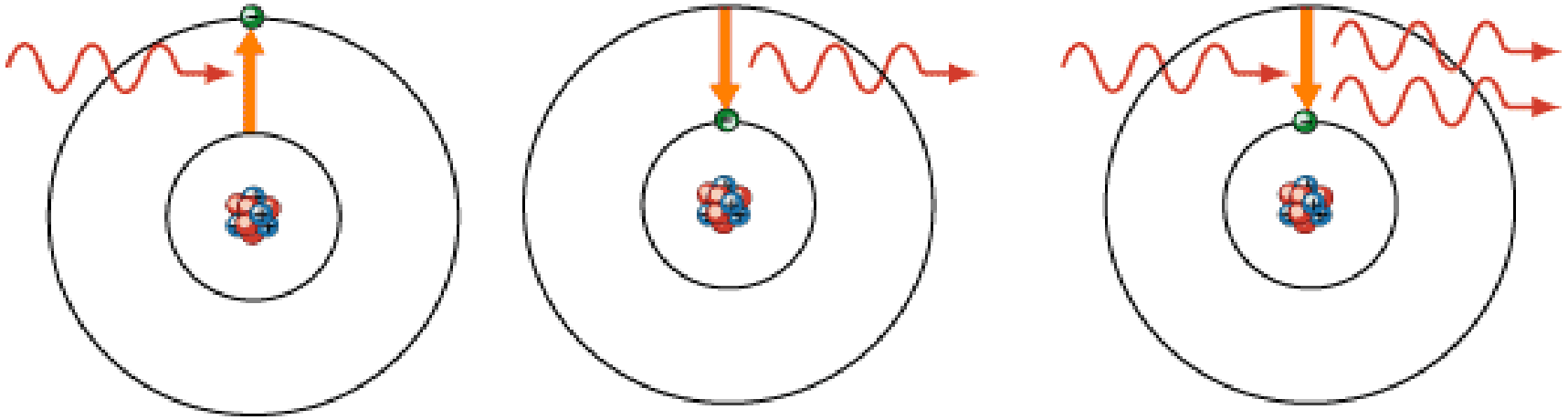
- L – Light
- A - Amplification
- S – Stimulated
- E – Emission
- R – Radiation

# LASER is a EM wave




**From left to right: gamma rays, X-rays, ultraviolet rays, visible spectrum, infrared, microwaves, radio waves.**

# Absorption , Spontaneous and Stimulated Emission of Radiation



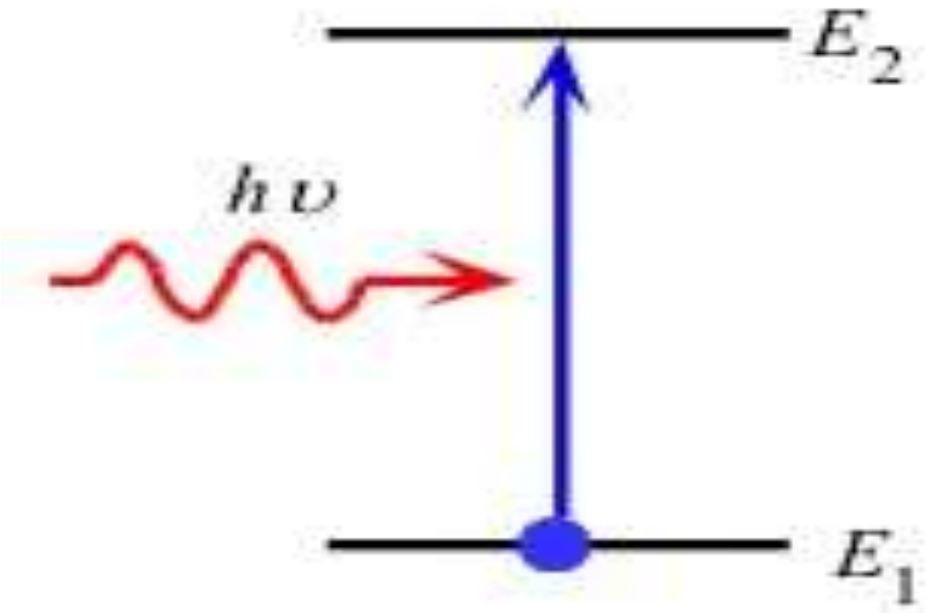
spontaneous absorption
(a)

spontaneous emission
(b)

stimulated emission
(c)

# Absorption of Radiation

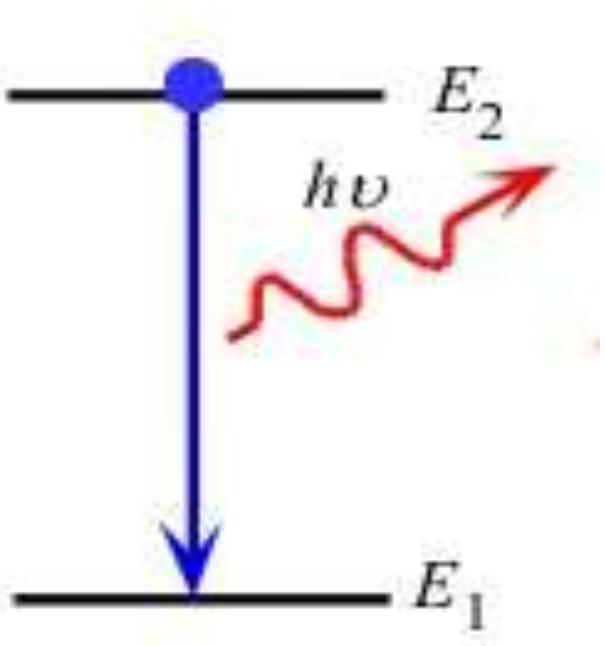
When an atom/ion/molecule in a lower energy level absorbs a photon of frequency hν and moves to an upper energy level refers as stimulated absorption.



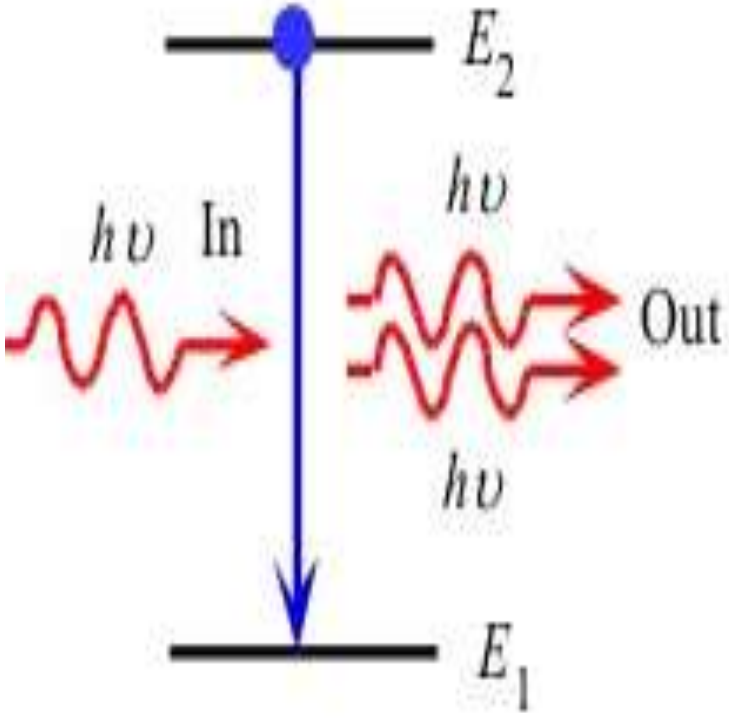
# Spontaneous Emission of Radiation

When an atom/ion in an upper energy level can decay automatically to the lower energy level and emit a photon of frequency hν (if the transition between E2 and E1) refers as spontaneous emission.

In this process emitted/outgoing photon has a random direction and phase. Also here higher energy level is unstable state.



# Stimulated Emission of Radiation

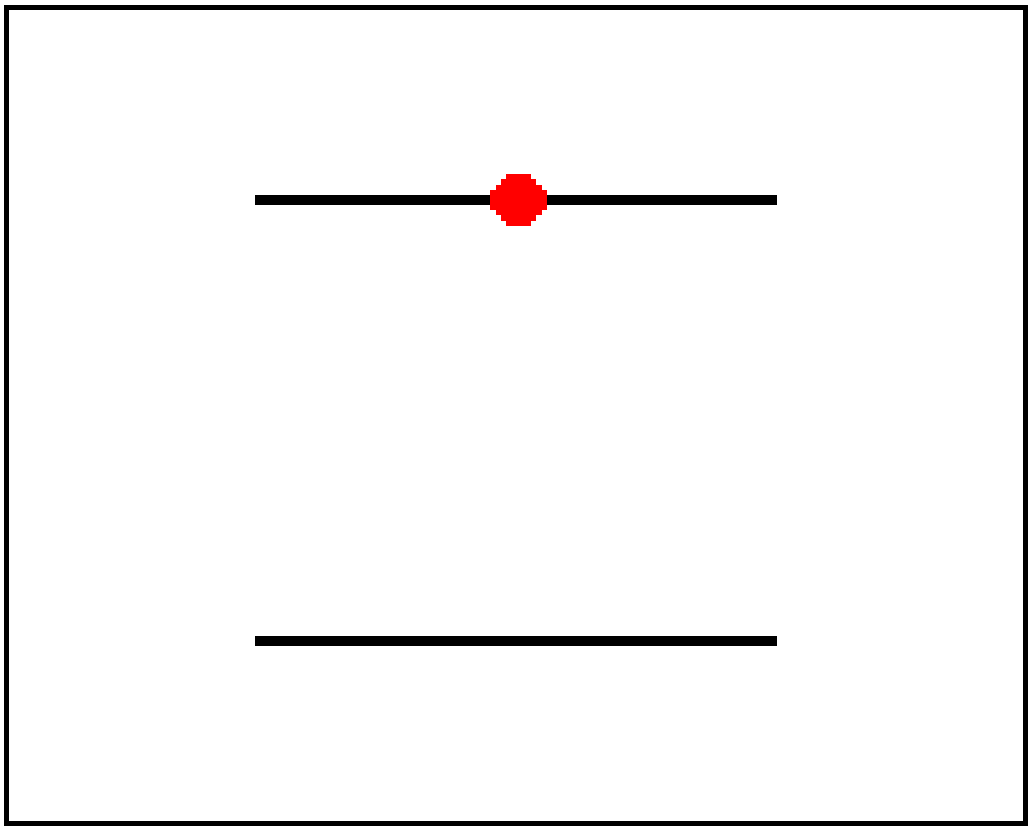



When an incident photon causes an upper level atom to decay to lower energy level, emitting a "stimulated" photon whose properties are identical to those of the incident photon refers as Stimulated Emission process.

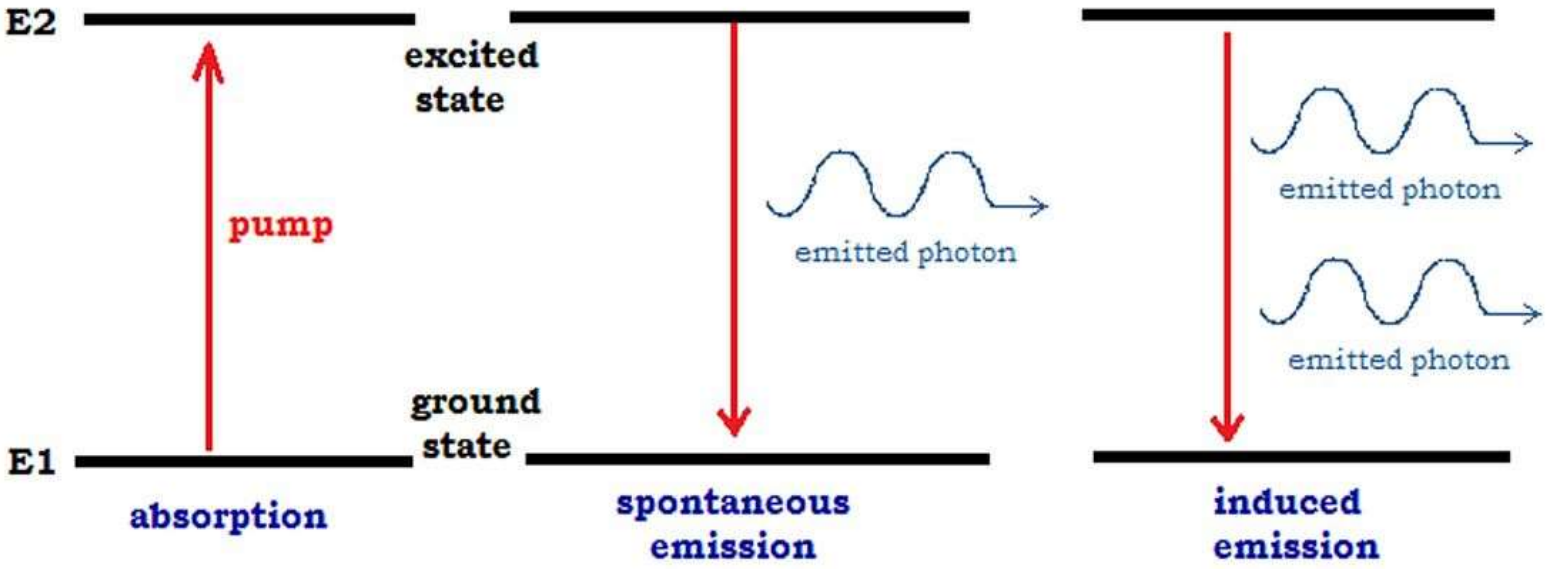
Here upper energy level is metastable state.

Outgoing photon/radiation is highly coherent

# Stimulated Emission of Radiation



# Absorption , Spontaneous and Stimulated Emission of Radiation



# MCQ

1.Laser is the short form of……

2. Laser beam is made of –

(a) Electrons (b)Highly coherent Photons

(c) Very light and elastic particles (d) None of them.

3. Characteristics of laser beam are

(a) Highly directional (b) Highly intense

(c) Highly monochromatic (d) All of them.

# Previous Year Questions

## Short answer type questions

1. What is Laser?
2. What do you mean by spontaneous emission of radiation**?** **[2017]**
3. What is stimulated emission of radiation? [**2013,2017**]
4. What is coherent light?

## Long answer type questions

1. What is Laser? Explain its principle. Also explain the principle of optical pumping. [**2009,2016**]
2. What are the important features of stimulated emission? Discuss the essential requirement of producing laser beam. [**2011**]

# Fibre Optics and Laser

# Lecture 6

**Unit: 9**

Physics

KAS 201

B.Tech (2nd Sem.)

Assistant Professor

Applied Sciences

# Topic Objective

- To provide the knowledge of Einstein's coefficients.
- To provide the knowledge of metastable state.
- To provide the knowledge of population inversion.
- To provide the knowledge of pumping.

# Topic Outcome

After completion of course students are;

- Able to relate Einstein's coefficients.
- Able to define metastable state.
- Able to define population inversion.
- Able to select appropriate technique of pumping.

# Prerequisite and Recap

- LASER is light amplification by stimulated emission of radiation
- Absorption of Radiation
- Spontaneous Emission of Radiation
- Stimulated Emission of Radiation

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# Today's Lecture

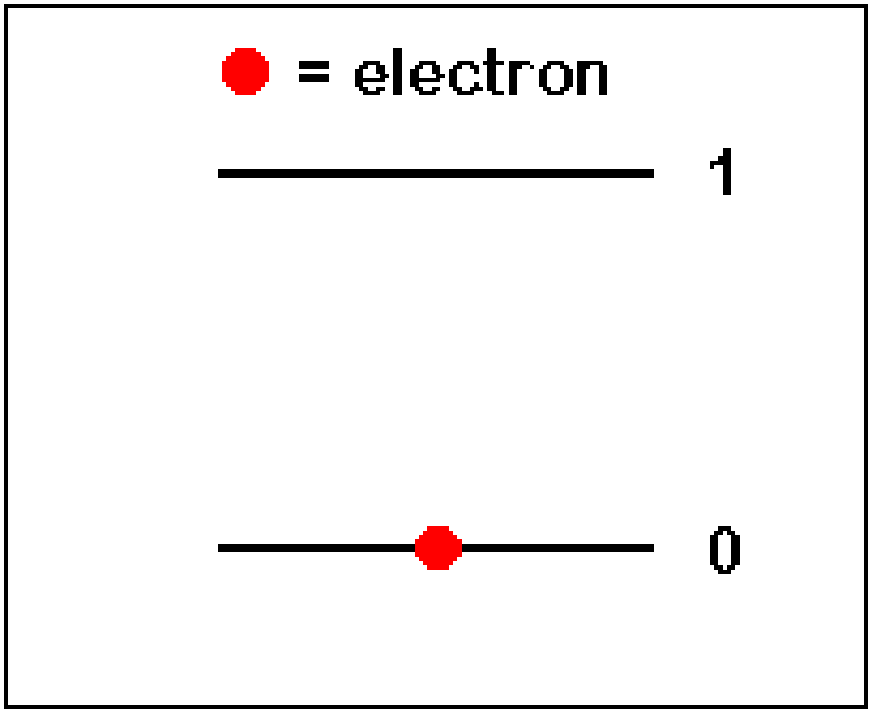
- Einstein Coefficient's
- Metastable State
- Population Inversion
- Pumping

# Einstein Coefficient's

The probability of stimulated absorption depends on energy density and is given as

$$P_{12} = B_{12}u(\nu)$$

Here, $B_{12}$ is Einstein's coefficient for absorption of radiation



The probability of spontaneous emission is

$$\left(P_{21}\right)_{\text{spontaneous}} = A_{21}$$

Here, $A_{21}$ is Einstein's coefficient for spontaneous emission.

The probability of stimulated emission is

$$\left(P_{21}\right)_{\text{stimulated}} = B_{21}u(\nu)$$

Here, $A_{21}$ is Einstein's coefficient for spontaneous emission.

Relation between Einstein's coefficients:

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3}$$

Here, h is Planck's constant

ν is frequency of radiation and

c is velocity of light.

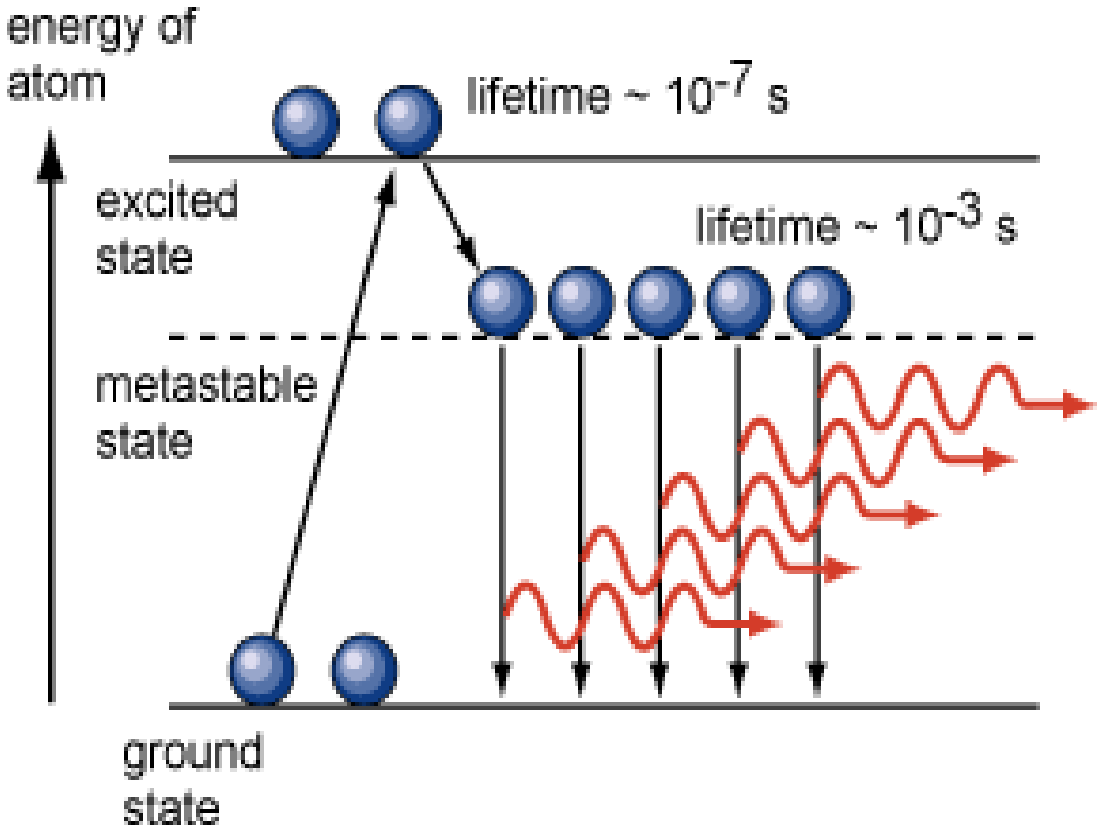
# Metastable State

- The atom remains in an excited state for a period of $10^{-8}$ sec.
- A long lived energy state ($10^{-3}$sec) is called Metastable state.
- If certain atoms are excited to the metastable state, the probability of spontaneous emission is negligible

# Population Inversion

$$N_1 = N_0 e^{-E_1/kT}$$

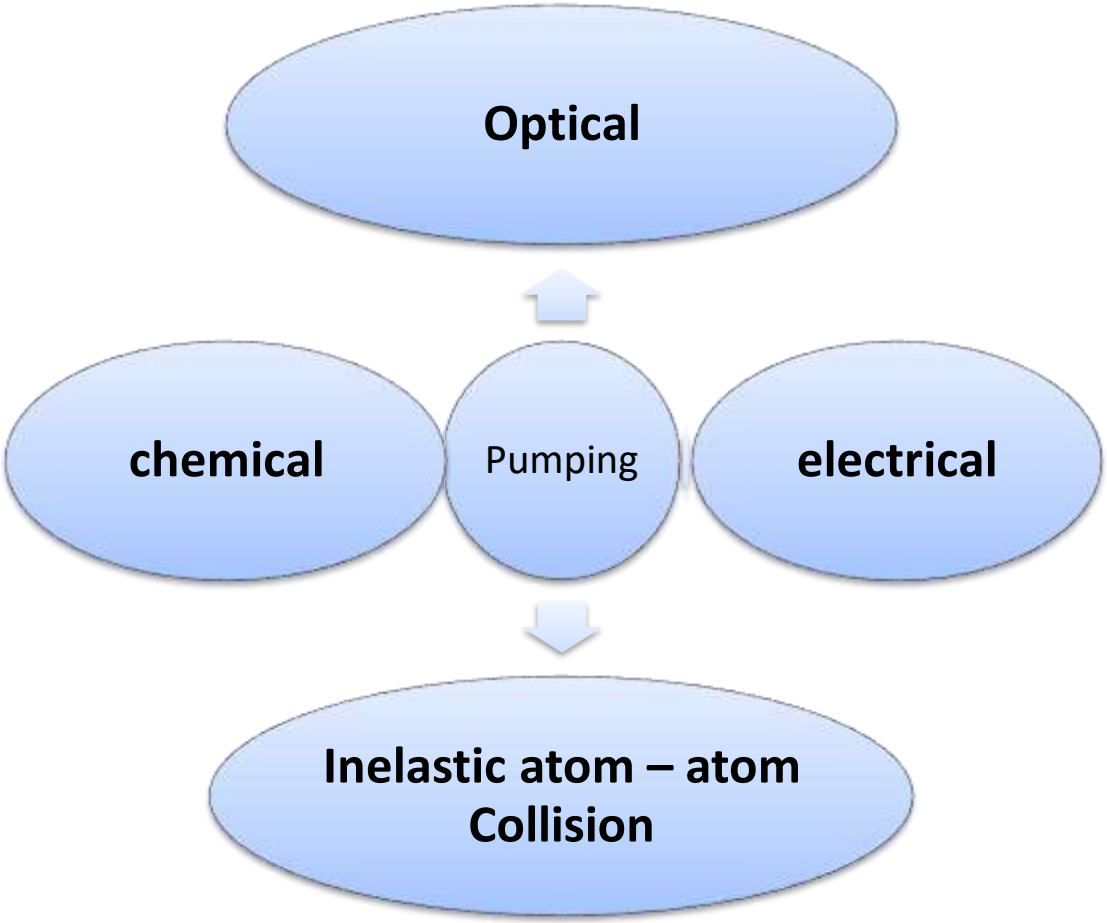
$$N_2 = N_0 e^{-E_2/kT}$$



$$\frac{N_1}{N_2} = N_0 e^{-(E_2 - E_1)/kT}$$

- In Normal State, $E_2 > E_1$ and $N_1 > N_2$
- In Population Inversion State $N_2 > N_1$
- Importance of Metastable state to achieve Population inversion

# Types of Pumping



# Quiz

1. Population inversion is not possible in ……level pumping scheme.
2. He- Ne laser employs
   a) Two level pumping scheme
   b) Three level pumping scheme
   c) Four level pumping scheme
   d) None of these
3. Ruby laser employs
   a) Two level pumping scheme
   b) Three level pumping scheme
   c) Four level pumping scheme
   d) None of these

# MCQ

1. The probability of spontaneous emission from a higher state 2 of energy $E_2$ to the lower state 1 of energy $E_1$ depends
   a) Only on the properties of state 1 and 2
   b) Only on the energy density of the incident radiation of frequency ν
   c) Both on properties of state 1 and 2 and the energy density of the incident radiation of frequency ν.
   d) Neither on properties of state 1 and 2 and the energy density of the incident radiation of frequency ν.

# Previous Year Questions

## Short answer type questions

1. What is the principle of Laser?
2. Define Population inversion. **[2017]**
3. What is Pumping?
4. Define metastable state. **[2016]**

## Long answer type questions

1. What are Einstein's coefficients? Obtain a relation between them. Also discuss the essential conditions for laser action. [2011, 2012,2016]

2. What are Einstein's coefficients 'A' and 'B'? Establish a relation between them. [2013]

# Fibre Optics and Laser

# Lecture 7

**Unit: 9**

Physics

KAS 201

B.Tech (2nd Sem.)

Assistant Professor

Applied Sciences

# Topic Objective

- To provide the knowledge of component of laser.
- To provide the knowledge of Ruby laser.

# Topic Outcome

After completion of course students are;

- Able to explain the component of laser.
- Able to explain construction, working and application of Ruby laser.

# Prerequisite and Recap

- No. of atoms in the higher energy state is higher than the no. of atoms in the lower energy state refers a Population Inversion
- Einstein Coefficient's
- To pump/excite the atoms to upper energy state refers as Pumping

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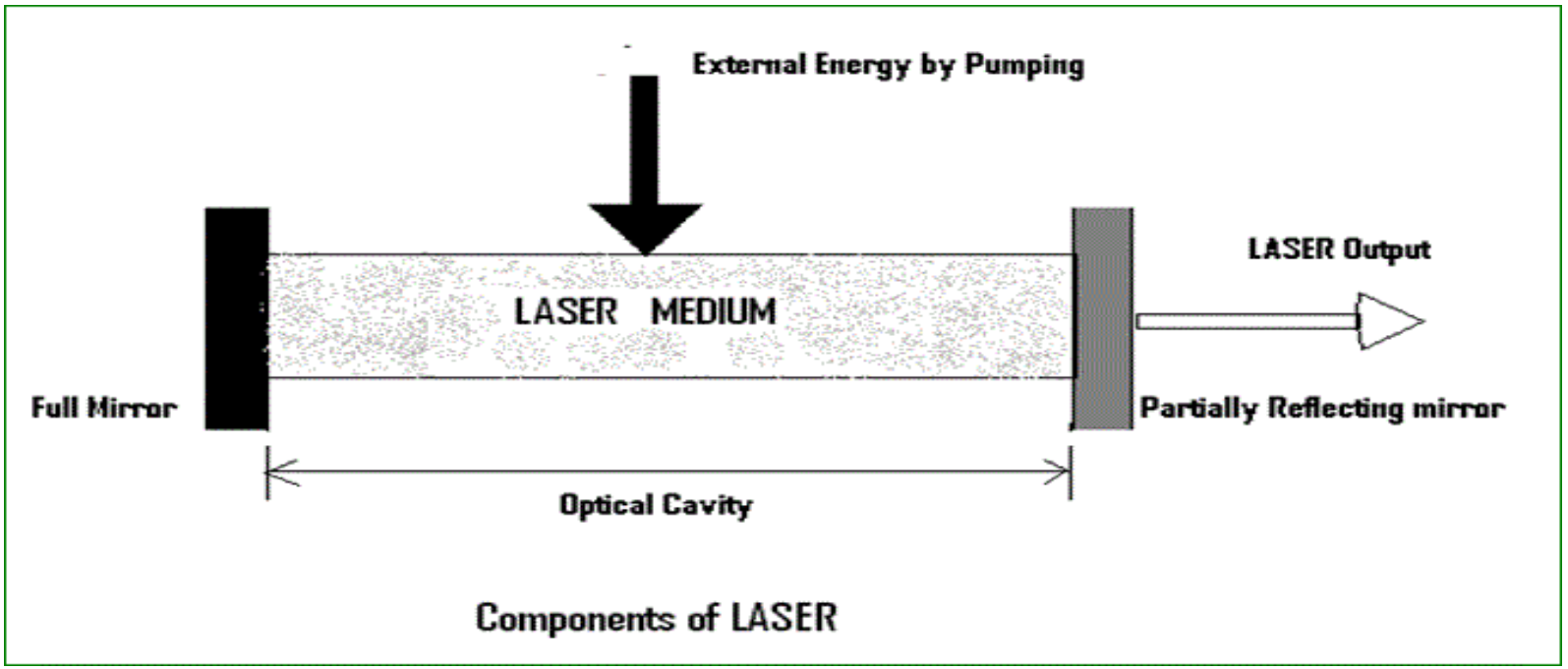
# Today's Lecture

- Components of LASER
- Types of LASER
- Ruby LASER
- Construction of Ruby LASER
- Working of Ruby LASER

# Main Components of LASER

A laser requires three components for operation

- **Active medium**
- **Pumping technique**
- **Optical resonator or Cavity**




Components of LASER

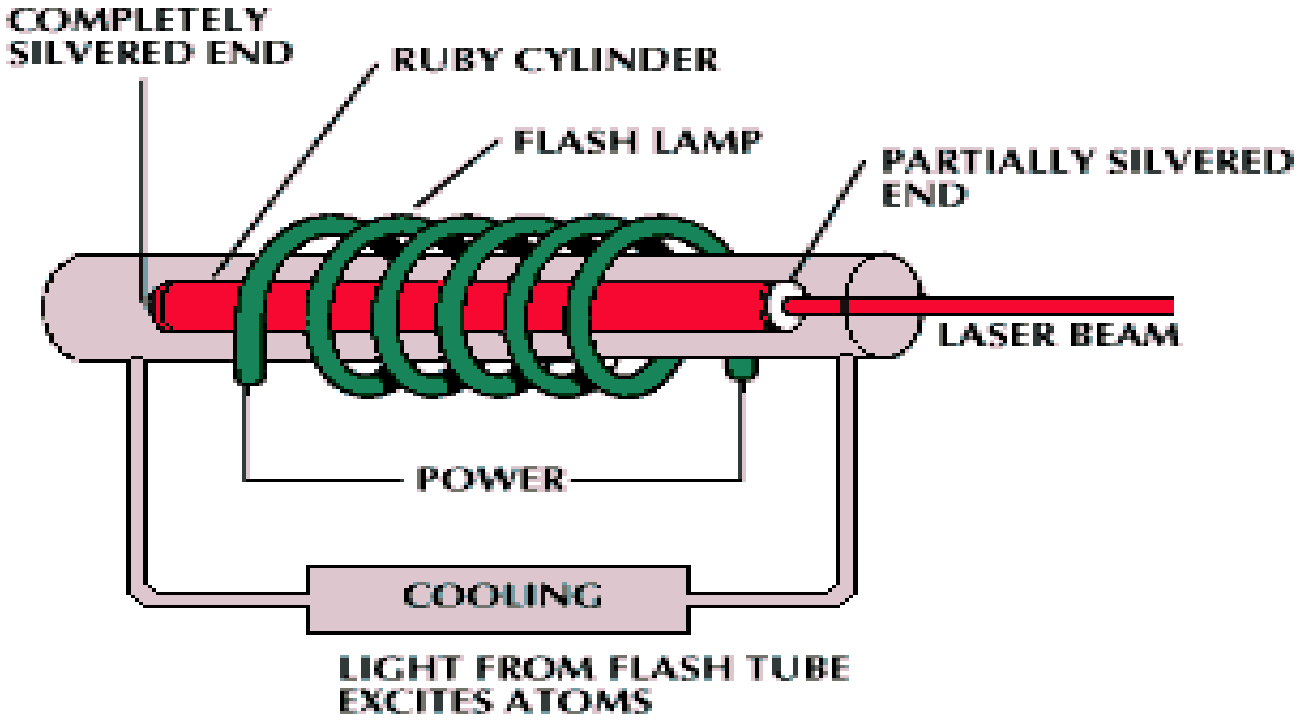
# Types of LASER

The lasers are mainly divided into four categories:

- Solid state lasers
- Gas lasers
- Liquid dye lasers
- Semiconductor lasers

# Ruby LASER

- **The ruby laser was the first laser developed by Maiman in 1960. It is a 3 level laser system. It is a first solid state laser.**



# Construction

**Ruby is a crystal of Aluminium oxide ($Al_2O_3$) which is shaped in a rod doped with 0.05% chromium oxide ($Cr_2O_3$). Thus $Cr^{+3}$ acts as an active medium.**

**A Xenon discharge tube is wrapped around this Ruby rod. Optical flashes from this acts as pumping source to excite the active medium to achieve population inversion.**

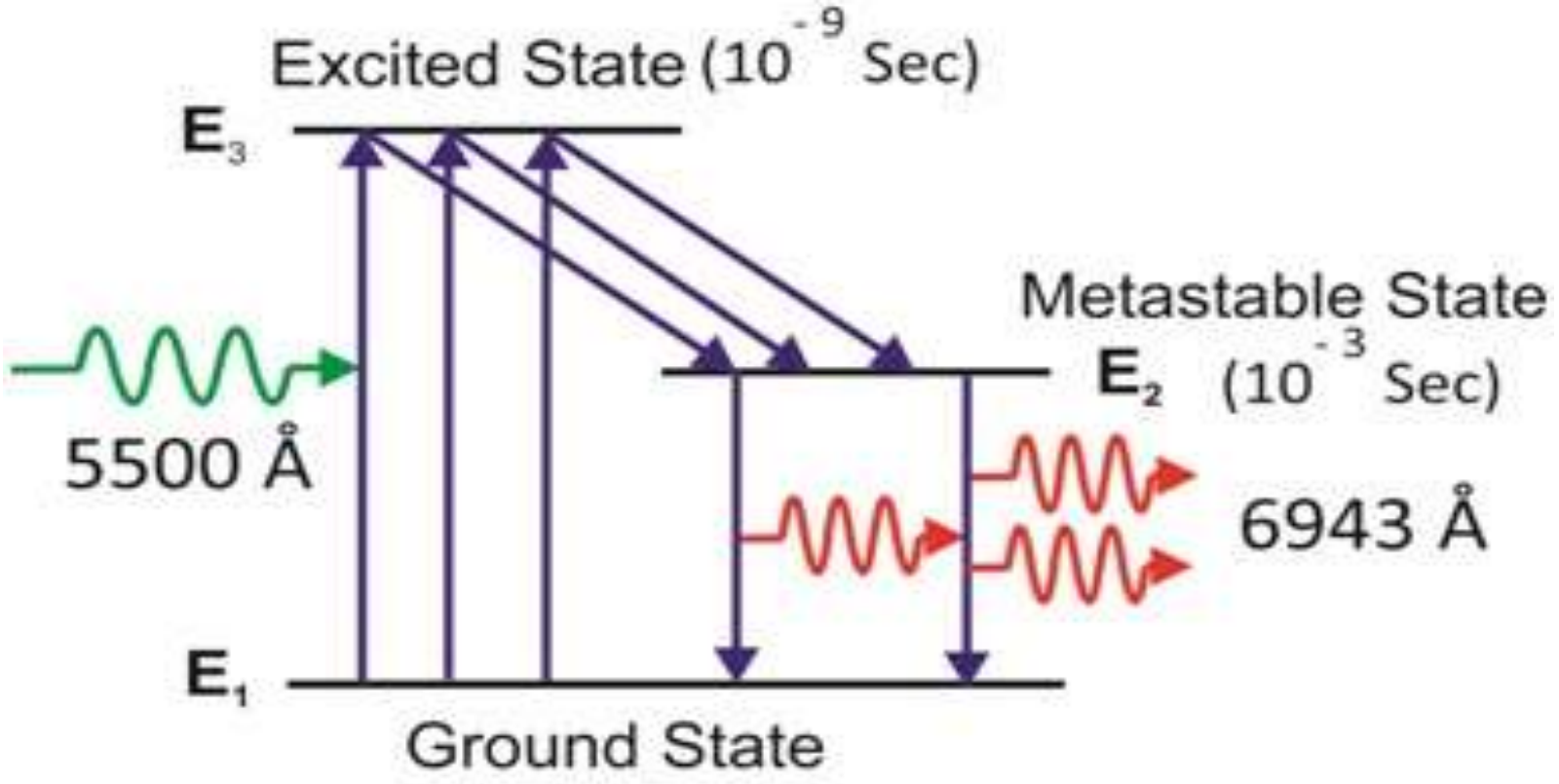
**One end of Ruby rod is made fully reflecting while the other end is made partially reflecting. This arrangement acts as optical resonator to facilitate the necessary photons required to gain stimulated emissions.**

**For cooling a water circulating glass tube is provided around the Ruby rod.**

# Characteristic and Applications

- **The ruby laser is a pulsed laser that is it emits the laser light in pulses.**
- **Out put power varies from $10^4$-$10^6$ watts.**
- **Used in welding, cutting, drilling etc.**

# Working of Ruby LASER




Energy Level Diagram of Ruby LASER

# Quiz

1. In ruby Laser which ion give rise to the Laser action?

(a) $Al_2O_3$ (b) $Al^{3+}$ (c) $Cr^{3+}$ (d) None of them

2. …….. pumping method is used in Ruby laser.

3. Ruby laser produce pulsed laser beam (true/False)

# Previous Year Questions

1. Describe the essential component of a Ruby Laser. Explain its working on the basis of the relevant energy diagram. [2013,2017]

2. What is Laser? Discuss the construction and working of a Ruby Laser, explaining the principle of population inversion. [2001, 2006,2017]

3. Explain the spontaneous and stimulated emission of radiation. Describe the working principle of a ruby laser. [2003, 2006, 2010]

# Fibre Optics and Laser

# Lecture 8

**Unit: 9**

Physics

KAS 201

B.Tech (2nd Sem.)

Assistant Professor

Applied Sciences

# Topic Objective

- To provide the knowledge of He-Ne laser.

# Topic Outcome

After completion of course students are;

- Able to explain construction, working and application of He-Ne laser.

# Prerequisite and Recap

- Components of LASER
- Ruby LASER

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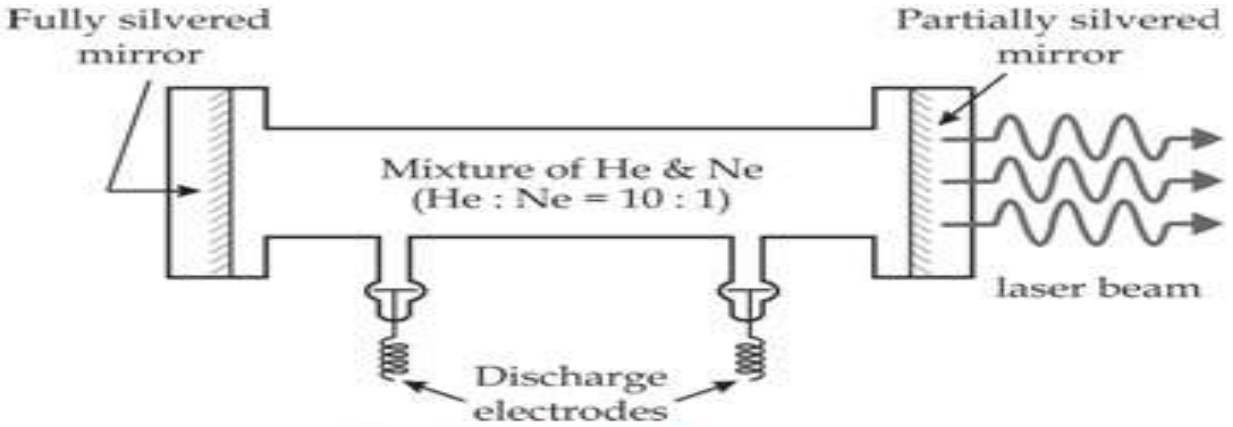
# Today's Lecture

- He-Ne LASER
- Construction of He-Ne LASER
- Working of He-Ne LASER

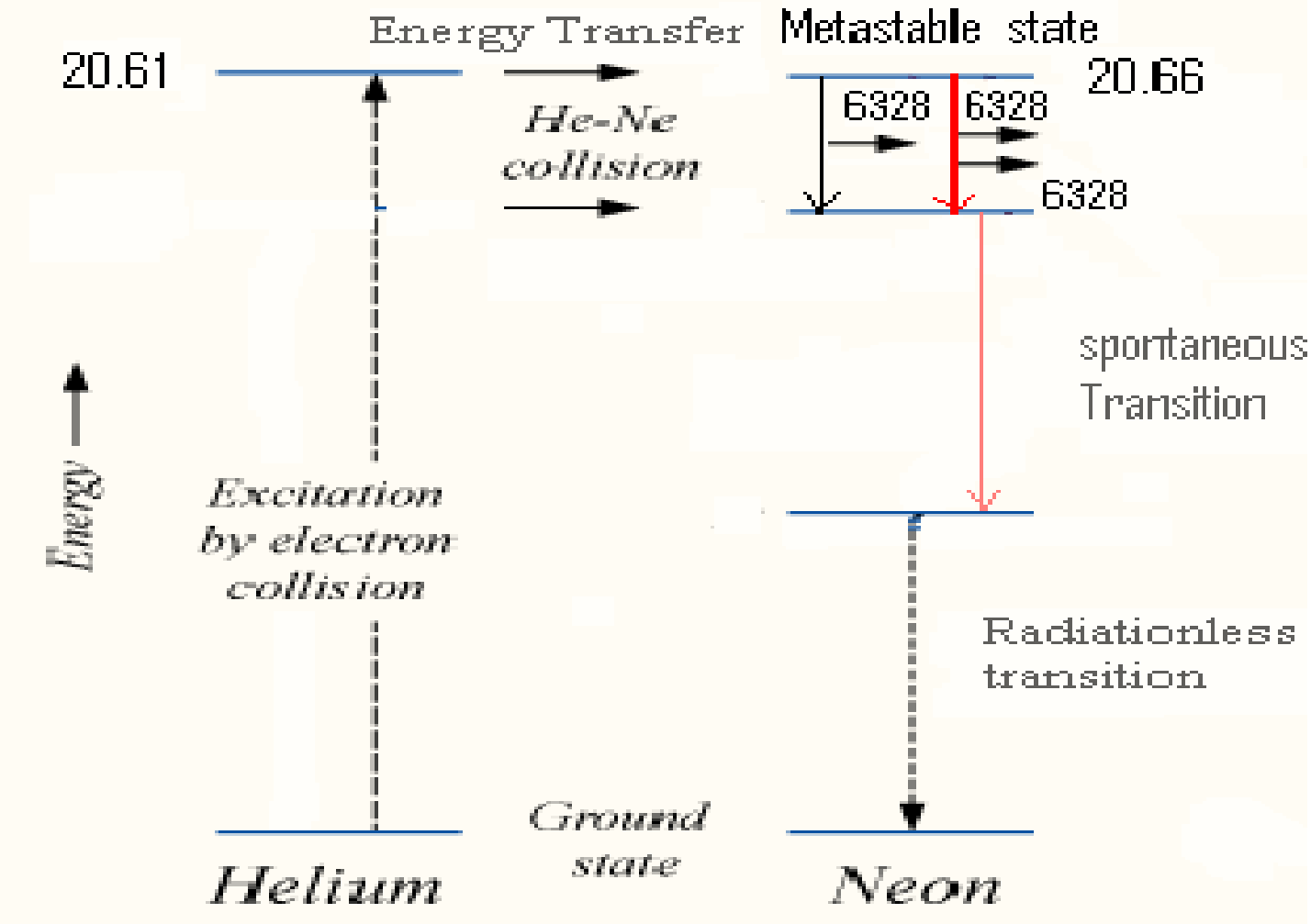
# He-Ne LASER

- Built by Ali Javan in 1961. First gaseous state laser.
- **Active medium**: Mixture of Helium and Neon (10:1 or 7:1 at a pressure of about 1 torr**)**
- **Pumping:** electrical discharge method
- **Optical cavity:** discharge tube is polished on both ends.



He-Ne LASER

# Working of He-Ne LASER



# Characteristic and Applications

- He-Ne laser is most commonly used laser for lab experiments.
- Typical power outputs of He-Ne laser lie between 1 to 50 mW of continuous wave for inputs of about 5-10 W.

# MCQ

1. He – Ne laser produces the Laser beam of wavelength
   (a) 6943 Å (b) 6328 Å (c) 6320 Å (d) 6940 Å.

2. The method of population inversion to the Laser action in He – Ne Laser is

(a) Molecular collision (b) Electric discharge (c) optical pumping (d) None of them.

# Previous Year Questions

1. Describe the construction and working of He – Ne laser.
[2011, 2012]

2. Draw a neat diagram of He – Ne laser and describe it's method of working. What are the characteristics of laser beam? Discuss it's important application.
[2004, 2009, 2011, 2012,2016]

# Fibre Optics and Laser

# Lecture 9

**Unit: 9**

Physics

KAS 201

B.Tech (2nd Sem.)

Assistant Professor

Applied Sciences

# Topic Objective

- To provide the knowledge of application laser.

# Topic Outcome

After completion of course students are;

- Able to explain the applications of laser.

# Prerequisite and Recap

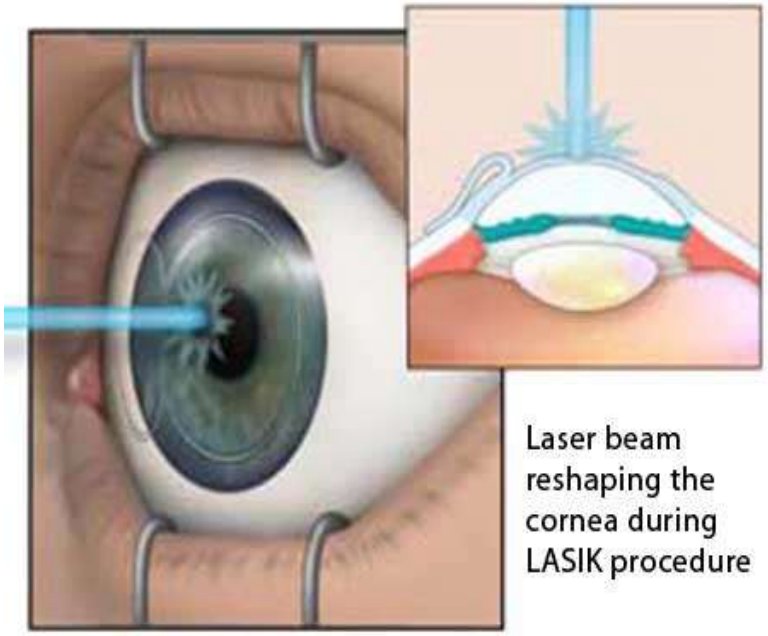
- He- Ne LASER

# Today's Lecture

- Applications of LASER

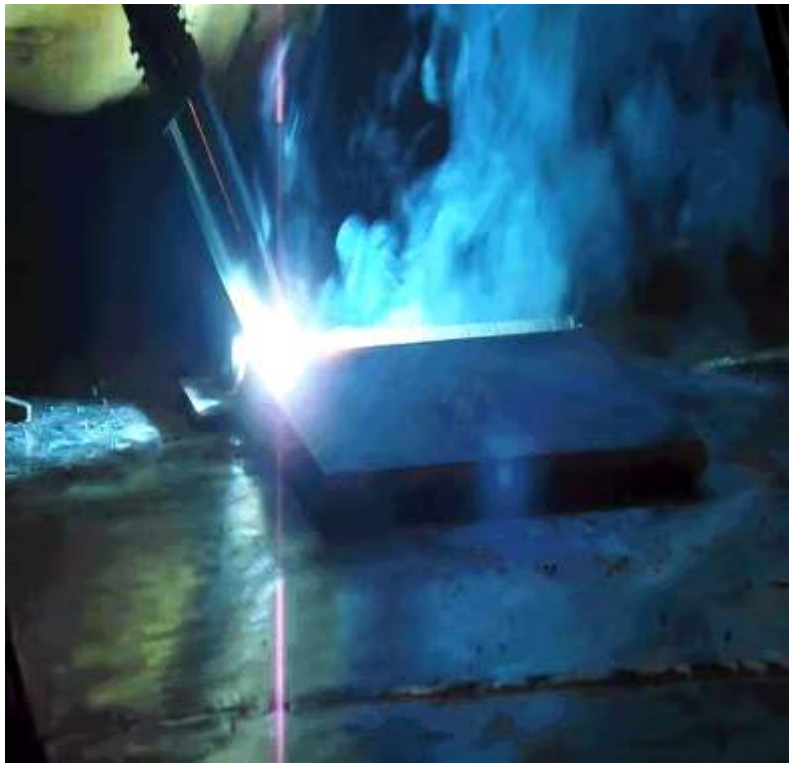
# Applications of LASER

Dental Surgery




Eye Surgery

# Applications of LASER



Welding


LASER Gun

# Communications Applications

Laser communication


In Optical Fiber communication

# Military applications

# You-tube Video Links

1. https://www.youtube.com/watch?v=_sUVXHfUVsY
2. https://www.youtube.com/watch?v=EBVNbRN805o
3. https://www.youtube.com/watch?v=yQ0lMSNuj_o
4. https://www.youtube.com/watch?v=RyY4PEpV2RQ

# Assignment

***One Word:***

- What is the principle of laser?
- Is metastable state is necessary for laser action?
- Which type of pumping method is used in ruby laser?
- Write the no. of energy levels involved in He- Ne laser.

***One line:***

- What is the full form of laser?
- What is electrical pumping?
- Why He – Ne laser is superior to Ruby laser?

# Assignment

***Short answer type:***

- What is population inversion and how it can be achieved?
- What is pumping action?
- What do you mean by metastable state?

***Long answer type:***

- Discuss the construction and working of a Ruby laser.
- Draw the neat diagram of He – Ne laser and describe its method of working. Discuss the properties of laser beam.
- Discuss the applications of laser.

# Previous Year Questions paper

Printed Page 1 of 2 | Sub Code: AS102

Paper Id: 199232 | Roll No:

**B. TECH**
**(SEM-I) THEORY EXAMINATION 2019-20**
**ENGINEERING PHYSICS I**

*Time: 3 Hours* | *Total Marks: 100*

**Note:** Attempt all Sections. If require any missing data; then choose suitably.

**SECTION A**

**1. Attempt *all* questions in brief.** **2 x 10 = 20**

a. Define inertial and non-inertial frame of reference with example.
b. Define proper and improper time interval.
c. Write down Maxwell's equation for free space.
d. Define poynting vector and write down its dimension.
e. Why Newton's rings are circular?
f. What do you mean by dispersive power of grating?
g. State two difference between interference and diffraction.
h. Define optical activity.
i. Define population inversion and pumping.
j. Define acceptance angle and numerical aperture.

**SECTION B**

# Previous Year Questions paper



## SECTION B

**2. Attempt any *three* of the following: 10x3=30**

a. What was the objective of conducting the Michelson-Morley experiment? Describe the experiment. How is the negative result of the experiment interpreted?

b. State and Deduce Poynting theorem for the flow of energy in an electromagnetic field.

c. Discuss the phenomenon of interference of light in thin films and find the condition of maxima and minima. Show that the interference patterns of reflected and transmitted monochromatic source of light are complementary.

d. Derive an expression for the intensity distribution due to Fraunhofer's diffraction by single slit. Show that the intensity of the first subsidiary maximum is about 4.5% of that of the principal maximum,

e. Describe the construction and working of Nicol Prism. Explain how Nicol prism acts as a polarizer and analyzer.

## SECTION C

**3. Attempt any *one* part of the following: 10x1=10**

a. Derive an expression for variation of mass with velocity.

b. Calculate the amount of work to be done to increase the speed of a electron from $0.8c$ to $0.9c$. Given the rest energy of electron =0.5MeV where $c$ is the velocity of light.

**4. Attempt any *one* part of the following: 10x1=10**

a. Write down Maxwell's equations in free space and show that E, H and direction of propagation from a set of orthogonal vectors.

b. Assuming that all the energy from a 1000 watt lamp is radiated uniformly; calculate the values of the intensities of electric and magnetic fields of radiation at a distance of 2m from the lamp.

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# Previous Year Questions paper

**Printed Page 2 of 2** **Sub Code:EAS101**

**Paper Id:** 199221 **Roll No:**

**5. Attempt any *one* part of the following:** **10 x 1 = 10**

a. Define resolving power and dispersive power of grating. Derive an expression for the resolving power of a plane transmission grating.

b. What are Einstein's coefficients? Derive Einstein's relation.

**6. Attempt any *one* part of the following:** **10 x 1 = 10**

a. What is double refraction? Explain the construction and working of Nicol prism.

b. Explain why two level laser systems does not have any physical significance? Describe the principle and working of three-level and four-level laser systems.

**7. Attempt any *one* part of the following:** **10 x 1 = 10**

a. Explain the basic principle of optical fibre. Discuss the optical fibre classification.

b. What is basic principle of holography? Describe the principle of holography using the processes of construction and reconstruction of image. Give some applications also.

Physical Constants

| | | |
|---|---|---|
| Rest mass of electron | $m_e$ | $= 9.1 \times 10^{-31}$ kg |
| Rest mass of Proton | $m_p$ | $= 1.67 \times 10^{-27}$ kg |
| Speed of light | c | $= 3 \times 10^{8}$ m/s |
| Planck's Constant | h | $= 6.63 \times 10^{-34}$ J-s |
| Charge on electron | e | $= 1.6 \times 10^{-19}$ C |
| Boltzmann's Constant | k | $= 1.38 \times 10^{-23}$ J-K$^{-1}$ |

# Expected Questions for University Exam

1. What is Laser? Explain its principle. Also explain the principle of optical pumping.
2. What are the characteristic properties of a laser beam? Describe its important applications.
3. Describe the construction and working of He – Ne laser.
4. What is Laser? Discuss the construction and working of a Ruby Laser, explaining the principle of population inversion.
5. Explain the spontaneous and stimulated emission of radiation. Describe the working principle of a ruby laser.

# Summary

- LASER is acronym of Light Amplification by Stimulated Emission of Radiation
- Laser light is produced by Stimulated emission of radiation.
- Population inversion is necessary for laser action
- Ruby laser is a three level laser
- He – Ne laser is a four level laser
- Laser have applications in the field of medicine, industry, defense, security etc

# References

1. Engineering Physics by SK Gupta

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# Thank You