Optics and Modern Physics

Optics: The study of light and electromagnetic waves

Reflection from a regular surface: When a ray of light strikes a glossy surface, the beam of light returns to the same medium. The phenomenon of a ray of light returning from such a surface is called reflection of light.

Laws of Reflection:

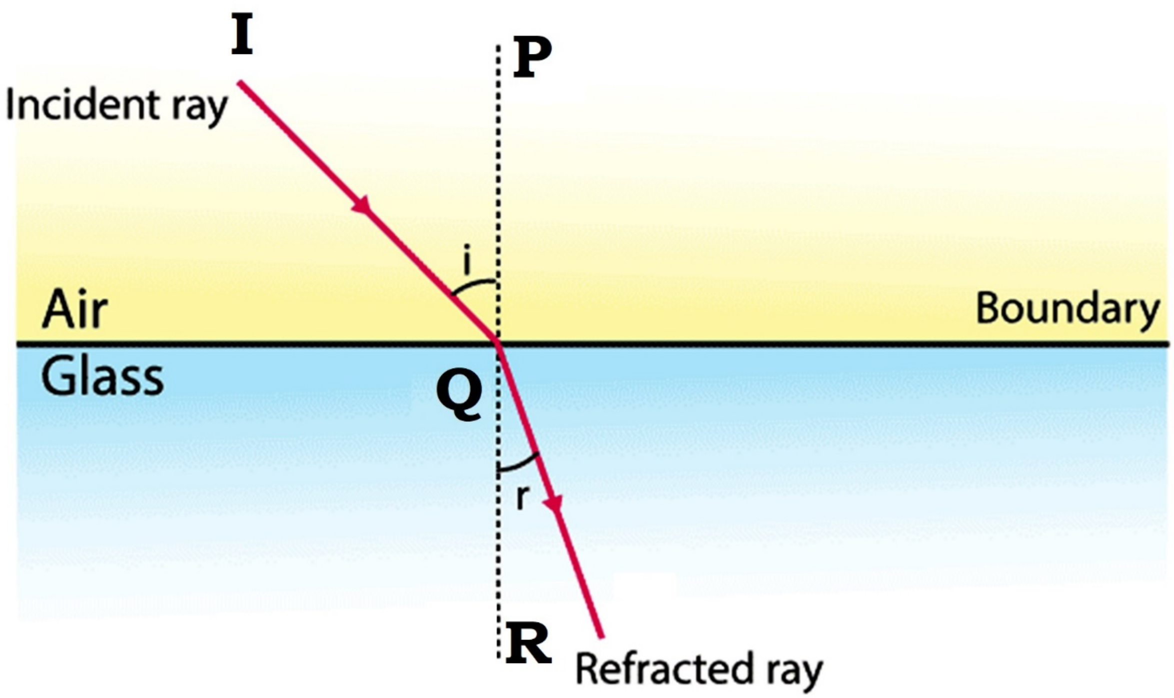
1. The incident ray and the reflected ray and the length are in the same plane.
2. Both the reflected ray and the reflected ray are in the opposite direction of the length.
3. The values of the angle of descent and the angle of reflection are the same.
4. The rays falling in the perpendicular direction are reflected in the same direction.

Refraction of light

It is our common experience that a ray of light moves in a straight path, but "*when a ray of light moves from one medium to another, it* *bends from the surface separating the two mediums. This bending of light is called the refraction of light."*

We know that light is a transverse wave, so its velocity changes when it moves from one medium to another. Thus, if it enters a dense medium from a thin medium, its velocity decreases.

As shown in the figure, when a ray of light I enters a thin medium such as air into a dense medium like glass, its velocity decreases



causing the light ray moves towards the normal PQR drawn perpendicular. Now when the curved ray enters a medium like glass into a thin medium like air, it moves away from the normal PQR due to its increase in velocity. Here it is the angle of incidence and that angle of refraction r.

Snell's law: When a ray of light travels from one medium to another, the ratio of their angle of incidence to their angle of incidence i and angle of refraction r remains constant.

$$\mu = \frac{\sin i}{\sin r} = constant$$

μ is called the refractive index of the medium

Suppose one medium has a refractive index μ_1 and the other medium has a refractive index μ_2. So, μ_{21} is called the refractive index of medium 2 relative to medium 1.

$$\mu_{21} = \frac{\sin i}{\sin r} = constant$$

Absolute and relative refractive index:

Absolute Refractive Index: The refractive index of a medium relative to air/vacuum is called the neutral refractive index.

The absolute refractive index is also known as the just *refractive index* of the medium.

Absolute Refractive Index: The ratio of the velocity of light in vacuum to the velocity of light in a medium is called the absolute refractive index or (only) refractive index of that medium.

$$\mu = \frac{Velocity\ of\ light\ in\ Vacuum}{Velocity\ of\ light\ in\ medoum} \dots\dots\dots\dots..(1)$$

$$\eta = \frac{c}{v} \dots\dots\dots\dots\dots\dots\dots(2)$$

Relative refractive index: The refractive index of one medium relative to another medium is called relative refractive index.

Suppose medium – 1 has the refractive index of η_1 and the other medium – 2 has the refractive index of η_2

Now if the velocity of light in medium – 1 is v_1, then its absolute refractive index,

$$\eta_1 = \frac{c}{v_1} \dots\dots\dots\dots\dots\dots\dots (3)$$

Similarly, now if the velocity of light in medium – 2 is v_2, then its absolute refractive index,

$$\eta_2 = \frac{c}{v_2} \dots\dots\dots\dots\dots\dots\dots (4)$$

Now taking the ratio of equations (4) and (3),

$$\therefore \eta_{21} = \frac{\eta_2}{\eta_1} = \frac{c/v_2}{c/v_1} = \frac{c}{v_2} \times \frac{v_1}{c}$$

$$\therefore \eta_{21} = \frac{v_1}{v_2} = \frac{Speed\ of\ light\ in\ medium - 1}{Speed\ of\ light\ in\ medium - 2} \dots\dots\dots\dots\dots\dots\dots (5)$$

η_{21} is called the relative refractive index of medium – 2 with respect to (or relative to) medium – 1.

Similarly, the relative curvature of medium – 1 with respect to (or relative to) medium – 2,

$$\therefore \eta_{12} = \frac{v_2}{v_1} = \frac{Speed\ of\ light\ in\ medium - 2}{Speed\ of\ light\ in\ medium - 1} \dots\dots\dots\dots\dots\dots\dots (6)$$

Now taking the multiples of equations (5) and (6),

$$\eta_{21} \times \eta_{12} = \frac{v_2}{v_1} \times \frac{v_1}{v_2}$$

$$\therefore \eta_{21} \times \eta_{12} = 1 \ldots \ldots \ldots \ldots \ldots \ldots \ldots (7)$$

$$\therefore \eta_{21} = \frac{1}{\eta_{12}} \Leftrightarrow \eta_{12} = \frac{1}{\eta_{21}} \ldots \ldots \ldots \ldots \ldots \ldots \ldots (8)$$

For rays of light refracting from water to glass using the above equation,

$$\therefore \eta_{gw} = \frac{\eta_g}{\eta_w}$$

$$\therefore \eta_{gw} = \frac{1}{\eta_{wg}} \Leftrightarrow \eta_{wg} = \frac{1}{\eta_{gw}}$$

Now, from Snell's law, to sum up these things,

$$\eta_{21} = \frac{\sin i}{\sin r} = \frac{\eta_2}{\eta_1} = \frac{v_2}{v_1}$$

$$\therefore \eta_1 \sin i = \eta_2 \sin r \ldots \ldots \ldots \ldots \ldots \ldots \ldots (9)$$

The above equation (9) is called an extended form of Snell's law.

As the medium is optically denser, the refractive index of that medium increases.

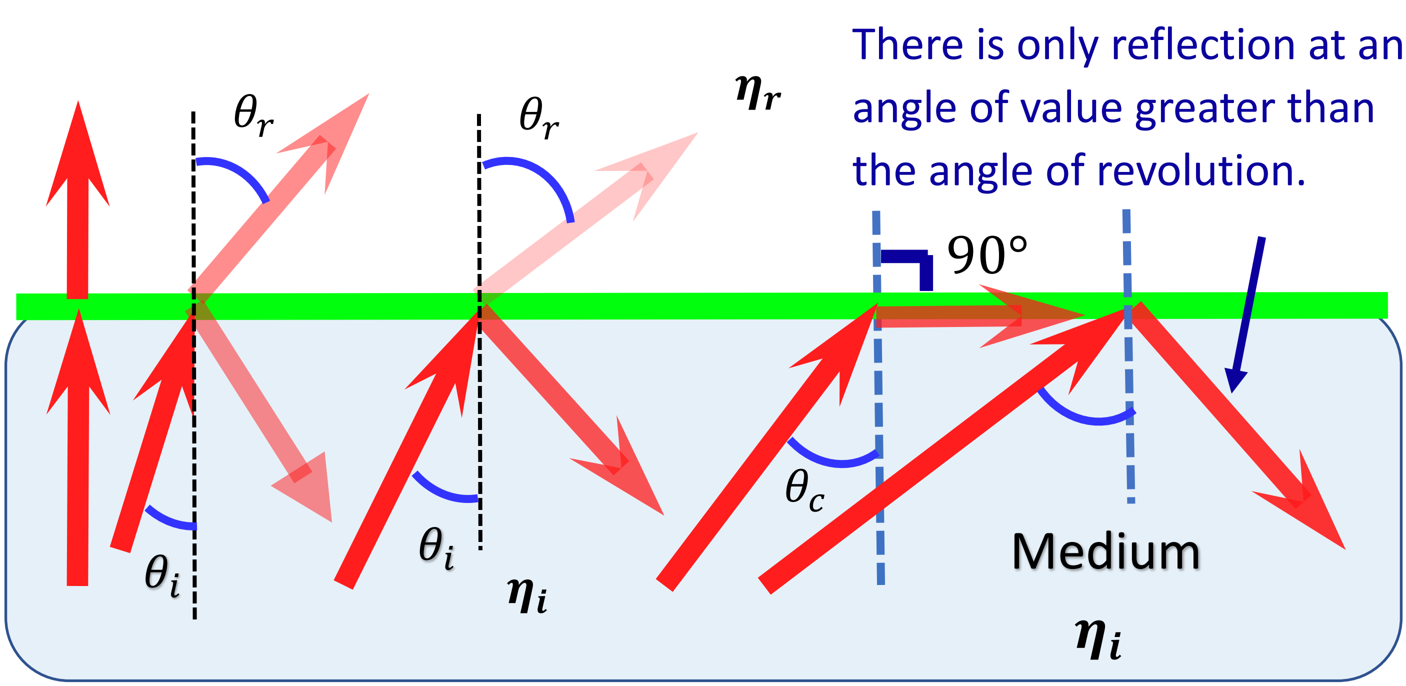
Total Internal Reflection (TIR)

Total Internal Reflection (TIR): This phenomenon works on the principle of refraction. We know that a ray of light from the surface separating the two media is partially reflected and partially refracted, but, in some cases, the ray of light is only reflected.

A vessel is filled with clean water as shown in the figure. The origin of a light s is kept at the bottom of the vessel. Four rays emanating from the source are shown.

Ray – 1: This *ray that falls perpendicularly to the surface of the water hence does not get refracted.*

As the incident angle θ_i is gradually increased, its refraction angle θ_r increases.



At certain value of incident angle, the light ray does not get refracted to air but instead, this ray moves parallel to the surface separating the two mediums at an angle $90°$.

Critical Angle θ_c: *The value of the angle of incidence for which the angle of refraction is* $90°$ *then that incident angle is called the critical angle.*

Total Internal Reflection: When a ray of light enters a thin medium from a dense medium, if the value of the angle of incidence is greater than the critical angle, then light is only reflected inside the same medium instead of being refracted to another medium. This phenomenon is called the Total Internal Reflection.

Examples:

1. During hot day, A mirage is seen in the desert or on the road of asphalt.
2. Sailors see steamers or ships hanging high in the air in the polar region where snow is always covered.
3. A glitter of diamonds.
4. An empty test tube of glass kept in the water shines.
5. The cracks in the glass of the vehicle also glow for the same reason.

Applications:

1. Fiber Optical Cable
2. SLR Camera

3. Endoscope (Endoscope)
4. Periscope (Periscope)
5. Binoculars
6. Prism (Prisms)

Critical angle: *The value of the angle of incidence for which the angle of refraction is* $90°$ *then that incident angle is called the critical angle*.

According to the figure shown above, if we take the refractive index η_i and the angle of incidence θ_i of the medium from which the ray of light is emerged and the refractive index η_r and the angle of refraction θ_r of the medium in which this ray of light is transmitted, then according to Snell's law,

$$\eta_i \sin\theta_i = \eta_r \sin\theta_r$$

Now when the value of the angle of incidence θ_i is equal to that of the critical angle θ_c,

$$\theta_i = \theta_c$$

When there is a total internal reflection and the angle of refraction is $\theta_r = 90°$ then,

$$\therefore \eta_i \sin\theta_c = \eta_r \sin 90°$$

$$\therefore \eta_i \sin\theta_c = \eta_r(1)$$

$$\therefore \eta_i \sin\theta_c = \eta_r$$

$$\therefore \sin\theta_c = \frac{\eta_r}{\eta_i}$$

$$\therefore \theta_c = \sin^{-1}\left(\frac{\eta_r}{\eta_i}\right)$$

The above equation gives the value of the angle of revolution.

The value of a $\frac{\eta_r}{\eta_i}$ must always be smaller than 1. If its value increases by 1, such a value of $\sin^{-1}$ cannot be obtained, which means that when a ray of light passes from a thin medium to a dense medium, its total internal reflection is not possible.

Conditions for complete internal reflection:

1. A ray of light should be moving from a dense medium to a thin medium.
2. The value of the angle of incidence (of the medium through which it is passing) should be greater than the value of the critical angle.

Now the values of critical angle for some of the best-known media:
(This is given only as a calculation for information and for example.)

The value of the revolution angle for water and air:

$$\eta_i = \eta_{water} = 1.33$$

$$\eta_r = \eta_{air} = 1.00$$

$$\therefore \theta_c = \sin^{-1}\left(\frac{\eta_{air}}{\eta_{water}}\right)$$

$$\therefore \theta_c = \sin^{-1}\left(\frac{1.00}{1.33}\right)$$

$$\therefore \theta_c = \sin^{-1}(0.7518)$$

$$\therefore \theta_c = 48.75° \leftarrow for\ water$$

The value of the revolution angle for glass and air:

$$\eta_i = \eta_{glass} = 1.52$$

$$\eta_r = \eta_{air} = 1.00$$

$$\therefore \theta_c = \sin^{-1}\left(\frac{\eta_{air}}{\eta_{glass}}\right)$$

$$\therefore \theta_c = \sin^{-1}\left(\frac{1.00}{1.52}\right)$$

$$\therefore \theta_c = \sin^{-1}(0.6578)$$

$$\therefore \theta_c = 41.13° \leftarrow for\ glass$$

The value of the revolution angle for diamond and air:

$$\eta_i = \eta_{diamond} = 2.42$$

$$\eta_r = \eta_{air} = 1.00$$

$$\therefore \theta_c = \sin^{-1}\left(\frac{\eta_{air}}{\eta_{diamond}}\right)$$

$$\therefore \theta_c = \sin^{-1}\left(\frac{1.00}{2.42}\right)$$

$$\therefore \theta_c = \sin^{-1}(0.4132)$$

$$\therefore \theta_c = 24.40° \leftarrow for\ diamond$$

LASER

LASER is a structure that produces LASER by the diffraction of light produced by the emitted emission of radiation.

LASER is a word created by combining the above words (Acronym), whose full name is as follows.

L: LIGHT

A: AMPLIFICATION by

S: STIMULATED

E: EMISSION of

R: RADIATION

Properties of normal light

1. Normal light has more than one wavelength; hence it is called polychromatic light.
2. The relation of phase between the rays of light emitted from the common source of light does not exist, that is, each ray of light has a different Phase. Therefore, they are not coherent.
3. The divergence of normal light increases, that is, as the distance increases, the spread of the rays of light in all directions increases, so its brightness and intensity decrease very rapidly. Thus, normal light is less low directional and less focused.

Properties of LASER light

1. Laser Light has the same wavelength; hence it is called monochromatic light.
2. The rays of light emitted in laser light are in the same art, that is, they are coherent.
3. As the beam distance of laser light increases, its divergence decreases slightly, so its brightness and intensity are maintained for a very long distance. Thus, LASER light is higher directional and more focused.

Difference Between Normal Light and LASER Light

Normal light	LASER light
Normal light emits wavelets in as many directions as possible.	LASER light emits wavelets in only one direction.
Not all photons of light emitted from the origin of normal light are in the same art.	All photons of light emitted from the LASER origin are in the same art.
Normal light is polychromatic.	LASER light is monochromatic.
The value of a common light divergence is extremely high.	The value of laser light expansion (Divergence) is extremely low.
The brightness and intensity of normal light decreases rapidly as the distance increases due to high expansion.	The brightness and intensity of laser light remain constant for a very long distance as the distance increases due to extremely low expansion.
Normal rays of light are not parallel to each other.	The rays of laser light are parallel to each other.

APPLICATIONS OF LASER

Medical Field

1. LASER is used to remove stones from the kidneys.
2. LASER is used for blood-less surgery in parts of the body, such as the liver, through which more blood flows.
3. LASER is used in extremely complex surgeries of delicate and sensitive organs such as the brain.
4. LASER is also used for permanent disposal of pimples, pimples, blemishes, wrinkles, bruises, stretch marks, birth marks or tattoos on other parts of the body, and unwanted hair.
5. LASER is used to clean teeth and make them white and shiny.
6. LASER is used for the treatment and surgery of cancerous tumors in the body.
7. LASER is used to remove eye numbers, correct the curvature radius of the kiki, and other eye surgeries.
8. In the medical field, a 0.5 μmLASER beam of as much thickness is used in place of the scalpel used for organ surgery.

Industry Field

1. Welding: LASER is used for welding metals that cannot be connected to each other by normal welding.
2. Drilling: LASER is used to make holes of a certain size by drilling in a sheet of metals with large thickness.
3. Cutting: In addition to metals, LASER is used to cut crystals such as glass and quartz.

4. Engraving: LASER is used for writing on metals, logos, pictures or writing on objects such as leather toys, bamboos.
5. Marking: On microscopic parts such as transistors, IC chips used in the electronics field that cannot be done by ink or other chemicals in that part. Laser is used to do this writing .
6. Fine shaping & Sharpening: LASER is used to give the fine shape of a metal tool as well as to make its edges.
7. Powder Coating: Protective layer on metals – LASER is used for powder coating.
8. Hardening: LASER is used to make tools made of metals hard enough not to break .
9. Quality checking: Laser is used for internal checking in tools made of metals.
10. Electronics: Laser is used for barcode scanner, thumb scanner, retina scanner, ATM machine, LASER printer, CD-DVD player used in the market.
11. Communication: LASER is used for communication in optical fiber.
12. Photolithography: LASER is used for the printing of PCB boards, which are very essential for electronic parts.
13. Civil Engineering: Laser is used for the level of flooring of buildings, surveymeasurements, direct excavation of long tunnels .
14. Chemical Industry: LASER is used to start and accelerate certain chemical processes.
15. Holography: LASER is used to create a 3D hologram.
16. Film Industry: LASER is used to write subtitles on reels of films .
17. Automobile Industry: LASER is used for the precise alignment of vehicle tires.
18. LASER Crystal: LASER is used to create a bubblegram within a transparent plastic or glass block.

19. OLED: LASER is used in the production of OLED screens on televisions and mobiles.
20. Garment Industry: In the textile industry, LASER is used to cut bulk textiles together into a certain size and shape .
21. 3D Scan: Laser is used in 3D scans used for the in-depth study of old installations, historical objects .
22. Accelerometer: LASER is used to measure the rotation or angular velocity of an object rotating at high speed.

Science and Technology

1. LASER is used to study Brownian motion.
2. LASER is used to find the speed of light.
3. LASER is used to calculate the number of atoms in a substance.
4. LASER is used to study the polluted gases in the atmosphere.
5. LASER is used to accurately determine the rate of rotation of the Earth.
6. Laser is used as a guide star to take high-resolution images of celestial objects in astronomy.
7. LASER is used for nuclear fusion.
8. LASER is used to accurately position a satellite into a geo-stationary orbit.
9. LASER is used to measure the exact location and distance of all the planets and their satellites in the solar system.
10. LASER is used for3D scans of outer space objects lying on the earth.
11. Laser is used to study spacecraft sent to other planets, the elements in the planet's soil and the gases in the atmosphere's structure.
12. LASER is used for remote sensing of the Earth.

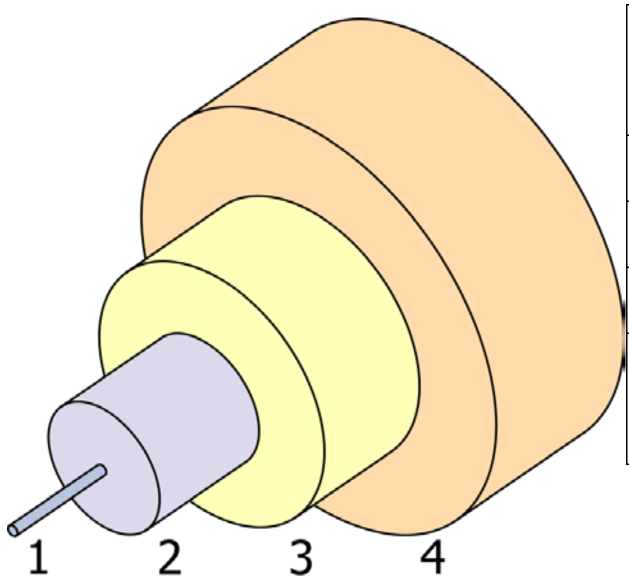
Military & Defense filed

1. LASER is used to measure the distance of objects far away from the LASER Range Finder.
2. LIDAR: LASER is used to know the location and velocity of an extremely fast missile coming from the enemy.
3. Tactical High Energy Lasers: The high-energy Tactical High Energy LASER is used to destroy missiles, aircraft or drones coming from the enemy.
4. Laser is used to take accurate targets in rifles or sniper guns used by soldiers.
5. Ring LASER Gyroscope: LASER is used to know the angle of rotation of objects coming from a distance.
6. LASER is used to secretly highlight specific targets for spy surveys in other areas during the night.
7. Gallium arsenide diode laser laser is used to create an invisible fence in the restricted area.
8. LASER is used to create a battlefield-like structure for soldiers to exercise.
9. Radio waves are used for protection which can be easily received and jammed. As a solution to this, there is $(10\ \mu m)$ no such danger in the communication of the infrared LASER in the middle range.

Optical Fiber

Optical fiber:

- Optical fiber has the same thickness as human hair.
- It is mainly made up of di-electric materials such as high purity glass or plastic.
- In it, rays of light are carried from one end to the other by full internal reflection.



Part No.	Part Name	Diameter
1	Core	$9\ \mu m$
2	Cladding	$125\ \mu m$
3	Coating	$250\ \mu m$
4	Buffer or jacket	$900\ \mu m$

Optical fiber composition:

Core (CORE):

- The core is the innermost cylindrical part
- It has diameter of $9\ \mu m$.

- This part is made up of dielectric materials such as high purity glass or plastic.
- Its refractive index is higher than the refractive index of the cladding.
- The ray of light spreads from the core itself and reaches the other end.

Cladding (CLADDING):

- The covering around the core is called cladding.
- It has diameter of around $125\ \mu m$.
- Its refractive index is less than the curvature of the core.
- It keeps the rays of light propagating in the core itself through full internal reflection.
- The larger the core, the more light can be absorbed into the cable, which is related to higher data conduction.

Coating :

- The coating keeps the cladding closed in the outer layer.
- Its diameter is almost the same.$250\ \mu m$
- It is the necessary plastic coating to strengthen the core and cladding, help absorb shock, and provide additional protection against excessive bending of the cable.
- This has no effect on the properties of the core or cladding.

Cable Jacket :

- This is the outer layer or cover of the cable.
- Its diameter is about $900\ \mu m$.

- Its purpose is to protect the cable from man-made and natural hazards such as construction work, fishing gear and sometimes shark fish.

ACCEPATNCE ANGLE

We have seen that light rays can propagate into optical fibers due to complete internal reflection. This is the ideal situation. Is it possible for light rays to propagate at all possible incident angles? For this, let us consider the geometry related to the launch of light rays into optical fiber.

- The angle at which the ray of light can carry the maximum value relative to the axis of the fiber is called the eceptance angle. θ_a
- Suppose that the core η_1 *has a curvature and* the cladding has a curvature. η_2 The medium from which the ray of light is emitted is the refractive index of the medium η_0 .
- Suppose the angle of incidence θ_i is and the angle of curvature. θ_r
- The surface separating the core and the cladding is the angle ahead. ϕ
- Now applying Snell's rule to the launch area of the fiber,

$$\eta_0 \sin \theta_i = \eta_1 \sin \theta_r$$

$$\therefore \frac{\sin\theta_i}{\sin\theta_r} = \frac{\eta_1}{\eta_0} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Now in$\Delta\ ABC$,

$$\theta_r + \phi = 90°$$

$$\therefore \theta_r = 90° - \phi$$

$$\therefore \sin\theta_r = \sin(90° - \phi) = \cos\phi \ldots\ldots\ldots (2)$$

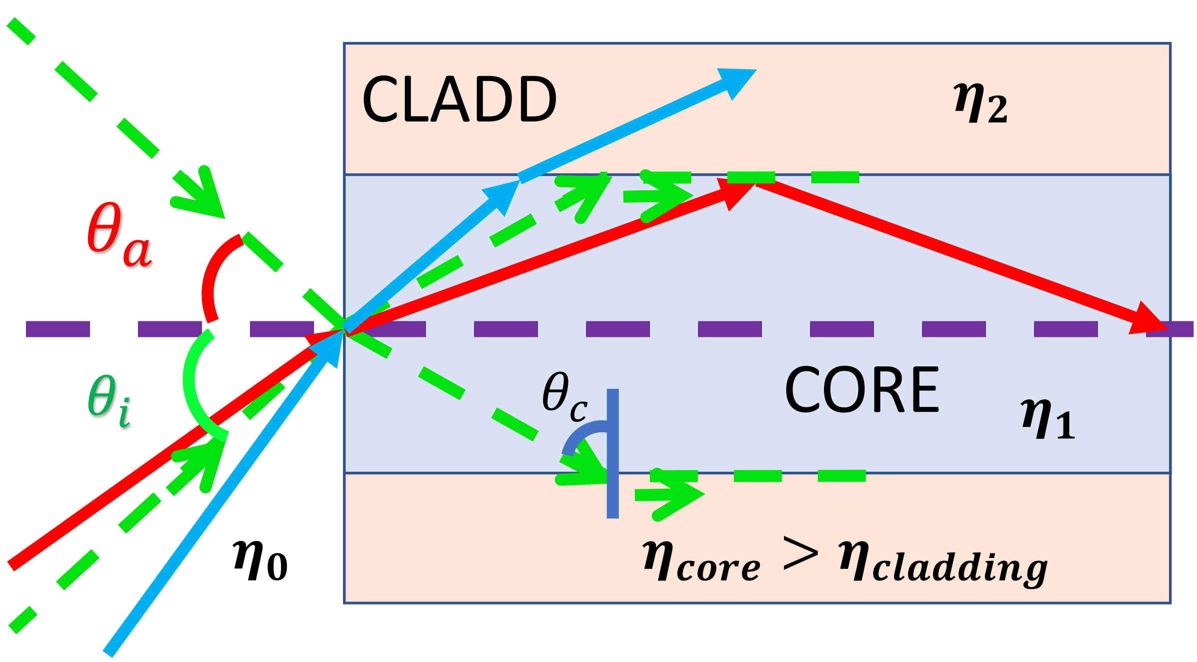
equation (2) The value of (1) Putting in,

$$\therefore \frac{\sin\theta_i}{\cos\phi} = \frac{\eta_1}{\eta_0}$$

$$\therefore \sin\theta_i = \frac{\eta_1}{\eta_0}\cos\phi \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Now if we continue to increase the value of the angle of incidence, then for a maximum value of a $\theta_{i\,max}$ maximum value. $\phi = \phi_c$

$$\therefore \sin\theta_{i\,max} = \frac{\eta_1}{\eta_0}\cos\phi_c \ldots\ldots\ldots\ldots\ldots\ldots (4)$$



Now applying Snell's law to the surface of the core and cladding, the angle of revolution becomes the angle of incidence and the curved angle will be the value. Hence90°,

$$\therefore \eta_1 \sin \phi_c = \eta_2 \sin 90°$$

$$\therefore \sin \phi_c = \frac{\eta_2}{\eta_1} \dots \dots \dots \dots \dots \dots (5)$$

Using trigonometric formula

$$\cos \phi_c = \sqrt{1 - \sin^2 \phi_c}$$

$$\therefore \cos \phi_c = \sqrt{1 - \left(\frac{\eta_2}{\eta_1}\right)^2}$$

$$\therefore \cos \phi_c = \sqrt{\frac{{\eta_1}^2 - {\eta_2}^2}{{\eta_1}^2}}$$

$$\therefore \cos \phi_c = \frac{1}{\eta_1}\sqrt{{\eta_1}^2 - {\eta_2}^2} \quad \dots \dots \dots \dots (6)$$

Putting in the value of the equation$(6)(4)$,

$$\therefore \sin \theta_{i\,max} = \frac{\eta_1}{\eta_0} \times \frac{1}{\eta_1}\sqrt{{\eta_1}^2 - {\eta_2}^2}$$

$$\therefore \sin \theta_{i\,max} = \frac{1}{\eta_0}\sqrt{{\eta_1}^2 - {\eta_2}^2} \quad \dots \dots \dots . (7)$$

The incident ray is mostly emitted from the air, so taking and writing its curvature.$\eta_0 = 1.00\ \theta_{i\,max} = \theta_0$

$$\therefore \sin\theta_0 = \sqrt{\eta_1{}^2 - \eta_2{}^2} \; \dots \dots \dots (8)$$

$$\theta_0 = \sin^{-1}\left(\sqrt{\eta_1{}^2 - \eta_2{}^2}\right) \; \dots \dots \dots (9)$$

θ_0 It is called the Acceptance Angle for optical fiber.

θ_0 For a given angle of greater value than this, the ray of light is carried from the core to the cladding, which leads to the wastage of optical energy.

$$2\theta_0 = 2\sin^{-1}\left(\sqrt{\eta_1{}^2 - \eta_2{}^2}\right) \; \dots \dots \dots (10)$$

$2\theta_0$ It is called the Acceptance Cone for optical fiber, which carries all the rays of light coming into this cone through the core by full internal reflection.

Numerical Aperture: The sin value of the Acceptance angle is called the numerical aperture for that fiber.

$$N.A. = \sin\theta_0 = \sqrt{\eta_1{}^2 - \eta_2{}^2} \; \dots \dots \dots (11)$$

Using the equation(6),

$$\therefore \cos\phi_c = \frac{1}{\eta_1}\sqrt{\eta_1{}^2 - \eta_2{}^2}$$

$$\therefore \eta_1 \cos\phi_c = \sqrt{\eta_1{}^2 - \eta_2{}^2}$$

The above price is the same. Putting in(11),

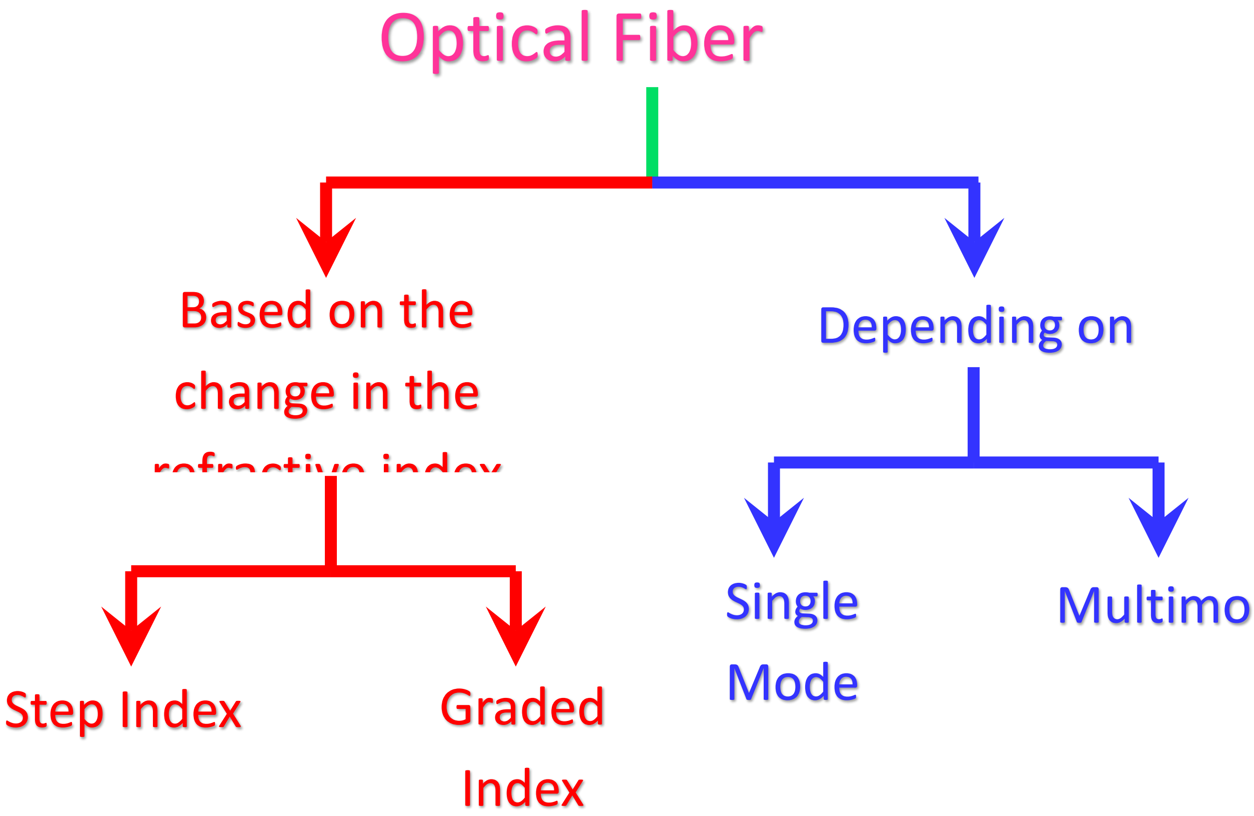
$$N.A. = \eta_1 \cos\phi_c \quad \dots\dots\dots.\dots(12)$$

Numerical aperture shows the ability of fiber to collect light.

It only depends on the values of the curvature of the core and the cladding.

As the value of numerical aperture increases, the ability to accept light from a source of light increases.

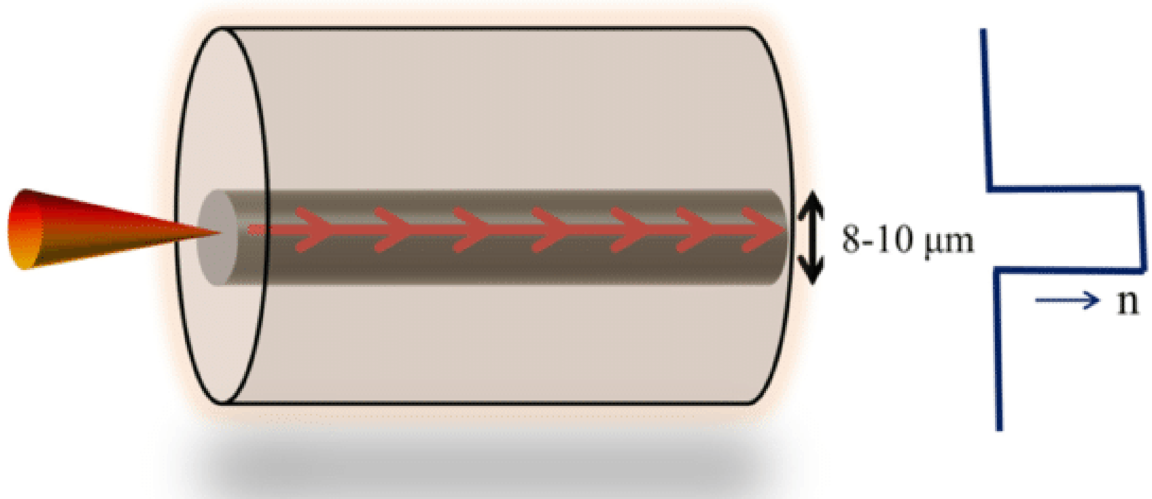
Types of optical fiber



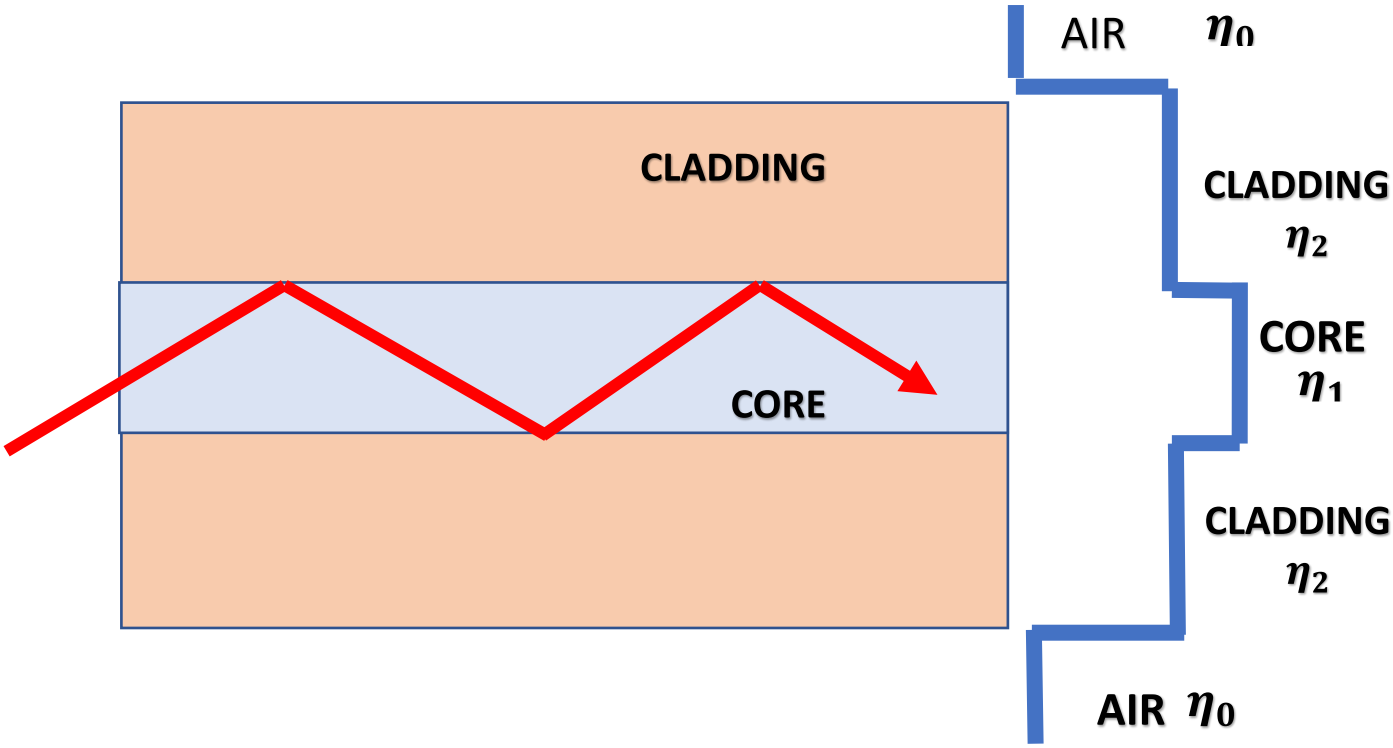
Step Index Optical Fiber:

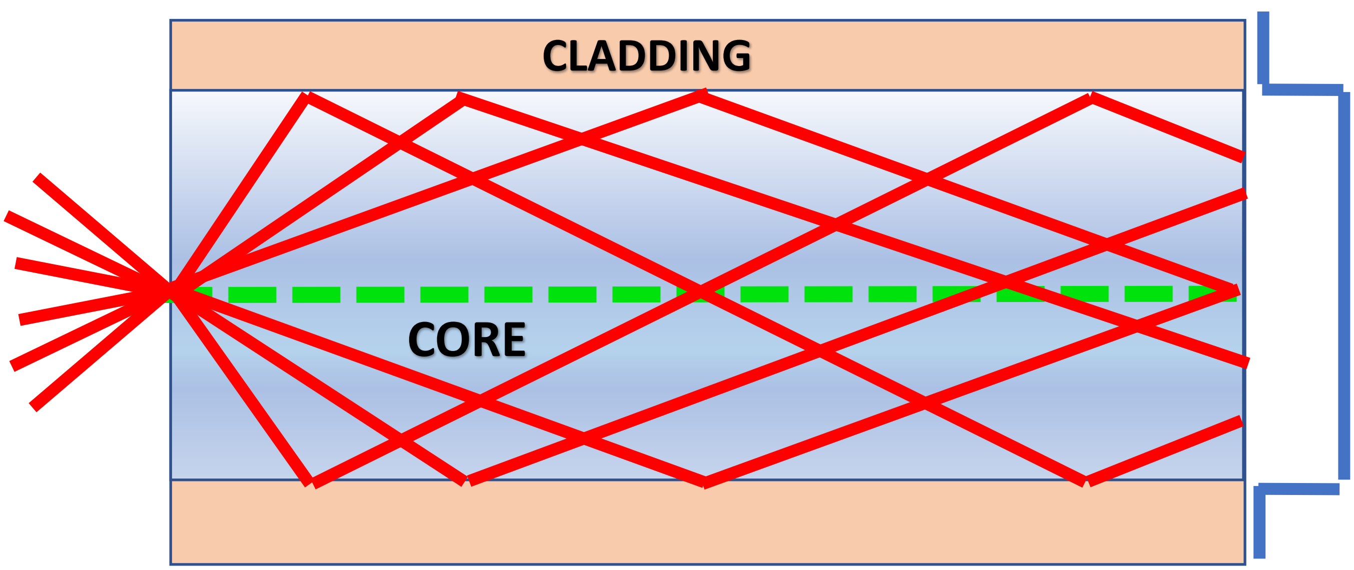
- The core of single mode has the diameter of 8 μm to 10 μm.
- Its cladding has diameter ranging from 70 μm to 125 μm.
- Its core has the same refractive index and there is a sudden decrease in the curvature of the cladding.
- In it, the rays of light move in the zigzag path.

- As it passes through it, the beam of light crosses the axis of fiber at each reflection.
- It has two types: (1) single mode multi mode(2)
- Single mode fiber has bandwidth of $100\ MHz$ while, multimode has bandwidth of $50\ MHz$.
- Single mode fiber is used for short distance communication.



Single-mode fiber has high bandwidth and is the most suitable type of fiber for long-distance networking. It has different typs.


AIR η_0
CLADDING
CLADDING η_2
CORE
CORE η_1
CLADDING η_2
AIR η_0


CLADDING
CORE

Applications of Optical Fiber Cable

1. Internet: Optical Fiber Cables transmit large amounts of data at a very high speed. Hence the technology is widely used in internet cables. As traditional compared to traditional copper wires, fiber optical cables are less bulky, lighter, more flexible, and carry more data.
2. Computer Networking: Networking between computers in the same building or in adjacent structures is made using optical cables easier and faster.
3. Medical Applications: Optical cables are widely used in the fields of medicine and research. Endoscopy is an important part of non-intrusive surgical methods. Endoscopy looks inside the body without surgery. In endoscopy, a bright light is used to illuminate the surgery area within the body, making it possible to reduce the number and size of incisions made.
4. Bio-Medical Research: Fiber optics cables are also used in microscopy and biomedical research.
5. Automotive Industry: Fiber optics cables play an important role in the lighting and security features of today's automobiles. They are widely used in lighting both the interior and exterior of vehicles. Because of its ability to conserve space and provide better lighting. Fiber Optics are used in more vehicles every day, also fiber optics cables can transmit signals between different parts of the vehicles at lighting speed. This makes them invaluable in the use of safety applications such as airbags and traction control.

6. Telephone: Making telephone calls within or outside the country has never been easier. With the use of fiber optics communication, you can connect faster and have clear conversations without any lag on either side.
7. Lighting and Decorations: The use of Optical-fiber lamps in the field of decorative lighting has also increased over the years. Fiber Optics cable provides an easy, economical and attractive solution to lighting projects. e.g.; artificial Christmas trees
8. Mechanical Inspections: Optical fiber cable is widely used in the inspection of inaccessible places. Some such applications are on-site inspection for engineers and pipe inspection for plumbers.
9. Cable Television: The use of fiber optical cables in the transmission of cable signals has grown explosively over the years. These cables are ideal for transmitting high-definition television because they have greater bandwidth and speed. Fiber Optics Cables are cheaper compared to the same quantity of copper wire.
10. Military and Space Applications: With the high level of data security required in military and aerospace applications, fiber optics cables offer the ideal solutions for data transmissions in these areas.
11. Optical Sensor: An optical sensor converts light rays into electronic signals. It measures a physical quantity of light and then translates it into a form that can be read by instructions. Optical sensors are used for counting or positioning of parts contact-less detection,

12. Communication: In a communication system, optical fiber cables are majorly used in telecommunications for transmitting and receiving purposes. It is used in various networking areas and even increases the speed and accuracy of transmission data. Compare to copper wire, fiber optics cables are lither more flexible and carry more data.
13. CCTV: Optical fibers are used in CCTV surveillance cameras. If you want to install a CCTV camera, then you should always do it with fiber cables, it will last for a long time.
14. Data Storage: For effective use of data storage, optical fibre has turned into the method of decision for electronic information move. Transmission misfortunes are a lot lower than in copper wire and the speed is a lot quicker.
15. Non-Imaging Optics: optical fibers route sunlight from the roof to lower parts of the building to cut down energy consumption.
16. Structural Health Monitoring: This type of sensor can detect stresses that may have a lasting impact on structures.
17. Spectroscopy: optical fiber bundles transmit light from a spectrometer to a substance that cannot be placed inside the spectrometer itself, in order to analyze its composition. A spectrometer analyzes substances by bouncing light off and through them. By using fibers, a spectrometer can be used to study objects remotely.

18. Optical Amplifier: An optical fiber doped with certain rare-earth elements such as erbium can be used as optical amplifier. Rare-earth-doped optical fibers can be used to provide signal amplification.
19. Fiber-optic sights: Handguns, rifles, and shotguns use optical fiber to improve the visibility of markings on the sight.