# Endoscopy
# The Scientific Principle Behind a Medical Application

*Thanks to Ahmed Gouda and Alaa Eldin Manaa for any visual representaion on this site*

# Endoscopy – the scientific principle behind a medical application

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## Abstract

*Through this paper, a widely used scientific application will be discussed and analyzed. The scientific application of endoscopy exploited the nobility of natural science, which is physics, to cure humans and lessen their suffering. This application relies in the first place on the scientific principle of total internal reflection. This is a physical phenomenon of light not following the general appearance of refracting through light-permeable materials. In this literature review article, the general uses for endoscopy will be examined. Besides, all the scientific details regarding total internal reflection will be elaborated. The article will end with showing the connection of how total internal reflection happens in microscopes and showing some of the newest medical advancements in the field of endoscopy.*


**Keywords**:

Total internal reflection, Endoscopy, Refraction index , Refractive angle, Critical angle, Reflection angle

## I. Introduction

Endoscopy is a medical application used by physicians to ease their mission of making accurate examinations for many cases. Endoscopic devices enable physicians to have a closer look at the internal organs of the patient; they transport live picturing of the patient's organs. Most endoscopes consist of a probe made from optical fiber; this probe is fixed with a source of light at the beginning of it and a camera at its end. During making the procedure of endoscopy, the doctor inserts the probe inside the patient's mouth; he elongates it until reaching the area of interest of diagnosis. Afterward, the camera at the bottom of the probe delivers an internal photo of the patient's organs.

Endoscopy helps in the identification of an enormous interval of diseases like inflammation, cancers, abnormalities in the pancreas, and blockages. Besides, endoscopy is much more faultless than x-rays in diagnosing the higher part of the digestive system, and it provides a more precise assertion for cancer size. Its advantage exceeds diagnosing the patient's condition. It has the feature of taking a small part of tissue (biopsy) to help doctors analyze it. Moreover, it benefits the surgeons to make surgical interventions without making large incisions.

The endoscopy mechanism depends on the scientific principle of total internal reflection to take inner picturing from inside the body. Therefore, clarifying the scientific principle of total internal reflection gives us the complete interpretation of the endoscopy mechanism.

## II. What is total internal reflection?

Before elaborating on the total internal reflection, we must first examine what happens to light waves when they move from a median to another. Light waves can record different observations while transitioning between materials. These most common observations are

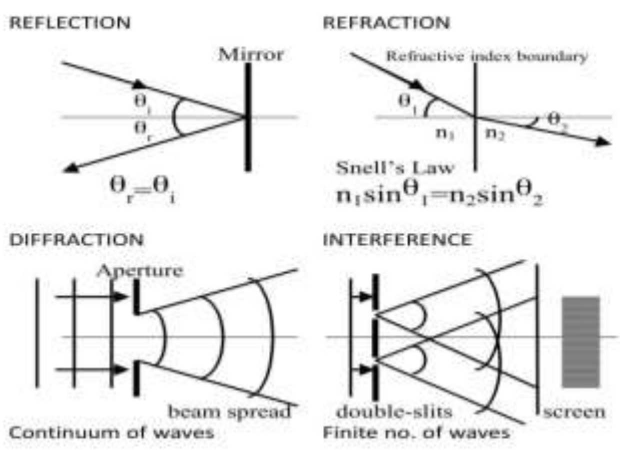
- Reflection
- Refraction
- Diffraction
- Interference

Reflection happens when the waves fall on a surface and bounce off the surface with an angle as same as the angle of falling. The waves do not cross to the other side from the surface.

Refraction happens when the waves fall on a surface and do not bounce off the surface. Instead, they pass through the surface to the other side behind it.

Diffraction happens when the light waves confront an obstacle having a passage smaller in area than the wavelength of these light waves therefore the waves pass through this small area and do not continue with their original shape.

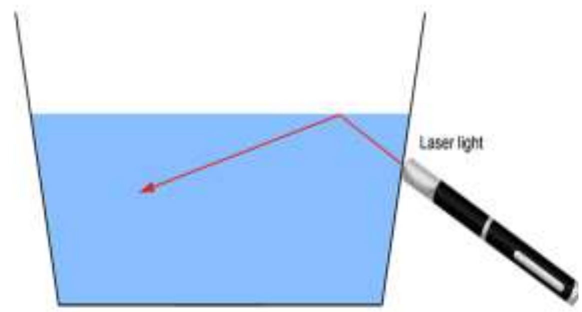
Interference occurs when two waves moving in the opposite direction interfere with each other. This may result in the cancellation of one of the waves or a general disturbance to them. [1] Figure (1) give a visualization for these 4 fundamental phenomenons




Fig(1):visualization for reflection, refraction, diffraction, and interference

After interpreting these four fundamental phenomenons, the question of what total internal reflection is can be raised.

Total internal reflection is a scientific observation when light rays come from their medium to encounter a light-permeable surface (like glass or water) but instead of refracting through this surface to the other medium, the rays reflect on the surface to their medium again. An illustrative photo for total internal reflection is shown in figure (2).




Fig(2): visualization for total internal reflection

This definition will lead us to the question: How does total reflection occur?

Before answering this question, we must define three different angles that occur when light fall on a surface splitting two different medians:

- Incidence angle: it is the angle at which the light rays fall on the surface.

- Critical angle: it is the greatest incident angle by which the light can fall on the surface and refract without reflection. The critical angle can be calculated by solving for the refractive index. When the light rays fall on the surface with the critical angle, the light refract with an angle of 90 degrees.

- Refraction angle: It is the angle created between the refracted light rays and the normal line perpendicular to the refraction surface..

Generally, the common observation when light falls on a boundary (for example air-water boundary) it refracts to the other medium. This path of light rays cannot be generalized for every condition, and it is controlled with different factors. The path of the light rays through a boundary, splitting different densities mediums, is determined based on two factors:

- The densities of the two mediums the light is moving between.
- The ratio between the incidence angle and the critical angle.

The density of the medium is responsible for an important variable that affects the speed of light through medians, thus affect its movement. This variable is the index of refraction, and it is calculated by the following equation: $n = \frac{c}{v}$ where n is the refractive index, c is the speed of light constant, and the velocity of light at this medium. From the equation, it can be said that the refractive index is a distinguishable property for matters that determine the speed of light through it, for example the refractive index for water is 1.333. These information can be used for utilization in the making of Snell's law that relates the incidence angle to the refraction angle.

$$n1\sin(\theta 1) = n2\sin(\theta 2)$$

Whereas n1 is the incident index, n2 is the refracted index, $\theta 1$ is the incident angle, and $\theta 2$ is the refracted angle.

Moreover, the angle of incidence increase is accompanied by an increase in the refraction angle as well until the angle of refraction reaches its largest value which is 90 degrees. In this case, the angle of incidence is called the critical angle, and the light is refracted directly towards the surface. Snell's law can be reformed to calculate the critical angle.

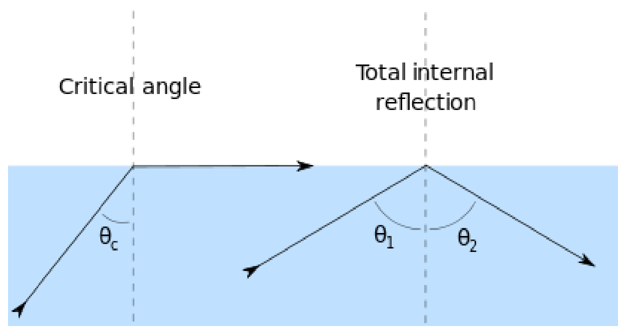
$$n1\sin(\theta c) = n2\sin(90) = n2$$

$\sin(\theta c) = \frac{n2}{n1}$ only valid when n1 > n2

As a result, it can be inferred that for total internal reflection to happen to conditions must be achieved:

- The incidence angle is bigger than the critical angle
- The light rays are travelling from a dense medium with a low refraction index to a rare medium with a high refractive index.

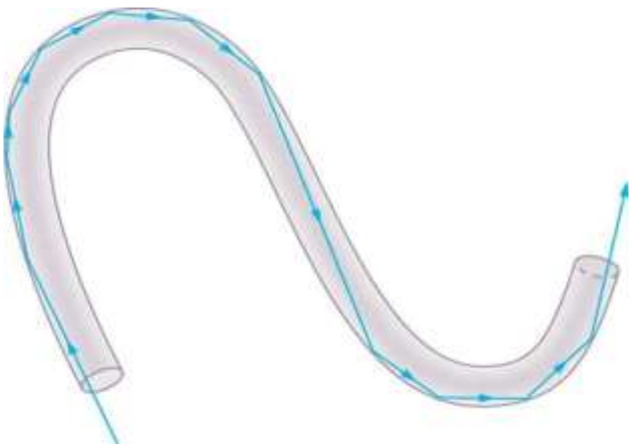
Figure (3) gives a representation for the two previously elaborated cases 1) when the incidence angle equals the critical angle 2) when the total internal reflection occurs [1] [2]




Fig(3): visualization for the 2 explained cases
On the left: critical angle = incidence angle
On the right: total internal reflection occurs

## III.How does Endoscopy rely on total internal reflection?

The procedure of regular endoscopy involves directing light in an optical fiber probe with an incidence angle higher than the critical angle of the probe. The light reflects on the probe's internal surface and continues its reflection until it reaches the specified organs for analysis. The arrival of light to the organs enables the camera to work and transmit a live picture from inside the human body. Figure(4) gives a representation of how light is reflected inside the endoscopes by following the phenomena of total internal reflection.



Fig(4):visual representation of how light is reflected through optical fibers in the endoscopes.

## IV. What are some of the enhancements in the field of endoscopy?

New endoscopic devices were developed to overcome the shortcomings in the classical endoscope. One of these shortcomings was the non-capability to reach the lower part of the digestive system. This deficiency was ended by the start of relying on capsule endoscopy controlled by magnetic fields. This mechanism elaborated in the article " Magnetically guided capsule endoscopy" represents an evolution in the field of endoscopic operations. This application primarily is a small capsuled swallowed by the patient that contains a small camera and a source of light. The source of light spread light rays in the digestive system and enable the camera to transmit the desired examination for the area of interest. The capsule is moved inside the body using a magnetic field to deliver it to the specified place for analysis. Therefore, it opens the gate for a real revolution in the field of endoscopy. [3]

## VI. Conclusion

In this paper, the scientific principle behind endoscopy was clarified. There was a clear and direct examination of how the observation of total internal reflection occurs, as it occurs when the incident angle exceeds the critical angle, and when the incident index is lower than the refractive index. Moreover, the total internal reflection phenomenon was related to the main idea that classical endoscopes base. Ultimately, all these scientific advancements in the field of endoscopy ensure how all the sciences are multidisciplinary for the purpose of utilizing humanity.

## VII. References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