# Hello optic Cabling

Name Classified

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# 1 Introduction

The use of light to convey information is not a new idea. Take for example the coastal lighthouses to guide boats, or the alarm lights of Gondor in The Lord of the Rings.

In telecommunications, the use of a waveguide to transmit a large quantity of information has been democratized since the 1960s. The evolution and integration of this technology into our daily lives is pushed forward every day because of increasing demand for bandwidth.

Optical fiber is often a better choice than cables with twisted pares, the optical fiber is being able to offer distant links of several tens of kilometers where the twisted pair can hardly exceed the 100 meters. In addition, the optical fiber is completely insensitive to electromagnetic disturbances.

In order to stay in touch with these constantly evolving technologies and to master its implementation, the engineer must understand the phenomena allowing the transport of information in light form and maintain their knowledge in line with market progress.

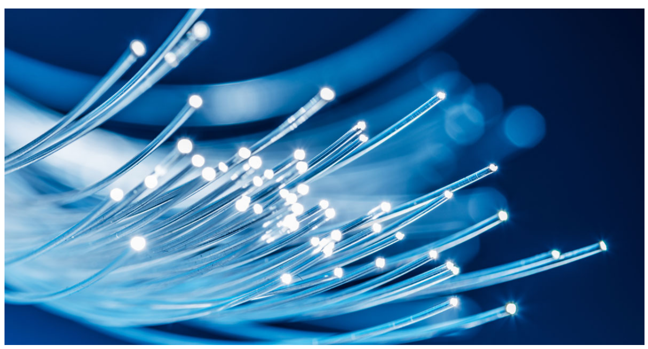

Figure 1: Isn't it beautiful?

# 2 Physical phenomenon

The physical phenomenon that allowed information to be transported is known and controlled for a long time. It is called **Total Reflexion**.

## 2.1 Optical Reflection

When the first ray called "incident" comes to be reflected on a completely reflecting surface (like a mirror), the ray will be deflected according to an angle identical in norm but in opposite to the angle of incidence (angle between the normal to the mirror and the light ray).

$$i = i'$$

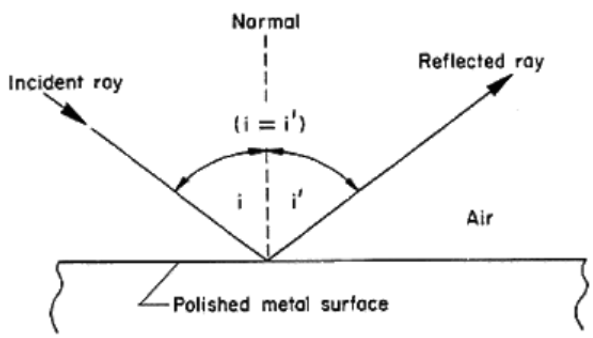


Figure 2: reflection

## 2.2 Optical Refraction

A refraction phenomenon is obtained when an incident ray strikes a surface between two environment of different optical index (Here air and water). The light ray will then divide, we will obtain a reflected ray (reflection phenomenon) as well as a refracted ray.

We will finally use **Snell-Descart's** law to determine the angle of refraction of the refracted light ray.

$$n_1 . \sin i_1 = n_2 . \sin i_2$$

In our example, the second environment is more refractive than the first one. Its refractive index n2 is greater than the refractive index of the first environment n1.

The refractive index can be calculated as the ratio between the speed of propagation of a light signal in space and the speed of propagation of the light signal in the environment considered.

$$n_{\text{environment}} = \frac{C_0}{C_{\text{environment}}}$$

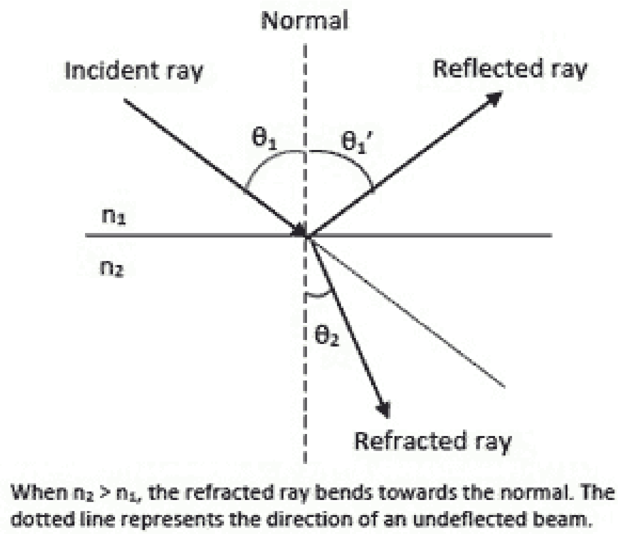


Figure 3: reflection

## 2.3 Total Reflection

In geometric optics, the phenomenon of total reflection occurs when a light ray arrives on the separation surface of two environment of different optical indices with an angle of incidence greater than a critical value: there is then no longer a refracted ray, only a reflected ray remains.

This phenomenon only occurs when the incident light ray is in a medium with a refractive index greater than the possible refracted ray: refraction of the glass / air type for example.

Remember the **Snell-Descart's** law:

$$n_1.\sin(i_1) = n_2.\sin(i_2)$$

where $n_i$ and $n_2$ are the respective indices of the environments 1 and 2 and $i_1$ and $i_2$ the angles formed with the normal by the incident ray and the refracted ray respectively.

We deduce the expression:

$$\sin(i_2) = \frac{n_1}{n_2}.\sin(i_1)$$

This equation has a solution in $i_2$ if and only if the right hand side is between -1 and +1. We can therefore see that for **$\mathbf{n_1}$ ¡ $\mathbf{n_2}$**, this equation always has a solution in $i_1$, that is to say that for **$\mathbf{n_1}$ ¡ $\mathbf{n_2}$**, there is always a refracted ray and there is never total reflection.

When $n_1$ ¿ $n_2$,

$$\frac{n_1}{n_2}.\sin(i_1)$$

Can take values outside the interval [-1.1]: there is then no refracted ray and the reflection is total.

The limit value of $i_2$ is the value when:

$$\frac{n_1}{n_2}.\sin(i_1) = 1$$

We can finally deduce then the limit incident angle $i_1$ such as:

$$i_{\text{limit}} = \arcsin(\frac{n_2}{n_1})$$

# 3 Constitution of Optical Fiber

## 3.1 Profiles of optical fibre

There is a lot of profile for optical fiber, but to make a long story short, we are going to study the simplest one to understand how it works.

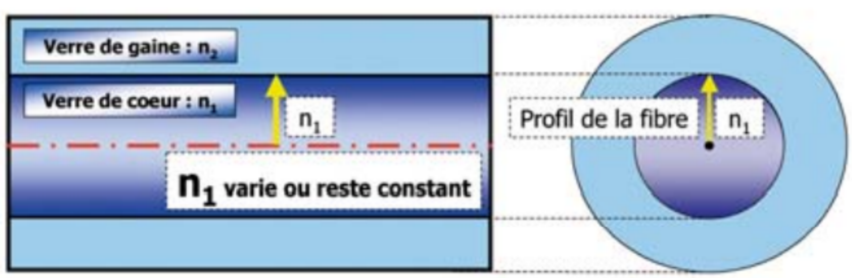


Figure 4: Optical fiber

An optical fiber is made up of two distinct parts, a core of glass of refractive index $n_1$ and a sheath of glass of refractive index $n_2$. The latter surrounds the heart. The index $n_1$ is greater than $n_2$ thus allowing total reflection. When considering the refractive index radially from the center of the heart to the sheath, we call this the **profile refractive index**. This index can be constant or vary. An envelope protective cover completely surrounds the sheath and thus provides protection mechanical to the core-sheath assembly.

## 3.2 Types of optical fiber

There is two types of optical fiber: **SINGLE-MODE** and **MULTI-MODE**

A mode is a ray of light propagating within the heart. At certain wavelengths (850 and 1300 nm) and with certain dimensions of the core (50 and 62.5 µm)

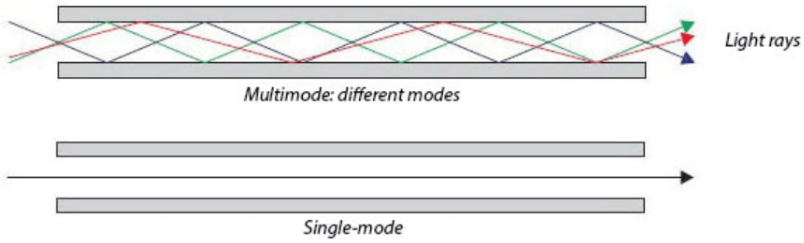


Figure 5: Single-mode vs Multi-mode

several light rays pass through the fiber that carries then the name of multimode. Conversely, a single-mode fiber does not allow spread with only one ray of light. It goes by the name of fundamental.

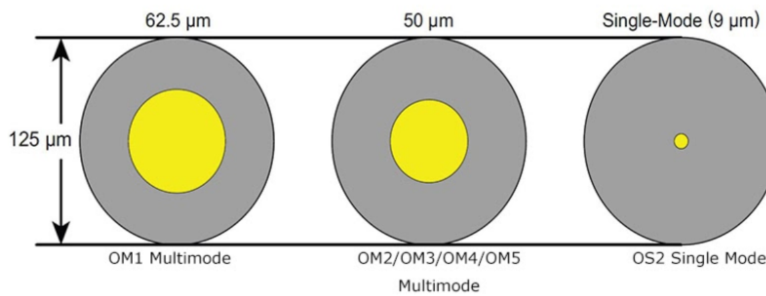


Figure 6: Optical fiber Core Diameters

Dimension of the heart:

- 62.5µm and 50µm for multi-modes ;
- 8µm and 9µm for monomodes ;

Wavelengths used:

- 850 and 1300nm for multimodes ;
- 1310, 1550 and 1625nm for monomodes ;

Of course, there is a reason to use one or a other. Multimodes are made to cover short distances (a few hundred meters to 2 km max). On the other hand, Singlemodes have the capacity to travel several tens of kilometers without require the use of a re-amplifier, their attenuation is much more lower than for multimodes.

## 3.3 Classification of optical fiber

The evolution of optical fibers has been significant over the past decade, the bandwidth of multimode fibers increased from 160 MHz.km to 2000 MHz.km. A classification system was therefore developed in order to list precisely the fibers and their performance allowing a faster and more precise choice depending on the technologies used.

| Minimum modal bandwidth MHz.km | | | | |
|---|---|---|---|---|
| Type of optical fiber | Strand diameter | Transmission bandwidth (overfilled) | | Effective bandwidth in laser emission |
| | | 850nm | 1300nm | 850nm |
| OM1 | 50 or 62.5 | 200 | 500 | unspecified |
| OM2 | 50 or 62.5 | 500 | 500 | unspecified |
| OM2 | 50 | 1500 | 500 | 200 |

Figure 7: Single-mode vs Multi-mode

# 4 Infrastructure - FTTH

An FTTH network (from Fiber to the Home) is a type of physical telecommunications network which allows an access to the Internet at very high speed and in which the optical fiber terminates at the subscriber's home.

In 2006, FTTH networks already existed in urban areas in Southeast Asia and the United States, as well as in some European cities. In France, the Pau Broadband Country network was a pioneer; among the current deployments, those in Paris and Hauts-de-Seine are the most advanced. Projects are also underway in some North African countries, particularly in Morocco, where some residential complexes are already equipped. In Switzerland, FTTH was launched by Sierre Energie with its Vario Project which is to be spread over 5 years.

## 4.1 FTTH P2P

The FTTH P2P (point to point) architecture is a fiber optic network deployment architecture, competing with PON and AON (fiber with active amplifier and multiplexer) architectures. It requires the installation of a continuous fiber and not shared between the NRO (Operator's Optical Connection Node) and the user (this part is never multiplexed). This architecture has the particularity of providing each network termination with a dedicated fiber.

This technology has the advantage of allowing the allocation of all the bandwidth potentially available on a fiber for a subscriber, unlike PON technology which shares the bandwidth of a fiber between the subscribers connected on the same PON tree (up to 'to 64 or 128 users). On the other hand, it has the drawback of requiring many fibers, which is expensive to manage (especially in an urban environment) and complicated to manage (especially within the NRO).

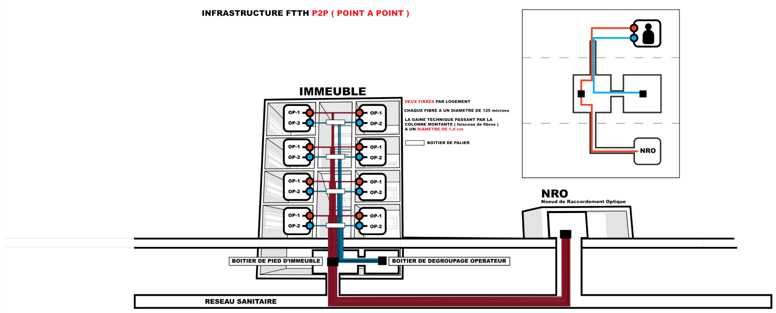


Figure 8: FTTH P2P

## 4.2 FTTH PON - Passive optical network

A passive optical network (PON), designates a level 1 optical fiber transport principle used in optical service networks (FTTx), characterized by a passive point-to-multipoint fiber architecture (several users share the same fiber and there is no active equipment between the exchange and the subscribers). There are different PON standards, among which GPON and EPON.

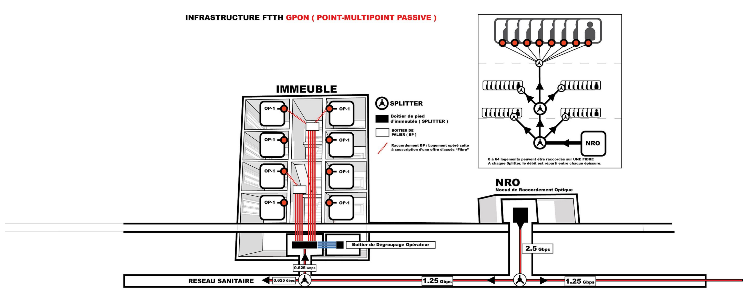


Figure 9: FTTH PON

## 5 Conclusion

"I always thought something was fundamentally wrong with the universe" [1]

## References

[1] D. Adams. *The Hitchhiker's Guide to the Galaxy.* San Val, 1995.