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Technical note #1

The limitations of an existing network infrastrusture for 10 Gb/s

CAILabs
Shaping the light

This document explains the limitations of existing multi-mode fibers infrastructures for a broadband deployment.

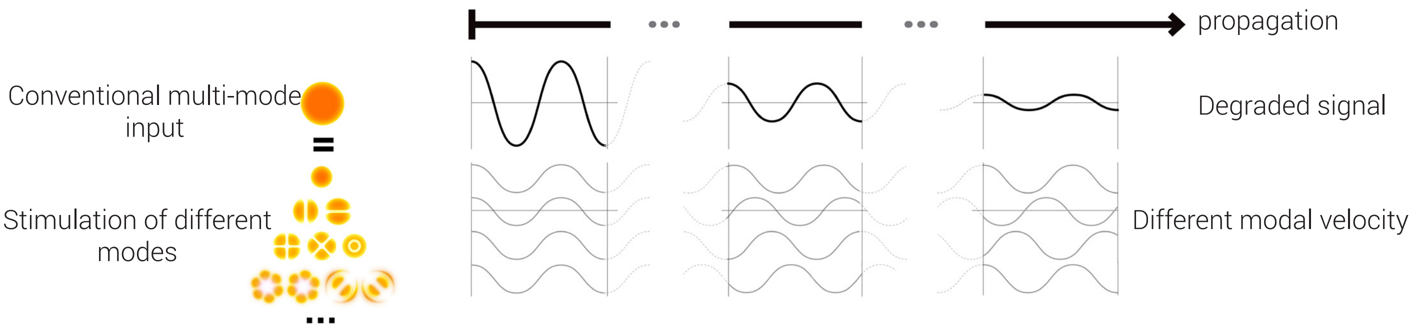
Over the past few years, lots of efforts have been done to develop new generations of 10 Gb/s optical transmission systems in Local Area Networks (LANs).

The number of high-bandwidth applications that continuously provide big data, video and audio files has strongly increased. Evolutions in IT such as the use of VoIP, videoconferences, on-line sharing applications, live applications, virtualization, cloud computing and shared storage, have increased traffic in the networks. Furthermore, the multiplication of mobile terminals and connected objects also increase the bandwidth needs. Bandwidth-consuming applications and latency-sensitive traffics are omnipresent in LANs. It is necessary to enable high quality and reliable transmission for these data flows.

Most of deployed multi-mode fibers (MMFs) cannot allow a bit rate of 10 Gb/s for long distances. This limitation is due to the design of these fibers that are optimized for short distances. Contrary to active components that can be upgraded easily through software or hardware upgrade, the optical cable infrastructure has fixed performances that can only be upgraded by changing fibers.

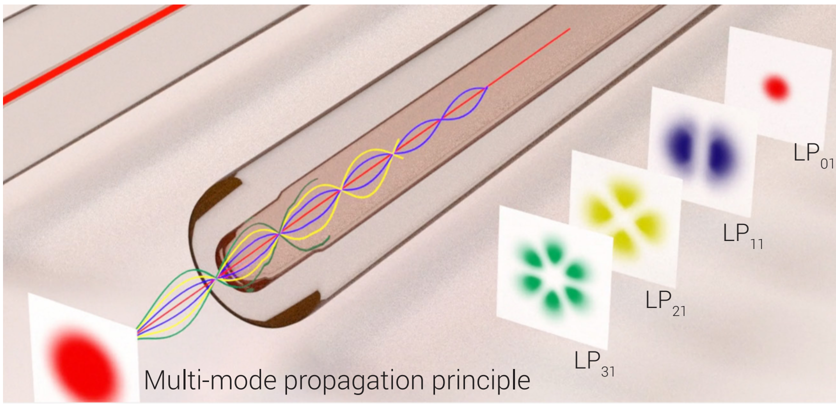
Use of optical fiber is dominant for data transmission because of low congestion, low linear losses, insensitivity to electromagnetic interferences, etc. However, fiber has performance limitations due to physical properties. Particularly, for the fibers deployed in the past, such as OM1 and OM2 fibers, modal dispersion induces limitations in transmission capacity.

Modal dispersion is a distortion mechanism observed in multi-mode fibers. The different modes of the fiber have different velocity, thus the signal is distorded during transmission.



In order to explain this phenomenon in details, let's focus on the physical properties of multi-mode fibers.

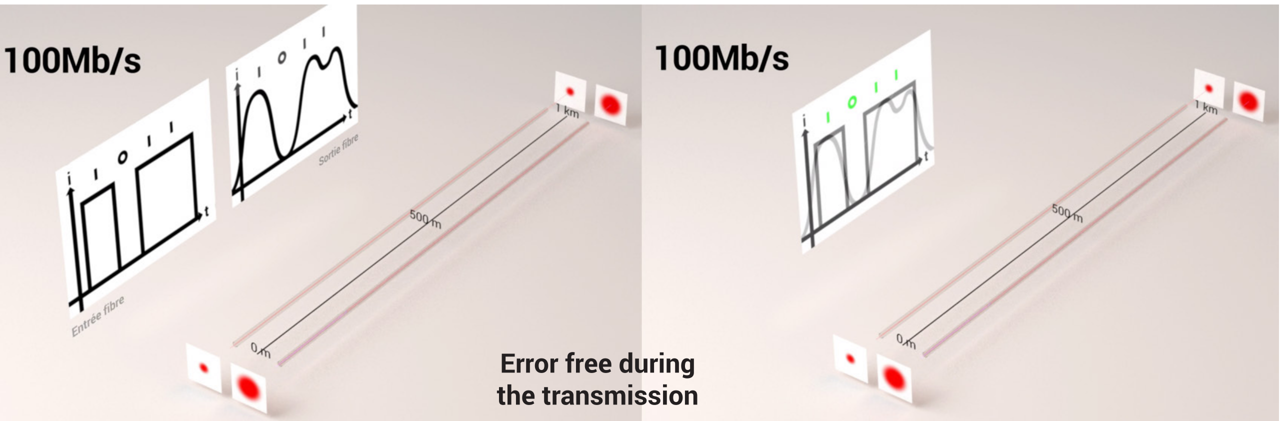
When the light from the transceiver enters in the multi-mode fiber, it splits in different beams called "modes". These light beams enter in the core of the fiber with different angles with respect to the fiber axis. Beams with a lower angle have a straighter path in the fiber core than beams with a higher angle which reflect many times during the propagation. Each mode propagates on its proper optical path in the fiber core. As a result, each mode has a different time of arrival at the end of the fiber. This phenomenon is called Differential Mode Delay (DMD).

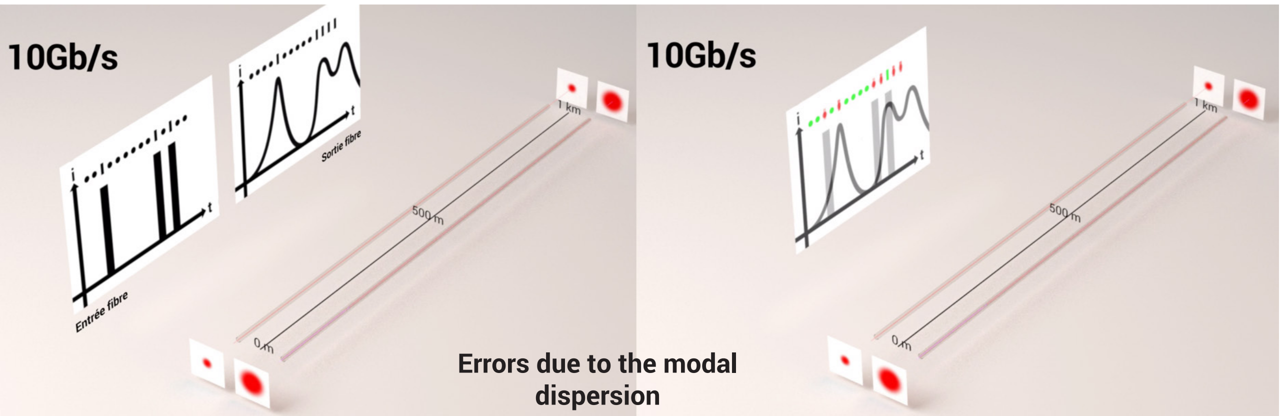


Multi-mode propagation principle

Because the different parts of the signal do not arrive simultaneously, the signal initially sent is distorted: due to the DMD, a light pulse can spread during the propagation in the multimode fiber, or in worst cases it can even split in two independent light pulses. This phenomenon creates inter-symbol interferences and it becomes impossible to reliably recover the transmitted data. The higher the transmitted throughput is, the higher the distorsion, especially for very short pulses: for example, pulses at 10 Gb/s are distant by 100 ps therefore very sensitive to dispersion phenomenon.

To summarize, DMD phenomenon degrades the bandwidth capacity of the fiber. For a given bit rate, it reduces the distance that can be attained reliably from the transmitter to the receiver (rf. Technical note #2 to know the maximum reach for a given bit rate depending on the type of the fiber).





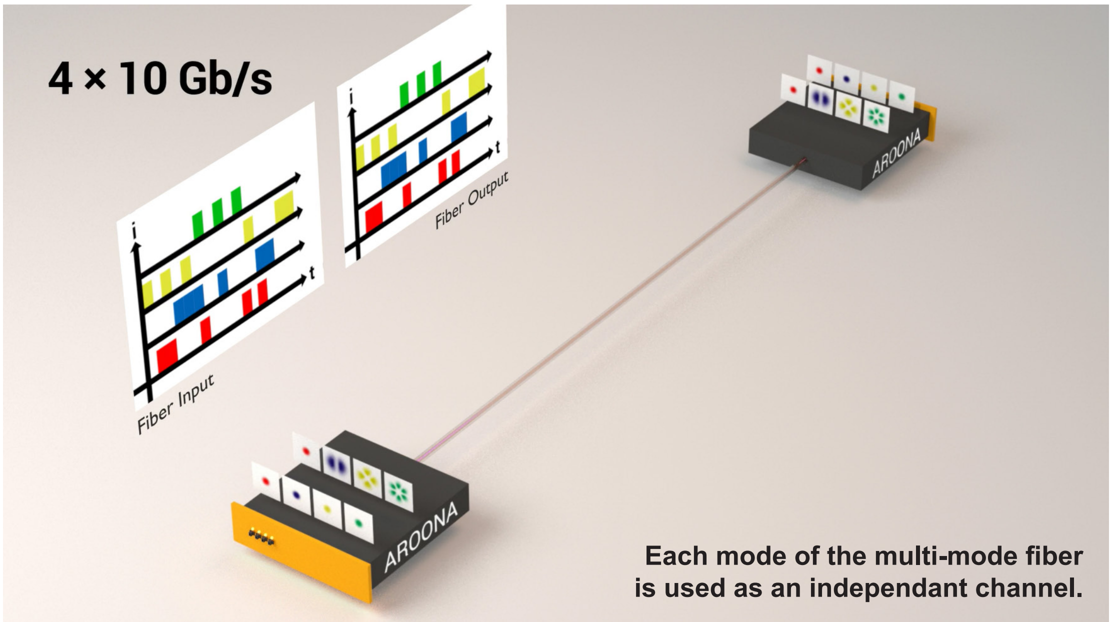
The refractive index profile of the fiber impacts strongly the velocity of the different modes of propagation causing DMD. Thus different generations of gradient index multi-mode fibers (OMx, x=1,2,3 or 4) have been produced reducing the time delay between modes depending on the type of fiber.

Comment: When the diameter of the fiber core is small enough to allow only one mode to propagate, we obtain optimal conditions of dispersion to reduce the time delay of the signal during the propagation. This type of fiber is called “single-mode fiber”.

Gigabit Ethernet was the first technology to encounter the problem of DMD because of the high-broadband transmission (i.e. bit time reduced). For 10 Gb/s systems, such as 10 Gigabit Ethernet, despite the use of an optimized laser, dispersion effects and interferences between modes degrade strongly the performances. It limits the maximal distance of transmission for multi-mode fibers of type OM3/OM4 to a few hundred meters and a few tens of meters for the first generation of multi-mode fibers such as OM1/OM2.

Replacing existing multimode fibers by standard single-mode fibers is one solution to avoid the limitation due to the DMD. But the deployment of a new cable can be very expensive and complex to implement.

CAILabs has developed a light shaping technology allowing to avoid modal dispersion for high-broadband transmission for existing multi-mode fibers. This technology can upgrade multi-mode fibers capacity up to 4 x 10 Gb/s for distances up to 10 km.



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