THE HARD THEORY

The Hard Theory

An introduction to fiber, should also include a section with some of the difficult theory. So if everything else in the book was very easily understood, then this section will be worth reading. If not, then you should miss this section, you can also call it the hard core section.

There are lots of problems or challenges with fiber, Attenuation, Reflections, Dispersion and so on. So here we will look at these problems.

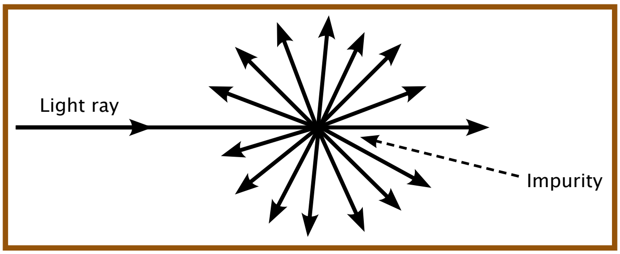
Attenuation

Attenuation is what limits the fiber length. The longer the fiber is, the more the light disappears. At last there is no signal left. In multimode installations, the distance is up to 2km, and in singlemode up to a good 100km, but distances of about 400km are possible, without amplifiers.

The Attenuation is about 2,5 dB in 50µm mm fiber at 850nm, and about 0,8dB at 1300nm. In single mode fiber the loss is about 0,4dB at 1310nm and about 0,2dB at 1550nm.

There are several causes of attenuation:

Scattering



As light travels through the fiber, it hits impurities. These impurities will cause the light to reflect in many different directions, giving a loss.

Absorption

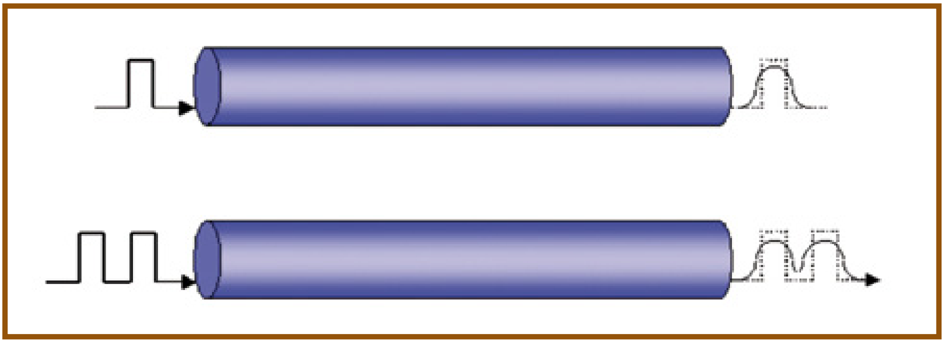
The light is also absorbed by the glass. This absorption is wavelength dependant, in the same way, as when you shine a light on a black or white wall. The black wall gets warmer, as it absorbs the light rays, whereas the white wall will reflect the light.

Radiation loss

Two types, micro and macro loss. Macro loss is due to the non accuracy between the core and the cladding, and micro loss is due to bending the fiber too sharply. For normal fiber the minimum bending diameter is 60mm, G.657A and B have reduced diameters.

Dispersion

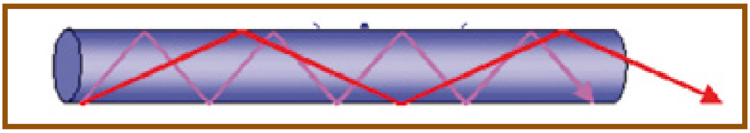
The next problem we have to deal with is dispersion. Dispersion is the flattening of the signal as it travels though the fiber.



In the first picture we can see that the signal is degraded as it travels through the fiber. The longer the fiber, the more flattening of the pulse. On the lower picture we can see two pulses. Notice, on the right hand side, that there is a problem distinguishing the one pulse from the other. This is called dispersion.

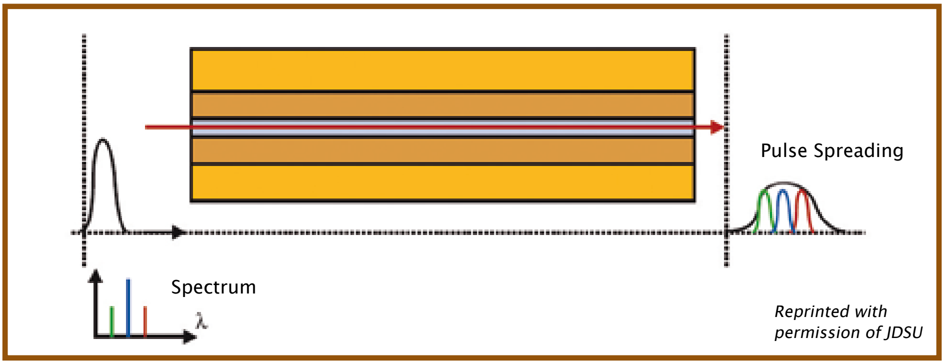
There are three types of dispersion. Modal, Chromatic, and polarization. They all influence the maximum speed of the signal, and the longer the distance, the lower the speed possible.

Modal Dispersion



As the core of the fiber is very large in multimode fiber(50µm,62,5µm) there is room for multiple modes of light (hence the name multimode). These modes travel through different routes in the fiber core, resulting in dispersion. This is only a problem in multimode fiber and the reason why the maximum speed is restricted to 1Gbit. It is possible to transmit up to 10Gbit, but then the limit is 300meters with OM3 fiber and 500meters with OM4 fiber.

Chromatic dispersion (CD)

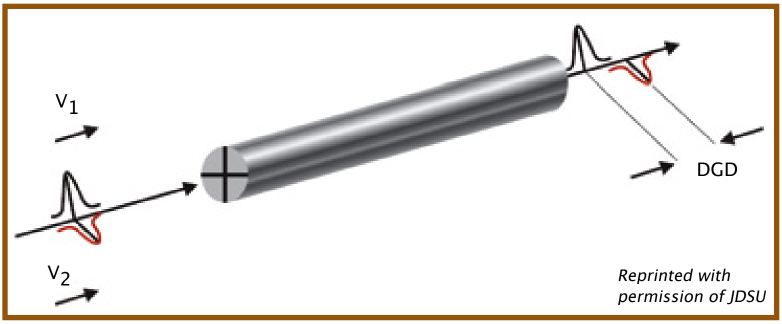


When we transmit light into the fiber, we usually talk about transmitting at one wavelength, 1310nm or 1550nm. But in fact our light source, (usually)transmits at several wavelengths, 1548, 1549, 1550, 1551, and 1552nm. When optical signals are transmitted through the fiber, the different wavelengths travel at different speeds. This is what we call chromatic dispersion.

SONET	SDH	Transmission Rate	Bit Time	CD Limit (ps/nm)
OC-1		51,84 Mb/s	19,29 ns	38461,538
OC-3	STM-1	155,52 Mb/s	6,43 ns	4328,824
OC-12	STM-4	622,08 Mb/s	1,61 ns	268,814
OC-24		1244,16 Mb/s (1,2 Gb/s)	803,76 ps	67,637
OC-48	STM-16	2488,32 Mb/s (2,5 Gb/s)	401,88 ps	16,640
OC-192	STM-64	9953,28 Mb/s (10 Gb/s)	100,47 ps	1,040
OC-768	STM-256	39813,12 Mb/s (40 Gb/s)	25,12 ps	65

He table here shows the maximum distance(ps/nm) for different speeds, If we use a piece of G.652 fiber and transmit at 1150nm, this will typically have a CD of about 18ps/nm. This means if we want to transmit at 40Gbit, then the maximum distance will be about 4km (65/18). If we transmit at 1310nm, where the CD can be about 3 ps/nm, then the maximum distance is about 30Km (65/3). So chromatic dispersion is very important. Measuring equipment is also very expensive. CD is always the same, and it is not influenced by temperature, pressure, and so on.

Polarization mode dispersion



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The next problem we have to deal with is polarization mode dispersion.

As light travels through fiber, it is polarized, either as horizontal or as vertical rays. These rays travel at different speeds, and can in fact change from vertical to horizontal, and back again.

SONET	SDH	Transmission Rate	Bit Time	PMD Limit
OC-1		51,84 Mb/s	19,29 ns	2 ns
OC-3	STM-1	155,52 Mb/s	6,43 ns	640 ps
OC-12	STM-4	622,08 Mb/s	1,61 ns	160 ps
OC-24		1244,16 Mb/s (1,2 Gb/s)	803,76 ps	80 ps
OC-48	STM-16	2488,32 Mb/s (2,5 Gb/s)	401,88 ps	40 ps
OC-192	STM-64	9953,28 Mb/s (10 Gb/s)	100,47 ps	10 ps
OC-768	STM-256	39813,12 Mb/s (40 Gb/s)	25,12 ps	2 ps

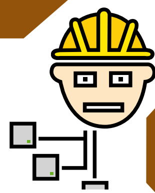
As with chromatic dispersion, this can affect communication at high speeds. As we can see, the total PMD for a 40Gbit (STM-256) link is 2ps. (0,000 000 000 002 seconds) PMD is very difficult to measure, and cannot be measured directly. The result is dependant on temperature, pressure, installation and cabling. In fact, making several measurements will give different results. So this is a great problem. But Polarization Mode Dispersion will influence the top speed f your fiber optical network.

Return Loss

Return loss is the total amount of reflections in an installation. The value has to be as high as possible. A value of 40dB is OK, a value of 50dB is good, and more than 60dB is very good. For high speed installations and analog TV installations, results should be over 60dB this is only achievable with APC connectors.

Reflections /Back Reflection

In an installation we have connectors and mechanical splices. These will usually produce reflections. It is important to use clean connectors of the right type as these items will have a great influence on the result. Reflections are measured in dB, and the lower the vale the better. A value of -30dB is better than a value of -25dB. A good value for single mode installations would be about -50dB, and for analog installations under -60dB. Back reflection is a measurement at one connector.



Insertion loss

When we talk about connectors, the term Insertion loss is often heard. This is the loss in a connector, (like the attenuation in fiber). Typical values are about 0,4dB for a pair.

This means that when we measure an installation, we need to measure:

Attenuation: The total loss in the installation (does it meet our budget?)

Return Loss: The total amount of reflections in the installations

CD: The total amount of chromatic dispersion in the installation

PMD: The total amount of polarization mod dispersion in the installation

OTDR trace: Gives us a picture of the quality of the installation, shows us where the good and bad parts are.

The last section of the book covers some of the courses that I deliver. And all these subjects are explained in greater detail.