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Optic Network and Advanced OTDR Operators Training

Fundamentals of Optic Fiber

Agenda

1) **Optical Network Communications**
2) **History Of Digital Communications**
3) **What Is Optic Fiber**
    a) **Overview of Optical Communications**
    b) **Optic Fiber Construction**
    c) **Fiber Types – Multi and Single Mode Operation**
4) **Methods For Joining Optic fiber**
    a) Reflectance and Attenuation
    b) Reflective Events – Through Connectors
    c) Non-Reflective Event – Splices

Agenda

5) **Optic Fibre Components**
   a) Identifying Fibre Types
      i. Single Mode
      ii. Multi Mode
   b) Optical Connectors
      i. Physical Connector Types
      ii. Connector Polishing
      iii. Angled Vs Flat Connectors

6) **Measuring Optical Power**
   a) The Watt as an Absolute Value
   b) Decibel
      i. Power Ratio
      ii. Logarithm
      iii. Loss Test Sets

Fundamentals of Optic Fiber

Introduction

This lesson describes the history of digital communications and the advancements in the technology from Morse Code right through to the current day where many millions of phone calls and Internet traffic can be transmitted on a single optic fiber.

By completing this lesson you will understand the rapid progression of digital communications, the major components of an Optic Fiber network and finally the system used for identifying specific optic fiber components in real data networks.

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History Of Digital Communications

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History Of Digital Communications

Digital communications work by converting information into digital data which is represented by turning a circuit on or off. This is known as binary data ("Bi" describes the fact that the data has two possible states – on or off sometimes referred to a 1 or 0)

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History Of Digital Communications

The idea of transporting data by converting information from a human readable form to on / off signals was conceived by Samuel Morse with his famous Morse Code. As with all communications its data rate is limited by the underlying technology which was in this case, the speed the operator could translate and send the message. A good Morse code operator could achieve between 3 – 7 BAUD (BAUD=Symbols per second).

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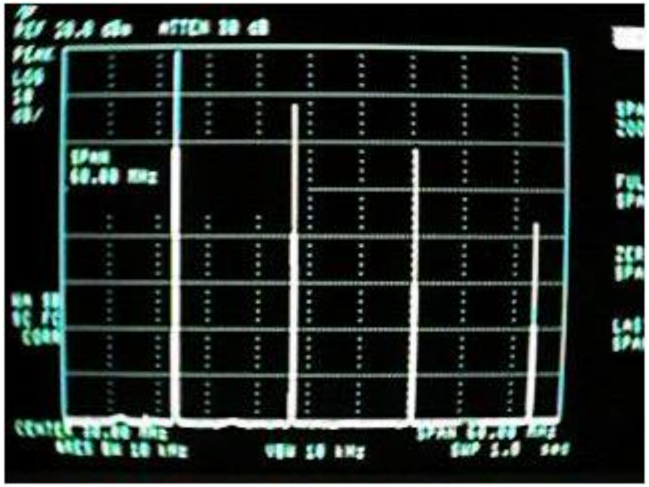
History Of Digital Communications

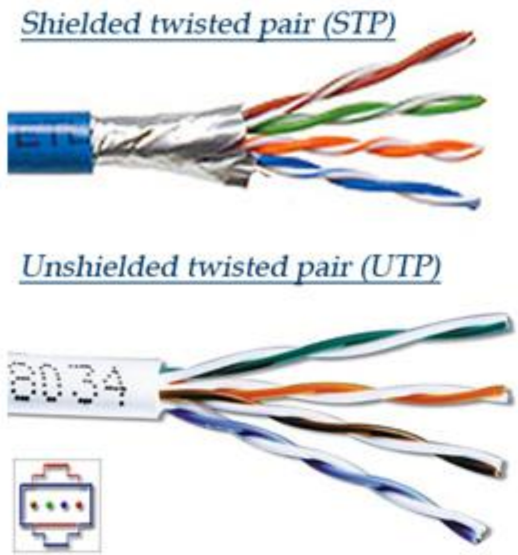
As the technology improved so did the data rate that was achievable. Digital data over High Frequency (H.F) radio (~ 3 – 30 MHz carrier frequency) could transmit from 9600 BAUD to a few hundred thousand BAUD. As with Morse Code, the data rate was limited by the underlying carrier capacity. To improve the data rate the carrier frequency had to increase.

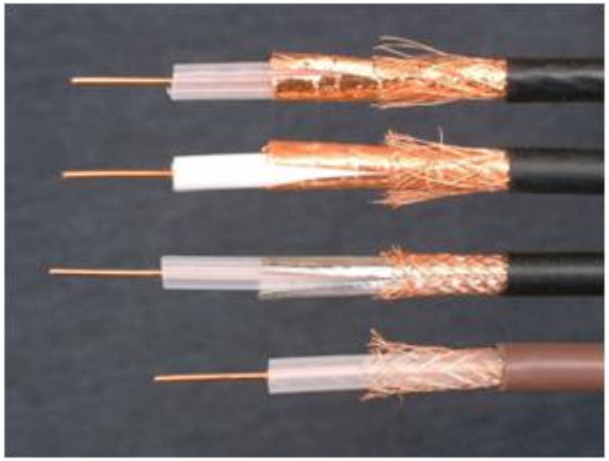


Fundamentals of Optic Fiber

History Of Digital Communications

This was improved with VHF / UHF radio which could transport many MBps. Above this frequency radio becomes a poor means of long rage data communications. Copper twisted pair and Coax cable increased the underlying carrier frequency or carry digital data directly to allow over 1GBps of data transfer.

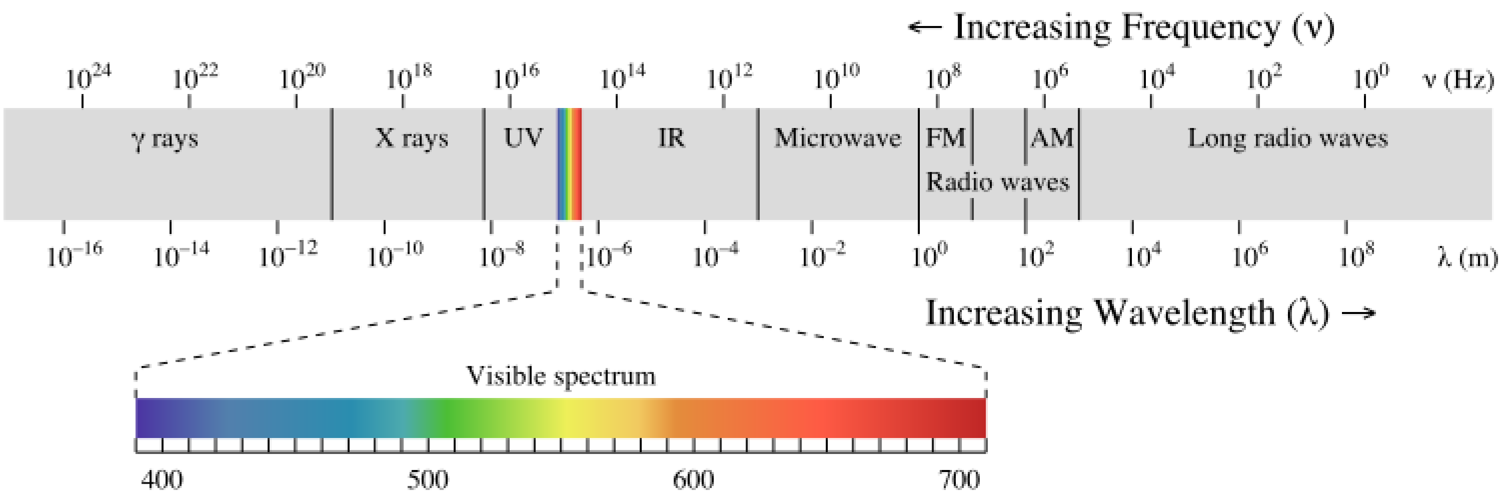




Fundamentals of Optic Fiber

History Of Digital Communications

In general, the higher the frequency the cable or carrier can support, the higher the data transfer capability is. Optical frequencies operate in the THz range which is many thousands of times higher than the copper equivalent.



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History Of Digital Communications

It is possible for optical signals to transmit up to 40GBps per channel and be able to transmit 80 channels per optic fiber. Using this general example, a single optic fiber thinner than a human hair can transmit:

3200 GBps (3.2 TBps) or 3200 000 000 000 bits per second.
This will carry 50 Million phone calls

Considering a cable about 5cm in diameter can carry 312 individual fibers it is easy to see that transporting data on optic fiber presents an enormous leap in capacity.

Fundamentals of Optic Fiber

History Of Digital Communications

Optical Data communications has increased in capability exponentially.

Current: .Multi channel > 40GBps per fiber over almost any distance when regenerated.

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Fundamentals of Optic Fiber

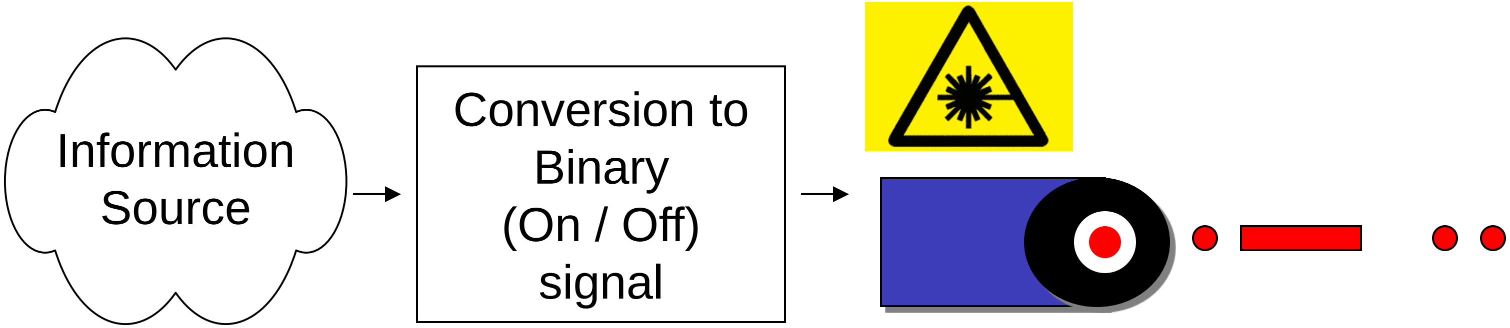
Overview of Optical Communications

Fundamentals of Optic Fiber

Overview of Optical Communications

•Optical Network communications are made possible by digitizing information and transmitting as on / off pulses of light through optic fiber.

Just like Morse Code (only MUCH faster), transmitting data over optic fiber first converts the information to be transmitted into binary data. The binary data is sent using optical power (photons) instead of audio power (beeps) like with Morse code



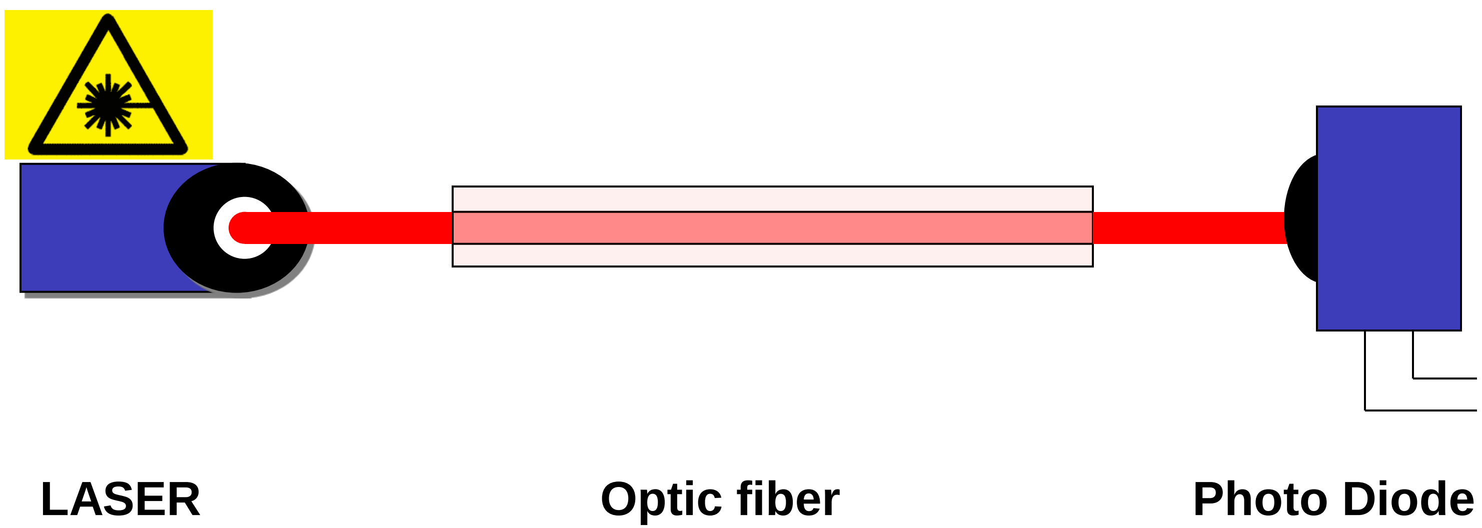
Optical Power LASER

Fundamentals of Optic Fiber

Overview of Optical Communications

An optical transmission system has 3 components (In each direction):

1) Transmitter (LASER)
2) Optical medium (Optic fiber)
3) Optical receiver (Photodiode)



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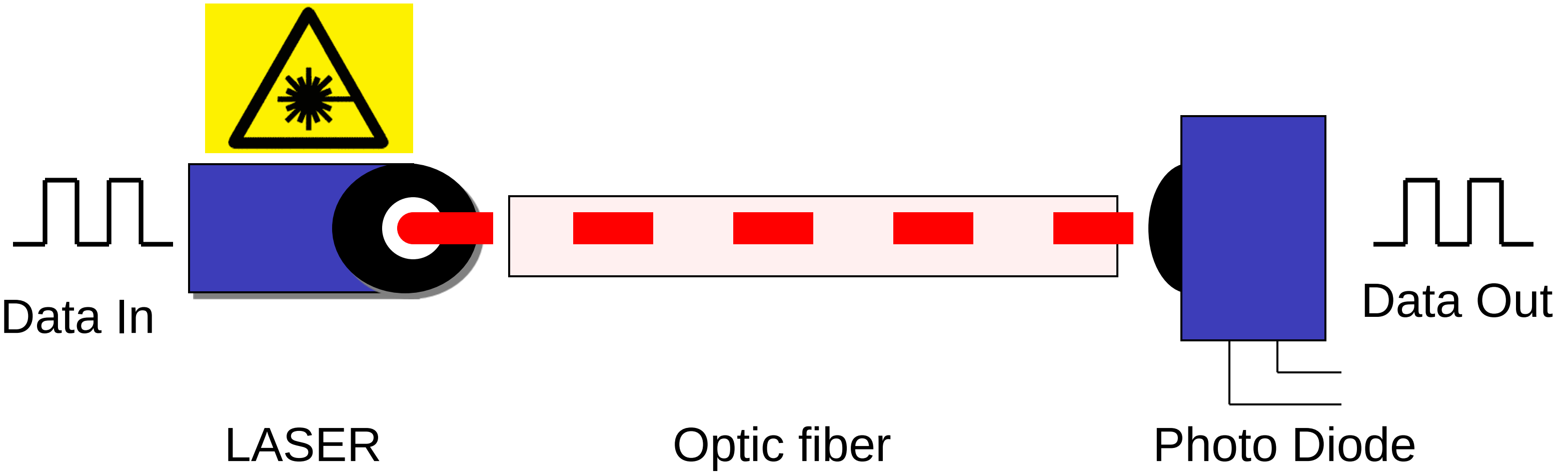
Overview of Optical Communications

The LASER converts electrical data to pulses of optical power that is suitable for long distance and high speed communications.
The Photo Diode converts the optical power back into an electrical data signal. In effect, the communicating devices don't know of the optical link between them



Fundamentals of Optic Fiber

Overview of Optical Communications

•On high quality systems with long range optic components the optical signal can typically travel a maximum of about 90 – 120kms before it needs regeneration.

•The optical signal can be directly boosted with an optical amplifier (EDFA) or converted back to an electrical signal and regenerated.

•Amplifying optically doesn’t fix timing drifts in the signal so every 5 – 10 hops of optical amplification the signal needs to be regenerated through an optical – electrical – optical conversation (OEO).

•This process is known as OEO or RRR (for Regenerate, Retime and Retransmit).

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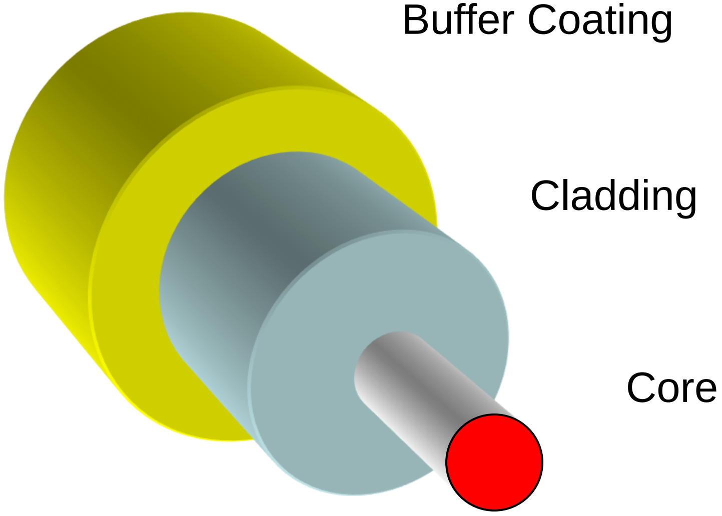
Fundamentals of Optic Fiber

Optical Fiber Construction

Fundamentals of Optic Fiber

Optic Fiber Construction

Optic fiber is constructed from the Core and the Cladding which work in unison to propagate the transmitted light. Around this is the strengthening components such as the buffer coat and outer jacket Below is a the construction of a typical bare fiber.



Fundamentals of Optic Fiber

Fiber Types – Multi and Single Mode Operation

Optical fiber is available in many varieties, each with specific characteristic used to answer different requirements. A discussion on each of the fiber types is beyond the scope of this course but it is important to know that all optical fiber can be separated into one of two main categories.

1) Single Mode Optical Fiber

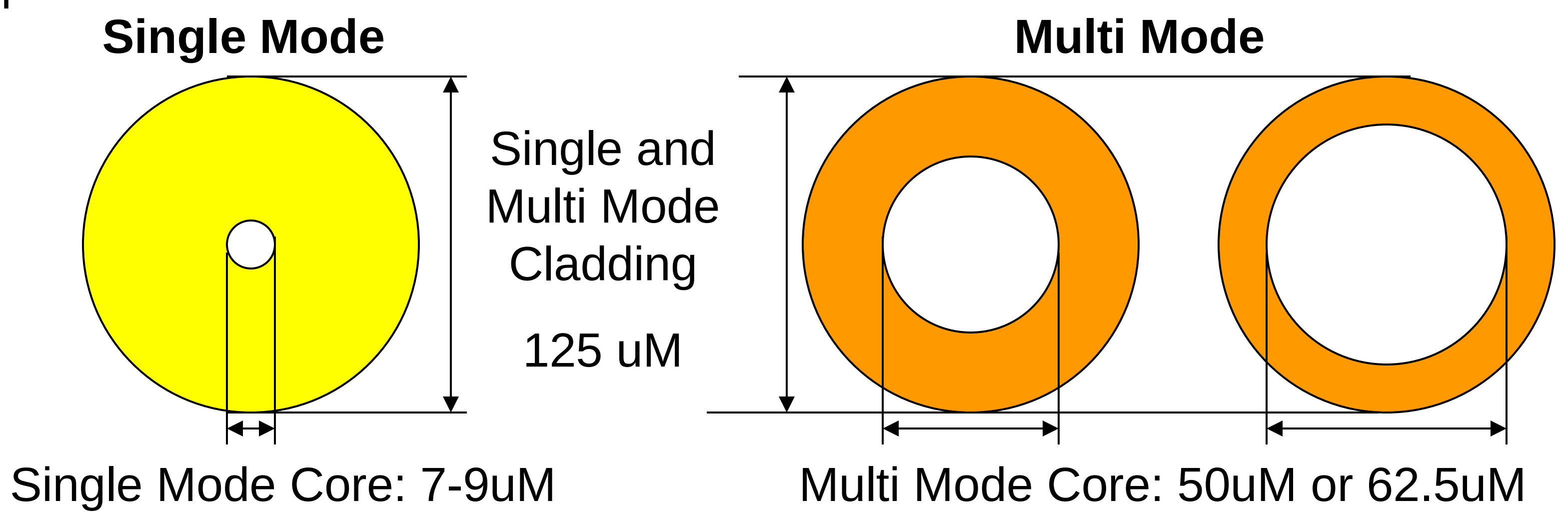
OR

2) Multi-Mode Optical Fiber.

Fundamentals of Optic Fiber

Fiber Types – Multi and Single Mode Operation

The main physical difference between Single-Mode and Multi-Mode optical fiber is the diameter of the core.



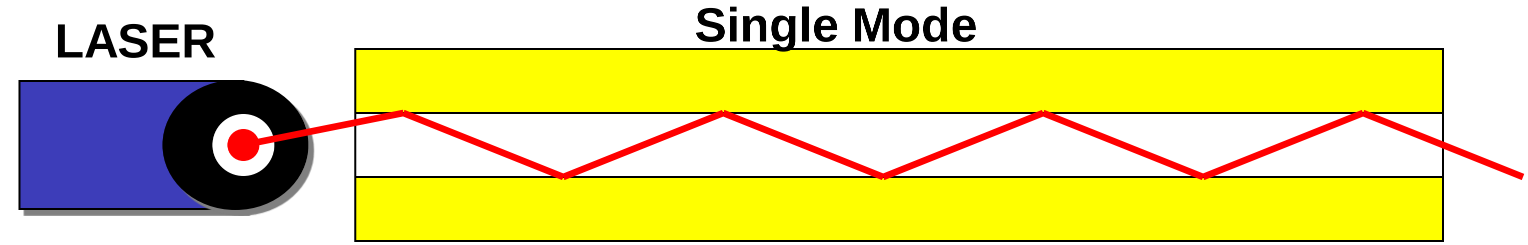
The Single-Mode Core will be between 7uM to 9uM but must be less that 10uM if it is to only allow a single optical path.

Multi Mode can be EITHER 50uM or 62.5uM cores

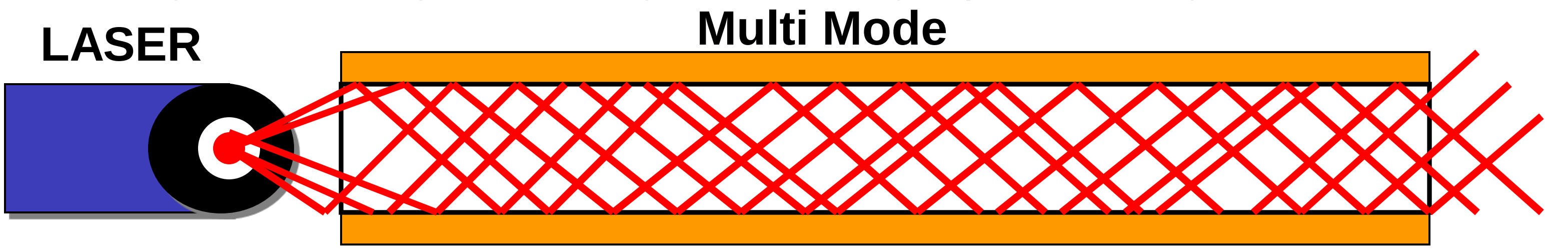
Fundamentals of Optic Fiber

Fiber Types – Multi and Single Mode Operation

The different sizes in the core diameter determine how many paths the light can take through the fiber



The core of Single Mode fiber is too narrow to allow multiple paths of light so the light can only take a single path through the fiber

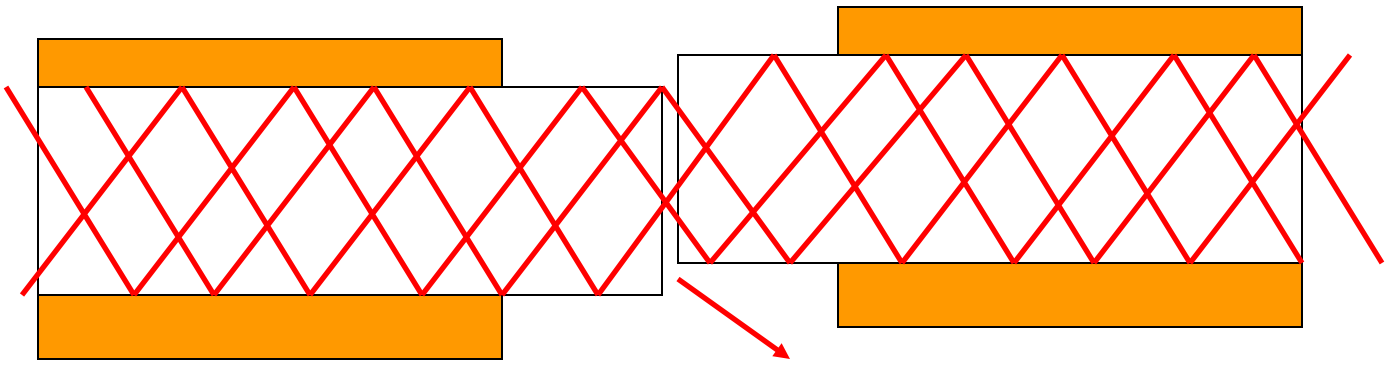


The core of Multi-Mode fiber is wider and allows multiple paths for the light to travel through the fiber.

Fundamentals of Optic Fiber

Fiber Types – Multi and Single Mode Operation

Because the core of Multi-Mode fiber is much larger it is easier to join by splicing or with optical through connectors. Multi mode connectors do not have to be as accurately machined or manufactured and are less likely to be effected by cleanness or scratching.

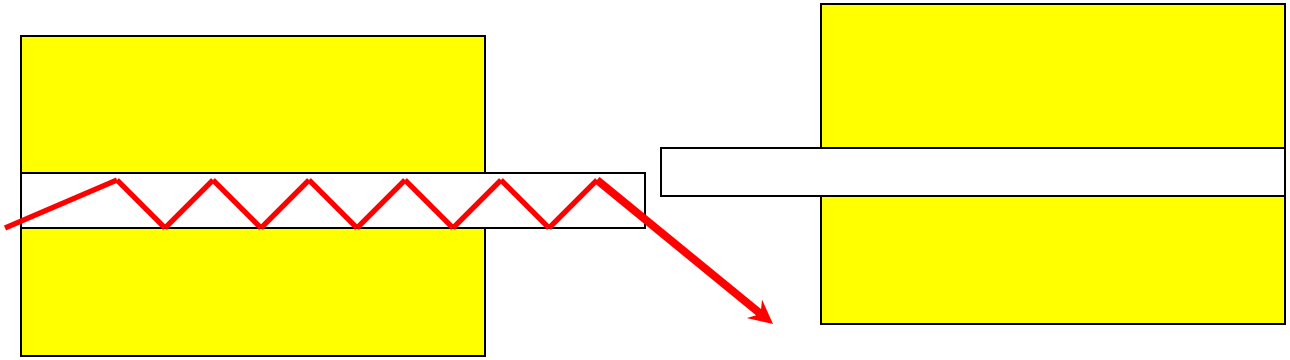


Even if the Multi-Mode core is slightly misaligned the majority of the optical power will not be blocked.

Fundamentals of Optic Fiber

Fiber Types – Multi and Single Mode Operation

The Single Mode core is much narrower, this makes it more difficult to join by splicing or with connectors. Single mode fiber and connectors need a great deal of accuracy during manufacturing and are more likely to be effected by cleanness or scratching. Because of these reasons single mode is more expensive and more difficult to work with.



A slightly misaligned core on single mode fiber can cause the join to lose a significant amount of the optical power.

Fundamentals of Optic Fiber

Fiber Types – Multi and Single Mode Operation

Why Use Single Mode?

If single mode is harder to work with, more expensive and more prone to failure why is it used?.

Like any technical consideration the answer is a trade-off between performance and cost.

Single Mode fiber is more expensive and harder to use but it is also much more efficient at transporting optical power. It is able to transmit a signal over 100 Km without any amplification where multi-mode fiber is limited to ~ 1Km.

Fundamentals of Optic Fiber

Fiber Types – Multi and Single Mode Operation - Summary.

•The two common types of optic fiber are Multi-Mode and Single Mode

•The main physical difference between them is the core diameter. Single mode is between 7 – 9 uM and Multimode is either 50uM or 62.5uM.

•Single mode fiber and components are more expensive and harder to work with but can span distances of over 100kms. It is used in long distance communications

•Multimode is less expensive and easier to work with but is limited to short runs of < 1km. Because if this it is most often limited within building and data center cabling.

Fundamentals of Optic Fiber

Conclusion

In this lesson we covered:

1) **History Of Digital Communications**

2) **Overview of Optical Communications**

3) **Fiber Types – Multi and Single Mode Operation**

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Fundamentals of Optic Fiber

Splicing, Joining and Fiber Components

Agenda

Fundamentals of Optic Fiber

1) **Methods For Joining Optic fiber**
    a) Reflectance and Attenuation
    b) Reflective Events – Through Connectors
    c) Non-Reflective Event – Splices

2) **Optic Fibre Components**
    a) Identifying Fibre Types
        i. Single Mode
        ii. Multi Mode
    b) Optical Connectors
        i. Physical Connector Types
        ii. Connector Polishing
        iii. Angled Vs Flat Connectors

Fundamentals of Optic Fiber

Introduction

This lesson describes the characteristics of various optic fibre joining methods and displays the components that optic fiber networks are constructed from. More advanced topics like attenuation and reflectance will also be introduced

By completing this lesson you will understand the major components of an Optic Fiber network, common methods of joining optic fiber and the different fiber types available.

Fundamentals of Optic Fiber

Joining Optical Fiber

When building an optic fiber network over extended distances it is impossible to lay a single length of fiber from end to end. To build large networks many shorter lengths (called spans) of fiber are physically joined together.

•Joints that are within the span of the fiber are generally made to be **permanent** as they will not need to be moved.

•Joints at exchanges and equipment termination points are often **temporary** so that new equipment can be switched in or the fiber re-routed or cut-over to a different path if required.

Fundamentals of Optic Fiber

Joining Optical Fiber – Joining Types

1) Temporary Joints:

A temporary joint is created by optical through connectors. Through connectors are physical connectors that present a clean end face of the two optic fibers to each other. The connector aligns the cores of the fiber very accurately and provides the mechanical force to hold them together. This connection is not as efficient as a permanent joint but is able to be disconnected and re-connected very easily.

2) Permanent Joints:

A permanent joint is called a splice. It is created by aligning and then melting the glass ends of the optic fiber together. When done correctly it forms a very efficient (low loss) joint that can't be easily removed or replaced.

Fundamentals of Optic Fiber

Joining Optical Fiber – Joining Types

There is a more common way to describe join types:

As Reflective or Non-Reflective Events

1) Reflective Events:

Through connectors present polished fiber ends together which create a slightly reflective surface and is therefore called a reflective event.

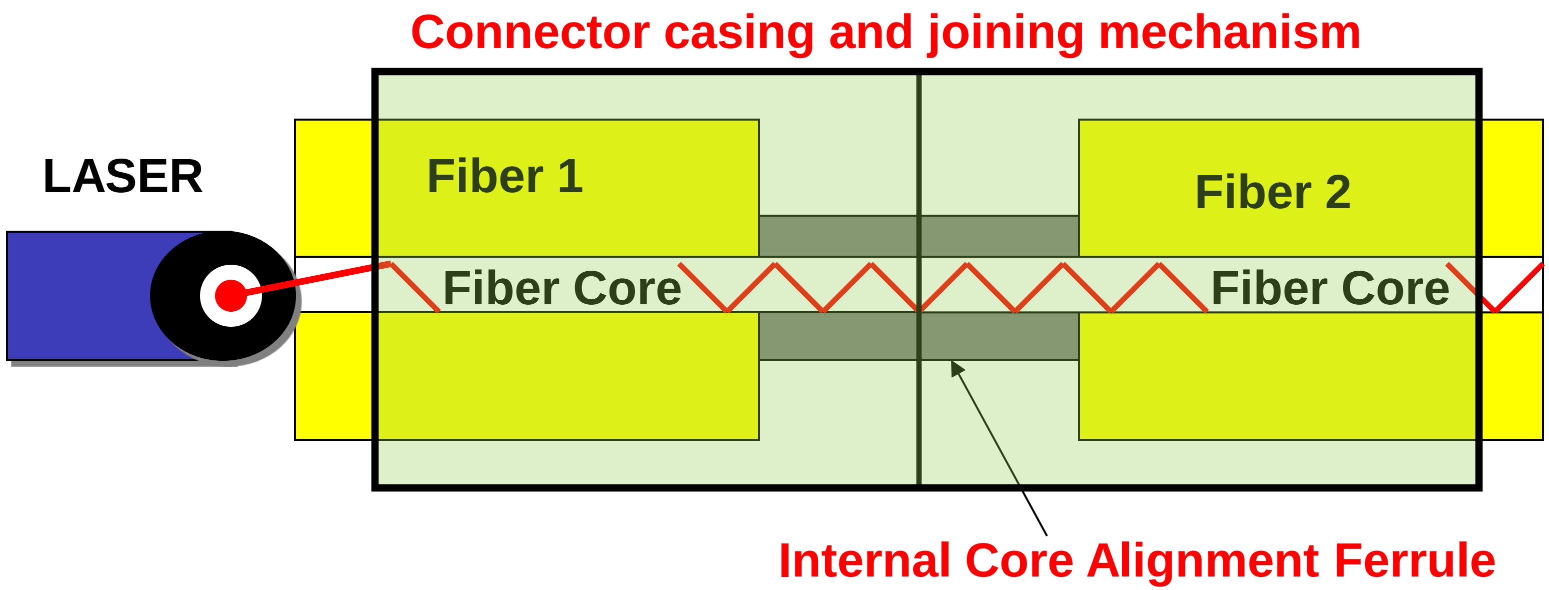
2) Non-Reflective Events:

A splice melts the glass together so has no reflective surfaces. Therefore, it is know as a non-reflective event

Fundamentals of Optic Fiber

Joining Optical Fiber - Reflective Events

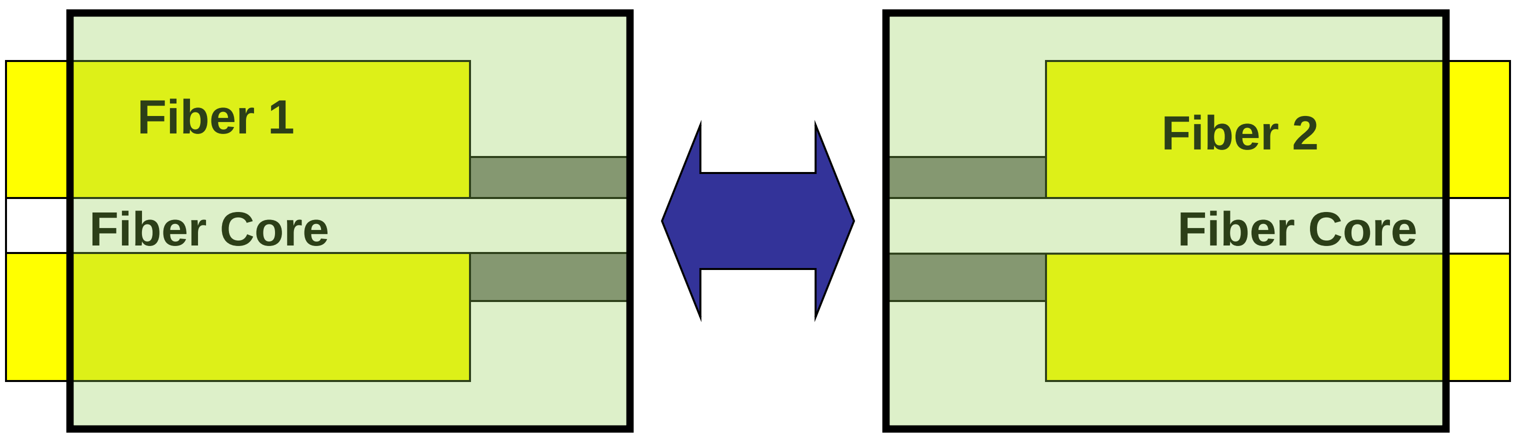
An optical through connector provides a means of temporarily connecting optic fibers by aligning their ends together very accurately so that the cores are able to pass optical power through the connection point.



Fundamentals of Optic Fiber

Joining Optical Fiber - Reflective Events

There is no permanent physical connection so the joint can be removed and connected to a new fiber.



New fiber with matching connector type

Fundamentals of Optic Fiber

Joining Optical Fiber - Reflective Events

If you consider an optical through connector as the joining of a very small but very clean piece of glass you should be able to understand that they are also slightly reflective.

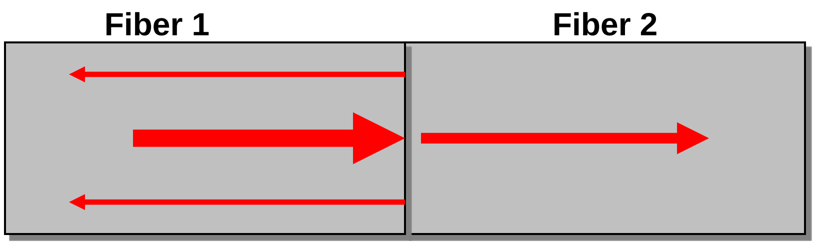
Just like a very clean window, some light will travel through the window but you will still see a reflection meaning some light was returned to you.

Fundamentals of Optic Fiber

Joining Optical Fiber - Reflective Events

Even though the surface area inside a connector is very small, it behaves in exactly the same way a large piece of clean glass does. That is; the surface becomes slightly reflective.

Polished Surface (Through Connector)



A small percentage of the optical power is reflected back to the source. This contributes to the loss at this event

A highly polished glass surface is transparent and allows most light to pass through but it also has a slightly reflective quality

Fundamentals of Optic Fiber

Reflective Events – Connector Polishing

Levels of Connector Face Polishing:
Inside of the actual physical connector the fiber cores are polished and shaped to create the best possible performance.

Physical Contact (PC) – Lowest level of connector polishing available and never actually implemented any more. The name however persists in some cases even when we are actually referring to SPC and UPC.

Super Physical Contact (SPC) – Intermediate level of polishing and also rarely deployed any more

Ultra Physical Contact (UPC) – maximum level of polishing and most common in favor of lesser polished connectors.

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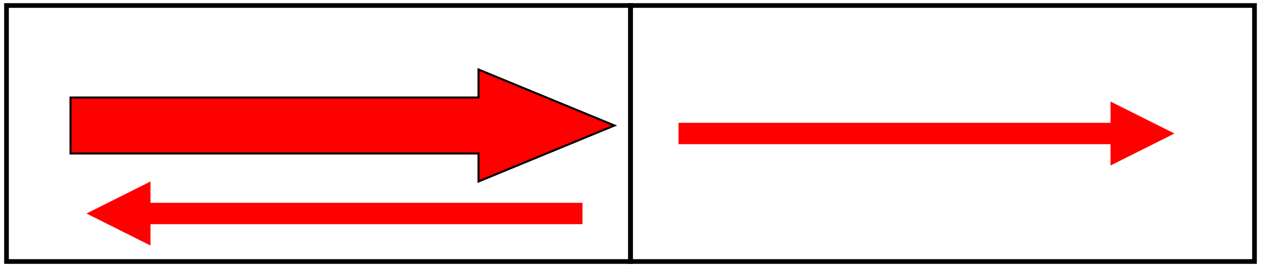
Reflective Events – Connector Polishing

Physical Contact (PC) Connector Face Example:



A PC connector has a relative low level of polishing and therefore presents a flat face with the maximum amount of surface area to reflect optical power back to the source.

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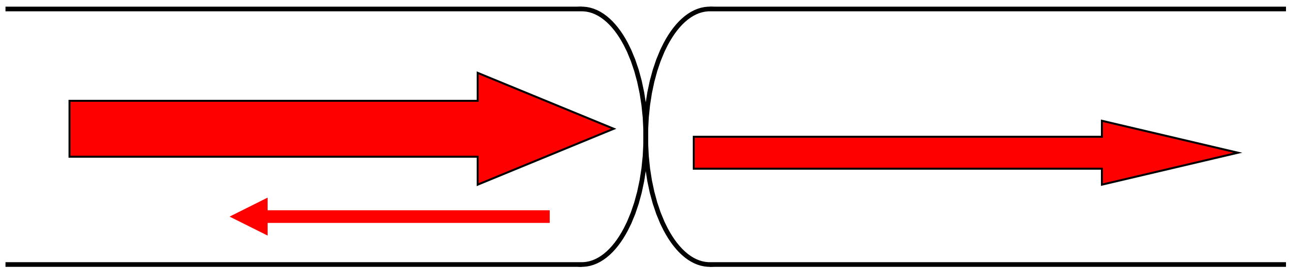
Reflective Events – Connector Polishing

Super Physical Contact (SPC) Connector Face Example:



An SPC connector has been polished to a greater lever which has rounded the connecting face. The reduced surface area at the actual contact point reduces the amount of optical power reflected back to the source and produces a better connection.

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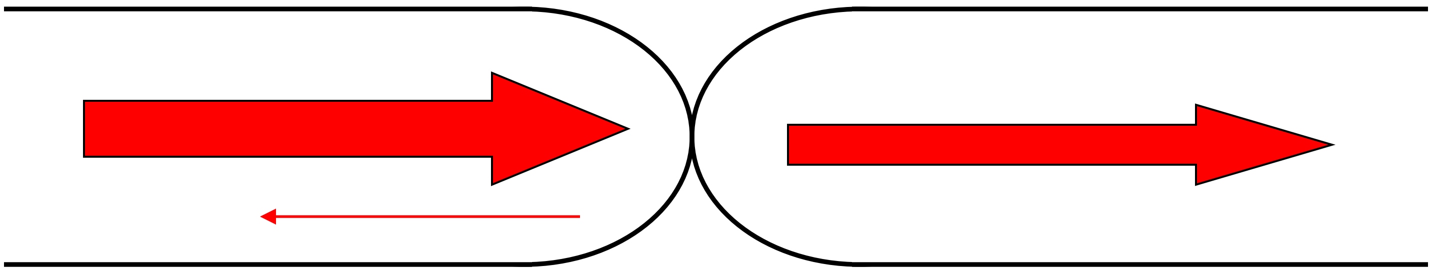
Reflective Events – Connector Polishing

Ultra Physical Contact (UPC) Connector Face Example:



A UPC connector has been polished to the highest level possible and presents the lowest amount of reflected light and the best over all result for this generation of connectors.

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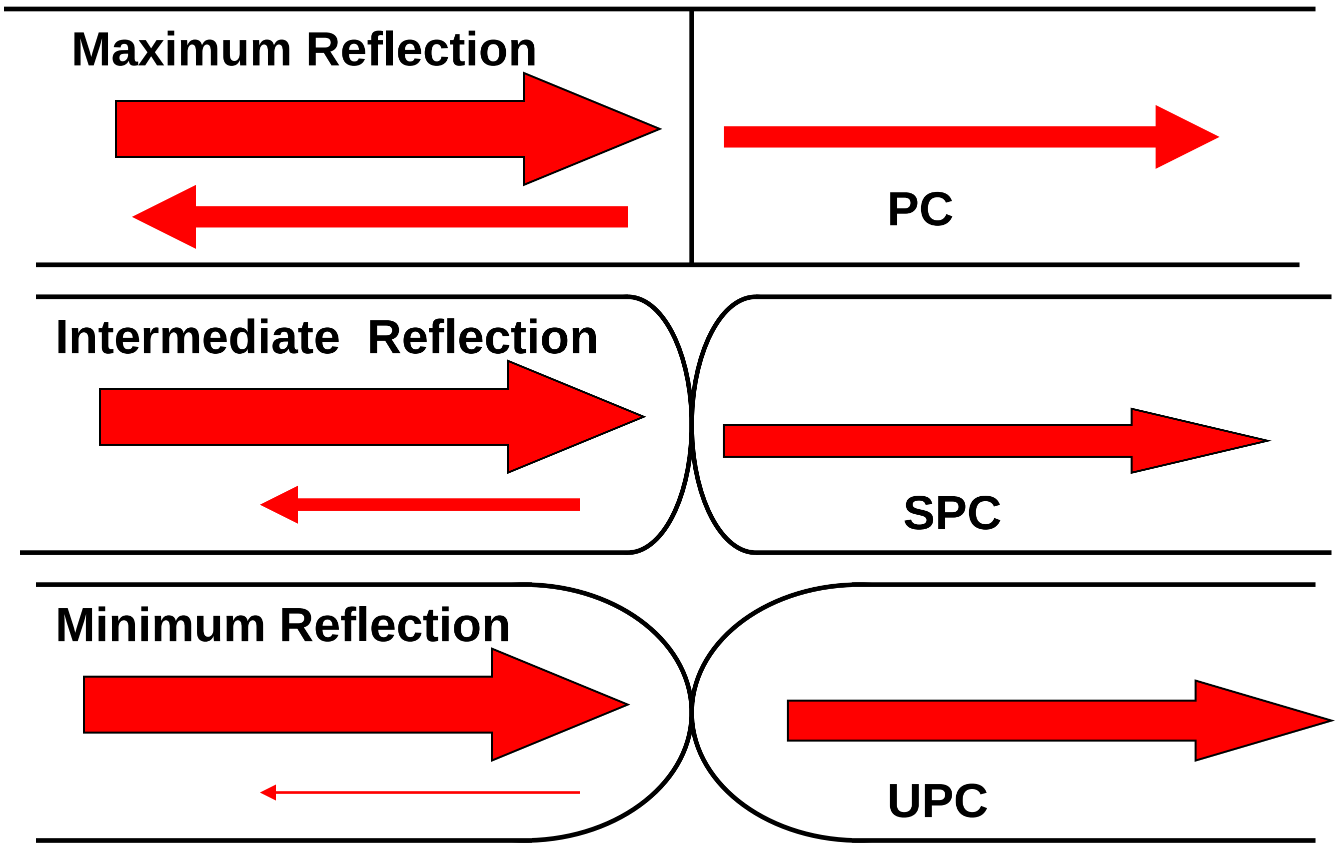
Reflective Events – Connector Polishing



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Reflective Events – Angled Vs Flat

Angled Vs Flat Connectors

In an effort to further reduce the level of light that is reflected to the transmitter, modern optical connectors have the actual connector face tapered (to ~7-8 degrees). In this case the connector is know as an Angled Connector opposed to the PC, SPC and UPC connector types which are called flat connectors.

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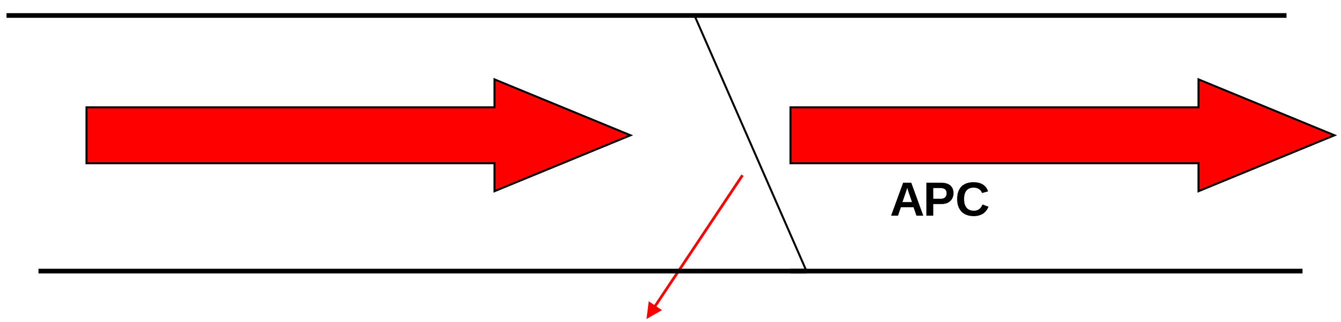
Reflective Events – Angled Vs Flat

Angled Vs Flat Connectors

The angled connector reduces reflectance further by directing any light away from the transmitter. This connector easily outperforms even a UPC connector type for both attenuation and reflectance.



The small amount of light reflected from the angled face of the APC connector is directed out of the fiber and away from the transmitter which greatly reduces reflectance.

Fundamentals of Optic Fiber

Reflective Events – Angled Vs Flat

Angled Vs Flat Connectors


SC/PC


SC/APC

The designation SC/APC describes an SC Type / ANGLED Physical Contact (APC).

SC/PC is a SC Physical Contact (Low Polished Flat) connector

An angled connector will always be green in color and is displayed on the right above. Flat connectors will generally be blue but can be gray, white, fawn or any color other than green depending on its age.

In the above example SC/APC refers to a Subscriber Connector (SC) / Angled Physical Contact (APC).

Fundamentals of Optic Fiber

Reflective Events – Comparison of Reflectance

To compare performance the below table details average reflectance levels of the connector types that have been discussed

Type	Polishing	Reflectance	% Returned
Physical Contact (PC)	Low	-35 dB	~ 0.031 %
Super Physical Contact (SPC)	Medium	-45 dB	~0.0031%
Ultra Physical Contact (UPC)	High	-55 dB	~0.00031%
Angled Physical Contact (APC)	Angled	-65 dB	~0.000031%

Much more detail on Reflectance and decibels are given in later modules. The reflectance has been converted to an approximate value of returned optical power compared to input power to demonstrate and compare the connector types.

Fundamentals of Optic Fiber

Reflective Events – Comparison of Attenuation

The various connector also present different amounts of optical loss or attenuation.

Type	Polishing	Attenuation	% Loss
Physical Contact (PC)	Low	0.75 dB	~ 15.8 %
Super Physical Contact (SPC)	Medium	0.65 dB	~13.9 %
Ultra Physical Contact (UPC)	High	0.5 dB	~10.9 %
Angled Physical Contact (APC)	Angled	0.25 dB	~5.5 %

Remember that the loss is a percentage of the input at each connector. Each connector attenuates the optical power that is presented to it from the connector in front of it so you can't add successive percentages to get the over all loss in a fiber.

Fundamentals of Optic Fiber

Reflective Events - Summary

- Reflective events are created when a polished fiber end is presented to the optical power source.

- The Flat connector types PC, SPC and UPC were a progressive attempt to reduce the level of reflectance on through connectors.

- Angled Connectors (APC) are the most common on newer networks and present a much lower reflection and better over all connection than any of the flat connector types.

- The actual reflectance is improved on more modern connector types as well i.e. SC compared to FC or ST.

Fundamentals of Optic Fiber

Joining Optical Fiber - Non-Reflective Events

The other kind of connecting event is a Non-Reflective event.

•A Non-Reflective event is created by splicing the fiber ends together

•Splicing is achieved when the fiber end faces are aligned and melted together by passing extremely high voltage electrical arcs across the ends. This generates the heat required to melt the glass together

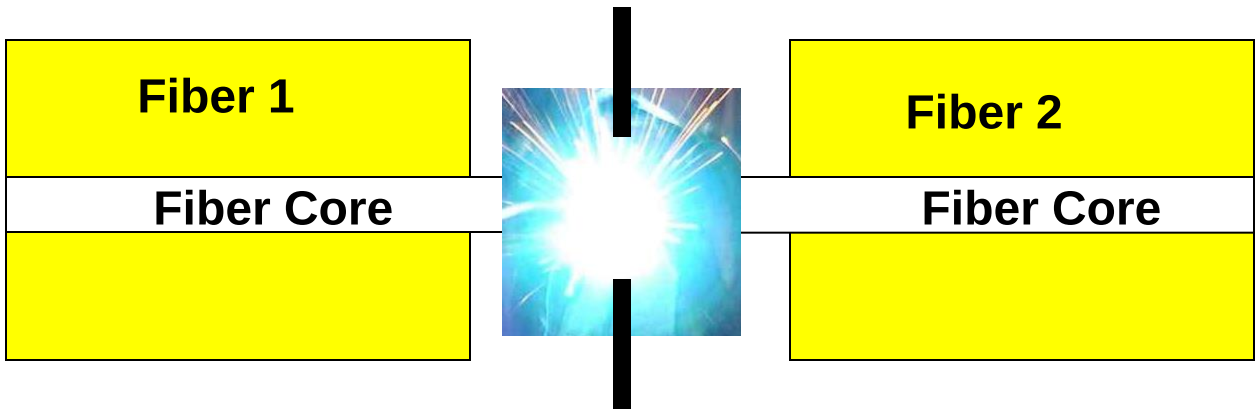
•Because the glass is melted together there is no polished surface area to reflect light. **A splice is therefore a Non-Reflective event**

•Because the glass has been melted together it is a permanent connection and can not be disconnected without breaking the joint

Fundamentals of Optic Fiber

Joining Optical Fiber - Non-Reflective Events

A splice is created by aligning and melting the fiber ends together. It is a permanent joint that can't be disconnected.

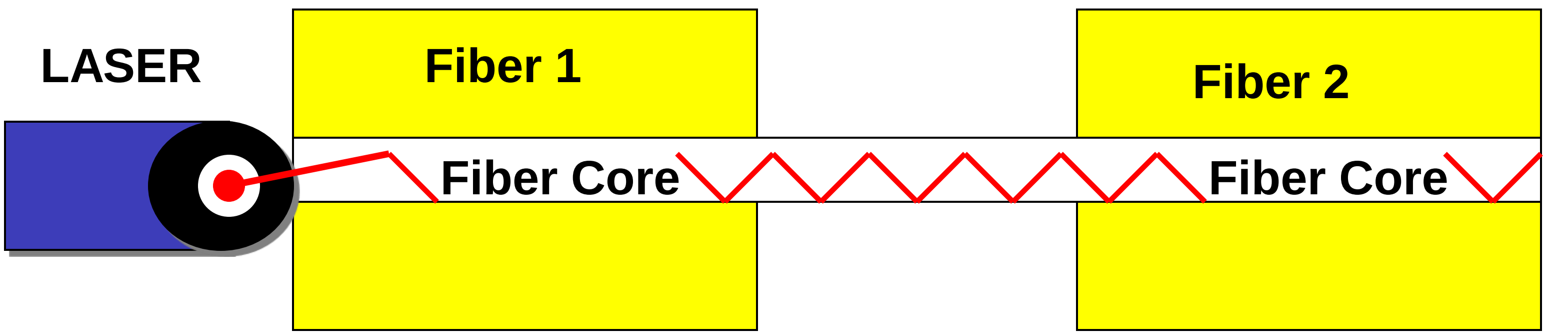


Splicing a pair of optic fibers consists of precisely aligning the cores together and sending a very high voltage electric arc through electrodes which generates enough heat to melt the glass of the fiber ends together

Fundamentals of Optic Fiber

Joining Optical Fiber - Non-Reflective Events

While the connection can't be easily changed, once a fiber has been spliced the loss and reflectance is significantly less than for a through connector.



Unlike a through connector that has a defined connection point, a spliced connection effectively brings the two ends together to become a single piece of glass.

Fundamentals of Optic Fiber

Joining Optical Fiber - Non-Reflective Events

Below is a comparison of the best connector, the Angled Physical Contact (APC) against an acceptable splice for reflectance and attenuation.

Join	Reflectance	% Reflectance	Attenuation	% Loss
APC	-65 dB	~0.000031%	0.25dB	~5.5 %
Splice	-80 dB	~0.000001%	0.05dB	~1.1 %

As you can see, a splice presents much better characteristics than a through connector but is much harder to perform and is also not able to be moved or re-connected.

Fundamentals of Optic Fiber

Joining Optical Fiber - Summary

In this section we discussed Reflective Events (Through Connectors) and Non-Reflective Events (Splices) as methods of joining optical fiber

•Through Connectors are reflective because of the clean polished glass end face. Polishing or tapering the end face to an angle reduces the amount of light that is reflected back to the source

•Optical through connectors reflect between 0.031% and 0.000031% of all optical power back to the source and between 15% and 5% of all optical power is lost across the joining point.

•Splices are non-reflective and only return roughly an equal amount of light as the fiber itself. A maximum of 1.1% but as low as 0.22% of the optical power is lost at a splice.

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Fundamentals of Optic Fiber

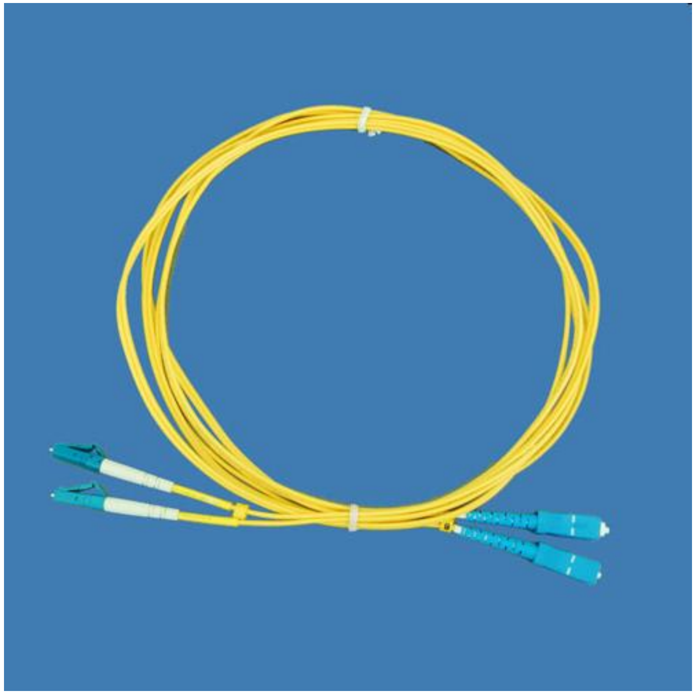
Optic Fiber Components

Fundamentals of Optic Fiber

Identifying Fiber Types

Single-Mode Fiber

Single-mode patch leads will (or at least should) always be yellow in color.



Fundamentals of Optic Fiber

Identifying Fiber Types

Multi-Mode fiber

Multi-mode patch leads will be orange or grey but in practice can be any color other than yellow.

Fundamentals of Optic Fiber

Optical Connector Types – Physical Types

Optical fiber connectors come in a variety of shapes, sizes and connection mechanisms.

Common connection mechanisms are:

- Click connection
- Threaded Connection
- Bayonet Connection

Common connector types are:

- ST
- LC
- FC
- ST

Fundamentals of Optic Fiber

Optical Connector Types – Physical Types

Common Physical Connector Types: Subscriber Connector (SC)

SC/PC

SC/APC

The SC connector is probably the most commonly used connector type, especially in single mode networks. It is a click in type of connection and creates in most conditions a high quality result. SC is also available and popular for more modern multi-mode networks.

Fundamentals of Optic Fiber

Optical Connector Types – Physical Types

Common Physical Connector Types: Lucent Connector (LC)

LC

LC connectors have only recently become available as angled connector types.

While available, it is uncommon to see them in multi-mode applications.

The LC connector is more prone to failure from damage or dirty contacts than SC connectors but are still very popular on single mode transmission equipment because it is roughly half the size of the SC connector. The LC connector is very used where miniaturization and connector density is important such as on transmission equipment patch panels..

Fundamentals of Optic Fiber

Optical Connector Types – Physical Types

Common Physical Connector Types: Fixed Connector (FC)

FC/PC

FC/APC

FC is a threaded type of connector that can be difficult to join when the patch panel is tightly spaced. The connector itself was very popular on both single and multi-mode networks but has been superseded by the SC connector. Due to its initial popularity it is still common to see these connector types on older networks but not often being deployed on new networks.

Fundamentals of Optic Fiber

Optical Connector Types – Physical Types

Common Physical Connector Types: Straight Tip (ST)

ST/PC

ST is a bayonet type of connector and is easier to use than some threaded connectors. The ST was popular on older multi-mode applications but creates an overall poor performing connection in modern terms and it is becoming rare to find these still in service.

Fundamentals of Optic Fiber

Conclusion

In this lesson we covered:

1) **Optic Fiber Connections**

2) **Optic Fiber Construction**

3) **Optic Fiber Components**

Fundamentals of Optic Fiber

Conclusion.

This concludes our introduction to Optical Fibre Networks.

Congratulations, your now ready to start the next session:

Advanced Optic Fiber Theory.