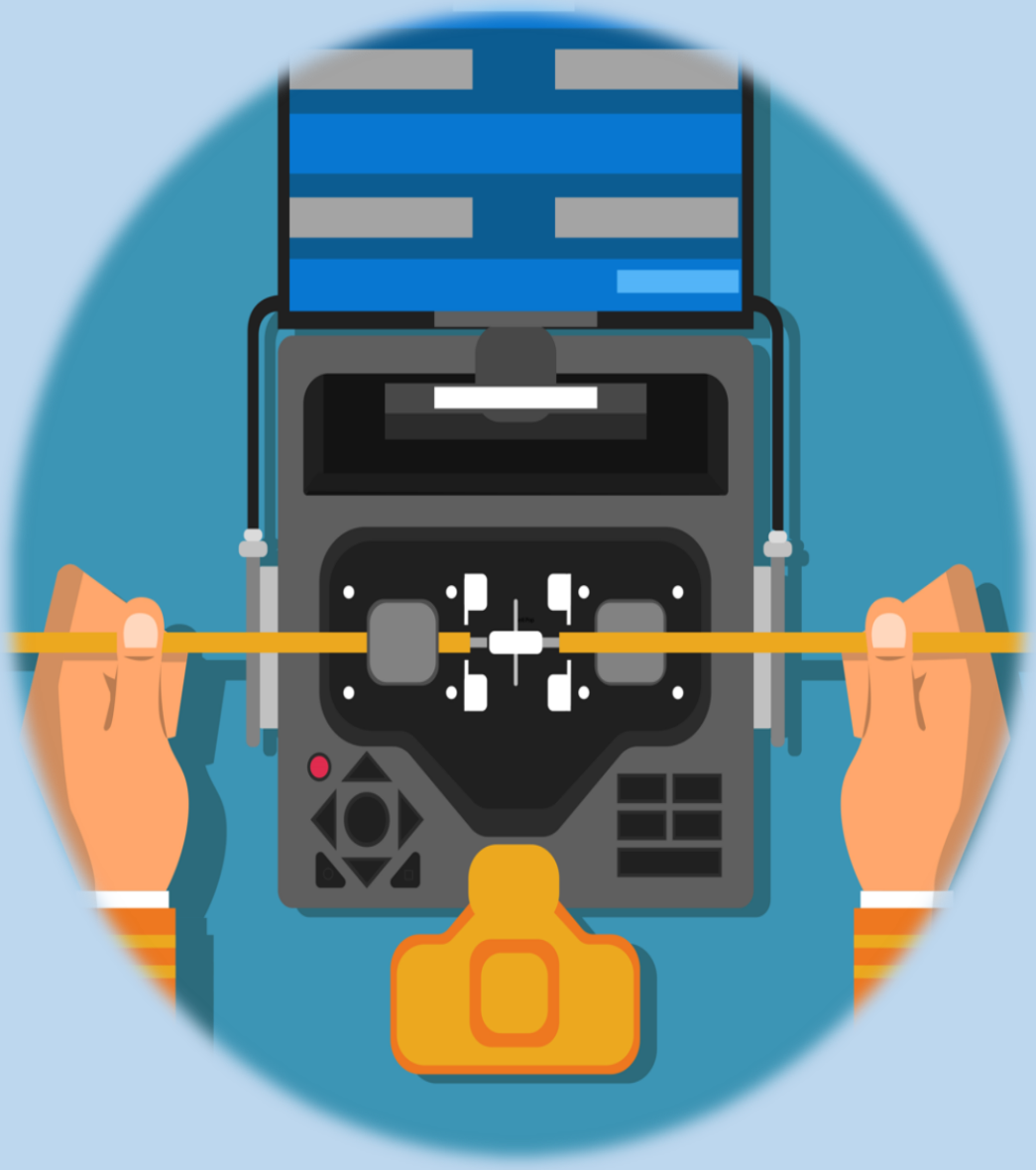
FIBER OPTIC AND SPLICING TECHNIQUE



WAN MOHD ZA'IM BIN WAN SALLEH
ENGKU NOR ZATUN NAJHAH BINTI KURASLI
NORZILAWATI BINTI ABDULLAH

Politeknik Kuala Terengganu
Electrical Engineering Department

FIBER OPTIC AND SPLICING TECHNIQUE

By:

WAN MOHD ZA'IM BIN WAN SALLEH
ENGKU NOR ZATUN NAJHAH BINTI KURASLI
NORZILAWATI BINTI ABDULLAH

First Published 2023
e ISBN 978-967-2240-46-4

Cover Design:
Wan Mohd Za'im Bin Wan Salleh

Author:
Wan Mohd Za'im Bin Wan Salleh I Engku Nor Zatun Najhah Binti Kurasli I Norzilawati Binti Abdullah

Published by:
Politeknik Kuala Terengganu
Jalan Sultan Ismail,
20200 Kuala Terengganu,
Terengganu

: http://www.pkt.edu.my

: 09-6204100 / 09-6204102

Cataloguing-in-Publication Data

Perpustakaan Negara Malaysia

A catalogue record for this book is available from the National Library of Malaysia

eISBN 978-967-2240-46-4

ABSTRACT

FIBER OPTIC AND SPLICING TECHNIQUE

This e-book introduces students with basic knowledge of Fiber Optic and splicing process in Fiber Optic cable. It will be expose splicing technique, ascertain differences characteristics between arc fusion and mechanical splicing. Also provide step by step the procedure of fusion splicing using splicing machine and lastly apply safety precaution in performing the procedure in splicing to avoid hazard.

This book contains SIX (6) main sections regardless with the topic of the subject cover in Fiber Optics Communication System learn by Polytechnics Student in Diploma of Electronics Engineering (Communication) program. The authors hope this book can provide useful resources to students and lecturers and can also be use as independent self-learning source.

PREFACE

In the name of Allah, The Most Gracious, The Most Merciful. Author deepest gratitude extends to Allah S.W.T for every patience, strength, determination and courage to carry out the writing of this Fiber Optic and Splicing Technique e-book.

Many thanks and appreciation are extended to our family and all colleagues of Electrical Engineering Department, Politeknik Kuala Terengganu for their views, helpful cooperation and encouraging comments. Finally, we are very proud and hope that this e-book can benefit the community, especially students and lecturers.

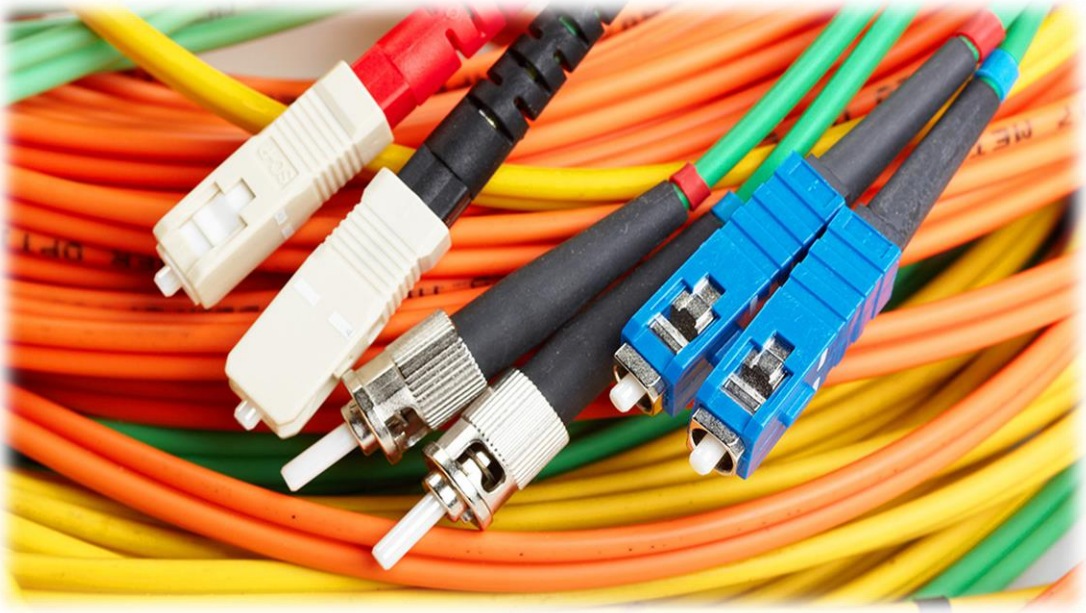
Thank you.

TABLE OF CONTENT

What Is Fiber Optic

A fiber optic cable is a network cable that contains strands of glass fibers inside an insulated casing. They're designed for long-distance, high performance data networking, and telecommunications.

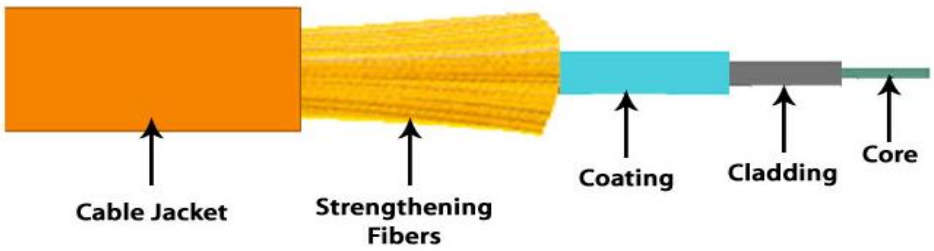
Compared to wired cables, fiber optic cables provide higher bandwidth and transmit data over longer distances. Fiber optic cables support much of the world's internet, cable television, and telephone systems.



Fiber optic cables carry communication signals using pulses of light generated by small lasers or light-emitting diodes.

How Fiber Optic Cables Work

A fiber optic cable consists of one or more strands of glass, each only slightly thicker than a human hair. The center of each strand is called the core, which provides the pathway for light to travel. The core is surrounded by a layer of glass called cladding that reflects light inward to avoid loss of signal and allow the light to pass through bends in the cable.



Basic Fiber Optic Cable Construction

Core
The light is "guided" down the center of the fiber called the "core". The core is designed to have a higher index of refraction, an optical parameter that is a measure of the speed of light in the material.

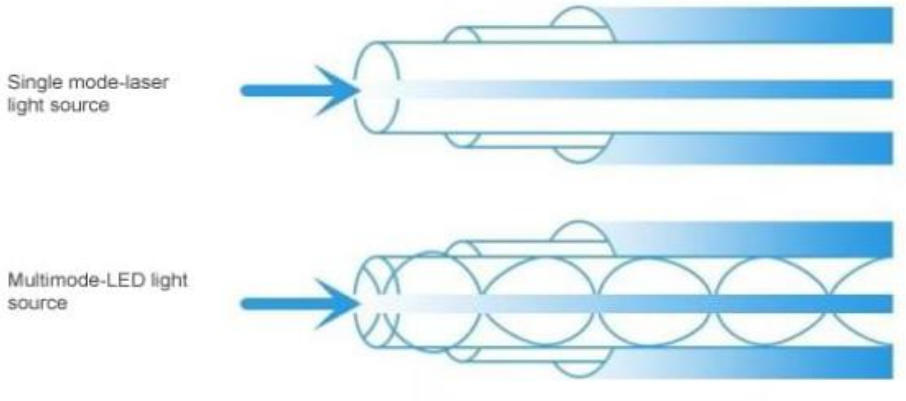
Cladding
Surrounded core to traps the light in the core using an optical technique called 'Total Internal Reflection'

Coating
used to help shield the core and cladding from damage.

Strengthening Fiber
surrounding the buffer, preventing stretch problems when the fiber cable is being pulled.

Cable Jacket
is added to protect against abrasion, solvents and other contaminants.

The two primary types of optical fiber cables are single mode and multi-mode. Single-mode fiber uses extremely thin glass strands and a laser to generate light, while multi-mode optical fiber cables use LEDs.



SINGLE MODE STEP INDEX FIBER

- It so called **Single Mode Step Index Fibers** because its core is so narrow.
- A Single Mode fiber can support only one mode.
- This is called the "Lowest Order Mode".

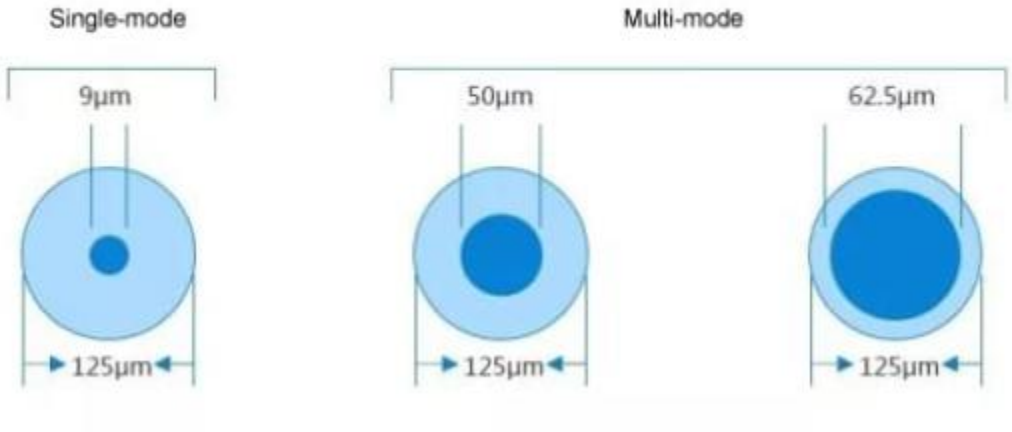
MULTIMODE STEP INDEX FIBER

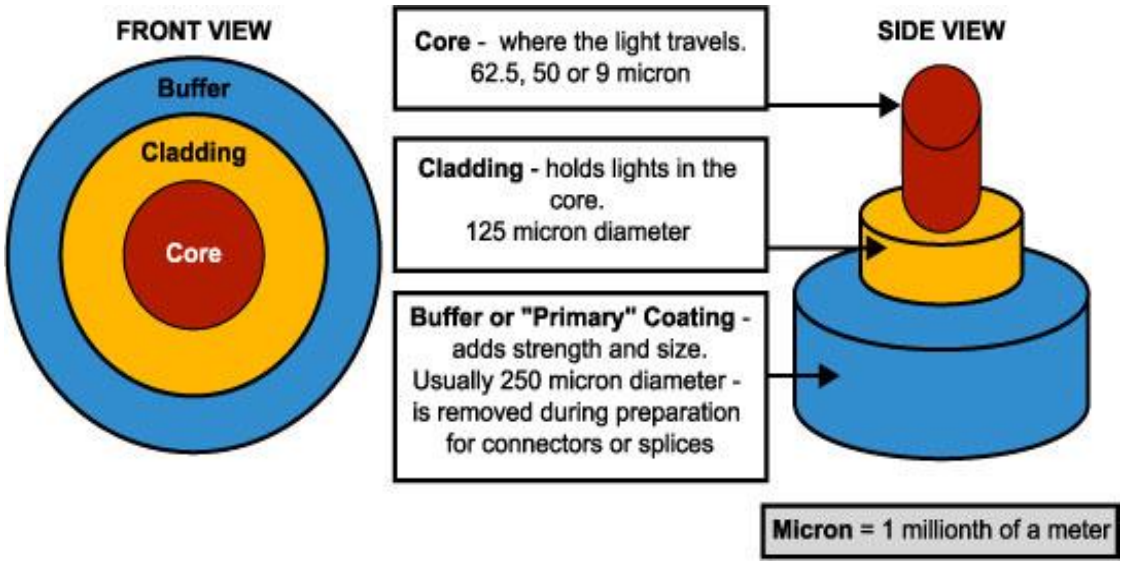
- the refractive index of the core is constant throughout the core
- The refractive index profile abruptly changes at junction of core and cladding

MULTIMODE GRADED INDEX FIBER

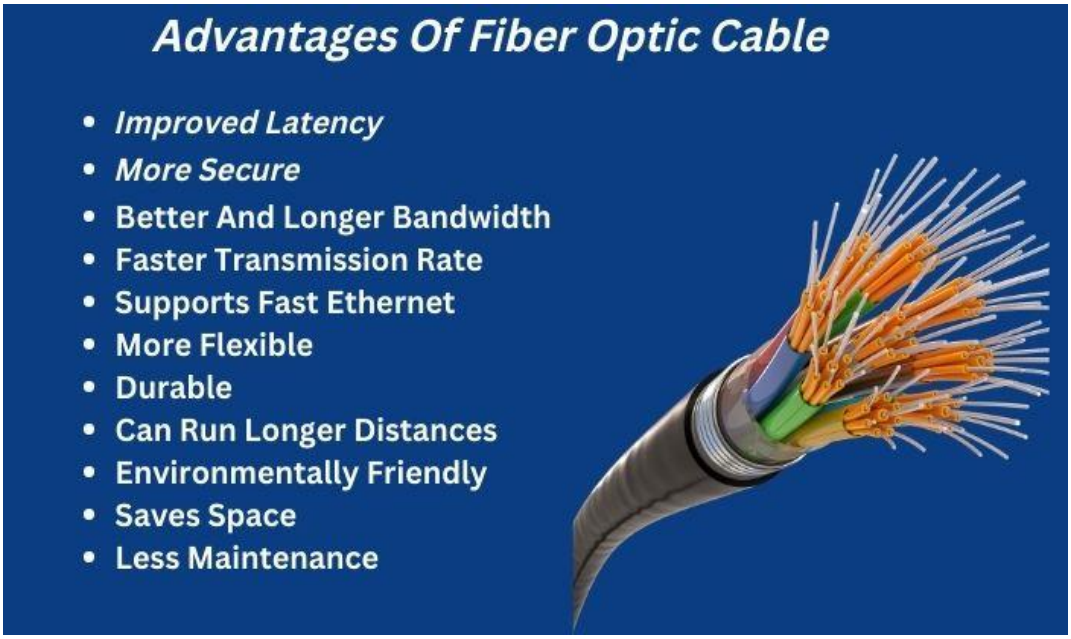
- In graded index fibre the highest refractive index is at centre and not constant.
- The refractive index is highest and centre and decrease gradually until it reaching core-cladding interface.
- Only multimode propagation is possible in graded index fibers.

Cladding diameter of multi-mode fiber and single-mode fiber are the same, the diameter is 125 μm, but the core diameter of multi-mode fiber is much larger than that of single-mode fiber. The core diameter of single-mode fiber is generally 9 μm. The core diameter of a multi-mode fiber is generally 50μm/62.5μm.





1.0 ADVANTAGES OF FIBER OPTIC



1. Improved latency

Fast and reliable internet connects your entire system in a blink. Fiber optic cable is one of the best options to get fast and reliable internet connection. With this cable, you do not need to wait for a long time for your file to upload. You can start watching your favorite video immediately without a glitch.

2. More Secure

Fiber optic cable is one of the most reliable types of communication media. Since it's less susceptible to damage, it's a better option than regular cables. You can also use encryption to secure your data and information. If we compare fiber cable with copper cable, fiber optic cable is 100 times more secure.

3. Better and longer Bandwidth

Fiber Optic Cable provides more bandwidth than any other type of cable. Bandwidth refers to the capacity of a channel or media to transmit information. More bandwidth means you can perform a higher number of tasks at one time.

You can also transfer a large amount of information with the aid of fiber optic cable. The bandwidth is so high that you can connect to multiple devices at the same time and reduce bottlenecks in your home network.

4. Faster Transmission Rate

Fiber optic cable is more resistant to noise and interference than copper cable. Therefore, the speed of data transfer is faster than copper cable. If you want to send large files, it's recommended that you should use fiber optic cables.

5. Supports Fast Ethernet

The Fast Ethernet was introduced in 1995. It uses the same wiring standard as the previous Ethernet standards. However, it's much faster than the original one. It offers a data rate of 100 Mbps and can be used for both commercial and residential purposes.

6. More Flexible

Fiber optic cable is more flexible than copper cable. It allows you to bend it into different shapes, which is great when you want to install the cable inside a wall.

You can also install it internally by drilling holes in walls and ceilings. Coaxial cable is a type of cable that uses copper. Fiber optic cable is a type of cable that uses glass.

7. Durable

Other advantages of Fiber Optic Cable include durability. It's a much more durable cable than copper cable. Other fiber optic cable advantages include the ability to carry multiple signals at once, which means you can connect many devices to your computer network. Fiber optic cables are a great way to get fast and reliable internet in your home or office.

8. Can run longer distances

Fiber optic cables are good at transmitting information over long distances. You can use a single cable to transmit data over a long distance. But the distance can depend on the type of fiber optic cable.

9. Environmentally friendly

Fiber optic cable internet is more environmentally friendly than wireless internet. It doesn't emit any harmful gases like other forms of network connections. It also uses less electricity than wireless connections. It's a good idea to switch to a fiber optic network as it's more environmentally friendly, reliable, and fast.

10. Saves Space

Optical fiber internet is another important reason to switch to fiber optic cable. It provides more bandwidth compared to other technologies, and this increases the speed of your internet connection.

It's a great way to save space in your home or office, because you don't need many wires for this type of network. You can save a lot of space by using fiber optic cable in your home or office. It's a better option than traditional copper wire because it allows you to get faster and more reliable internet.

11. Less maintenance

Fiber optics internet is not as maintenance-intensive compared to copper cable. It's all but immune to external and internal interference. Unlike copper wire, it doesn't change its shape or size whenever the weather changes.

12. Telemedicine

Fiber optic internet connections are a great way to connect people with disabilities to the internet. It's also useful for environmental and medical research. Fiber optic cable is a reliable way of connecting people in rural areas and inaccessible areas.

13. Better Gameplay

Fiber optic internet is good for gaming as it has a much faster connection speed. You can enjoy an amazing gaming experience with fiber optic cable. You don't need to worry about the reliability or speed of your internet connection when playing games on your computer.

14. Better TV Quality

Fiber optic communication is much better compared to traditional cable such as cable television. You can enjoy a better TV viewing experience with fiber optic cable, because it has a much faster connection speed than traditional cable. With fiber optic internet connections, you can enjoy crystal clear images and exceptional sound quality.

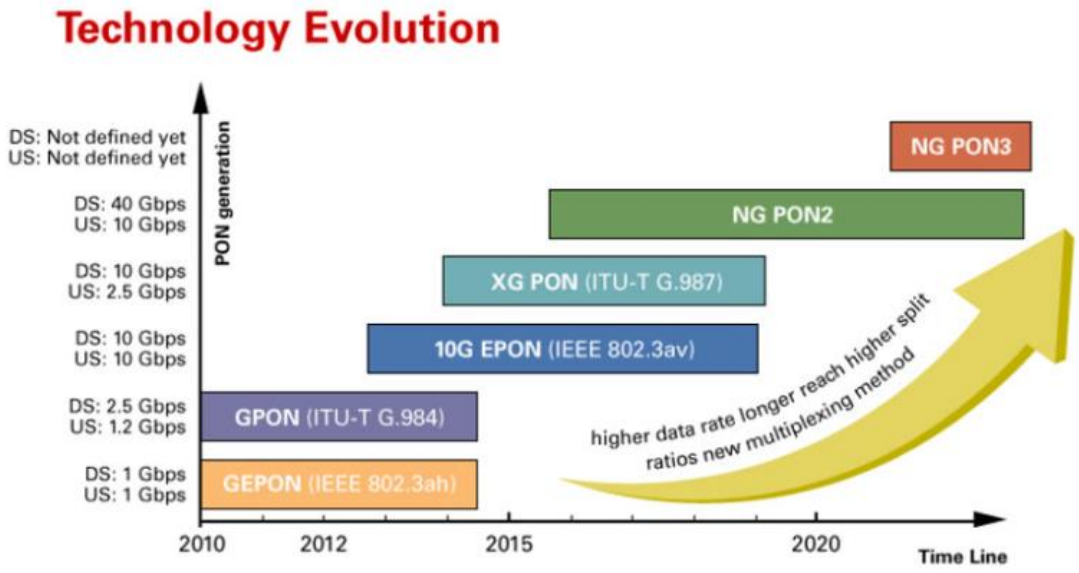
15. Lighter and Cheaper

Fiber optic cable is also lighter and cheaper compared to copper wire. It's less susceptible to damage. It's also a better choice for aerial placement versus traditional cable. We can also use it in place of expensive armored cable.

2.0 PASSIVE OPTICAL NETWORK (PON)

What is a passive optical network (PON)

A passive optical network (PON) is a system commonly used by telecommunications network providers that brings fiber optic cabling and signals all or most of the way to the end user. Depending on where the PON terminates, the system can be described as fiber to the curb, fiber to the building or fiber to the home.

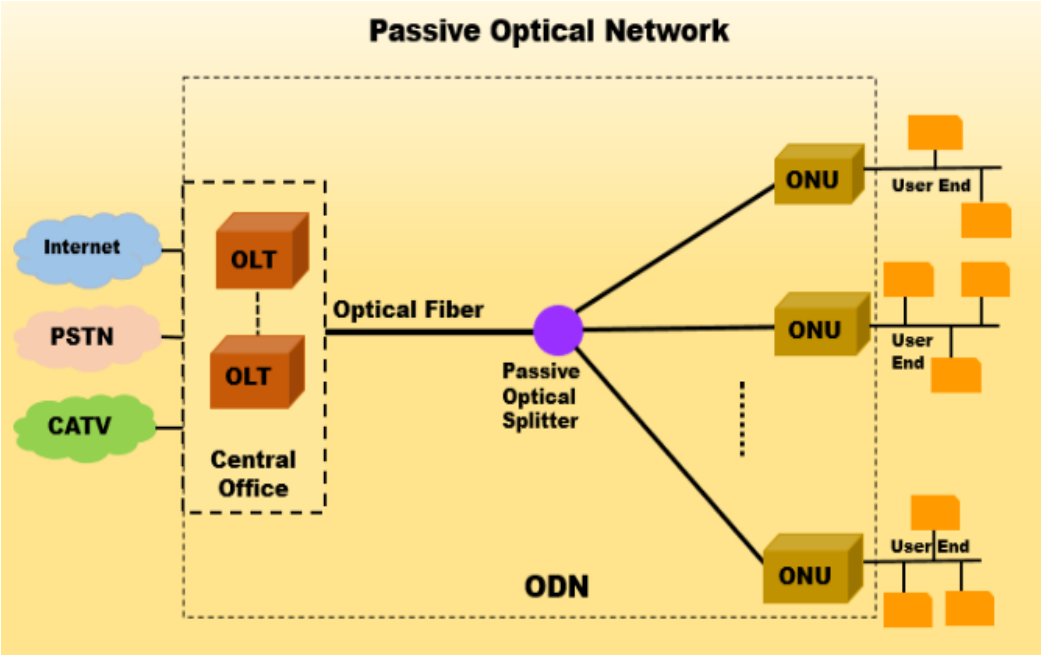


PON-NEtwork-Evolvment

Types of passive optical network (PON)

	BPON	GPON	EPON
Standard	ITU-T G.983	ITU-T G.984	IEEE 802.3ah (1 Gb/s) IEEE 802.3av (10Gb/s)
Downstream Bitrate	155, 622 Mb/s, 1.2 Gb/s	155, 622 Mb/s, 1.2, 2.5 Gb/s	1.25 Gb/s, 10.3 Gb/s
Upstream Bitrate	155, 622 Mb/s	155, 622 Mb/s, 1.2, 2.5 Gb/s	1.25 Gb/s, 1.25 or 10.3 Gb/s
Downstream Wavelength	1490, 1550	1490	1490, 1550
Upstream Wavelength	1310	1310	1310
Protocol	ATM	Ethernet over ATM/IP or TDM	Ethernet
Video	RF at 1550 or IP at 1490	RF at 1550 or IP at 1490	IP Video
Max PON Splits	32	64	16
Power Budget	~13dB (min) to 28dB (max) w/32 split	~13dB (min) to 28dB (max) w/32 split	-
Coverage	<20 km	<60 km	<20 km

How does a PON work



- A PON system utilizes a passive splitter that takes one input and splits it to "broadcast" signals downstream to many users.
- This reduces the cost of the system substantially by sharing one set of electronics and an expensive laser with up to 32 homes.
- Upstream, the passive splitter acts as a combiner to connect all users to the same shared PON port.
- An inexpensive laser is used for the home to send signals back to the FTTH system in the central office.

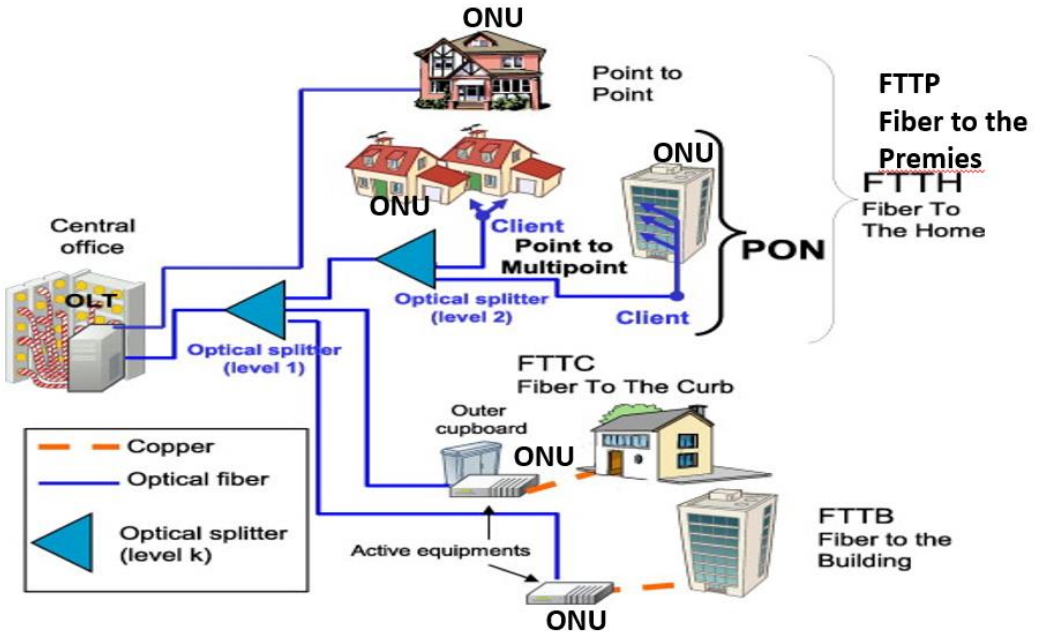
There are two main standards for PON architectures: Gigabit PON (GPON) and Ethernet PON (EPON). Both have specifications for data transfer speeds of 1 Gbps to 10 Gbps. Since communication flows from one source (service provider) to multiple subscribers, PON architectures use point-to-multipoint links. Using a splitter, a single fiber-optic strand from an optical line terminal (OLT) can be replicated across many branches to deliver service to 128 unique locations.

To set up a PON architecture, the service provider starts by building an optical fiber network. The access end of this fiber network connects directly to clients, while the other end connects to a router/switch using an OLT located in a service provider central office or point of presence (POP). The OLT converts Ethernet traffic into PON traffic.

The ONU/ONT directs the fiber-optic wavelengths to one of several places near subscribers:

- Fiber to the home (FTTH)
- Fiber to the building (FTTB)
- Fiber to the curb (FTTC)
- Fiber to the premises (FTTP)

Type Fiber In The Loop (FITL) Network Architecture



FTTP - The term FTTP (fiber-to-the-premises) is used as a general way to refer to high-speed connectivity optical fiber run into a subscriber's home from a central location. FTTP can be used to reference either FTTH or FTTB fiber optic connections.

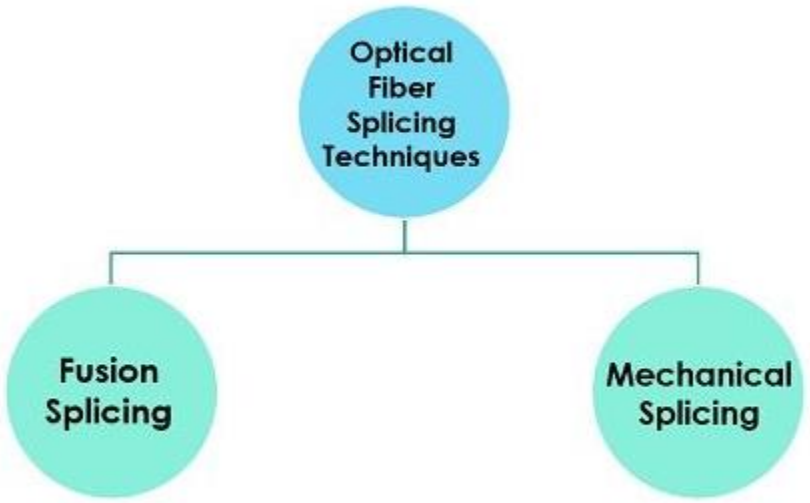
FTTC - fiber running directly from the central Office to the outdoor shelters on curbs near homes or any business environment.

FTTB - fiber reaches the boundary of the building, such as the basement in a multi-dwelling unit, with the final connection to the individual living space being made via alternative means.

FTTH - fiber reaches the boundary of the living space, such as a box on the outside wall of a home.

4.0 FIBER OPTIC SPLICING TECHNIQUE

Splicing of optical fibers is a technique used to join two optical fibers. This technique is used in optical fiber communication, in order to form long optical links for better as well as long-distance optical signal transmission. Splicing basically provides permanent or semi-permanent joints.



Fusion Splicing

Fusion splicing offers a unique solution to conjoin the optic materials through the use of a fusion splicer. This piece of equipment is a great resource as it provides a safe and easy solution. It first aligns the two fiber ends it is joining together and then proceeds to produce an electric arch that welds them together. This takes away human-error and promotes team member safety.

However, these large machines are usually expensive and while they do a great job, a properly trained team member can usually perform the same routine just as effectively.

Mechanical Splicing

The mechanical splicing technique does not require a large fusion splicer. Instead, mechanical splicing uses a small mechanical splice securing fiber optic ends against one another. After the two ends are secured, a clasp or adhesive piece is used to hold the two ends in place.

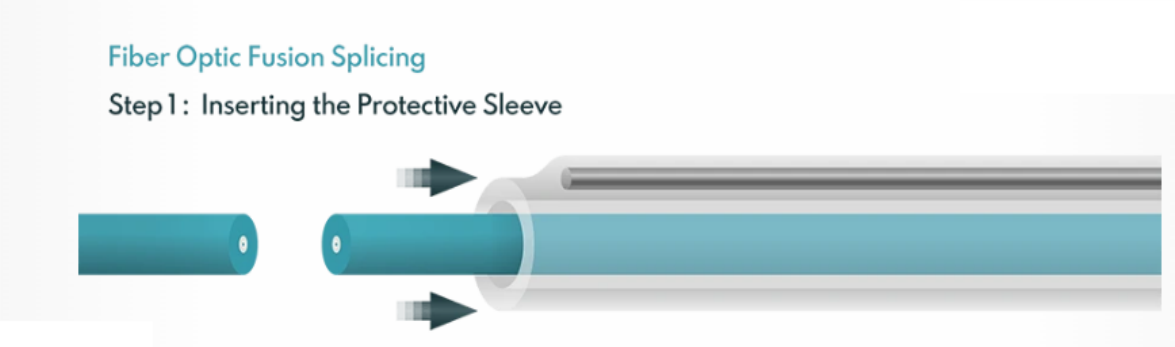
This method uses no welding and is a fast, easy way to repair or lengthen fiber optic cables. However, this method provides a larger loss in connectivity than fusion splicing. While faster, this can prove to be a problem when thinking about increasing bandwidth usage across the nation.

Step By Step the Procedure of Fusion Splicing Using Splicing Machine

Main Steps of How to Do Fusion Splicing of Optical Fibers.

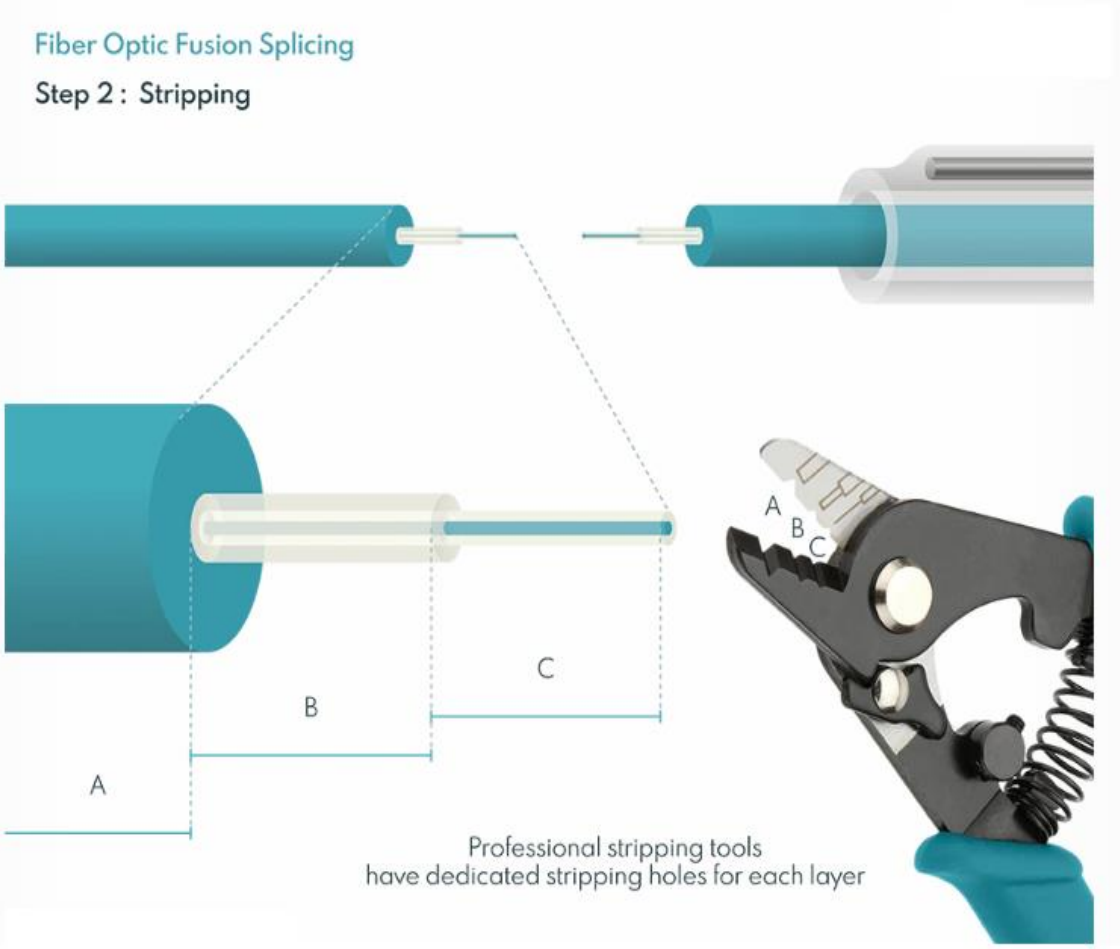
1. Insert One Side of Fiber in the Splice Protective Sleeve.

Although, protecting the fusions splice part of the fiber is last step of this process, a technician should not forget to insert the heat shrink protection sleeve onto one side of the fibers. The protection sleeve is usually a solid tube that can be put on a fiber end but cannot be wrapped around the fiber after it has been spliced. In addition, the splicing area must be very clean and the fusion device must be place on a stable surface.



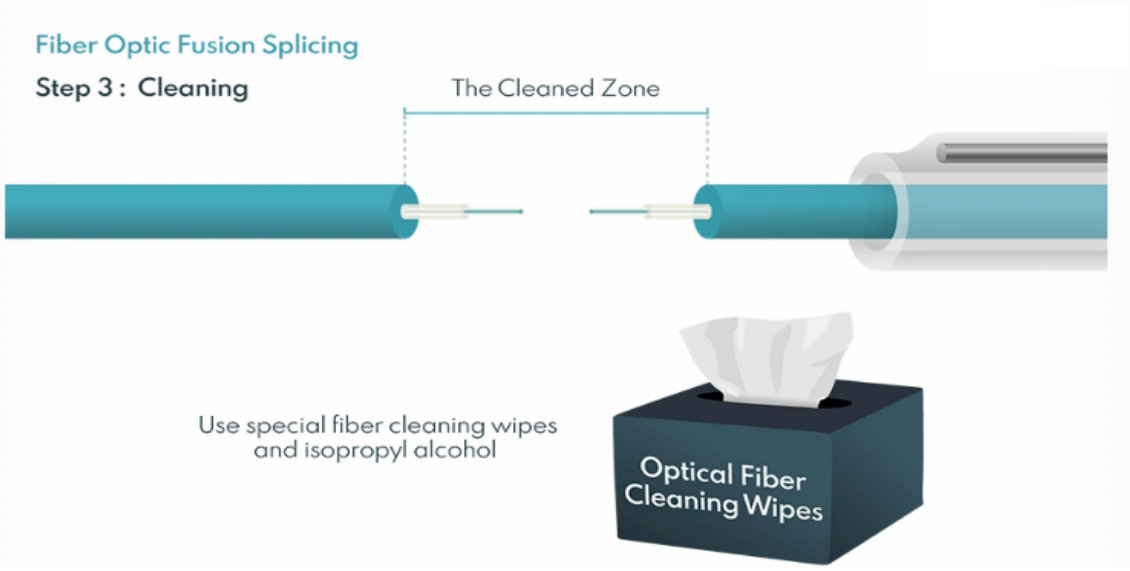
2. Strip the Fibers' Buffer Coatings Accurately.

In order to fuse two fiber ends together they need to be stripped down to the cladding layer; only the core and the cladding layer of the fiber can be fused together and the all buffer and coating layers must be removed. There are professional stripping tools for optical fibers, which usually have dedicated stripping holes for the 250μm buffer, tight buffer layer and other additional coating layers and jackets. The more a technician practices fiber stripping, the more accurately they can do it efficiently in a one-slide maneuver for each stripped layer. The fusion device has instruction on the stripping lengths of each layer and some devices have fiber detachable holders for easier handling of the fiber, especially if it is a Ribbon cable, which has multiple fibers that can be fused at the same time.



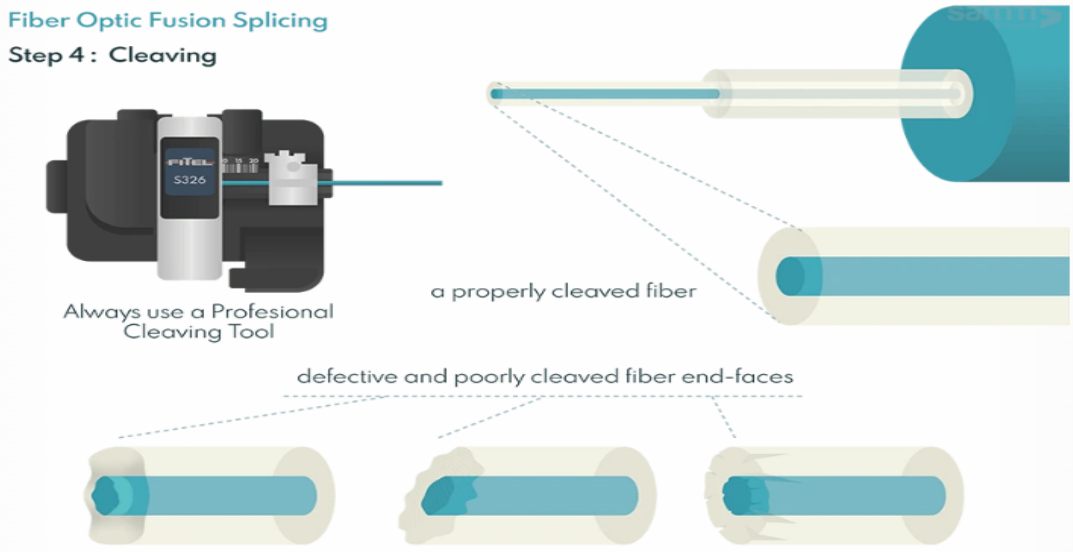
3. Clean the Fibers from Remaining Coating Particles.

The stripping tool might leave some waste particles of the stripped buffer and coating layers. This waste can be easily cleaned using isopropyl alcohol and specially designed fiber cleaning wipes. Please not that regular cleaning wipe might scratch the fiber from the sides, and there is no need to clean the end face of the fibers excessively because they are to be cleaved in the next step.



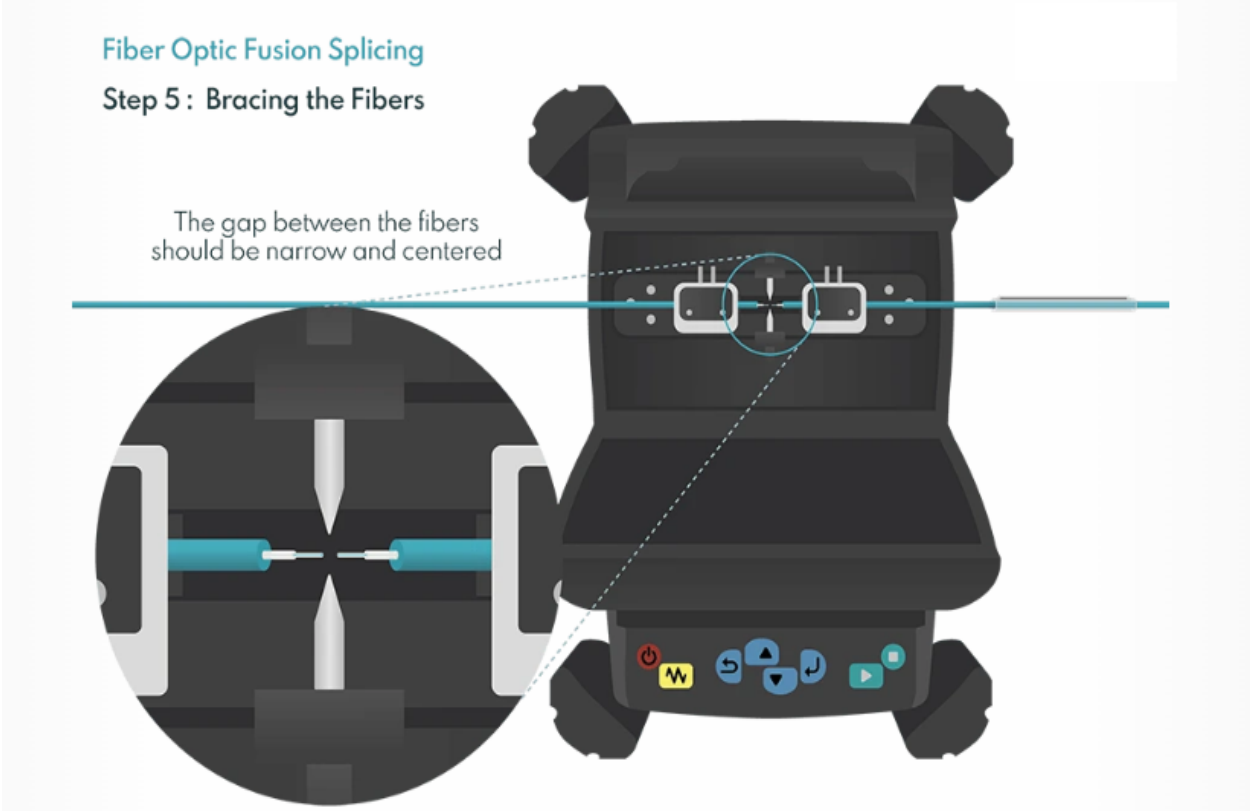
4. Cleave the Ends of Fibers at Precisely 90° Angle.

A fusion-splicing device usually comes with a compatible fiber cleaver, which is a tool the trims the tip of a fiber strand at exactly 90° angle. An optical fiber cannot be cut using any kind of cutters or scissors, or else the end face of the fiber would be deformed and result in signal loss after splicing. For ribbon fiber cables, there are special cleavers that are deigned to cleave up to 12 fibers or more at the same time.



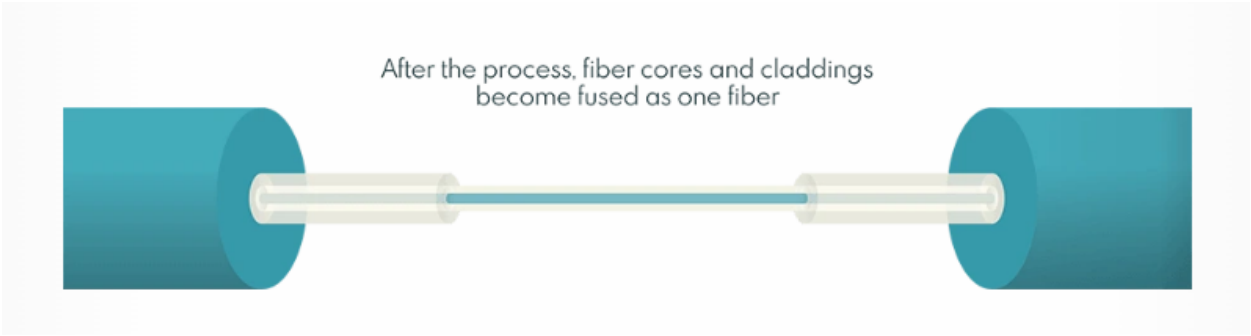
5. Brace the Fibers in the Fusion Splicing Device.

Place the ends sides of stripped fiber in the allocated slots on the device and make sure the gap between them is appropriately small and centralized in between the heating electrodes. Splice fusion devices generally have detachable holders or fixed clamps that secure the fibers in place, and make the positioning step quite easy to do repeatedly. When you are using a ribbon fusion device, it should have special tiny guides to keep the fibers aligned and separated by equal distances.



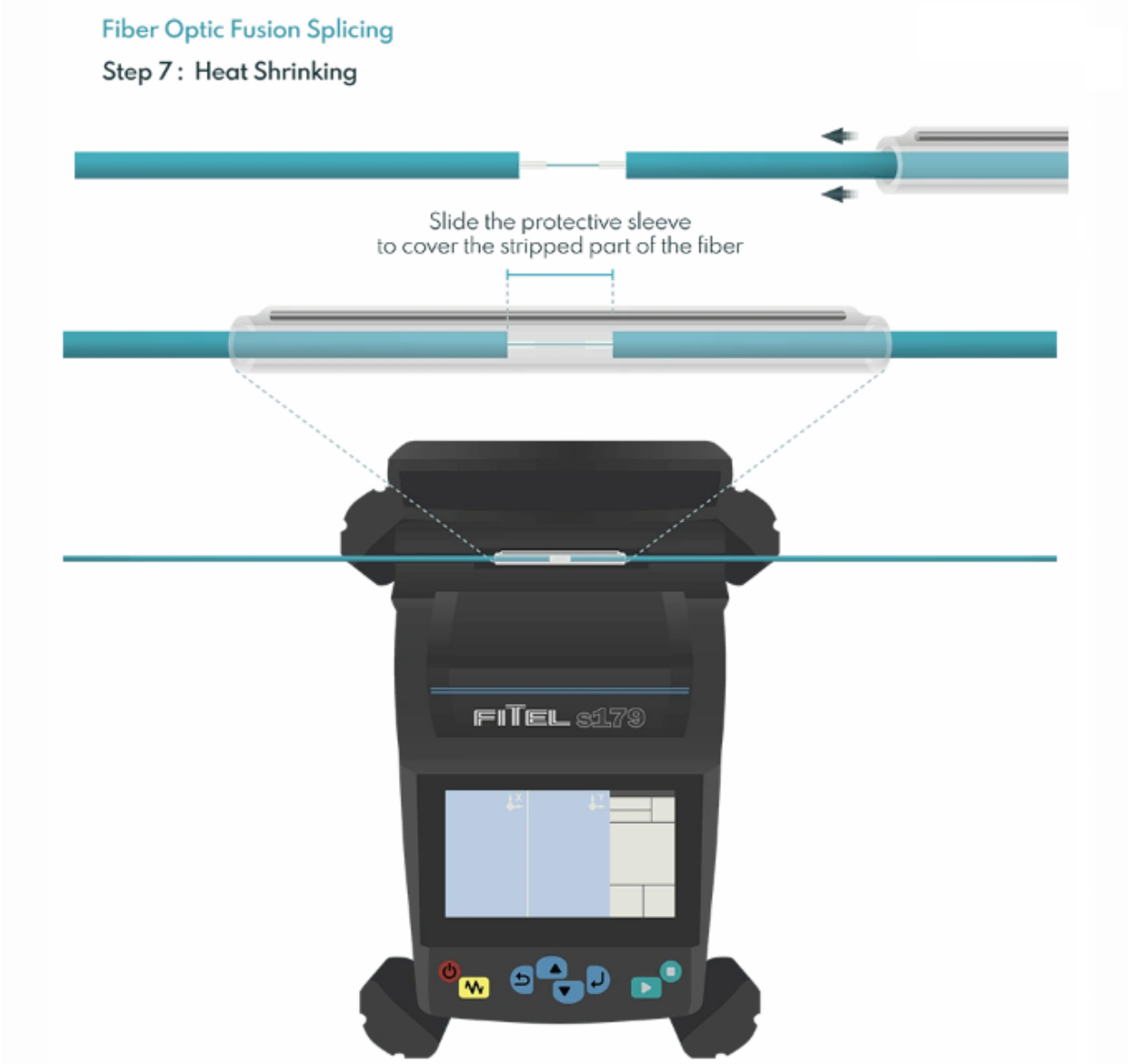
6. Start the Fusion Splicing Process.

Before activating the alignment and fusion process; make sure the setting of the device are set correctly for the type, single mode or multi-mode for example, and the number of fibers to be spliced. Fibers are very delicate, and the correct settings help the device apply the correct amount of heat and push the fibers together at the correct speed to have perfect splicing results and zero signal loss. Besides, in modern devices the final alignment, the electric heating and the fusion process are all done automatically and the fusion device has a magnifying camera that demonstrates the alignment and fusion process on the screen. The final estimated fiber loss will be displayed on screen, and it should be as close as possible to 00.00dB for a better connection. After the process ends, the two sides of fiber become one continuous strand, but we need to handle them carefully while doing the last protection step.

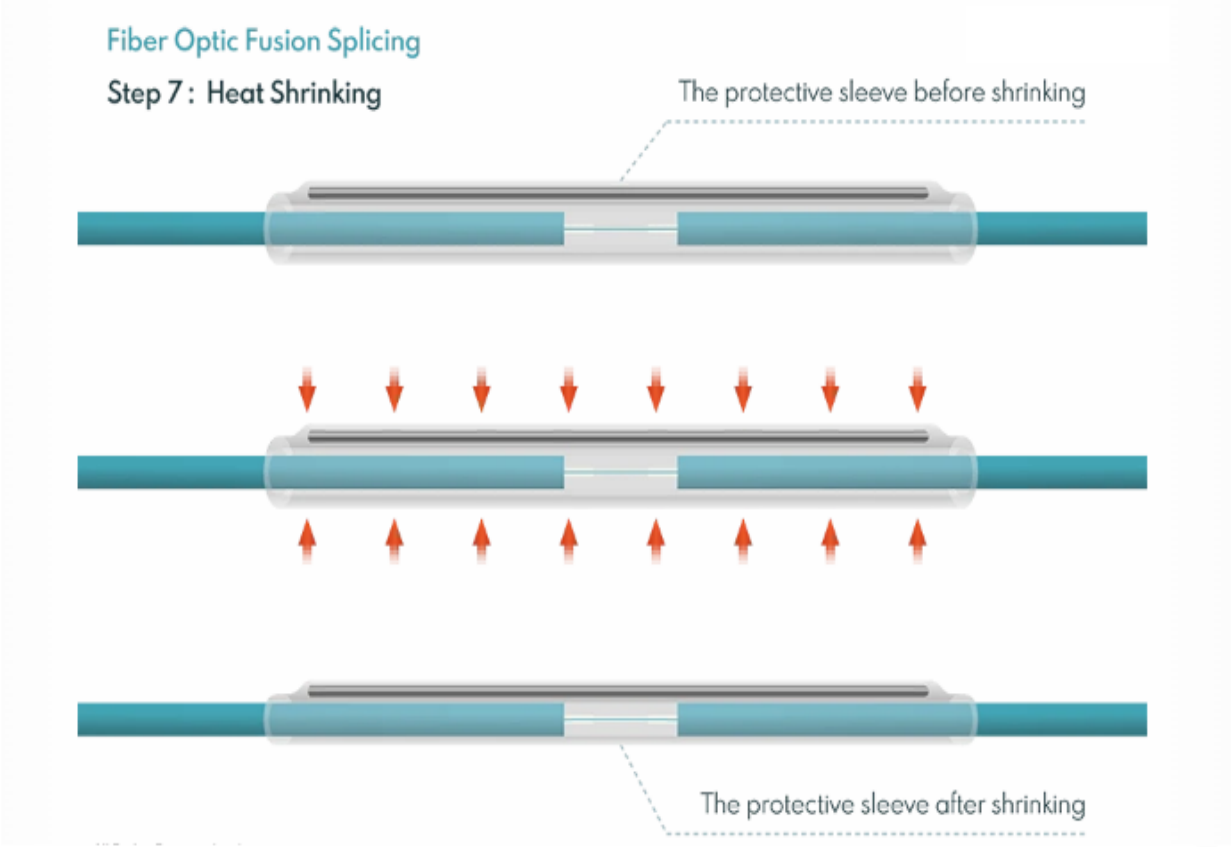


7. Heat Shrink the Protective Sleeve Around the Splice.

Finally, we can apply the heat shrink protective sleeve, which we left on one side of fiber, on the spliced part of the fiber. However, you need to make sure to hold the fiber from the side where the sleeve is, and push the sleeve away to the middle, and not hold the far side of the fiber and pull the sleeve towards your hand. Otherwise, the movement of the sleeve might pressure the splicing point and damage it.



After completely covering the stripped splicing part of the fiber with the protective sleeve, you can now place them together in the allocated heat-shrinking slot and start the sleeve heating step. The device will beep when the heating is finished and the sleeve becomes tightly sealed onto the spliced fiber and you the splicing of the fiber is now complete.

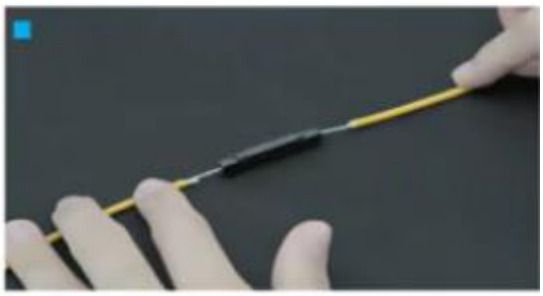


Step By Step the Procedure of Fusion Splicing Using Mechanical Splicing

STEP 1:

Preparing the fiber - Strip the protective coatings, jackets, tubes, strength members, etc. leaving only the bare fiber showing. The main concern here is cleanliness. Clean the fiber using an optic cleaning wipe with isopropyl alcohol.

STEP 2:



Mechanically join the fibers - There is no heat used in this method. Simply position the fiber ends together inside the mechanical splice unit. The index matching gel inside the mechanical splice apparatus will help couple the light from one fiber end to the other. Older apparatus will have an epoxy rather than the index matching gel holding the cores together.

Step 3:

Once fibers are spliced, we place them in a splice tray and then in a splice closure. Outside plant closures don't need to use heat. We carefully seal shrink tubing to prevent moisture damage from the splices.

4.1 OPTICAL FIBER SPLICE LOSS

Definition

Fusion splicing is a technique to join two fibers ends. Optical power loss at the splicing point is known as splice loss.

An Optical Time Domain Reflectometer (OTDR) can be used for splice loss measurement. A cable section-containing splices are normally shown as knees on the optical power loss OTDR graph. Fiber splice can be classified as Intrinsic and Extrinsic parameters.

Intrinsic Parameters

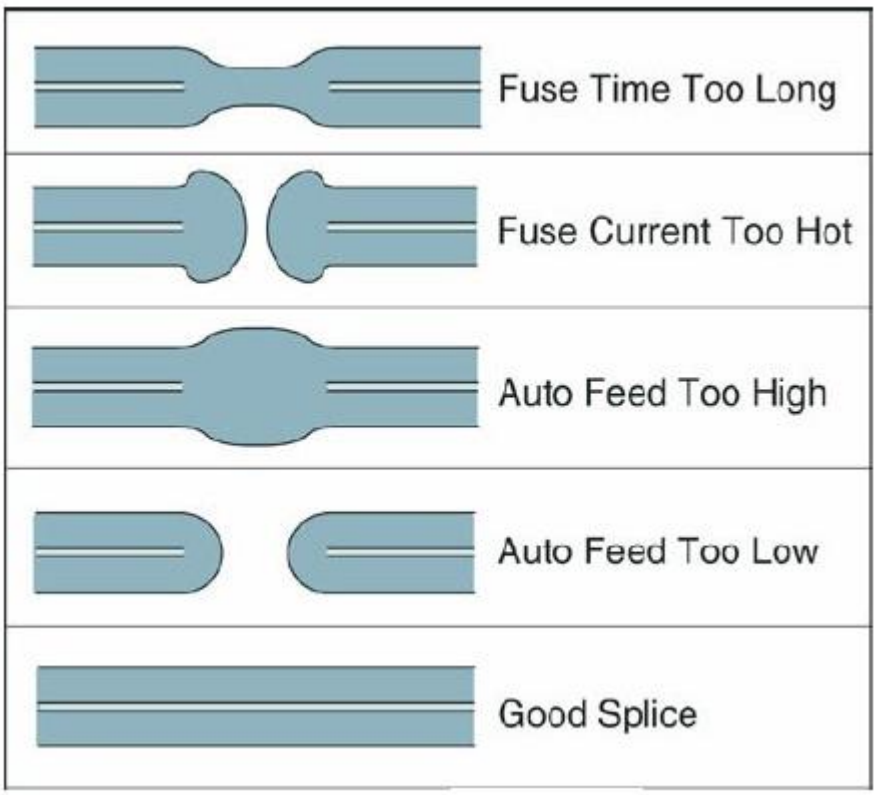
Intrinsic or fiber related parameters are determined when the fiber is manufactured and cannot be controlled by the individual doing splicing.

Extrinsic Parameters

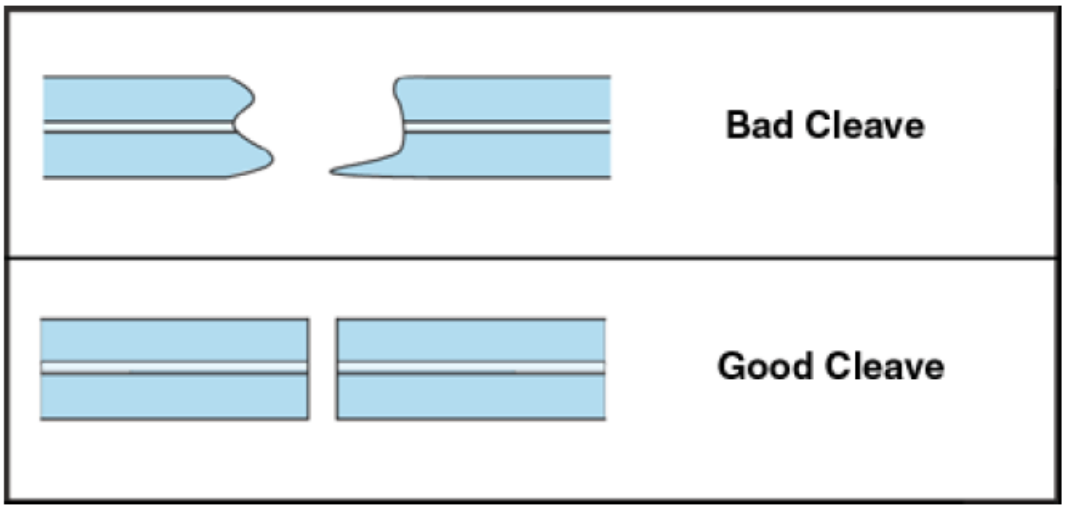
Extrinsic, or splice process related parameters are those induced by splicing methods and procedures. Splice process parameters include lateral and angular alignment, contamination at the fiber end and core deformation due to un-optimized heating & pressing.

These external parameters can be controlled/minimized by improving skill of the individual doing splicing and by automated fiber alignment and fusion cycles.

It has been observed that splice loss between two identical fibers with same MFD and geometry parameters is as high as 0.04 dB. This excess loss is due to miss alignment and other splicing process parameters.



Other important extrinsic parameter is fiber end angle. Proper fiber end preparation is the most fundamental step to get acceptable splice loss. Generally, end angle less than two degrees gives acceptable field splice loss. End angle is dependent on condition of cleaver and cleaver blade. Typical end angle of well – maintained cleaver is around one-half degree. Figure4 is showing comparison between bad and good cleaving. It has been observed that extrinsic parameters can give splice loss as high as 0.4 dB. By controlling extrinsic parameters, acceptable field splice loss can be achieved.



5.0 DIFFERENCES CHARACTERISTICS BETWEEN ARC FUSION AND MECHANICAL SPLICING

Characteristic	Arc Fusion	Mechanical
Fiber alignment mechanism	machine is used to precisely align the two fiber ends then the glass ends are "fused" or "welded" together using some type of heat or electric arc.	simple alignment devices to hold the two fiber ends in an alignment fixture with a transparent gel or optical adhesive.
Loss and back reflection	lower loss (Typical loss: 0.1 dB) and less back reflection	higher loss (Typical loss: 0.3 dB) and greater reflectance
Fiber types	are used primarily with single mode fiber	work with both single and multi-mode fiber.

Differentiate between Arc Fusion and Mechanical Splicing

6.0 SAFETY PRECAUTION IN PERFORMING THE PROCEDURE IN SPLICING

1. Keep all food and beverages out of the work area. If fiber particles are ingested, they can cause internal hemorrhaging.

2. Wear disposable aprons to minimize fiber particles on your clothing. Fiber particles on your clothing can later get into food, drinks, and/or be ingested by other means.

3. Always wear protective gloves and safety glasses with side shields. Treat fiber optic splinters the same as you would glass splinters.

4. Never look directly into the end of fiber cables especially with a microscope until you are positive that there is no light source at the other end. Use a fiber optic power meter to make certain the fiber is dark. When using an optical tracer or continuity checker, look at the fiber from an angle at least 6 inches away from your eye to determine if the visible light is present.

5. Only work in well-ventilated areas.

6. Contact lens wearers must not handle their lenses until they have thoroughly washed their hands.

7. Do not touch your eyes while working with fiber optic systems until your hands have been thoroughly washed.

8. Keep all combustible materials safely away from the curing ovens.

9. Put all cut fiber pieces in a safe place.

10. Thoroughly clean your work area when you are done.

11. Do not smoke while working with fiber optic systems.

REFERENCES

1. https://www.cablematters.com/Blog/Networking/single-mode-vs-multimode-fiber-optic-cables

2. https://advantageslist.com/what-are-the-advantages-of-fiber-optic-cable/

3. http://fowiki.com/b/development-of-passive-optical-networks-pons/

4. https://www.researchgate.net/figure/Passive-Optical-Network-Architecture-The-PON-architecture-consists-of-three-main-units_fig2_328117687

5. https://www.adbcompanies.com/single-post/fiber-optic-splicing-explained

6. https://telecom.samm.com/steps-of-fusion-splicing-fiber-optic-cables

FIBER OPTIC AND SPLICING TECHNIQUE

e ISBN 978-967-2240-46-4

POLITEKNIK KUALA TERENGGANU
JALAN SULTAN ISMAIL
20200 KUALA TERENGGANU
TERENGGANU
http://www.pkt.edu.my