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Introduction

Welcome to Fibertronics

Fibertronics was established in 2009 in Melbourne, Florida, USA with the goal of providing reliable, consistent and quality products to its customers.

Despite our rapid growth we have remained flexible, giving us the edge over our competitors and allowing us to provide superior custom manufactured fiber optic cable assemblies, as well as other fiber optic devices to our customers at incredibly competitive prices.

Fast delivery and great service help set us apart. Whether you are looking for standard patch cords, restocking orders or simply have questions regarding custom cable assembly, Fibertronics has both the experience and resources to help you out.

For more product information or a quick quote why not give our friendly service consultants a call on (877) 320 3143.

Using this Manual

This Training Manual is organized so that you can quickly find, read, and understand the information that you want. It’s also organized in such a way as to allow you to skip ahead and move on to the parts that are relevant to you should you be looking for a quick solution.
Understanding the Icons

Throughout this training manual you may encounter various icons, each of these serves a different purpose from highlighting valuable information to providing helpful tips and hints.

**Important**
This icon highlights important and useful information, pay close attention as information found here is vital to your understanding.

**Tips, Hints and Advice**
Useful tips, hints as well as advice are described where you see this icon. These will help you get the most from this manual.

**Advanced Users Information**
Designed to assist advanced learners these sections will shed light on more complex subjects. Even if you’re new it won’t hurt to look and who knows, it might be useful in the future.
Splicing Fiber Explained

In This Section
- Introduction to Splicing Fiber Optic Cable
- Fusion Splicing vs Mechanical Splicing
- The Differences (Cost & Performance Analysis)

Introduction to Splicing Fiber Optic Cable

Splicing Fiber is simply joining two optical fibers together by making use of heat. The two optical fibers should be fused in such a way as to allow light to be passed through them without scattering or reflecting light back at the point of the splice.

The heat used to fuse the two fibers together is usually in the form of an electric arc (Fusion Splicing), however it can also be achieved using a laser or even gas flame (Mechanical Splicing).

Fusion Splicing vs Mechanical Splicing

As mentioned earlier there are two types of splicing, Fusion splicing and Mechanical splicing. They both essentially accomplish the same thing in that they join two optical fibers together and hold them together allowing an optical signal can pass through the join.

**Fusion Splicing** is a point at which optical fibers that have been melted together by making use of a machine know as Fusion Splicer. The Fusion Splicer performs two basic functions:
1. Aligning of the fibers
2. Melting them together, typically this is done using an electric arc.

**Mechanical Splicing** is done via simple alignment devices and does not permanently join fibers together. Mechanical Splices are designed to hold two separate fiber ends in a precisely aligned position allowing light to pass across the join from one fiber into the other.

Perhaps the best way to think of the difference between the two methods is to think of Fusion Splicing as being done via a specialist machine (Fusion Splicer) creating a single fiber. Mechanical Splicing as being done manually with basic tools and simply aligning two separate fibers.

**The Differences (Cost & Performance Analysis)**

**The Cost**
Due to requiring a specialist equipment to perform a Fusion Splice the initial investment in this method is typically much greater. It does however offer a much lower cost per splice saving money in the long term. Typically, it costs between $0.50 to $1.50 per splice when making use of a Fusion Splicer.

Mechanical Splicing does not generally require a large upfront investment in tools, but the trade-off on this is a much higher variable cost at $10 to $30 per splice. The more splicing done the more the cost builds up using this method.
Performance
With a mechanical splice, the typical insertion loss (IL) is higher, between 0.2 dB and 0.75 dB. This is because the two fibers are simply aligned and not physically joined together.

Fusion splicing offers far lower insertion loss and a better performance overall. This is because fusion splicing provides a continuous connection between two fibers and not just a temporary join. The typical loss in fusion splice is < 0.1 dB, this will mean far better protection against cable failure and weak signals.

Conclusion
Fusion splicing overall far lower insertion loss and greater reflectance performance, far surpassing mechanical splicing. The initial investment however is significantly higher due to the equipment required.

Most large telecoms companies invest in fusion splicing for what are known as long-haul single-mode networks. They will however still make use of mechanical splicing techniques for shorter, local cable projects.
Fusion Splicing

In This Section

- Fusion Splicers Explained
- What You’ll Need
- The Correct Environment for Fusion Splicing

Fusion Splicers Explained

As described the Fusion Splicer is the device that will be used to join the fibers together. There are primarily 2 types of Fusion Splicers in use today.

- Core Alignment
- V-Groove

Core Alignment

This is the most popular type of Fusion Splicer. While it is more expensive and complex, it is also far more powerful and flexible while being less sensitive to variations within the cable. Core Alignment Fusion Splicers use a combination of image and light detection systems to measure and measure the fiber core positioning during alignment of the fibers on the X, Y and Z axis'. The result is a superior splice as the it can compensate for things such as offset due to contamination or core-cladding mismatches.
Core Alignment Fusion Splicers make use of a Profile Alignment System (PAS) where light is shone into the fiber and embedded cameras are used to identify the core of the fiber by detecting the difference in the refraction of light caused at the core/cladding interface.

V-Groove
Also known as Cladding Alignment Fusion Splicers, this technology relies on the accurate pre-alignment of V-Grooves that grip the outer-surface of the cladding of the fiber. The only movement of the fibers in this process is along the Z Axis as the splicer brings the fiber together. The advantage of this method is its relatively lower cost and speed; however, this is offset by potential contamination on the fibers or the V-Grooves themselves which may affect the X or Y alignment.

What You’ll Need

Fusion splicing is straightforward and beyond the Fusion Splicer itself only some basic fiber optic tools are required. Below is a list of some of the equipment you will need.

1. Fiber Strippers
2. Kevlar Cutter
3. Splice Sleeves
4. Alcohol Wipes
5. Fiber Optic Cleaver
6. Microscope (Not mandatory, but very useful for checking fiber ends once the fiber has been spliced)
7. Fusion Splicer
The Correct Environment for Fusion Splicing

Fusion Splicing should ideally be done in a very clean environment, this helps to prevent dust and other contaminants from interfering with the Fusion Splicing process. Temperature is also very important when it comes to the area in which you will be splicing fiber. Ideally the temperature should be between 15ºC to 28ºC (approximately room temperature).

While the Fusion Splicer works between -10ºC and +5ºC and the closure can be installed at a temperature between -1ºC and +45ºC, it is best to ensure that the conditions are optimum to ensure maximum efficiency of the splice.
The Fusion Splicing Process

In This Section

- Step 1: Prepare the Cable
- Step 2: Clean, Cleave and Clean Again
- Step 3: Fusion Splicing
- Step 4: Evaluating the Splice
- Step 5: Protect the Fiber

Step 1: Prepare the Cable

While may sound easy enough unfortunately, it is not quite as simple as stripping the coating of your average house-hold copper cable.

First remove the polymer coating by making use of Fiber Strippers, which are specially designed for stripping the coating off the fiber. Ideally 1 ½ inches (38 mm) should be removed from each end of the fiber being joined. This should be done incrementally and gently while ensuring the stripper is held at a slight angle during the process.
With the coating stripped from the fibers it is now time to simply clip away any excess, exposed Kevlar with your Kevlar cutter.

Once completed slide one of your Splice Sleeves onto one of your fiber, you may not be able to do this once you have spliced the two fibers together, so it is best to do it now and avoid problems later.

**Step 2: Clean, Cleave and Clean Again**

Keeping the fibers clean is of the utmost importance when it comes to fusion splicing. It cannot be repeated enough, ensure that the fibers you are working with are cleaned after every major interaction with them. You do this by gently wiping them down with Alcohol Wipes.

Once clean it is time to cleave the fibers. The fiber should ideally be cleaved using what is known as the score-and-break method, this is done to ensure that the end face is perfectly flat and perpendicular to the axis of the fiber. This is best done by making use of a quality Fiber Optic Cleaver. The closer the cleave angle is to 90 degrees on both fibers the better, this will result in less optical loss from the splice.
After cleaving both fibers it is time to once again clean the ends with the Alcohol Wipes.

**Step 3: Fusion Splicing**

It is now time to make use of the Fusion Splicer, begin by placing each fiber into the guides on the Fusion Splicer and clamping them into places securely.

Close the lid of the splicer and using he monitor on the Fusion Splicer select the correct settings and program the correct fiber types into it.

The fiber ends will be automatically moved into position, at this point a pre-fuse cycle will begin and any remaining dirt on the fiber ends should be removed as preheating begins.

Next the fusion splicer will attempt to align the two fibers by inspecting the cleaves. As previously mentioned, bad cleaves will result in misalignment and will be rejected. If the cleaves are good the fibers will be fused by an automatic arc cycle that heats the ends and feeds the fibers together at a controlled rate.
Once fusion has been completed the Fusion Splicer will inspect the splice and will attempt to estimate the total optical loss of the splice. Should the splice need to be remade it will display a notification stating this. Once correctly fused together it is now time to remove the fibers from the guides and move the splice protector over the splice and shrink it to fit (Most Fusion Splicers have a heating device for heat shrinking protective fiber sleeves onto the fiber).

**Step 4: Evaluating the Splice**

It is best to visually inspect the splice after program has been run. This can be done by inspecting both the X and Y views on the Fusion Splicer. Some flaws do not affect optical transmission and can be passed as acceptable. Some fibers may also cause black or white lines to appear in the splice, these are typically not faults but are caused by making use of fibers that are either fluorine-doped or titanium coated.

Some flaws in the splice are considered unacceptable and will require starting the process over. These can include black spots, lines, very large core offsets, bubbles and bulges. The following is a diagram displaying both acceptable and unacceptable defects within a splice.
Step 5: Protect the Fiber

It is vitally important to protect the fiber from both bending and tensile forces so that the splice will not break during normal use and handling.

A typical Fusion Splice has a tensile strength between 0.5lbs (220g) and 1.5lbs (680g) and will not break during handling. It is however very important to provide additional protection from excessive bending and pulling. This can be done via the use of shrink tubing, silicone gel and or mechanical crimp protectors which will keep the splice protected from the elements as well as breakage.
The field of fiber optics is vast and contains hundreds of important terms that are extremely useful to understand when working in the industry.

Unfortunately, due to this vast number of terms we are unable to list them all within this single training manual. We have however done our best to compile a list that incorporates the most important terms used within this manual.

**Attenuation**
The reduction in optical power as it passes along a fiber, usually expressed in decibels (dB). See optical loss.

**Back Reflection**
That portion of fiber optic attenuation resulting of conversion of optical power to heat.

**Cable**
One or more fibers enclosed in protective coverings and strength members.

**Multimode Fiber**
A fiber with core diameter much larger than the wavelength of light transmitted that allows many modes of light to propagate. Commonly used with LED sources for lower speed, short distance links.

**Network**
A system of cables, hardware and equipment used for communications.

**Optical Fiber**
An optical waveguide, comprised of a light carrying core and cladding which traps light in the core.
Cladding
The lower refractive index optical coating over the core of the fiber that "traps" light into the core. Connector: A device that provides for a demountable connection between two fibers or a fiber and an active device and provides protection for the fiber.

Core
The center of the optical fiber through which light is transmitted.

Decibel (dB)
A unit of measurement of optical power which indicates relative power on a logarithmic scale, sometimes called dBr. dB=10 log (power ratio)

Fiber optics
Light transmission through flexible transmissive fibers for communications or lighting.

Fusion splicer
An instrument that splices fibers by fusing or welding them, typically by electrical arc.

Insertion loss
The loss caused by the insertion of a component such as a splice or connector in an optical fiber.

Optical Return Loss, Back Reflection
Light reflected from the cleaved or polished end of a fiber caused by the difference of refractive indices of air and glass. Typically, 4% of the incident light. Expressed in dB relative to incident power.

Refractive Index
A property of optical materials that relates to the velocity of light in the material.

Scattering
The change of direction of light after striking small particles that causes loss in optical fibers.

Single-mode Fiber
A fiber with a small core, only a few times the wavelength of light transmitted, that only allows one mode of light to propagate. Commonly used with laser sources for high speed, long distance links.

Splice (Fusion or Mechanical)
A device that provides for a connection between two fibers, typically intended to be permanent.
**Jacket**  
The protective outer coating of the cable.

**Loss, Optical**  
The amount of optical power lost as light is transmitted through fiber, splices, couplers, etc.

**Mechanical Splice**  
A semi-permanent connection between two fibers made with an alignment device and index matching fluid or adhesive.

**Micron (*m)**  
A unit of measure, 10^-6 m, used to measure wavelength of light.

**Termination**  
Preparation of the end of a fiber to allow connection to another fiber or an active device, sometimes also called "connectorization".

**Total Internal Reflection**  
Confinement of light into the core of a fiber by the reflection off the core-cladding boundary.

**Wavelength**  
A measure of the color of light, usually expressed in nanometers (nm) or microns (*m)