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STANDARDS

Interface Practices Subcommittee

SCTE STANDARD

SCTE 134 2021

Fusion Splicing Equipment and Applications for the Cable/Broadband Industry

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1. Introduction

1.1. Executive Summary

This document provides a brief overview of fusion splicing equipment and methods, particularly those of interest to the cable / broadband industry.

1.2. Scope

This standard defines the equipment, methods, and practices used within the cable/broadband industry to obtain consistent low loss fusion splice connections between optical fibers.

1.3. Benefits

Fusion splicing provides distinct advantages over mechanical splicing. Splice losses are typically lower and are not subject to environmental limitations that mechanical splices typically suffer from. Fusion splicing comes into play either with splicing on connectors or pigtails, or possibly during installation and/or repair where direct cable-to-cable splicing is needed.

1.4. Intended Audience

This standard provides a general overview of equipment and techniques of interest to engineers and technicians within the industry.

1.5. Areas for Further Investigation or to be Added in Future Versions

As technology advances and matures, new equipment and techniques will be covered. For example, laser cleaving is becoming more popular in the connector industry but has not yet entered the splicing field. If such advances are made, it will be added to the standard.

2. Normative References

The following documents contain provisions, which, through reference in this text, constitute provisions of this document. At the time of Subcommittee approval, the editions indicated were valid. All documents are subject to revision; and while parties to any agreement based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed below, they are reminded that newer editions of those documents might not be compatible with the referenced version.

2.1. SCTE References

- No normative references are applicable.

2.2. Standards from Other Organizations

- No normative references are applicable.

2.3. Published Materials

- No normative references are applicable.

3. Informative References

The following documents might provide valuable information to the reader but are not required when complying with this document.

3.1. SCTE References

- No informative references are applicable.

3.2. Standards from Other Organizations

- No informative references are applicable.

3.3. Published Materials

- No informative references are applicable.

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shall not	This phrase means that the item is an absolute prohibition of this document.
forbidden	This word means the value specified shall never be used.
should	This word or the adjective "*recommended*" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood, and the case carefully weighted before choosing a different course.
should not	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
may	This word or the adjective "*optional*" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.
deprecated	Use is permissible for legacy purposes only. Deprecated features may be removed from future versions of this document. Implementations should avoid use of deprecated features.

5. Abbreviations

LID	local injection and detection
L-PAS	lens – profile alignment system
MFD	mode field diameter
PAS	profile alignment system

6. Fusion Splicing Basics

Fusion splicing consists of aligning and permanently fusing together stripped, cleaned and cleaved optical fibers with a high temperature arc. It provides a fast, reliable, low-loss, connection by creating a permanent and transparent joint between two fiber ends. Fusion splices provide a high-quality joint with the lowest loss (in the range of 0.01 dB to 0.10 dB for single-mode fibers) and are practically non-reflective.

7. Equipment

7.1. Fusion Splicers

Fusion splicers are typically used in the field or within a Lab/OEM environment. While many splicers may be used in either environment, some splicers are designed for specific performance environments.

7.2. Alignment Methods

Two fiber alignment techniques are:

- Passive alignment (Single-axis)
- Active alignment (Multi-axis)

7.2.1. Passive

Passive alignment systems do not move the fibers in the x or y axes but move the fibers in the z axis only (single-axis).

This technique is used in fixed v-groove machines. Fiber alignment is dependent on how the fibers are positioned relative to each other in the precision cut grooves in the x and y axes. In order to achieve a good quality splice, the two fiber ends must be aligned correctly.

The cleanliness and good condition of the v-grooves are important to ensure that the fibers are positioned in the v-groove to allow the proper alignment necessary for a good quality splice.

7.2.2. Active

Active alignment systems detect and compensate for any fiber misalignment, moving the fibers in the x, y and z axes (multi-axis).

Active alignment methods fall within one of the following categories:

- LID™ system (Local Injection and Detection)
- CDS (Core Detection System)
- L-PAS™ (Lens – Profile Alignment System)
- PAS (Profile Alignment System)

7.2.2.1. Local Injection and Detection (LID)

The LID system aligns and monitors the fusion splice with an optical transmitter and receiver. This allows for the cores to be optimally aligned. A source (transmitter) injects a light signal into the fiber through a bending coupler and a power meter (receiver) measures the received light signal through another coupler. When the transmitted signal is at its maximum level, both fiber cores are perfectly aligned. The transmitted signal from the LID source is present throughout the process, allowing effective control of the splice process. The LID™ system provides a splice loss measurement after the splice is complete by comparing the post-splice light level to the pre-splice level.

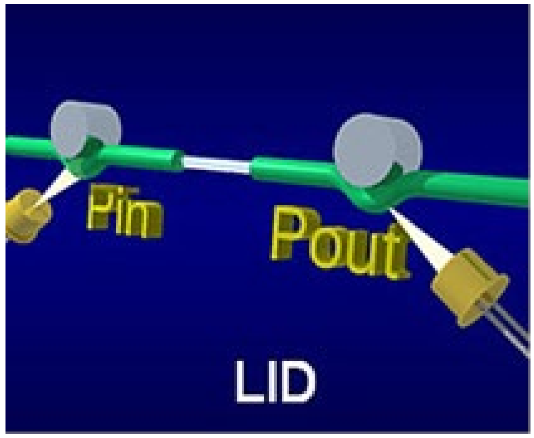

Figure 1 - Alignment Through Lid Analysis

7.2.2.2. CDS

Another active alignment method, the Core Detection System (CDS) uses the luminescence properties of optical glass. The core and the cladding of optical fiber have different optical properties. Due to the different doping of the fiber core, it glows brighter than the cladding when an arc is applied to the fiber. To detect the core, a short arc is fired that allows the core-cladding-contrast to be detected.

Figure 2 - Alignment Through CDS Analysis

7.2.2.3. Lens – Profile Alignment System (L-PAS)

With an L-PAS alignment method, an optical system consisting of cameras, lenses, prisms and LEDs are used to make the fiber visible. The fiber image is generated by a backlit arrangement, using LEDs that shine through prisms which then project the shadow of the fiber through lenses, onto a camera. The fiber alignment is analyzed by comparing the positions of the two fibers. The system "sees" mostly the cladding, producing alignment using the relative cladding diameters.

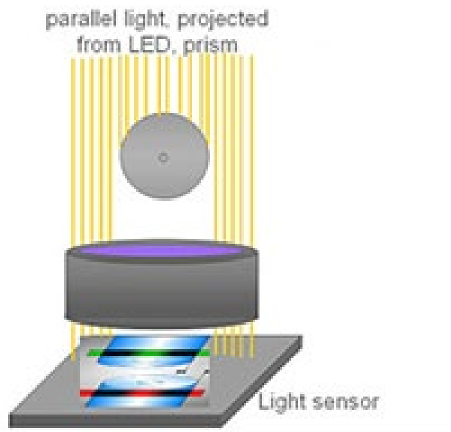

Figure 3 - Alignment Through L-PAS Analysis

7.2.2.4. Profile Alignment System (PAS)

The Profile Alignment System works on the same principle as the L-PAS system with the exception that in addition to "seeing" an image of the cladding, focus lenses also allow an image of the core to be detected as well.

7.2.3. Considerations

When choosing the right fusion splicer for a particular application it is important to take into consideration some of the following aspects:

- Loss requirements – Determine the loss requirement of the application. Active core alignment splicers provide more precise and lower loss results than passive alignment systems.
- Value – In general active alignment units are more expensive; however they typically provide lower splice loss and can be used wherever a passive alignment unit can. It is important to determine what application will be most often used and match those needs to the right fusion splicer.
- Features and ease of use are important when choosing the splicer; this increases productivity and allows various skill levels of personnel to use the machine. Combination -style splicers combine various tools within a single chassis versus Standard splicers which are grouped with other tools (such as strippers and cleavers).
- Alignment methods – Splicing 250 um fiber and 200 um fiber leads to challenges of properly holding and aligning the fiber. Using the correct fiber equipment holders and clamps will properly allow the fiber to be captured and presented in the V-grooves.

Figure 4 - "Combination Style" Arc Splicer

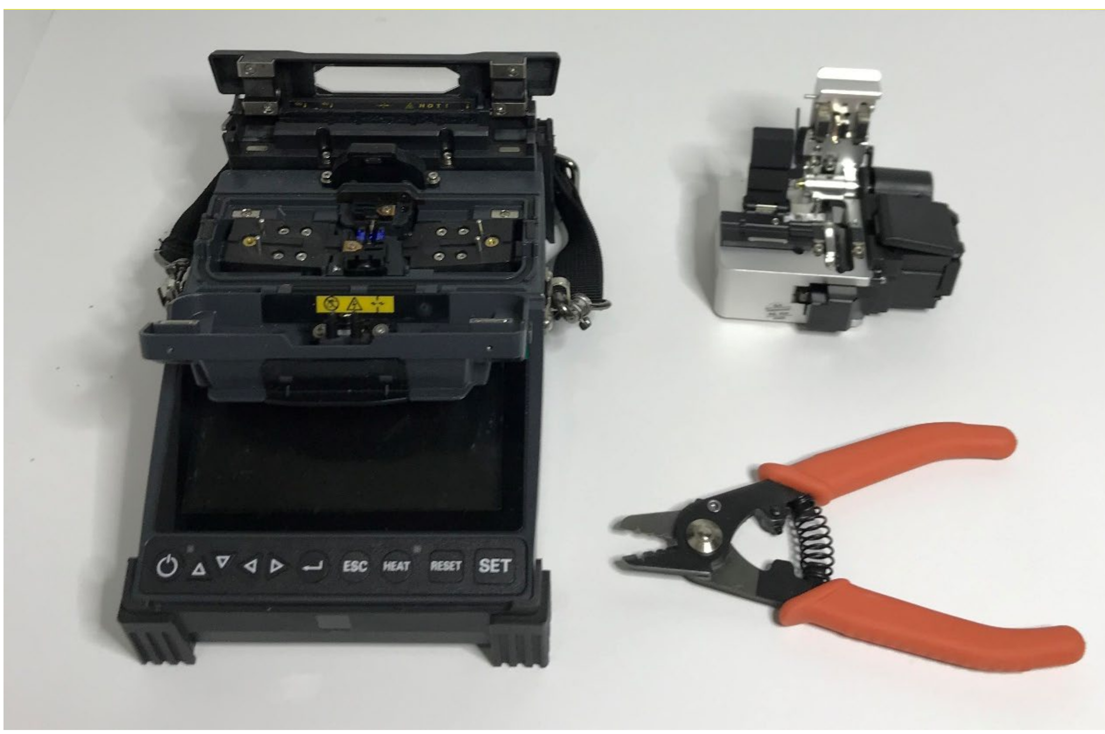

Figure 5 - "Standard Style" Arc Splicer Plus Accessories

7.3. Coating Strippers

In order to perform a fusion splice the optical fiber must be stripped down to the bare glass. The coating can be removed by various techniques:

- Mechanical stripping
- Thermal stripping
- Chemical stripping
- Arc stripping

Regardless of the method used to strip the coating, it is important to use the correct tools and techniques to prevent damage to the bare glass. Ensuring the fiber is not damaged is critical to creating a low loss, strong splice.

7.3.1. Mechanical Stripping

Removal of coating is performed using a tool that physically “shaves” the coating off. This may be accomplished by machining the tool with a precise profile to match the fiber itself. Advantages are that it is fast and inexpensive, usually found in a variety of hand tools (typically used for single-fiber applications). Disadvantages include reliance on skilled operator technique and potential for scratching of the glass due to physical contact with the tool surfaces.

7.3.2. Thermal Stripping

Thermal stripping uses heat to soften the coating prior to removal. Heating the coating allows much easier removal and lessens the possibility of physical damage to the glass itself. Thermal stripping can be used with single-fiber splicing but is normally used with multi-fiber splicing since up to twelve fibers are being stripped simultaneously. Thermal stripping is usually more of an automatic process (the equipment does most of the work) and is more friendly to a novice operator.

Figure 6 - Mechanical Stripper vs Thermal Stripper

7.3.3. Chemical Stripping

Chemical stripping uses the application of a chemical to soften the coating, possibly causing it to blister. This allows the material to be wiped away and removed. Care must be taken so that the chemicals used are not harmful to the glass or to the operator applying them.

7.3.4. Arc Stripping

Removal of the coating is performed using a high-temperature arc plasma, similar to the arc generated during the splicing operation itself. Care must be taken to avoid thermal shock to the fiber during the stripping process.

7.4. Cleavers

7.4.1. Theory of Operation

To achieve good splice results, it is extremely important for the fiber ends to be properly cleaved. Consistent, good quality end faces can be only achieved if the cleaver is well maintained. Cleave angle deviations or chips and knicks in the end-face, can only be compensated for by using unusually high fiber feed during the fusion process. This can create a splice with an outer cladding that may look good but the actual loss could in fact be high due to core bending. For best results, the smaller the core, (for instance single-mode fiber), the lower the tolerance of cleave angle deviation.

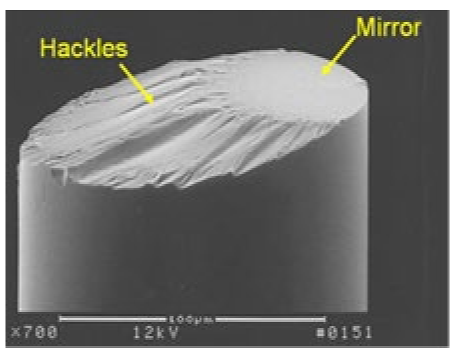

Figure 7 - Profile of a Cleaved Fiber

Various cleavers are available that operate in different ways but the general principles for cleaving the fiber are:

1. Score - A score is introduced into the glass
2. Bend - The glass is bent to propagate the score
3. Tension - Tension is applied to separate glass

7.4.2. Types of Cleavers

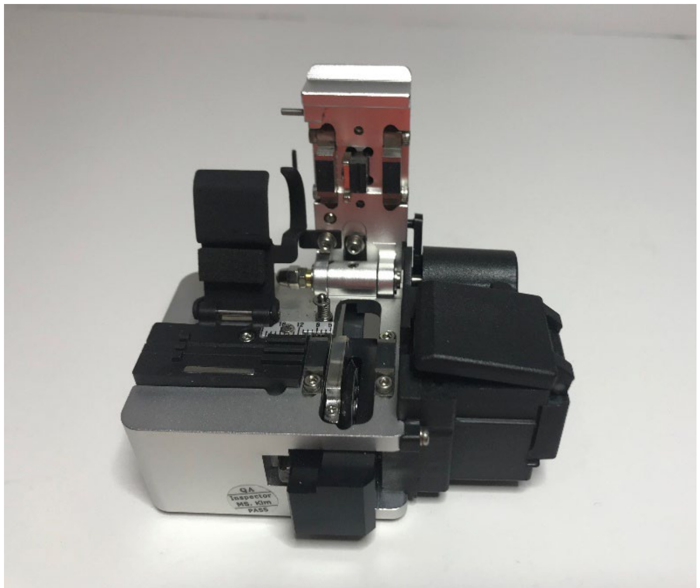

Figure 8 - Single Fiber Cleaver

Single fiber cleavers are designed for cleaving one fiber at a time and providing a high-quality end face angle that will lead to low loss splices.

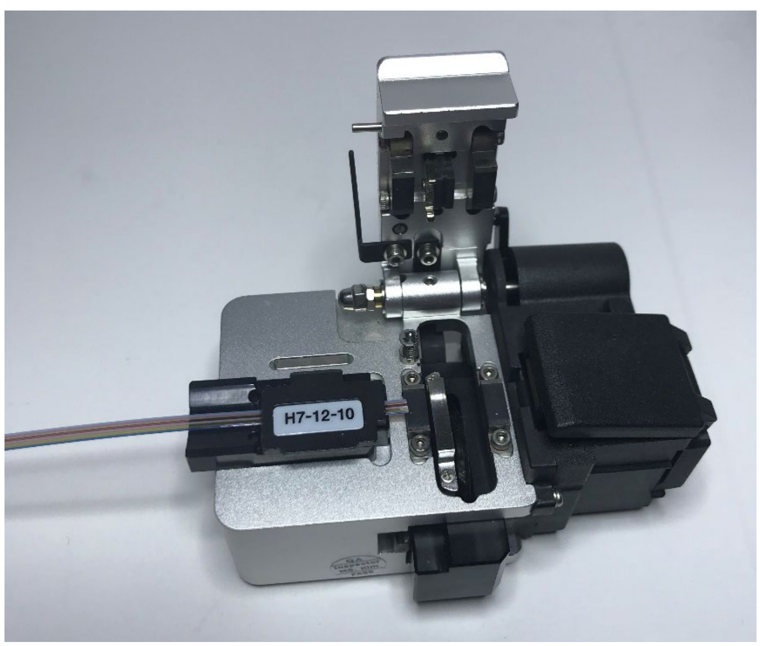

Figure 9 - Multi Fiber Cleaver

Most multi-fiber cleavers can cleave multiple or single fibers. In many instances a different handler or adapter may be necessary to accommodate single fiber cleaving.

7.4.3. Considerations

As with fusion splicers it is important to consider several aspects when choosing a cleaver for a particular application.

- Performance – A good cleave is essential to obtain good low loss splices.
- Usability – Ease of use is important for users and in obtaining consistent high-quality results.
- Quality of cleave – In order to obtain quality cleaves from a cleaver it is important that the cleaver is:
    - Clean – fiber and cleaver
    - The blade is kept and maintained in good condition. Many systems now use an auto-rotation blade to extend blade life, or use on-board monitoring to track lifetime performance and notify the operator that a blade chage is necessary.
    - Proper operating technique is followed

7.5. Splice protection

After the fibers have been successfully spliced together it is important to protect the joint. There are various options for splice protection. One of the most common techniques is a heat shrink sleeve. This sleeve is placed over the fiber prior to splicing and placed away from the splice point during preparation and fusing. After the splice is complete the heat shrink is placed over the splice point. It is then placed in a heat shrink oven, where the material is heated and shrunk down over the fiber, providing protection to the joint.

Clamshell type protectors are also available. These protectors commonly have a hinged joint that allows it to be placed on the splice point after completion of the splice. Most version use adhesive in a groove to hold the fiber while the other half of the “clamshell” is closed on the fiber holding and protecting the joint.

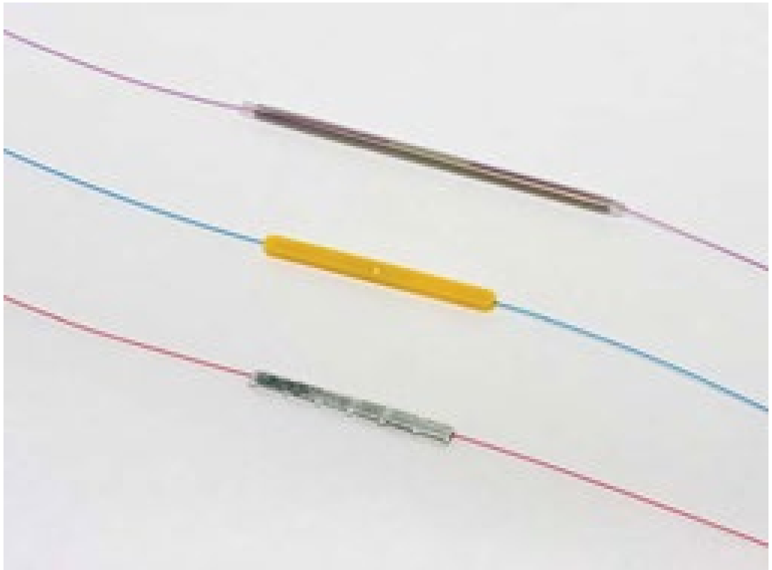

Figure 10 - Splice Sleeves

8. Methods And Practices

8.1. Generic Procedures – Single fiber splicing

The preparation process before inserting the fiber into the splicer is very important. Optical fibers must have the coating removed down to the bare glass. The fibers must be cleaned properly and must have a good quality cleave. It is important to be aware of and use the correct cleave length for the particular fusion splicer that is being used. This length varies with splicer manufactures, so it is recommended to consult the operating manual for the specific unit before beginning the splice process. The three main steps to preparing the fiber are:

Figure 11 - Step 1: Strip

All coatings (900 µm, 250 µm and/or 200 µm) should be removed and bare glass exposed.

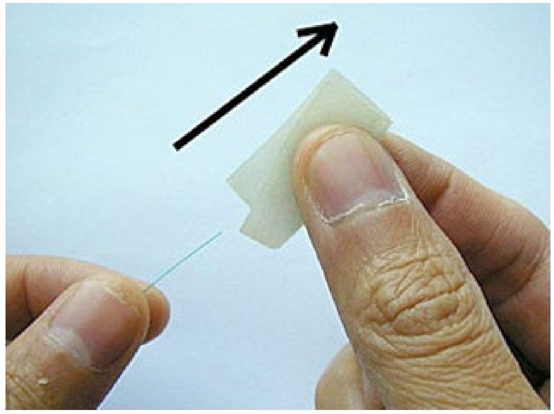

Figure 12 - Step 2: Clean

The bare glass should be cleaned to remove all contaminants. The most common cleaning method is to use a clean lint free wipe saturated with 99% isopropyl alcohol. This wipe is pulled over the bare glass removing any acrylate coating and other contaminant that may be on the bare glass. It is important to ensure that the glass is not touched with the bare fingers or contaminated with anything after the cleaning step, as this can adversely affect the cleaving, alignment and fusion process. Non-alcohol low-residue cleaners are increasing in popularity and can also be used

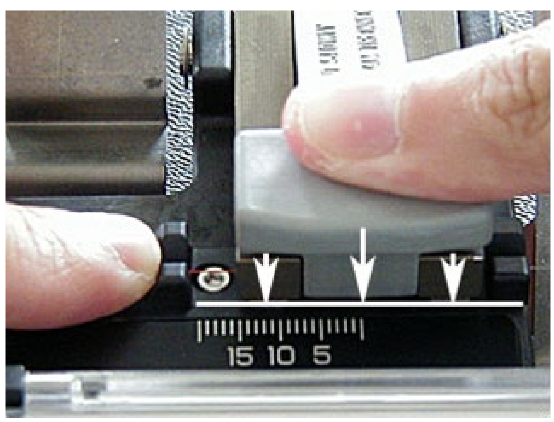

Figure 13 - Step 3: Cleave

Cleaving of optical fibers involves several processes. The fiber is inserted into the cleaver after being cleaned. The cleave process is achieved through a combined movement of scoring and breaking. Both fiber ends can then be inserted into the splicer and are ready to be spliced together. The fiber's end face quality affects the final splice result. The better and cleaner the fiber end faces are, the lower is the splice loss that can be achieved

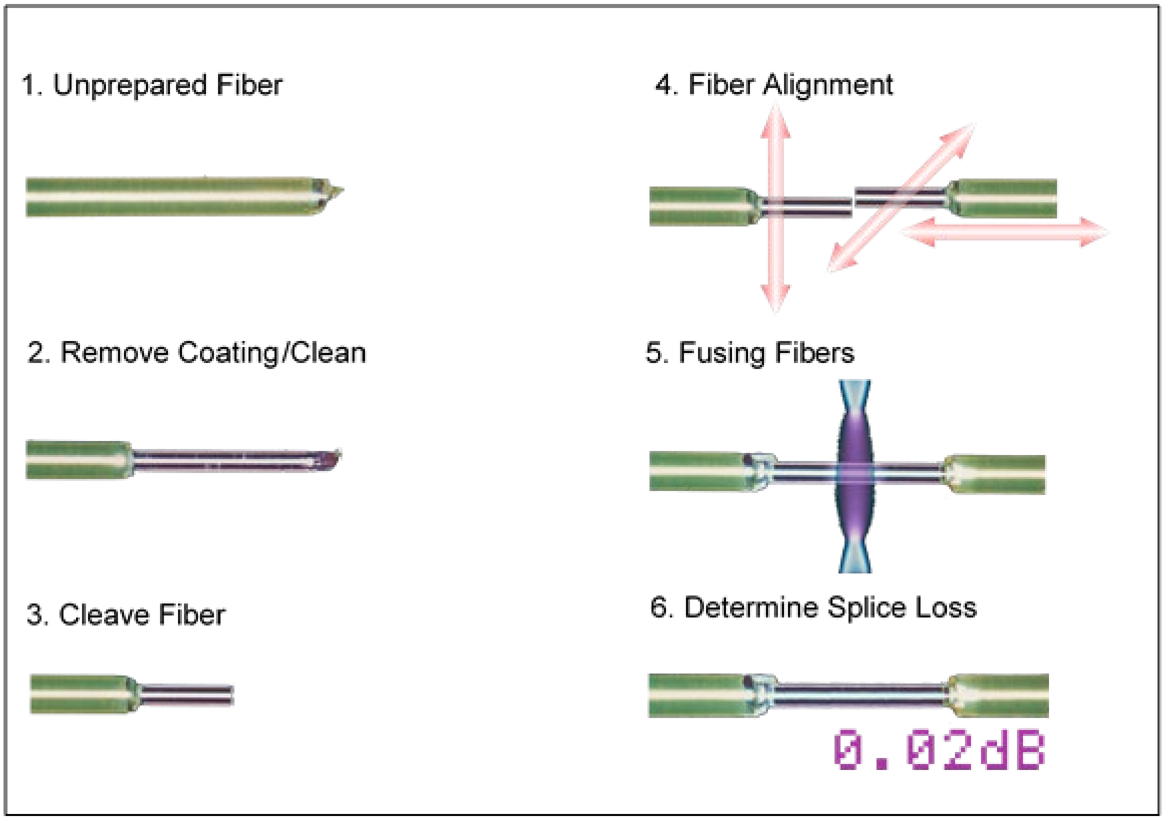

Figure 14 - Basic Steps in Fusion Splicing Process

8.1.1. Factors that affect splice loss

Cleanliness: It is very important that the fibers and equipment are clean. Dirt and contaminants can cause (1) misalignment issues, (2) increased loss and (3) degradation of equipment.

Fiber Geometry: The position of the core relative to the center of the fiber will affect splice loss. If fibers with eccentricity offsets are being spliced, active core alignment units will provide the best splice loss results.

Equipment: It is important to use the correct equipment for the specific application and ensure it is used and maintained correctly. Proper maintenance of mechanical and optical systems on fusion splicing equipment is necessary to insure it functions correctly and provides future use. Use of appropriate holders and/or clamps for the correct fiber type supports lower fiber loss.

Training/skill level: Fusion splicing requires proper training and personnel development in order to obtain consistent good quality low loss splices.

8.1.2. Multiple Fiber (Mass splicing)

Multiple fibers may be spliced together simultaneously. This is commonly referred to as mass splicing. Mass fusion splicing is the same in principle to single fiber splicing. There are some differences in the process.

Mass fusion splicers use the passive alignment system with a fixed v-groove. The fibers can be in ribbon form, may be ribbonized by the craftsperson from individual fibers, or may be loose when used in combination with specialized holding equipment. The multiple fibers are stripped (usually with a thermal stripper), cleaned and then cleaved simultaneously to ensure the fibers are the same length.

The fibers are inserted into the fusion splicer and the process is essentially the same as with single fiber splicing. The splice point can be protected with heat shrink sleeves.

Multiple ribbon types of different spacings (200 / 200 um, 250/250 um, 200 / 250 um etc) requires the usage of correct ribbonizing methods and equipment holders to correctly position the fibers and reduce splice loss.

9. Loss Value

A typical loss value is usually less than 0.1 dB (in singlemode fiber).

10. Testing

10.1. Importance of Testing

It is important to test optical fiber systems in order to:

- Verify the system works correctly
- Ensure splices are acceptable
- Identifies problems
- Provides baseline for maintenance and troubleshooting

10.2. Testing Methods

An optical fiber system can be tested using:

- Power meter/source
- Optical Time Domain Reflectometer (OTDR)

The meter/source method tests the entire system. It determines end to end loss including any components and fiber in the system. This is a good way to get actual values for the entire system; however it does not allow individual splices or components to be singled out.

The OTDR operates on a principle known as Rayleigh backscatter. Light is input into one end of the system. A certain amount of light is reflected back from events. Events can be fusion splices, connectors, mechanical splices etc. The OTDR interprets these events and determines where they are located along the fiber and the attenuation value.

This can be used to verify specific splice loss values and where they are located in the system. This information can be saved for documentation proposes and validation of the system.

OTDR analysis is limited by the resolution of the device being used. This limitation is exhibited by the minimum measurement distance between events that can be determined. Unfortunately, for most splice-on-connectors the distance between the splice and the connector endface does not allow the OTDR to measure both events; rather it will show a single event with represents a combination of the splice joint the connector endface.