Installation Practice IP-028
December 2011

Guidelines for Optical Fiber Splicing

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1. Introduction

A fiber splice is a permanent connection between two optical fibers. Optical fiber splicing is required to create a continuous optical path for signal transmission from one fiber length to another. Two types of fiber splicing are currently available - *Fusion* and *Mechanical*. This document describes the equipment, tools and materials that are used to splice both single-fiber and fiber-ribbons.

2. Preparation for Fiber Splicing

2.1 Tools and Equipment: In general, an enclosed splicing vehicle or trailer (Figure 1) is recommended for use during optical fiber splicing. Most splicing equipment operates more effectively in a controlled environment that is free of wind, dust, and high levels of humidity. Uncontrolled environmental conditions can negatively affect the splice quality.

Figure 1 – Splicing Trailer

The splicing vehicle should be equipped with a generator to power the lights, splicing equipment, power tools, radios, etc. The vehicle should have a cable entry door, a work table, and shelving or cabinets to accommodate splice closures, tools, equipment, and consumables. The vehicle should be equipped as required with strobe lights, safety cones, and traffic warning signs. Depending on the expected weather conditions, the splicing vehicle should also be equipped with an HVAC system (heating, ventilating, and air conditioning).

Portable work tents are recommended for splice locations that have difficult or impossible vehicle access (e.g., for emergency restorations).

Most of the hand tools required for cable sheath removal are standard tools such as a utility knife, snips, side cutting pliers, etc. However, once the sheath is removed, specialized tools may be required to remove the central core tube or buffer tube(s) and expose the optical fibers. In particular, specialized slitting tools are required to open the central core tube or buffer tube(s) at mid-span sheath openings. Mid-span access without the correct tool will greatly increase the risk of damage to the fiber. Please contact OFS at 888-FIBER-HELP (888-342-3743) if you need further information regarding OFS cable access tools.

Specific tools may also be required to assemble some types of splice closures. Consult the manufacturer's instructions for information regarding specific tool requirements.

2.2 Cable Preparation: Cable preparation and handling procedures are available for OFS cables. Please contact OFS at 888-FIBER-HELP (888-342-3743) to obtain the documentation for your particular cable design. Refer to the splice closure documentation for the recommended cut lengths for the cable jacket, armor, strength members, buffer tubes, and fibers as required for splicing.

Prior to splicing, all cables should be clearly marked at the point where the cable enters the splice closure. All of the required buffer tube and fiber slack must be considered before cutting the cable. Carefully trim the cable jackets, shields, core wrappings, strength members, and buffer tubes as required. Remove any water-blocking compounds and install any required cable breakout fittings according to the closure instructions. Fasten the cables and strength members to the splice closure. Route and fasten the buffer tubes to the splice organizers. Mark the cables, buffer tubes, and fibers as required for identification during splicing. Temporarily fasten the cables and splice closure on the work table in preparation for fiber splicing.

2.3 Fiber Stripping: Fiber coating can be removed using a mechanical stripping tool, thermal stripping tool, or a chemical stripper. For typical coated fiber, mechanical stripping (Figure 2) is preferred because it is fast, safe, inexpensive, and creates a well defined coating termination. Chemical strippers that soften the fiber coatings are slower and create a poorly defined coating termination. Additionally, residual action of chemicals may cause the fiber coating to soften and degrade and potentially cause splice failures long after the splice has been completed. To prevent long term failure, all fibers exposed to a chemical solvent must be thoroughly cleaned after stripping.

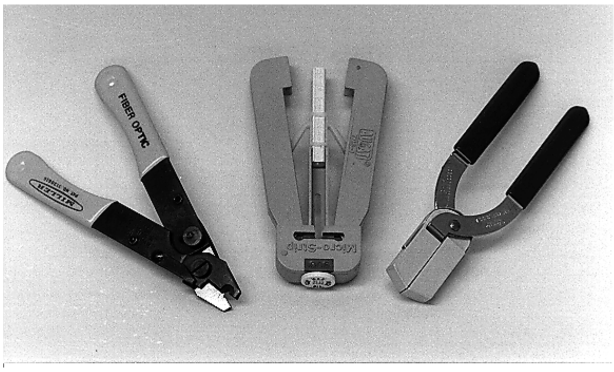

Figure 2 – Mechanical Stripping Tools

Thermal strippers are recommended for fiber ribbons because the matrix material and fiber coating are removed in a single operation. The thermal stripper also provides a well defined coating termination. Thermal ribbon strippers are currently available for 12- and 24-fiber ribbons. The thermal strippers can also be used to strip ribbon subgroups, e.g., 4, 6, or 8 fiber ribbons.

In order to effectively remove the protective coatings from the fiber, the exact fiber type must be known so that the proper stripping tool is used. For OSP cables, most single-mode fibers have a cladding diameter of 125 µm and a coating diameter of 250 µm. The fiber stripping tool must accommodate these dimensions. To avoid damage to the glass surface, no more than two inches of the coating should be stripped at one time.

Building cables, patch cords, and pigtails are typically constructed with tight buffered fibers. Tight buffered fiber has an additional protective coating with a larger outside diameter of 900 µm. Some tight buffered coatings must be stripped in small increments, i.e., 1/4 to 1/2 inch lengths, to avoid fiber breakage.

Any coating residue that remains after stripping should be removed from the bare fiber surface. Coating residue can degrade the performance of the fiber cleaving tool and affect the splice loss. Bare fibers should be cleaned with isopropyl alcohol and a lint free wipe after stripping.

After stripping and cleaning, bare fibers should be handled as little as possible until the cleaving and splicing operations are complete. This will minimize the chance of contaminating the fibers with dirt, dust, or body oils which may contribute to high splice loss and low tensile strength. It is also important to complete the remaining splicing operations as quickly as possible to minimize the fiber exposure to airborne contamination.

2.4 Fiber Cleaving: The goal of fiber cleaving is to produce a flat, smooth, perpendicular fiber end-face. The quality of the fiber cleave is one of the most important factors in producing low-loss fusion and mechanical splices. The cleaving method must produce a clean surface with no lips, chips, and a fiber cleave angle $\leq 1°$.

It also is important to cleave the fiber so that the minimum required length of fiber is exposed beyond the coating. This minimizes mechanical damage to the glass due to inadvertent contact with other objects and reduces the glass surface area exposed to contamination. Before proceeding, cleave quality should be verified under at least 50X magnification and re-cleaved if necessary. Some fusion splicers have built-in viewers for this purpose.

There are a wide variety of cleavers (Figure 3) available that will produce thousands of high quality fiber cleaves before requiring maintenance or blade replacement. Ribbon cleavers are similar to the single fiber cleavers but cleave the entire fiber ribbon in one operation (up to 24 fibers).

Figure 3 – Precision Fiber Cleaver

3. Splicing

3.1 Fusion Splicing (Single Fibers): A fusion splice is made by applying localized heat to fuse or melt two lengths of optical fiber together to form a single continuous fiber. It is performed with a specialized instrument called a fusion splicer. The fusion splicer includes a monitor for viewing the fiber splice, precision micro-positioners to align the fibers, and electrodes to generate the heat and fuse the fibers. The fusion cycle consists of a pre-burn to remove contaminants from the fiber ends, automatic alignment of the fibers, and an electric arc to fuse the fibers together. Depending on the fiber type, fusion splice attenuation is typically in the range of 0.05 to 0.10 dB for single-mode fibers. Most fusion splicers share the following key features.

- Pre-programmed and user adjustable settings for the electric arc.
- Micro-positioners to align the fibers.
- A video monitor to observe the condition of the fiber cleave and fiber alignment.
- Internal batteries for field operation (portable units).
- Precision fiber cleaver.
- Heater for heat-shrink sleeves.

3.2 Fixed V-Groove Fusion Splicer: Fixed V-Groove (clad alignment) splicers use precision V-grooves to align the fibers in the X- and Y-axes. After placing the fibers in the V-grooves, they are aligned together in the axial direction only (Z-axis). There is no adjustment in the X- and Y-axes. V-groove alignment machines rely on the accuracy of the fiber geometry to achieve low splice attenuation. Typical splice attenuation of 0.05 dB can be achieved for standard single-mode fibers. Although the typical splice attenuation is not as low as some of the more sophisticated fusion splicers (e.g., PAS and LID splicers), they are lower cost, small in size, and can typically operate on an internal battery. They are becoming increasingly popular for fiber-to-the-home and emergency restoration applications (Figure 4).

Figure 4 – OFS Fitel® S123C Clad Alignment Splicer

3.3 Active Clad Alignment Fusion Splicer: Active clad alignment splicers provide X-Y-Z positioning of the V-grooves to finely position the fiber ends. Consequently, these splicers can compensate for common fixed V-groove splicing errors such as dirty V-grooves and fiber curl. Active clad alignment splicers can achieve a typical splice loss of 0.04 dB for standard single-mode fibers. The splicers are portable, light weight, and can operate using an internal battery. Active clad alignment splicers are commonly used in FTTX, metro, and long-haul applications (Figure 5).

Figure 5 – OFS Fitel® S153A Active Clad Alignment Splicer

3.4 Profile Alignment Fusion Splicer: Profile alignment splicers (PAS), or core alignment splicers, use imaging techniques to produce an image of the fiber cores. The fiber cores are then aligned in the X-, Y- and Z-axes and fused together. The alignment and fusion process is fully automated. PAS fusion splicing systems (Figure 6) provide splice loss estimation and also perform an automatic proof-test for tensile strength of the splice. Typical splice attenuation for standard single-mode fibers is 0.02 dB.

Figure 6 – Fitel S178A Core Alignment Splicer

3.5 Local Injection and Detection Fusion Splicer: Local injection and detection (LID) fusion splicers use a self-contained optical power injection and detection system to optimize the fiber alignment prior to splicing. The fibers on either side of the splice point are bent around small cylindrical mandrels to allow the injection of light through the fiber coating on the input side and detection on the output side. The fiber alignment is then adjusted to maximize power transmission through the fiber junction. At the point of maximum power transmission, the fibers are fused together thus minimizing the splice loss. Splice loss is displayed after the fusion splice is completed. Typical splice loss for standard single-mode fibers is 0.02 dB.

3.6 Mass Fusion Splicing (Ribbon Fibers): Mass fusion splicers are used to splice multiple fibers in a single operation. The multiple fibers are arranged in a “fiber ribbon” that may contain as many as 24 fibers laid parallel to one another, side by side, and fastened together in a matrix material. Because the fibers in each ribbon are held in a common fixture, the alignment of individual fibers is impossible. Most mass fusion machines use fixed V-groove technology to achieve fiber alignment.

Most mass fusion splicers units can splice fiber-ribbons containing 4, 6, 8, or 12 fibers. Some mass fusion splicers are capable of splicing 24-fiber ribbon. Alternatively, 24-fiber ribbons can be split into 12-fiber subunits and spliced using a 12-fiber mass fusion splicer. Fiber stripping is accomplished using a special multi-fiber thermal stripper. A multi-fiber precision cleaver is used to cleave the optical ribbon fiber.

Mass fusion splicing is typically used with ribbon cable designs; however, individual fibers in loose tube cables can be "ribbonized" in the field. The individual fibers are ribbonized using special tools and kits that are available from most manufacturers of fusion splice equipment. Ribbonizing individual fibers may be desirable when splicing high-fiber-count loose-tube cables.

3.7 Mechanical Splicing: A mechanical splice is formed when two fibers are physically mated but are not fused together. Index matching gel is typically used to fill the air gap at the fiber interface and prevent optical reflections that would otherwise occur at the glass/air/glass interface. Minimizing optical reflections is particularly important in analog transmission systems where back-reflected light can induce modal noise that interferes with transmission quality. Figure 7 shows several single-fiber mechanical splices and their relative size compared to a dime. Typical insertion losses for singlemode mechanical splices range from 0.05 to 0.20dB.

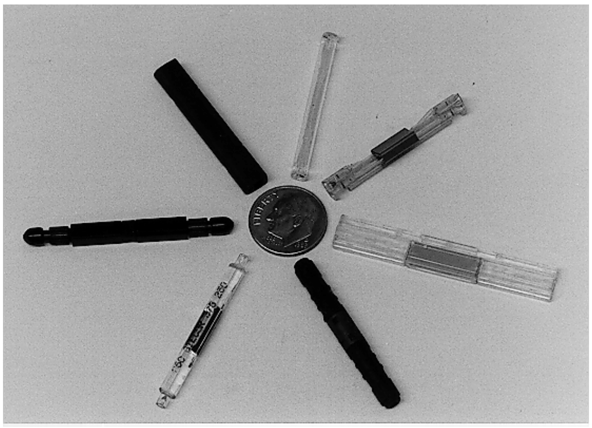

Figure 7 – Mechanical fiber splices.

3.8 V-Groove Alignment Mechanical Splice: Most mechanical splices use some variation of V-grove technology to align the fibers and are designed to be permanent splices. The fiber cladding is guided by the inside surface of the splice cavities. Consequently, the relative positioning of the fiber cores is dependent on the geometric precision of the splice sleeve and the core/clad concentricity of the fibers. Some mechanical splices allow for further fine tuning of the splice by rotating the fibers relative to one another to better align the fiber cores.

3.9 Power Alignment – Mechanical Splice: If the mechanical splice is adjustable, the optimum fiber alignment can be determined using the power alignment method. A light source is connected to the input end of one fiber, light is transmitted through the splice point, and the output power is measured at the output end of the second fiber. The fiber alignment is then adjusted to maximize power transmission through the mechanical splice. This alignment method requires three technicians – one to monitor the input power, another to monitor the output power, and a third at the splice point to align the mechanical splice. Communication between all technicians is required. Once the optimum alignment is determined, the splice is permanently secured by mechanical compression or epoxy bonding.

3.10 Local Injection and Detection – Mechanical Splice: If the mechanical splice is adjustable, local injection and detection methods can be used to optimize the alignment of the mechanical splice. Similar to LID fusion splice techniques, the fibers on either side of the mechanical splice are bent around small cylindrical mandrels to allow the injection of light through the fiber coating on the input side and detection on the output side. The fiber alignment is then adjusted to maximize optical power transmission through the splice point. Once the optimum alignment is determined, the splice is permanently secured by mechanical compression or epoxy bonding.

3.11 Mechanical Splicing – Optical Ribbon Fiber: There are several manufacturers of multiple-fiber mechanical splices. These splices can accommodate 4-, 6-, 8-, or 12-fiber ribbons and are factory assembled and ready for fiber insertion. Multi-fiber splices adequately align and retain the fibers in a protective housing. As in mass fusion splicing, fiber stripping is accomplished using a special multi-fiber thermal stripper, and a multi-fiber precision cleaver is used to cleave the optical ribbon fiber.

3.12 Splice Protection - Single Fibers and Fiber-Ribbons: After the splice is made, there are several methods of protecting and reinforcing the bare fiber. Most fusion splicing units utilize a built in heater to thermally shrink a reinforced sleeve around the splice joint for protection. Heat shrinkable sleeves must be placed on the fiber before splicing, positioned on the splice after fusion, and then placed in the heating device. Protective splints or crimp sleeves can be placed on the unprotected fiber after the splice is completed and do not require a heater or power supply. Some splice organizers incorporate a system where spliced fibers are placed in a holding device and covered with an RTV sealant to protect the fiber from mechanical shock, dust and dirt, and to limit the amount of moisture reaching the stripped fiber.

If you have any questions or need additional information, please contact OFS Customer Support at 1-888-FIBER-HELP (1-888-342-3743)