

Mass Fusion Splicing of Optical Fiber Ribbon Cables

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Issued

January 2014

Abstract

To build a fiber optic network, one may eventually join two fiber ends with a connector or fusion splicer. Ribbon cable can be spliced more rapidly by using mass fusion splicing technique. This application note provides basic understanding and process of mass fusion splicing of optical fiber ribbons.

Keywords

Mass fusion splicing, Optical fiber ribbon

1. Principles of Fusion Splicing

Fusion splice is a junction of two or more optical fibers that have been melted together. This is accomplished with a machine called a fusion splicer that performs two basic functions: aligning of the fibers and melting them together, typically using an electric arc. When more than one fibers are spliced together, it is called “mass fusion splicing.” The following are key attributes of a fusion splicer.

- **Fiber Check**- Verifies the fiber in the cable
- **Alignment Check**- Verifies that fibers are correctly aligned.
- **End-face Check**- Verifies that both side fibers are cleaved to the tolerance required by that splicer.
- **Electrode Check**- Automatic reminder to clean electrodes after a certain number of splices; may tell conditions of electrodes.
- **Arc Check**- Tests the current conditions (hardware and environmental) to warn if arc current needs to be adjusted.
- **Altitude Compensation**- Automatically adjusts the arc current for the altitude entered.
- **Battery Warning**- Warns of impending low battery to give user time to change batteries.

2. Fusion splicing of fiber

The fusion splicer aligns the fibers, and then checks for any problems. If no problems are found, it is ready to actually perform the fusion splice by creating an arc between two electrodes. As the arc is generated, the splicer begins to push the fibers towards each other. Due to heat generated by the electric arc, fibers start to melt away from each other, but the splicer pushes the fibers forward faster than the rate at which they are melting back. The fibers meet in the middle and melt together. *Figure 1* shows the tools and materials needed to achieve a good splice.

3. Mass fusion splicing of optical fiber ribbon

Mass fusion splicing consists of seven basic steps;

Step 1 Cleaning of fiber ribbon

Step 2 Stripping of secondary coating & cleaning

Step 3 Cleaving of fiber ribbon

Step 4 Setting splicer parameters

Step 5 Fuse the ribbon fibers

Step 6 Protect and storage of fiber ribbon by heat shrink sleeve

Step 7 Splice loss estimation

Splicing Machine		Splice protection sleeve	
Alcohol dispenser & Tissue paper		Holders	
Hot Jacket stripper		Cleaver	

Figure 1- Common Tools and Materials for Fusion Splicing

3.1 Cleaning of fiber ribbon

Cleaning of the fiber ribbon is first performed using tissue paper and inspecting for any damage in fiber ribbon coating before loading in to holders.

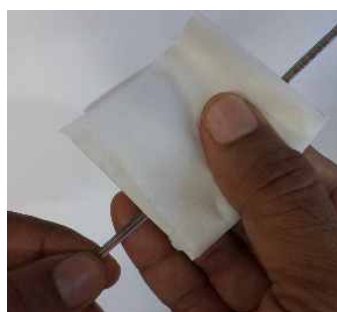


Figure 2- Fiber Ribbon Cleaning

It is important to ensure that the coating over the fiber ribbon stripe does not disturb/damage and printing over the fiber ribbon does not erase during fiber ribbon cleaning, dry tissue paper is preferable. Next the protection sleeve is inserted over the ribbon as shown in Figure 3. And the fiber ribbon is loaded in holders as shown in Figure 4.



Figure 3- Splice protect heat shrink sleeve

Suitable holders for both left & right side fiber ribbons to be spliced have to be selected and the fiber ribbon stripe has to be securely and properly placed in the inbuilt ribbon slot in the holder.

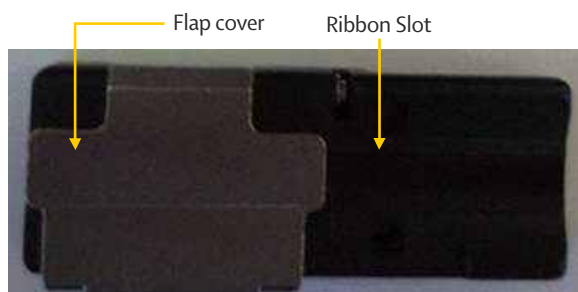


Figure 4- Ribbon fiber holders

As shown in *Figure 5*, approximately 25-30 mm fiber ribbon should remain outside after closing flap of the holder and it is important to ensure no damage occurs to ribbon coating or edge fibers. Also position of edge fiber colors in both ribbons should remain the same while loading in the splicing unit.



Figure 5- Placing of Fiber Ribbon in holders

3.2 Stripping of ribbon coating & fibers secondary coating

Hot jacket stripper (*Figure 6*) removes the ribbon and fiber coating and works on the principle of heating. In order to achieve this, the clamp and top cover of the hot jacket stripper is opened and the ribbon fiber holder is set on the holder base of the stripper (*Figure 7*). The clamp and top cover are closed. Firmly holding the holder base and body of the stripper, heat is applied for approximately 5 seconds and the holder base is gently pulled away to remove the ribbon and fiber coating (*Figure 8a* and *Figure 8b*).



Figure 6- Hot jacket stripper/thermal stripper



Figure 7- Placing the holder in Hot jacket stripper/thermal stripper

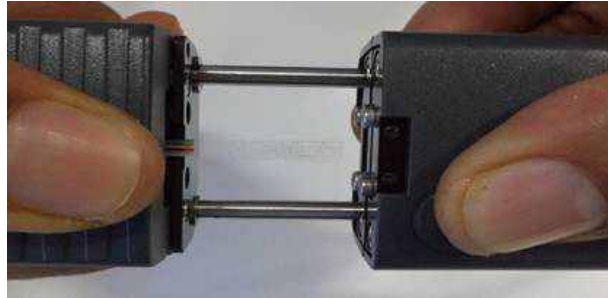


Figure 8a- Hot jacket stripper/thermal stripper operations



Figure 8b- Hot jacket stripper/thermal stripper operations

The coating stripped fiber ribbon is cleaned by pure alcohol (purity >99%) soaked tissue paper, ensuring no fiber damage or scrub during cleaning (*Figure 9a*). There may be cases in which adjoining fibers are arranged over each other due to adhesion of alcohol to fiber surfaces. In that case, gently flick the fiber ends to align the fibers (*Figure 9b*).



Figure 9a- Cleaning of stripped fiber

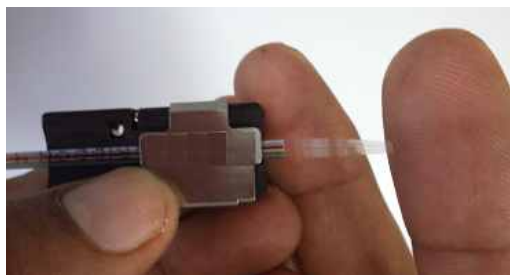


Figure 9b- Aligning stripped fiber after cleaning

Strip away all the protective coatings, jackets, tubes etc., until only the bare fiber is left behind. . Ensure fiber is clean before proceeding to the cleaving step.

3.3 Cleaving of ribbon fibers

Cleaving the fiber properly is the key to successful splicing. It is virtually impossible to make a good fusion splice with a poor cleave and in case of fiber ribbon, all fibers in the ribbon must be cleaved in a single cut.



Figure 10a- High Precision Cleaver

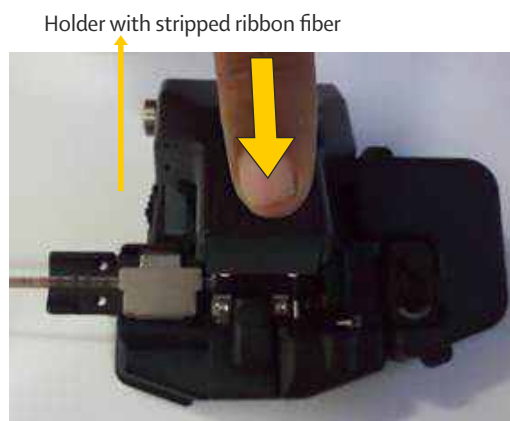


Figure 10b- Ribbon holder placed for cleaving

The coating stripped ribbon fiber holder is placed on cleaver unit so as to cleave at the proper length. The cleaver arm is pressed down gently and the ribbon fiber holder is then removed and any scrap fiber is carefully discarded (*Figure 10a* and *Figure 10b*).

3.4 Setting splicer parameters

The mass fusion splicer machine parameters are set as instructed by machine manufacturer/manual. Main parameters are fiber type, fiber count in ribbon (4/6/8/12), and splice mode.

3.5 Fiber Fusing

To perform fiber fusing the user should follow the procedure in the splicer manual. It will generally involve opening the splicer cover and placing the ribbon fiber holders in the splicer. The platform where ribbon holder is placed, contains two guide pins. Once the ribbon holder is placed, the two guide pins enter into the two holes of the holder so that the holder is firmly fixed for alignment. Care must be taken to ensure the prepared fibers tips do not touch any object (*Figure 11* and *Figure 12*).

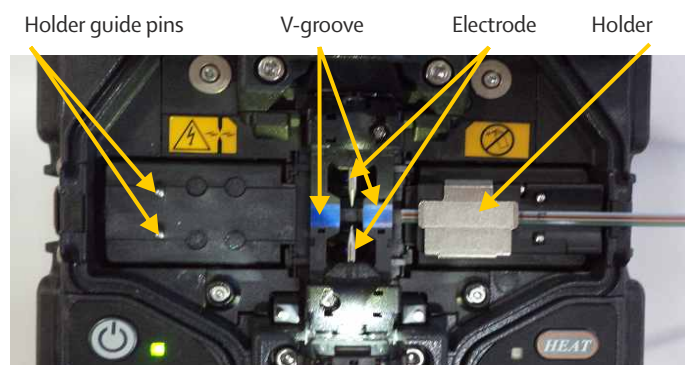


Figure 11- Splicing unit



Figure 12- Splicer unit with ribbon holders

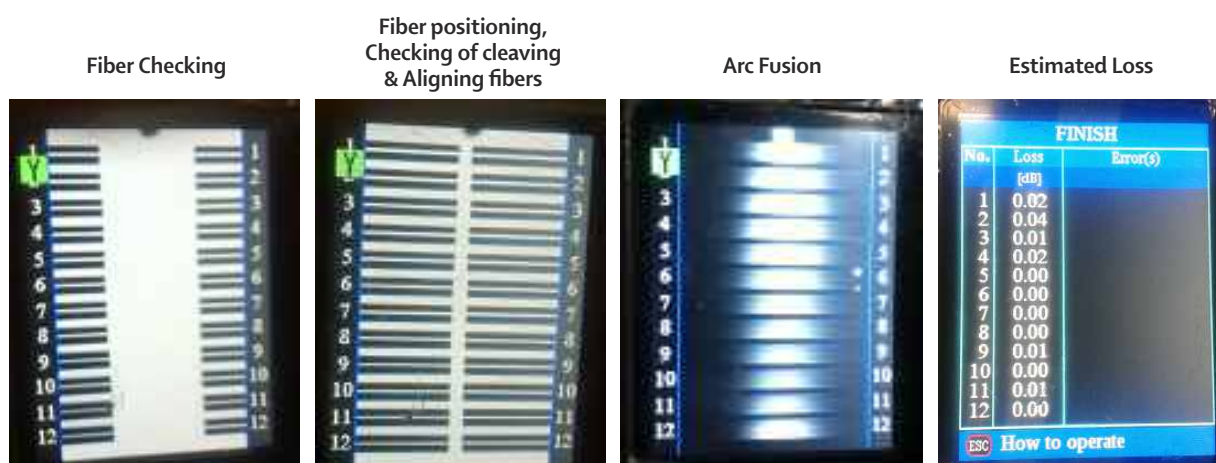


Figure 13- Fusion process of 12 fiber ribbon as seen on the splicer display

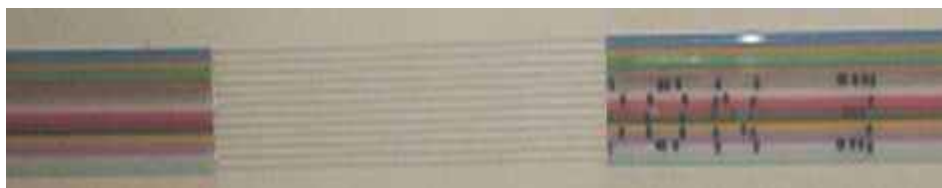


Figure 14- Spliced 12 fiber ribbon

Fusion splicing consists of two steps- aligning and heating.

Once the splicer cover is closed, fusion splice procedure starts automatically if the machine set in automatic mode. The fusion splicing process should end in an estimated splice loss as shown in Figure 13.

If any error or warning appears on the screen during splicing procedure, corrective action should be taken as per the error message.

Proof Test : A proof test applies a small amount of tension on the newly completed splice to verify that it is physically acceptable. Prior to remove the spliced fiber from the fusion splicer, proof-test is performed to ensure that the splice is strong enough to survive handling, packaging and extended use. It is a double check of what the splicer just did to verify that nothing strange happened and that the splice point will bear the necessary handling stresses to protect it permanently.

Protect the spliced fiber array is the next step. A good splice will not break during normal handling, but it must be protected from bending, twisting and tensile forces.

3.6 Fusion splice Protection / Heat-shrink sleeve

A heat-shrink sleeve is a small plastic tube with a small rigid bar placed inside it. After the fiber fusing operation, the heat-shrink sleeve is moved over the spliced portion and placed in a heat-shrink oven (usually attached with the fusion splicer). The oven shrinks the sleeve around the splice and after the oven cycles off, the splice is removed and placed into a splice tray.



Figure 15- Spliced ribbon fiber with protection sleeve

3.7 Splice loss estimation

There are two ways to analyze the outcome of a fusion splice: using video cameras or optical power analysis.

Most fusion splicers can estimate the splice loss within a certain degree of accuracy. Optical (LID-System Unit) or video analysis are most common techniques to estimate splice loss. Multi-mode fibers are easy to align due to larger cores. Fibers with smaller cores are more difficult to splice (harder to align) and therefore requires an estimated splice loss to understand whether the splice is good or bad. Splice loss estimation is frequently used during long haul network because the craftsman wants to know the results without performing extra testing.

4.0 Splice loss measurement

Accurate splice loss measurement requires optical time domain reflectometer (OTDR) testing. OTDR measurements are taken from each end of the fiber. The two results are then averaged to determine true loss of each splice point. A one-way OTDR measurement can be misleading due to differences in the mode field diameter (MFD) from one fiber to another.

4.1 Measurement of splice loss by OTDR

While measuring the splice loss by OTDR from one end of the fiber the measured sharp fall in power, is called as loss & when measured from the other end the measured increase in power level is called as gain. Losses are measured when direction of measurement is from smaller MFD fiber to a larger MFD fiber. Similarly gainers are measured when direction of measurement is from larger MFD fiber to a smaller MFD fiber (Figure 16).



Fig. 16: OTDR trace at splice point

This kind of loss & gain is measured due to the fact that fibers with differing MFD's will backscatter different amount of light. Since the OTDR uses the backscattering technique for loss measurement, the loss measurement measured by an OTDR will vary significantly from the measurement of the same splice in the other direction.

Measuring the splice loss from both the ends by OTDR and then averaging the algebraic sum of both the measurements yields the true splice loss. This will cancel out the backscatter effects, leaving only the actual splice loss in dB at the splice point.

$$\text{Splice Loss} = \frac{L1 + (-L2)}{2} \text{ dB}$$

4.2 Factors affecting splice loss

There are four main factors that affect splice loss.

A. Splicer: Fusion current and fusion time are two factors that affect the splice loss the most. To a certain degree different combinations of these two parameters can provide same results, e.g. increasing the fusion time slightly and decreasing the fusion current. Most of the other splicer parameters have to be significantly changed to have a noticeable effect on the splice loss. Other splicer parameters influencing splice splice loss are V-groove, clad alignment, core alignment and cleave quality of fiber end faces.

B. User Skills: Cleanliness, operation of equipment, and ability to recognize and correct poor preconditions will affect the measured splice loss.

C. Fiber characteristics: Good Geometry, mainly the mode field diameter of the fiber.

D. Environmental factors:

- Cold and hot ambient temperature can affect splice loss, but they can be compensated by increasing or decreasing the fusion current respectively.
- Humidity does not generally affect single-mode or multi-mode splicing.
- Humidity can affect the cleanliness of the electrodes, therefore more checks of electrodes is recommended for humid conditions.
- Splicing at high altitude (3,000ft) requires a higher fusion current.
- Batteries experience decreased life in cold areas.

Some splicer can compensate for environmental conditions like adjusting the fusion current. This real time monitoring allows for better control of the fusion process and results in low-loss splices. In addition, most splicers provide altitude compensation once the operator enters the altitude.

Arc: The discharge of high voltage electricity generated between two electrodes in a fusion splicer. The arc temperature is approximately 1600-1700°C.

Auto-feed (z-feed): The amount of fiber pushed ahead while being melted back during the fusion step.

Bi-directional Averaging (OTDR): OTDR measurements taken from each end of the fiber and the two results are averaged to give the true loss of a splice point.

Cleaning Arc: A brief electric arc that burns remaining small dust particles off of the fiber prior to splicing.

Cleave Angle: The angle that the fiber's end-face makes from the perpendicular. Different splicers require different angles to make acceptable splices. Some splicer can compensate for poor cleave angles (up to a certain amount) by automatically adjusting the auto-feed.

Cleaver (Cutter): A tool used to cleave (cut) fiber optic fiber very precisely leaving fibers with almost perpendicular end-faces.

Electrode: A precisely machined conductor which directs the high voltage arc across a gap to melt the fiber optic fiber.

End-face: The cleaved end of a fiber must be almost perpendicular for successful splicing.

Fixed V-Grooves: The channels in which fibers are placed in a passive alignment splicer.

Fuse time optimization: Splicer automatically compensating for variations in temperature, humidity, and other operating conditions by using direct feedback from the LID-System® unit during the actual fusing operation (during arcing).

Fusion Splice: The controlled aligning, melting, and pushing together of two optical fiber ends resulting in a transparent, non-reflective joint.



Index Matching Gel: A gel that is used to help transfer light from fiber to fiber in a mechanical splice with minimum loss of light.

LID-System Unit: A Local Injection and Detection System that injects light directly into the fiber core for alignment.

Matchsticks: When fiber burns completely back and does not fuse together at all, the result is commonly called 'matchsticks' because the end of each fiber looks like a matchstick.

Mass Splicing: Splicing together more than one splice joint at the same time. The most common types of mass splices are 6- and 12- fiber ribbon mass splices.

Mechanical Splice: An alternative to fusion splicing that forms a joint between two fibers by precisely aligning the fiber ends and holding them together.

Neck down: This results when the fiber at the splice point is thinner (narrower) than the rest of the fiber. This is often due to the fusion current or the fusion time to set too high or too long.

OTDR (Optical Test Domain Reflectometer): A test device that measures loss along a fiber by injecting light at one end and measuring how much is reflected all along the length of the fiber.

PAS (Profile Alignment System): A system where the splicer uses small video cameras for alignment and measurement.

Pre-fuse: A short electric arc that softens the fiber end-face prior to the fusing step.

Ribbon Fiber: Ribbon Fiber consists of two or more fibers placed side by side and covered with matrix material to hold them together.

Splice loss estimation: An automated but less accurate measurement of the splice loss by the splicer to provide a quick indication of the quality of the splice.

Typical Field loss: Indicates expected performance under actual field conditions, allowing for variations in climate, cleanliness, cleaving and operator training.

V-Groove: V-shaped groove that the fiber lies in to properly align it for the splicing process.

Video: Indicates that the splicer is equipped with one or more video cameras that are used for alignment and/or loss estimation.