# Optical Fiber Fusion Splicer

*Noriyuki* Kawanishi[1]

*The essential requirements for establishing a low-loss and high-speed telecommunication line using optical fibers are high performance and quality splicing technology. The simple connection of optical fibers using optical connectors and mechanical splices is increasing. However, the fusion splice is needed for long-haul and high-capacity trunk communications such as submarine optical fiber cable. This requires not only ultra low loss and low back reflection, but also long-term reliability and strength of the fusion splice. The fusion splice is also used when splicing specialty optical fibers for light amplification and high power laser transmission for use in various medical procedures or machining applications. In addition to the splicing technology, fiber cleaving and splice protection technologies are also important steps in the splicing process. In this paper, we introduce the features of each technology owned by our company.*

## 1. Introduction

In the 1970s, while transmission loss of optical fibers had been decreasing, splicing loss was not improved significantly. The optical transmission loss achieved was less than 0.2 dB/km. However, splicing loss of single mode optical fiber was more than 0.2 dB. This problem came from not only an unstable heating source and poor cleave surface of fiber ends, but also large core offset from the fiber center.

We solved various technical issues and proceeded to release a multimode optical fiber fusion splicer in 1979 and single mode optical fiber fusion splicer in 1985. Furthermore, we released a core alignment fusion splicer capable of splicing single mode fibers that have large core offset with low splicing loss in 1985. These splicers made it possible to deploy optical fiber cables practically, thus contributing to the prologue for the age of telecommunication. Splicing technologies continued to develop. The latest core-alignment splicer can splice single mode optical fibers less than an average of 0.02 dB splice loss. Also, optical fiber cleavers can cleave fibers less than an average of 0.5degree cleave angle.

## 2. Splicing Technology

### *2.1 Core Alignment Fusion Splicer*

We have developed various kinds of fusion splicers to meet various application requirements. The fusion splicers that are mostly used in the world are the core alignment fusion splicers. These splicers can measure core position with high accuracy by using an objective lens such as Fig.1.

The optical fiber is aligned by a movable v-groove alignment mechanism and heated by electric discharge between tungsten electrodes.

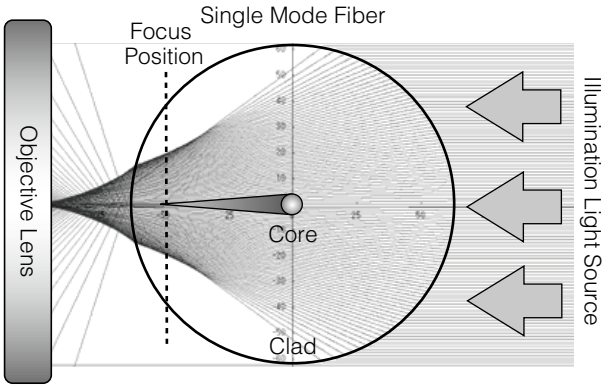



**Fig. 1. Core Position Measurement.**

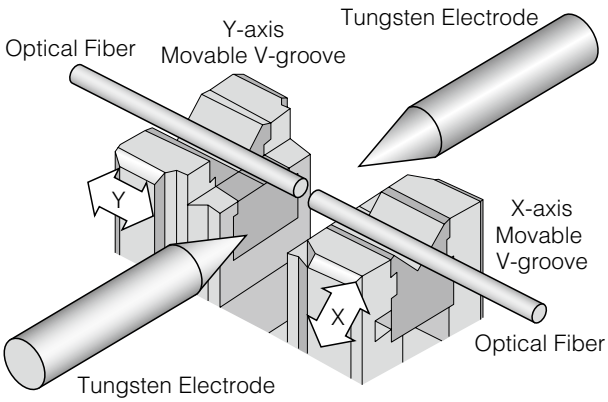



**Fig. 2. Alignment with Movable V-groove and Fusion Splice.**

1 Precision Instruments products Department

Also, since core alignment fusion splicers can identify different types of fibers such as single mode (ITU-T G.652 or G.657), dispersion shifted (ITU-T G.653 or G.655) or multi mode (ITU-T G.651) by analyzing refractive index profiles from fiber image, the splicers have the function to select the best splicing conditions for each fiber automatically.

Fusion splicers used to be thought of as big, heavy, expensive and easily damaged. The FSM-60S shown in the Fig.3 is the first splicer in the world to have resistance against drop impacts from 760 mm height, so that FSM-60S has been trusted in our industry as not being easily damaged, even it is dropped repeatedly. The FSM-60S, capable of splicing fibers with the lowest splice loss in the world even if the fibers have high core position eccentricity, is the splicer best suitable for fiber cable deployment.

The advantages and disadvantages for core alignment fusion splicers are described below.

[Advantage]

- Fiber offset because of dust on the fiber or V-groove is removed by core alignment mechanism.
- Splice loss caused by core eccentricity is removed.

[Disadvantage]

- Core alignment mechanism and focus mechanism for optical fiber is necessary.

### *2.2 Mass fusion splicer for ribbon fiber*

Mass fusion splicing enhances work efficiency in the case ribbon fibers are used. Thus, we provide mass fusion splicers for ribbon fiber splicing. Since each pitch of fiber is as narrow as 250 um on ribbon fiber, it is difficult to apply movable v-grooves for each fiber. Thus, fixed v-groove is used for ribbon fiber splicing as Fig.4.

**Fig. 3. Core Alignment Fusion Splicer FSM-60S[1].**

The problem of this fixed v-groove method is large offset because of dust on the optical fiber or v-groove. It is difficult to avoid dust completely in outdoor work. Offset amount between left and right optical fibers is in proportion to this dust size. Self-alignment effect by surface melting tension solves this problem as Fig. 5.

Optical fibers melt and soften as temperature of the fibers increases. The offset of splicing point is self-aligned by surface melting tension of the softened optical fiber. Though the deformation of the splicing point could remain, the splice loss is much lower than the case when core offset remains.

Electric discharge time for mass fusion splicers is designed to be long in order to let self-alignment by surface tension work effectively.

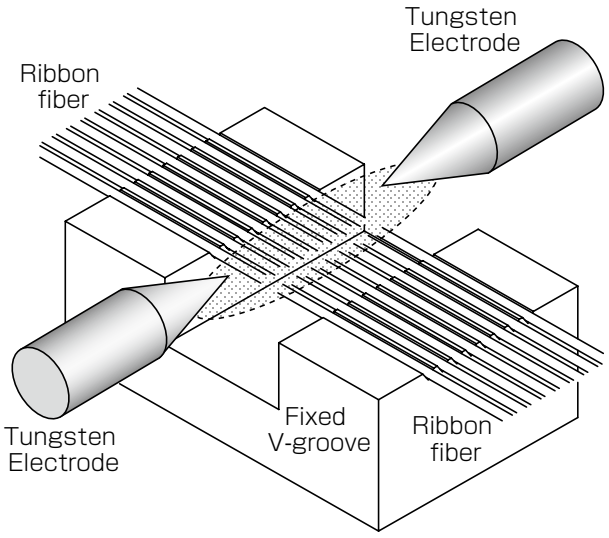



**Fig. 4. Splicing Method with Fixed V-groove.**

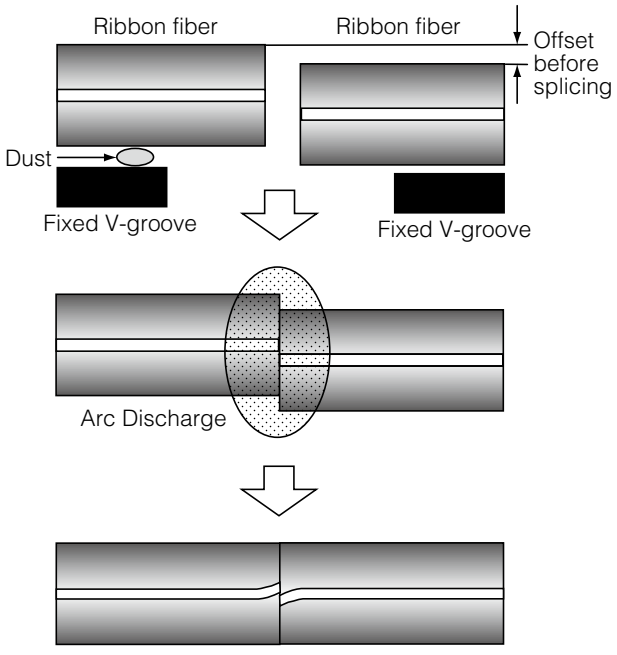



**Fig. 5. Self-alignment effect by Surface Melting Tension.**

Fig.6 shows a ribbon fiber that is heated by electric discharge.

In recent years, as optical fiber has been connected to homes, demand of compact and light fusion splicers has been rising. Fig.7 shows our FTTH fusion splicer, which is the smallest and lightest weight fusion splicer in the world. The FTTH fusion splicer is one of the mass fusion splicers specifically designed to be small and light weight.

The advantages and disadvantages for mass fusion splicer for ribbon fiber are detailed below.

[Advantage]

- Ribbon fiber is spliced all at once so that operation time is shorter than the case when each single fiber is spliced separately.
- Number of movable parts is small.

**Fig. 6. Heating Ribbon Fiber with Electric Discharge.**

**Fig. 7. FTTH Application Fusion Splicer[2].**

[Disadvantage]

- Dust on the optical fiber surface or v-groove may affect splice loss.
- Core eccentricity of optical fiber increases splice loss.

### *2.3 Specialty fiber fusion splicer*

Optical fiber applications have expanded to many fields other than telecommunications. We developed a specialty fiber fusion splicer that has an adjustable fiber clamping position mechanism, electrode oscillating mechanism, and optical fiber end-view image observation system in order to splice various types, such as polarization maintaining fibers and large diameter fibers for high power laser transmission. Fig.8 shows the appearance of this splicer.

Cladding diameters of specialty fibers vary. The diameter ranges from 60 um to more than 1000 um. Thus the fiber clamping mechanism is very important for the specialty fiber splicer. The splicer needs to align left and right optical fibers with high accuracy, and to also clamp the optical fibers securely and strongly to eliminate fiber offset caused by impact when the fiber end faces touch each other. Fig.9 shows the clamping mechanism which is able to adjust the

**Fig. 8. Specialty Fiber Fusion Splicer.**

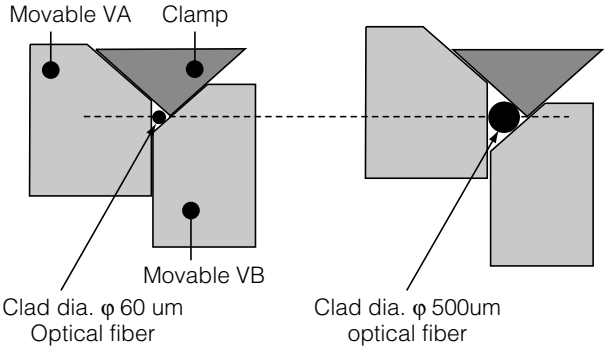



**Fig. 9. Adjustable Clamping Mechanism for Optical Fibers[3].**

v-groove positions so that various cladding or coating diameters are clamped securely and aligned.

In the case of heating and melting large diameter optical fibers, the temperature distribution would be uneven since the heating range between electrodes is narrow. The specialty fiber fusion splicer has the function that oscillates the electrodes to heat the optical fibers evenly. Fig.10 shows the principal of the electrode oscillating discharge mechanism.

Furthermore, the specialty fiber fusion splicer has a mirror to observe the fiber end-view image. Fig.11 shows the picture of the optical fiber end-view image.

Conventional splicers observe the refractive index of optical fiber only from the side-view. However, this specialty fiber fusion splicer is able to observe both the side-view and end-view image to analyze the refractive index from both views.

Using these functions, our splicer can splice various types of optical fibers such as PM fibers and multi-core fibers with top performance in the world.

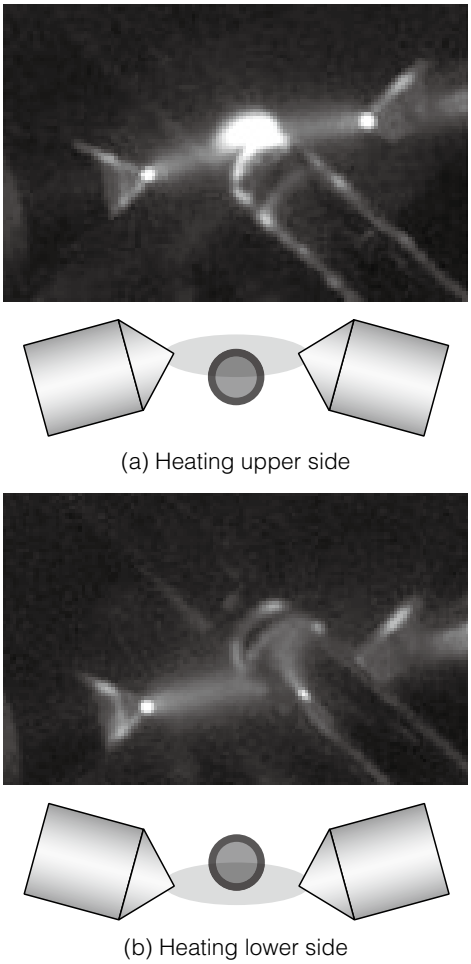



**Fig. 10. Discharge Electrodes Vibrating Mechanism[4].**

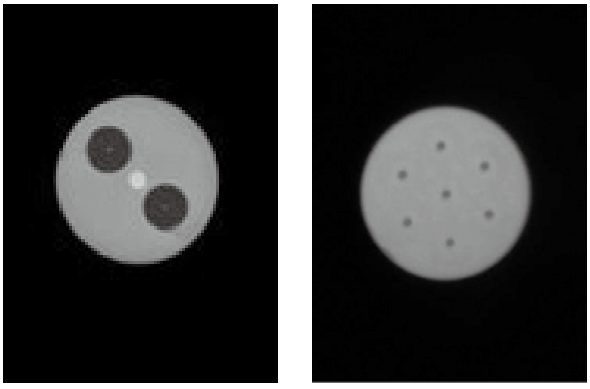


**Fig. 11. Optical Fiber End-View Image[4].**

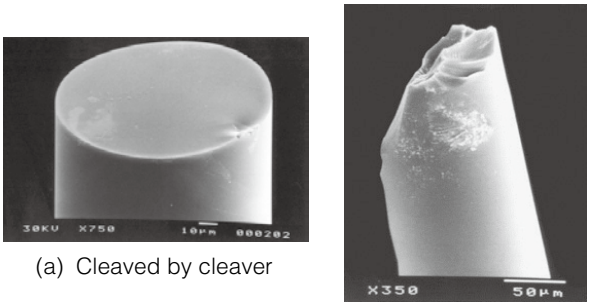
## 3. Cleaving technology

It is important for low loss fusion splicing to cleave optical fibers with high quality. In Fig.12 the left side picture shows the cleaved end of the optical fiber cleaved by our cleaver. The right side picture shows the fiber end that is broken off by hand.

The fusion splicer has the function that prepares cleaved fiber ends by melting surfaces before splicing. It is difficult to form the broken end of fibers. A high quality cleaved surface is necessary to achieve lower splice loss. Fig.13 shows our cleaver. The cleaver scribes a fiber by using a metal disk blade and then folds to break the fiber when cleaving.

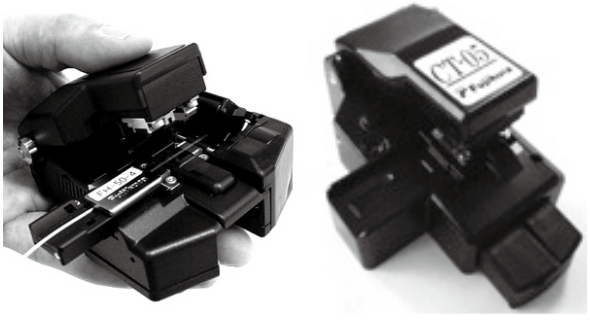
These optical fiber cleavers using a metal disk blade can cleave optical fibers 48,000 times per a blade in a harsh environment such as construction fields.

On the other hand a diamond blade is used for the high performance cleaver to cleave specialty optical




(a) Cleaved by cleaver (b) Broken by hand

**Fig. 12. Cleaved Optical Fiber End observed with SEM.**




(a) Ribbon fiber use[5] (b) Single fiber use

**Fig. 13. Optical Fiber Cleaver with Metal Disk Blade.**

**Fig. 14. Specialty Fiber Cleaver with Diamond Blade.**

fibers instead of a metal disk blade. Fig.14 shows the specialty fiber cleaver that can cleave the fibers precisely. Furthermore the cleaver can cleave a fiber so that the fiber end is angled. We have provided different types of fiber cleavers to meet the requirements that come from various applications and specifications of fibers.

## 4. Protection technology

The protection technology of the splicing point is one of the important technologies for reliability of fusion splicing. Fig.15 shows the structure of a heat shrinkable splice protection sleeve.

Heat shrinkable protection sleeves protect the splicing point by covering the fibers with hot-melt. The outer heat shrinkable tube works to form the shape of hot-melt to fit various coating diameters of optical fibers. The outer heat shrinkable tube also works to push the air out of the tube by shrinking from the center to the edges sequentially. The protection sleeve protects the splice point against harmful materials outside the sleeve, such as moisture. A stainless rod is

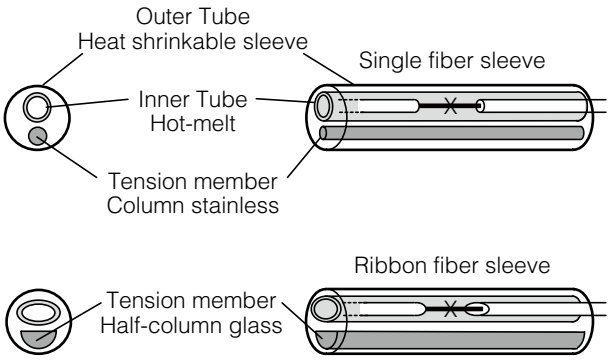



**Fig. 15. Heat Shrinkable Splice Protection Sleeve.**

used in the single fiber sleeves to reinforce the splice point to withstand bending force or tension. In the case of the ribbon fiber sleeves, a glass rod is used instead. These protection sleeves shrink in about 30 seconds using the heater unit of the fusion splicers.

## 5. Conclusion

We have developed fusion splicing, cleaving, and splice protection technologies for many years. We will continue to contribute to the evolution of optical network infrastructures and many new and emerging fields by further development of these technologies.

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