New Core Alignment Fusion Splicer FSM-50S

Shigeru Saito, *Katsumi* Sasaki, *Kenji* Takahashi,
Koji Ohzawa, *Taku* Otani and *Srachate* Chumpol

For many years, most fiber optic splicing in the core and edges of the network has been predominantly performed by core alignment fusion splicers, which produce the lowest possible splice losses. Customer requirements have continued to evolve, and in addition to low splice losses, customers now require exceptional portability, high yield, fast splicing, fail-safe functions to prevent faulty splices from being made, and skill-free easy operation. Fujikura has responded to these new requirements by developing a new core alignment fusion splicer, which is the fastest, smallest, lightest and easiest to use in its class.

1. Introduction

In Asian countries such as China, economic development has led to expansion of the telecom infrastructure, and a subsequent increase in fiber splicing. This splicing occurs in diversified environments, including aerial splicing and splicing in tight indoor spaces.

Therefore, improvements were needed in the portability of the splicer, including reductions in size and weight.

In the overseas markets where single fiber splicing is common, splice time and splice protection sleeve shrinkage time reduction were necessary to reduce the overall cost of splicing.

The skill level of the operators continues to drop, but construction contractors cannot tolerate rework that is generated by an unskilled operator. Therefore, customers of Fujikura demand ease of use and error-proofing to allow unskilled operators to successfully use the splicer with minimal training.

A new core alignment fusion splicer, the FSM-50S, has been designed to meet these new industry requirements. It has the following features:

(1) Smallest in the industry 150mm^3
(2) Lightest 2.8 kg
(3) Quickest 9 s, when splicing SMF fiber
35-s splice protection sleeve shrink time
(4) Improvements in workability
Reduction in the number of steps to make a splice
(5) Error proofing
Real-time arc power compensation function and abnormality identification

2. Outline of New Splicer

The new splicer is shown in Fig. 1.

Specification comparison with the previous Fujikura core alignment splicer, the FSM-40S, is shown in Table 1.

Details are explained in the following section.

3. Detail

3.1 Size Reduction

In order to reduce the size of the core alignment fusion splicer, we needed to reduce the size of two pairs of optical observation systems and two pairs of optical fiber alignment systems.

The objective lens was optimized for fiber observation. As a result, the optical distance was shortened in half compared with the conventional machine (FSM-40S) (refer to Fig. 2.)

In addition, the size of the alignment mechanism was reduced to approximately half using a board spring system without narrowing the alignment range. These changes enabled the dimensions of the FSM-50S to be reduced to 150 mm^3.

Fig. 1. FSM-50S Appearance.

Table 1. Comparison of Specifications

Item	New model FSM-50S	Conventional splicer FSM-40S
1. Portable Performance		
Dimensions	150×150×150 mm	172×186×180 mm
Weight	2.8 kg	4.9 kg
2. Splice Performance		
Average splice loss	SMF: 0.02 dB	SMF: 0.02dB
Splice time	9 seconds	15 seconds
Heat time	35 seconds	60 seconds
Battery life	200 splices	50 splices
3. Operation Performance		
Steps to make a splice	11 actions	17 actions
Time to make a splice	77 sec/splice	123 sec/splice
Additional functions	Sleeve centering function	–
Monitor options	Available to change front / rear	Fixed (front or rear)
LCD monitor	5.6 inches	5.0 inches
4. Error Proofing Functions		
Arc power calibration	Auto	Manual
Detection of abnormal arc discharge	Arc delay · Dust burned	–
Observation of fiber end face	Angle · Lip · Chip	Angle

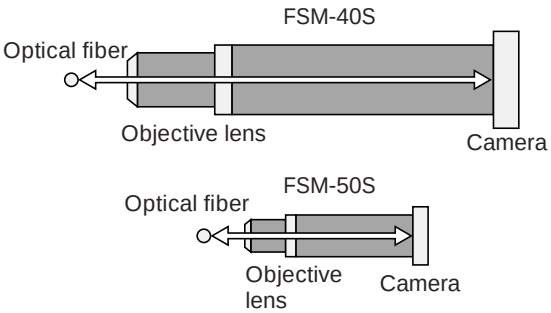

Fig. 2. Comparison of Optical Observation System.

3.2 Weight Reduction

A splicer is a precision instrument. High precision and high reliability are required of each component.

For this reason, the main parts of FSM-40S consisted of the aluminum die casts instead of resin parts. In the FSM-50S, a magnesium die cast was adopted to further reduce the weight. This change, along with reducing the number of parts, resulted in a weight reduction of approximately 40% from the FSM-40S.

3.3 Increase in Speed

3.3.1 Reduction in Splice Time

The alignment operation of the optical fibers consumes most of the time in the splicing operation.

Alignment was performed by repeating the movement and position measurement two or more times in the FSM-40S, since the amount prediction of movements of an optical fiber was difficult.

In FSM-50S, the alignment operation is completed typically only once using a mechanism that makes the prediction of movements easy, and by adopting an algorithm with high prediction accuracy.

Consequently, the splicing time for a single-mode fiber splice has been reduced to an average of 9 s.

3.3.2 Reduction in Sleeve Heating Time

The heater was arranged in the center of the sleeve heater oven, and the temperature slope was used from the FSM-40S using heat-conduction resistance. These designs prevented the bubbles from forming in the splice protector. Average reinforcement heating-time of 35 s were attained in the FSM-50S using a single splice protector with a length of 60 mm. This was accomplished by simultaneous heating using two or more heaters, maintaining the temperature slope.

3.4 Operation Improvements

3.4.1 Splice Operation Reduction

In the FSM-50S, as shown in Table 2, the number of steps in a splice procedure was cut to 11, and the time to complete a splice was shortened to 77 s. As a result, an unskilled operator can master the splicing

Table 2. Comparison of Splice Operation

	New model FSM-50S	Conventional splicer FSM-40S	
	11 steps 77sec.	17 steps 123sec.	
10 sec.	1.Set left optical fiber Close sheath clamp 2.Set right optical fiber Close sheath clamp 3.Close wind protector cover	1.Set left optical fiber Close sheath clamp 2.Set right optical fiber Close sheath clamp 3.Close the left fiber clamp 4.Close the right fiber clamp 5.Close wind protector cover 6.Push the SET switch	15 sec.
9 sec.	<Splicing>	<Splicing>	15 sec.
20 sec.	4.Open wind protector cover 5.Open left sheath clamp 6.Open right sheath clamp 7.Remove the fiber 8.Slide the fiber protection sleeve to the center of the splice and move it to the tube heater 9.Place fiber with protection sleeve in tube heater 10.Push the HEAT switch	7.Open wind protector cover 8.Open left fiber clamp 9.Open right fiber clamp 10.Open left sheath clamp 11.Open right sheath clamp 12.Remove the fiber 13.Slide the fiber protection sleeve to the center of the splice 14.Place fiber with protection sleeve in tube heater 15.Slide the protection sleeve to the tube heater proper position 16.Push the HEAT switch	30 sec.
35 sec.	<Heating>	<Heating>	60 sec.
3 sec.	11.Remove the fiber	17.Remove the fiber	3 sec.

process quickly and easily.

3.4.2 Improvement in Operability of the Tube Heater

As shown in Fig. 3, in the conventional machine (FSM-40S), the protection sleeve should be placed in the center of the tube heater.

However, adjusting the protection sleeve to the proper position is difficult, especially when the fiber coating edge is not colored (transparent) and the protection sleeve is colored.

To solve this problem, a centering function was included in the FSM-50S to improve this portion of the operation.

The operation procedure for the protection sleeve centering device is shown in Fig. 4 and below:

1. Hold the left fiber with the left hand at the edge of wind protector.
2. Place protection sleeve on the centering device located on the tube heater.
3. Slide spliced fiber slowly to the right until the left hand reaches the edge of the tube heater with hooked protection sleeve on the centering device.
4. Transfer fiber with protection sleeve from centering device to tube heater and slide spliced fiber to the right until the left hand reaches the edge of the tube heater.

Even if the operator does not carry out a visual check, the protection sleeve can be placed in the exact position without the need of additional shifting or adjustment once it is in the heater.

3.4.3 Monitor Position and Change in Splicing Direction

When splicing, the optimal direction of the splicing process changes in accordance to the type and position of the closure or splice tray.

In the FSM-40S, two models, a front operation type and a back operation type, were needed to address each type of splicing.

The FSM-50S was designed so that the splicer can be operated from either direction, reducing the need for a customer to carry two types of splicers in the inventory.

The appearance of the splicer when performing front operation and back operation functions is shown in Fig. 5.

This change was accomplished by extending the movable range of the LCD monitor and by enabling the operation button on the front and rear of the splicer.

The flexibility enabled by the splicer allows the operator to gain productivity by using the correct position for the splicing activity being performed.

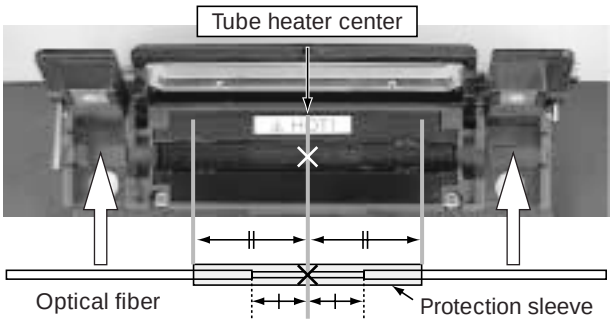

Fig. 3. Centering Operation of Protection Sleeve.

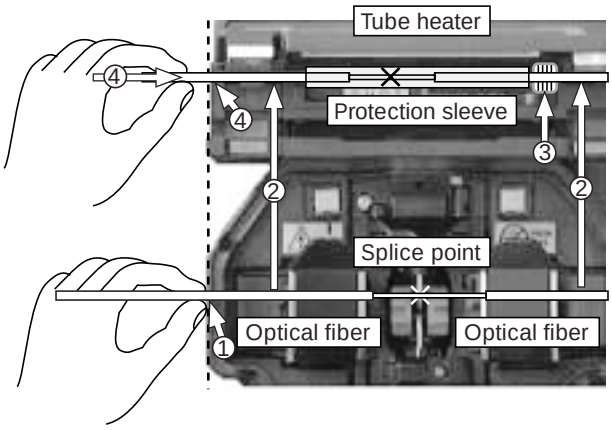

Fig. 4. Centering Function of Protection Sleeve.

Front operation

Back operation

Fig. 5. Change of Operating Direction.

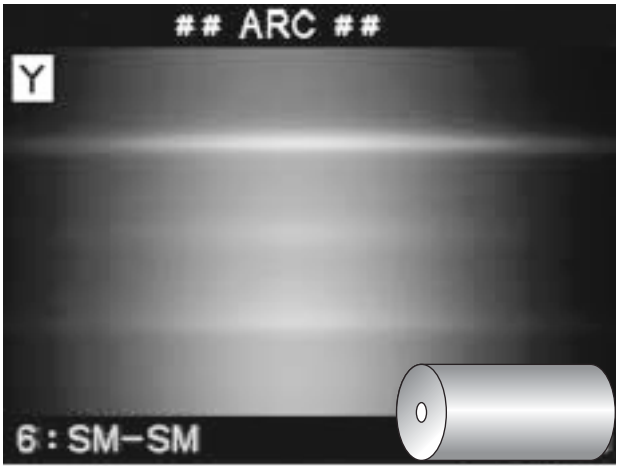

Fig. 6. Thermal Luminescence of Optical Fiber.

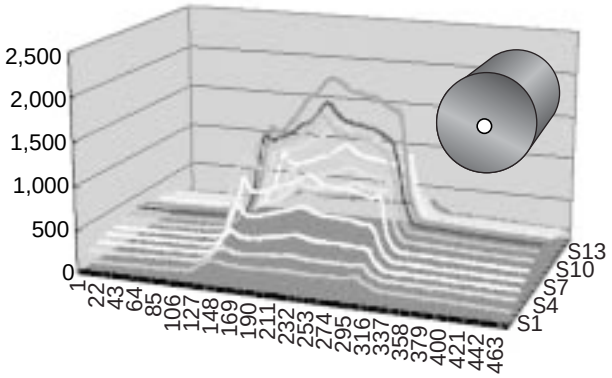

Fig. 7. Brightness Distribution of Thermal Luminescence.

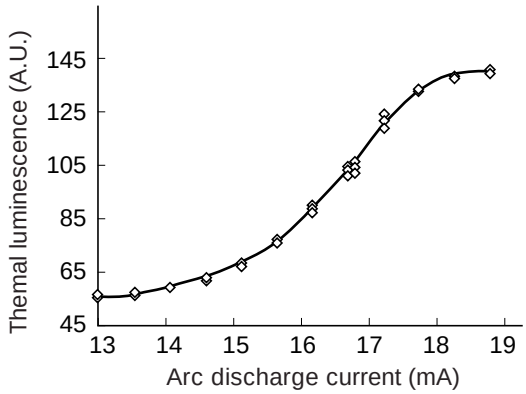

Fig. 8. Relation between Arc Discharge Current and Thermal Luminescence.

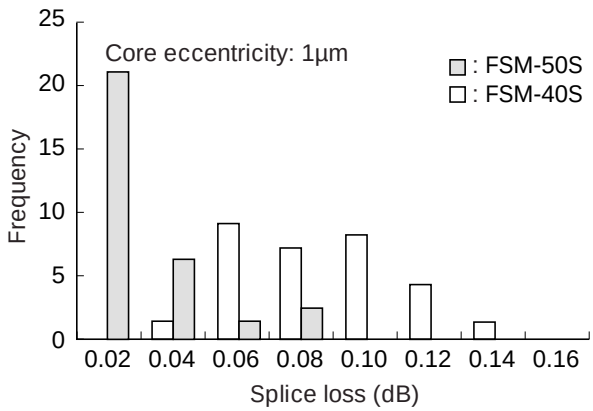

Fig. 9. Comparison of Arc Calibration Method.

3.5 Error-Proofing Features

3.5.1 Compensation of the Arc Discharge Energy Method

It is a common understanding that consistent low splice loss is dependent on the optimum amount of heat being delivered to the fiber being spliced. However, glass deposits formed on the tip of electrodes, or frequent pressure changes make it difficult for these functions to correctly calibrate the arc power[1)].

Conventional fusion splicers are equipped with a series of devices (atmospheric pressure sensor, temperature sensor and humidity sensor) and functions that calibrate arc power. However, there is no function to correctly calibrate the arc power for glass deposits formed on the tip of the electrodes. The operator has to perform the arc calibration function before splicing each day.

The FSM-50S calibrates the amount of heat delivered to the fiber in real time by observing thermal luminescence of optical fiber during the arc discharge process when splicing.

Figure 6 shows the picture of thermal luminescence of an optical fiber during arc discharge, and Fig. 7 shows brightness distribution of thermal luminescence[2)].

There is a relation between thermal luminescence of an optical fiber and arc discharge current as shown in Fig. 8.

The above relation allows the arc power to be compensated with high accuracy by introducing a feedback loop utilizing the thermal luminescence of the optical fiber during each splice and comparing it to standard thermal luminescence from an optimal arc discharge.

The result of the splice loss using SMF with high eccentricity under unstable arc is shown in Fig. 9.

The figure is compared with splice loss by manual arc calibration of FSM-40S and by the real-time automatic feedback of FSM-50S.

Thus, in any environment, stable and low splice loss can be acquired by real-time feedback to arc discharge power.

3.5.2 Detection of Various Abnormalities

Abnormalities normally identified by the splicing skilled operator during a visual check on the monitor were quantitatively measured by image processing. When the splicer detects these abnormalities, it prompts the operator to discontinue the splicing

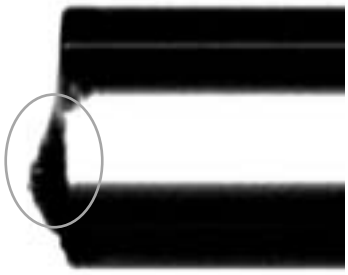

Fig. 10. Lip of Fiber End.

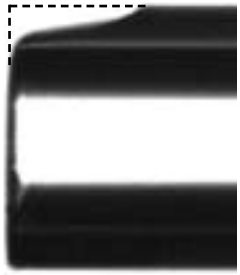

Fig. 11. Chip of Fiber End.

process and start over.

The detection functions added to the FSM-50S are shown below:

(1) Measurement of the lip amount of optical fiber end (refer to Fig.10).
(2) Measurement of the chip amount of optical fiber end (refer to Fig.11).
(3) Measurement of delay time until arc shifts to regular arc discharge.
(4) Measurement of luminescence in which dust is burned during arc discharge.

These additional functions allow even unskilled operators to achieve perfect splices every time.

4. Conclusion

The FSM-50S core alignment splicer is the fastest, smallest, lightest and easiest to use in its class. It not only produces low splice losses but also enables operation by unskilled operators and has a number of error-proofing functions to prevent faulty splicing.

References

1) Bert Zamzow, et al.: New High Durability Electrodes with Arc Stabilizers for Extended Service Cycles and Increased Performance, International Wire & Cable Symposium, pp. 207-213, 2000
2) S. Saito, et al.: Discharge power control for fusion splice of optical fiber, Proc. of OFC 2004, pp. 203-206