Low Fusion Splice Loss Technique for Multicore Fiber with 2- and 3-electrode Fusion Splicers

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Abstract: Splice loss of 4-core fiber using 2-electrode fusion splicer by automatic rotational alignment with duration time of 150 sec is reduced to 0.07 dB, getting closer to 0.02 dB by 3-electrode fusion splicer.

1. Introduction

In recent years, much attention has been drawn to space division multiplexing transmission technology using multi-core fiber (MCF), much research of MCF has been actively reported. One of the strategies for accelerating commercialization of MCF is to choose identical cladding diameter with conventional 125um single-mode fibers for optical telecommunication system applications [1, 2]. MCF with standard cladding diameter presents advantages over established fiber cable technologies together with available equipment used in splicing fiber.

The splicing is an essential technology to deploy MCF in optical fiber networks. The MCF has multiple cores and a marker inside which needs to be precisely aligned before splicing, and prior to the alignment, it is necessary to identify the position of cores and marker. The identification of cores and a marker are commonly done by using two microscopes each with a side-view (on X & Y axes). Two MCFs are aligned not only in the standard two microscope axes (X & Y) but also by aligning the two MCF fiber markers and cores by rotating the fibers. As the accuracy of alignment directly impacts on the splice loss, much research of rotational alignment technologies to achieve low splice loss has been reported [3, 4]. Besides the alignment of cores and the marker, a splicing method is another important factor to achieve low splice loss. Fusion splicing, which melts the glass of fiber by heat and joins them together permanently, is the one of the splicing methods which can obtain both low splice loss and long-term joint durability. Flame, filament, CO2 laser and arc discharging are popular heat source technologies. Of these the arc discharging is the most common in commercially available fusion splicers. The arc discharging is generated between two horizontal electrodes and its shape is linear as shown in Figure 1(a). In case of larger diameter fiber, a 3-electrode system with an equilateral triangular shape (Figure 1(b)) arc discharging has been used. The difference of the shape of arc discharging has an impact on the splice loss, and the triangular shape with 3-electrodes seems to be advantageous over the linear shape with 2-electrodes in splicing MCF. While 3-electrode fusion splicers have achieved much lower than 0.1 dB in average splice loss [3, 5], 2-electrode fusion splicers have not achieved the same level as 3-electrode has done [4]. It is desirable to achieve low splice loss with 2-electrode fusion splicers since the cost and availability of splicing tools is one of the key drivers for proliferation of MCF in commercial telecom network.

In this report, it is demonstrated that splice loss can be reduced by optimizing fusion splice condition, in fusion by carefully splicing 4-core fiber with standard cladding diameter of 125 μm using 2-electrode fusion splicers, which is less expensive and more general usage. It is shown that average splice loss of lower than 0.1 dB even for a 2-electrode splicer has been achieved by carefully optimizing conditions related to arc discharging.

2. MCF and MCF Alignment

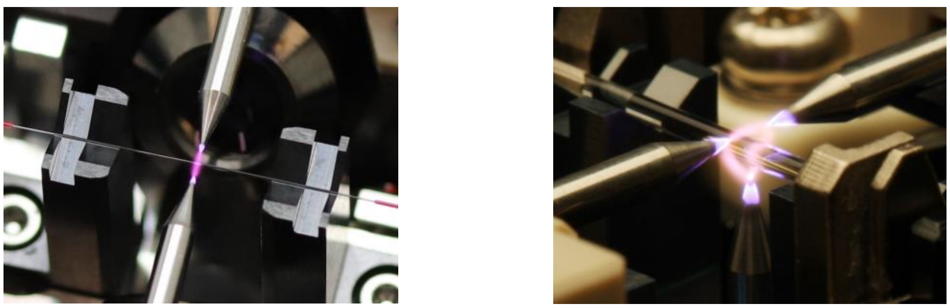
Design of 4-core fiber, which is used in this experiment, is shown as Figure 2 (a). MCF used in this experiment has 4 cores whose pitches are 40 μm, and standard cladding diameter of 125 μm. In addition, 4-core fiber has a marker to identify the core number, and the material the marker is of a lower refractive index glass. The characteristic of this fiber conforms to ITU-T G.657.A2 standard. Figure 2 (b) shows a picture of a cross section of the 4-core fiber used in this experiment.

In this report, the fusion splicer S185PMLDF (made by FITEL), which has side-observation microscopes and a mechanism to rotate fibers around the main axis of the fiber, was used as an MCF fusion splicer. The splicer acquires the brightness profile data of fiber from side while rotating the fibers as shown Figure 3 and calculates the rotational angle required to match the marker and the cores based on the acquired brightness profile data, then rotates MCF automatically. The success rate of marker identification was 100% when the splice time was 150 seconds. The average splice loss of 0.02 dB was achieved using a 3-electrode fusion splicer S185PMROF (also made by FITEL). This average loss is equivalent to $\pm$0.62 μm of rotational misalignment, indicating this alignment method is sufficiently accurate.

3. MCF Fusion Splice Experiment

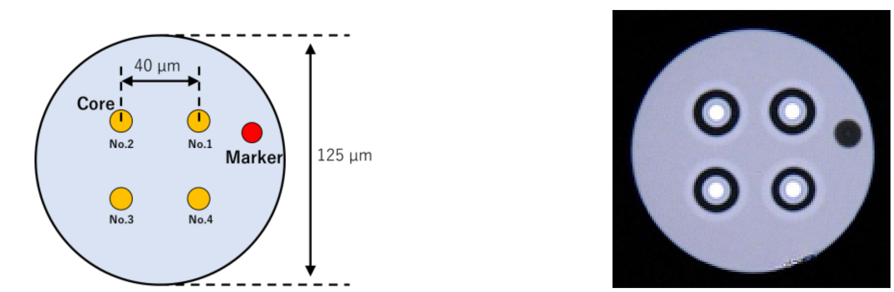
Fusion splicing experiment of 4-core fiber shown in Figure 2 was performed using a 2-electrode fusion splicer S185PMLDF. Major factors having a large impact for splice loss are heating temperature of fiber, heating time etc. The heating temperature can be controlled by controlling the electric arc current. Figure 4 (1) shows the splice loss distribution for different electric currents after optimizing other factors. The splice loss was measured 10 times for each electric current setting used. The result indicates that splice loss is reduced at an optimal electric current and that was found to be 11.47 mA in this experiment. Figure 4 (b) shows the average splice loss result measured 50 times using the finally optimized fusion splicing conditions. Figure 3 (c) shows the average loss for each core in Figure 4 (b). The definition of core number is as Figure 2 (a). Finally, the ave. splice loss of 0.07 dB was achieved.

The splicing experiment using 3-electrode fusion splicer was also performed. Same automatic rotation alignment of 2-electrode experiment was used. Figure 4 (d) shows as the result of average splice loss with a 3-electrode fusion splicer.



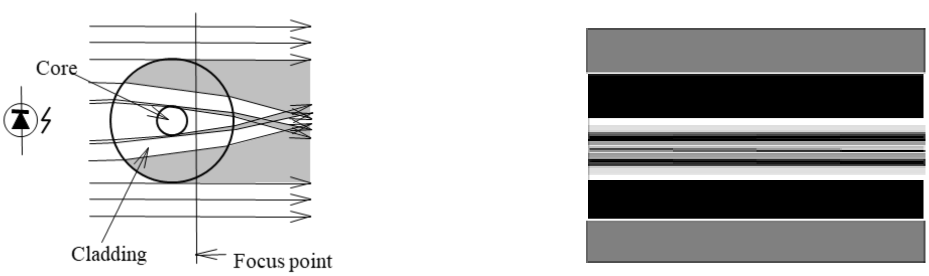
(a) 2-electrode arc discharge (b) 3-electrode arc discharge

Fig. 1 Pictures of arc discharge systems



(a) Design of 4 core fiber (b) Picture of 4 core fiber

Fig. 2 Design of MCF for MCF splice experiment



(a) Schematic diagram of light passing through a fiber (b) Image of transmitted light

Fig. 3 Principle of core position measurement

As the result, the average loss was 0.02 dB. The reason of the difference of splice loss between a 2-electrode splicer and a 3-electrode splicer is clearly attributed to the difference of the shape of arc discharge since the same automatic rotation alignment method was used. The result of 2-electrode fusion splicer did not outperform 3-electrode fusion splicer in terms of splice loss, nevertheless, achieved lower splice loss than 0.1 dB after optimizing fusion splicing factors.

3. Conclusion

We demonstrated that splice loss of 4-core fiber with standard cladding diameter of 125 μm using 2-electrode fusion splicer, which is less expensive and more widely used than 3-electrode fusion splicer, can be reduced to 0.07dB in average by optimizing fusion splicing factors.

4. References

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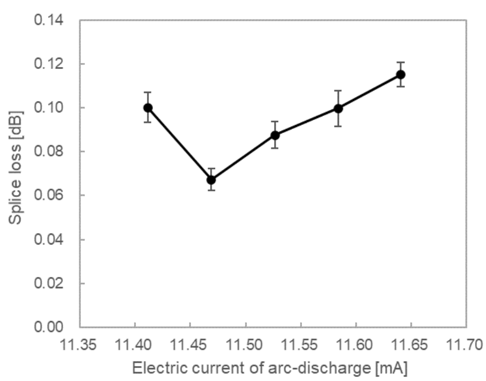
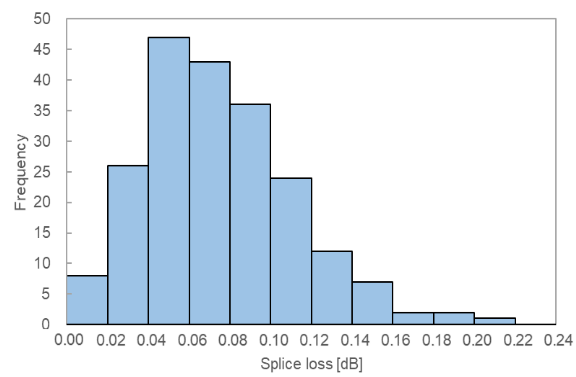
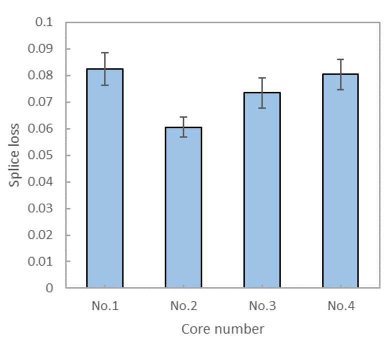


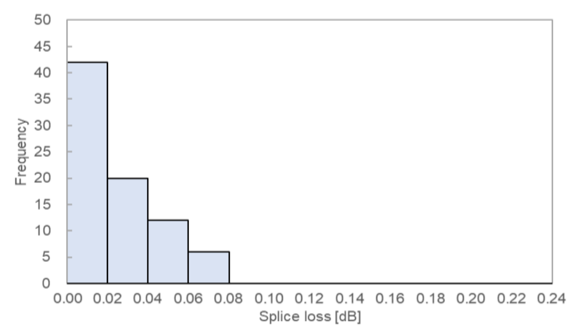
(a) Electric current dependence of average splice loss with standard error bar



(b) Average splice loss at optimized condition



(c) Average splice loss of each core with standard error bar with 2-electrode



(d) Average splice loss with 3-electrode

Fig. 4 Splice loss of 4 core fiber