# Supplementary Material 1: Single-mode Sapphire Fiber Temperature Sensor

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This Supplementary Material provides further details about the splicing parameters used in the paper. We used a Sumitomo Type-72C DH Core Aligning Fusion Splicer to splice the 100-µm diameter sapphire fiber (Jiangsu Jingying Optoelectronics Technology) to the 125-µm silica single-mode fiber (SMF28e+ or equivalent). The splicing was performed following the process described in our manuscript. The full list of splicing parameters for our customised splicing program is provided in Table 1. See Reference [1] for the meanings of the parameters.

**Table 1**: Customized splice program for the sapphire-silica splice (entire list included) for the Sumitomo Type-72C fusion splicer.

| | |
|---|---|
| Arc Power | STD – 40 step |
| Auto Power | Off |
| Gapset Position | STD + 0 dot |
| Cleaning Arc Time | 0.12 sec |
| Gap | 15.00 µm |
| Cleave Angle Limit | 20.00 deg |
| Fiber Detection | Off |
| Core Angle Limit | 5.00 deg |
| Arc Time | 2.00 sec |
| Prefuse Time | 0.15 sec |
| Prefuse Power | 100% |
| Overlap | 15 µm |
| Fiber Pulling | Off |
| Align Method | Diameter |
| Splice Method | Manual |
| Wavelength | 1.55 µm |
| MFD-L | 8.90 µm |
| MFD-R | 50.00 µm |
| MFD Mismatch Coef. | 1.50 |
| Est. Loss Coef. | 1.00 |
| Minimum Loss | 0.00 dB |
| Est. Loss Limit | 99.00 dB |
| Rearc Time | 1.50 sec |
| Rearc Power | Standard + 0 step |
| Proof Test | Off |
| Bubble Check | Off |

While the splicer does not have a designated program for splicing crystalline fiber to silica fiber, the optimum splicing parameters were found using an iterative process. Figures 1 to 8 show some images of example splices, taken with the built-in splicer camera. Figure 1 shows the fibers aligned before splicing, while Figure 2 shows the fibers after a good splice. Figures 3 to 8 show examples of bad splices, together with our suggestions for troubleshooting the failed splices.

The parameters listed in Table 1 give a greater than 50% splicing success rate, providing the sapphire fiber has a nicely polished end-facet, and the waveguide is close to the center of the sapphire fiber. We realize that the exact splicing parameters are different from splicer to splicer. However, we hope this Supplementary Material can provide some guidance for future research on splicing single-mode sapphire waveguides to single-mode silica-core optical fiber.

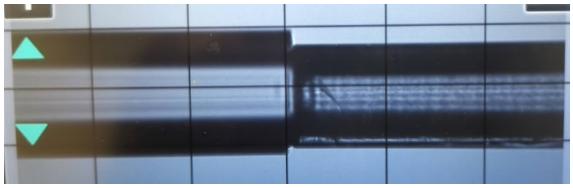


**Fig. 1**. Before splice: A silica fiber (SMF28e+, left) and a sapphire fiber (Jiangsu Jingying Optoelectronics Technology, right) inside the fusion splicer. The laser-written waveguide can be seen inside the sapphire fiber, as well as the small crack close the facet as a result of polishing. However, the precise location of the waveguide core cannot be identified due to the limited imaging capabilities of the splicer. The fibers were aligned using the iterative process described in detail in Section IV of the manuscript.

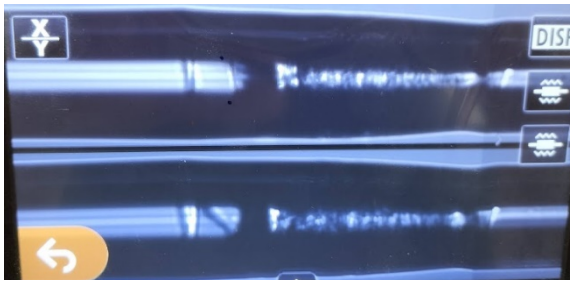


Fig. 2. After splice: An example of a good splice joint, where the waveguide core has been properly aligned with the single-mode fiber core. Please see Section IV of the manuscript for more details.



**Fig. 3**. Example of a failed splice joint: The splicing joint was fine and mechanically stable. However, the silica fiber shifted during splicing in the Y direction, causing misalignment between the silica fiber core and the sapphire fiber waveguide core. The failed splice was caused by inefficient polishing of the sapphire fiber end facet.

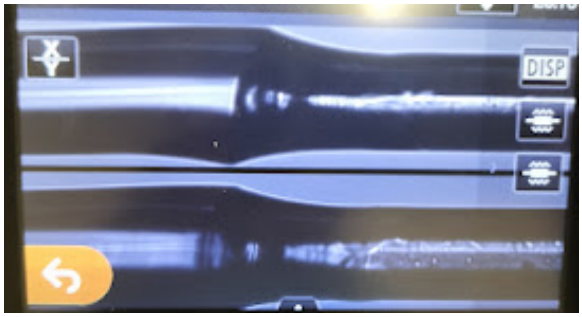



**Fig. 4**. Example of another failed splice joint: The silica fiber deformed during splicing and the cores were misaligned, which could be due to insufficient polishing or the sapphire waveguide not being located close enough to the center of the sapphire fiber. This could also be caused by the overlap distance being too large or the gap distance too small.

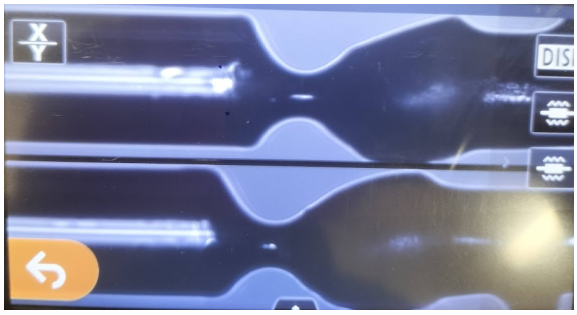


**Fig. 5**. Example of a failed splice joint: Both fibers were tapered and there was excess damage to the sapphire fiber. The arc time or arc current needs to be reduced. The gap needs to be decreased or the overlap needs to be increased.

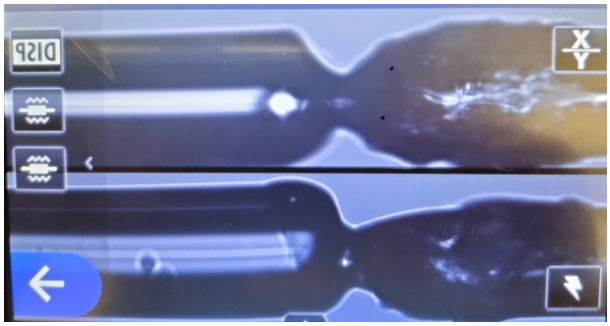


**Fig. 6**. Example of a failed splice joint: Both fibers were tapered and the sapphire fiber was slightly damaged. The arc time or arc current needs to be reduced. Either the gap needs to be slightly increased or the overlap needs to be slightly increased.

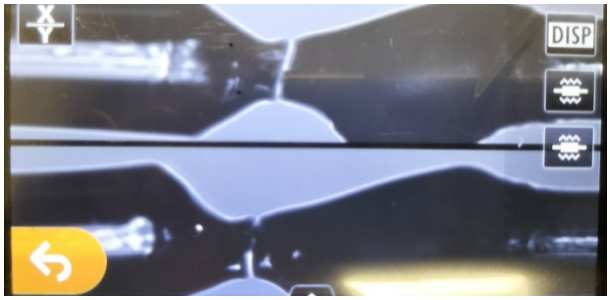



**Fig. 7**. Example of a failed splice joint: Both fibers were tapered, the sapphire fiber was slightly damaged, and the splicing joint cracked. The arc time or arc current needs to be reduced. The gap needs to be slightly increased or the overlap needs to be slightly increased. The crack is caused by insufficient polishing.

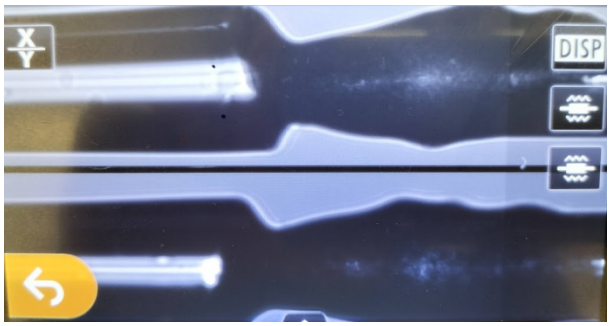



**Fig. 8**. Example of a failed splice joint: The sapphire fiber was excessively damaged and the silica fiber was deformed. The arc time or arc current needs to be reduced.

## Reference

[1] *Guide to operation TYPE-72C +*, OME2024078 / Ver.1.03, Sumitomo Electric Industries, Ltd., Tokyo, Japan, 2020, pp. 4-8.