Workability Improvement of Field Assembly Connectors and the Expansion of Their Application Domain

Daizo NISHIOKA*, Takayasu YAMAUCHI, Yasushi KIMURA, Yukihiro YOKOMACHI, Masahiro HAMADA and Kazuhito SAITO

This report describes workability advancement in field assembly connectors and their expanding applications. We have made every kind of improvement to the field assembly connectors throughout our manufacturing and development process aiming at excellent workability and accuracy in fiber de-installation and connector installation. As a result, we have successfully created a skill-free fiber butt-coupling method used for mechanical splice parts and an optical connector to visualize whether the assembly is successful or not on site. Furthermore, we have developed a high-performance connector which realizes a low return loss with angle splice technologies.

Keywords: mechanical splice, field assembly connector, FTTH, optical connector

1. Introduction

As Fiber-to the home (FTTH) service is rapidly increasing its popularity throughout the world, construction work to lead optical drop cable into houses needs to be streamlined.

In such construction, field assembly connectors are widely used due to the applicability to cable wiring and compact bodies which are easily stored in optical fiber housings such as optical network units (ONUs).

Thus field assembly connectors are attracting worldwide attention not only from the FTTH market but also from the optical LAN market for their capabilities.

We have made every kind of improvement to the field assembly connectors throughout our manufacturing and development process aiming at excellent workability and accuracy in fiber de-installation and connector installation. As a result, we have successfully created a skill-free fiber butt-coupling method used for mechanical splice parts and an optical connector to visualize whether the assembly is successful or not. Furthermore, we have developed a high-performance connector which realizes a low return loss. This report describes such advancement of the field assembly connector technologies.

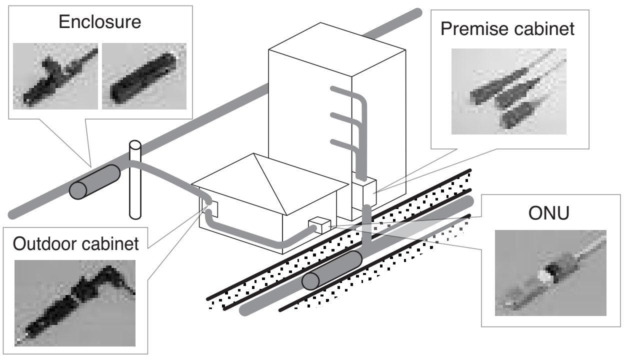

Fig. 1. Application domain of field assembly connectors in Japan

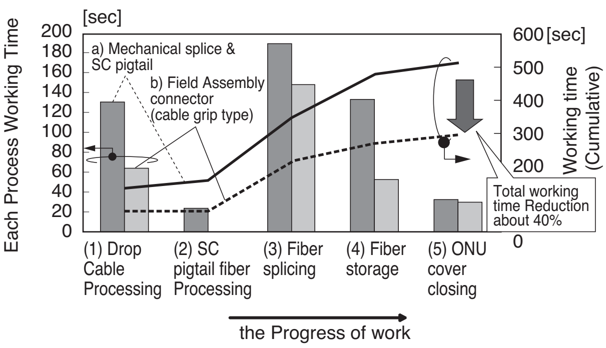

Fig. 2. Comparison of working time of fiber installation at ONU (Mechanical splice vs Field Assembly connector)

2. Application domain of field assembly connector

Figure 1 shows application areas of field assembly connectors in Japan. There are many areas in which field assembly connectors are used for FTTH access networks, such as in an enclosure, outside cabinet of home, inside ONU, and premise cabinet. By using these connectors, reduction/good arrangement of extra cable length, and to simplify fiber storing in an ONU or enclosure are realized.

Figure 2 shows working time comparison in ONU fiber installation between using SC connector pigtail and a mechanical splice, and a field assembly connector. The field assembly connector is a cable grip type, which can be assembled directly on the end of cable [(1) (2) (3)]. The horizontal axis shows element work in progress, and the vertical axis of left hand means an each process working time. We confirmed a large difference in process working time. As a result, cumulative working time, which is shown by the vertical axis of right hand, is shorter by 40% in a field assembly connector than in a mechanical splice and SC pigtail.

In addition to this time saving effect, it is expected that damages to fiber or mechanical splice parts by accidentally pinching will be prevented on connection changes or fiber route switching.

Consequently, from the standpoint of good arrangement, time reduction and quality management, field assembly connectors are mainly used currently.

3. Field assembly connectors which improve assembly success rate

3-1 Internal structure of connector

Figure 3 shows the internal structure of our field assembly connector. Optical fiber is built into a ferrule of the connector, and the ferrule end face is polished in a factory. Moreover, to allow for the mechanical fixation of optical fiber, a mechanical splice is formed at the end of the ferrule.

This mechanical splice is composed of plate A having a V groove, plate B which is flat above the V grove, and a clamp for the insertion of the two plates. The optical fiber has been positioned with high accuracy between the V groove and plate B, held securely by the spring power of the clamp.

Built-in fiber endface contains refractive index matching gel whose refractive index is the almost same as glass, and thus this structure can realize stable fiber splicing without generating the discontinuity of the refractive index with the insertion fiber.

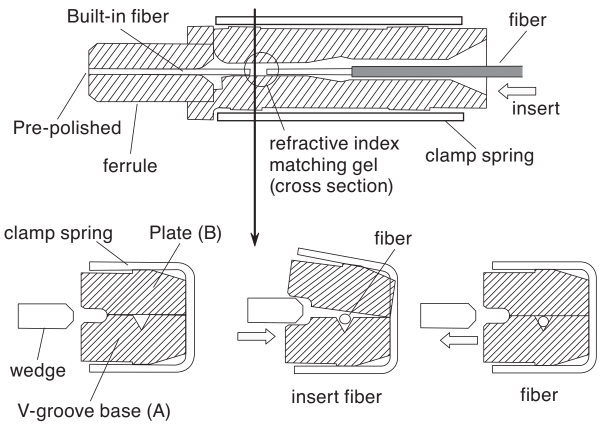

Fig. 3. Fundamental structure and mechanism of mechanical splice

3-2 Conditions of easy installation of field installable connectors

Through our development process, we considered that the following conditions are required in order to realize the stable assembly success rate and good workability of connectors.

1) No special tools: A worker of a construction company can work without additional equipment, except a stripper and a cleaver which are commonly used in construction.
2) Fiber length confirmation feature: Fiber length confirmation gauge is equipped in connector parts. This feature leads to smooth work because the worker can confirm it in a sequence of working process. Fiber length is very important in success of connector assembly.
3) Equipment of fiber insertion guide: This is necessary for stable fiber insertion after cleaving. This feature can prevent from damaging caused by fiber top contact with something.
4) Keeping insertion fiber butt-coupling with built-in fiber: An evidence of insertion fiber contact with built-in fiber is bending of fiber coating outside the connector. The bending is desirable to be kept in that shape after the fiber contact. This feature leads to certain fiber contact.
5) Judgment of good or no good assembly on site: A worker can judge an assembly connector is good or no good assembly on site.
6) Elimination the number of unnecessary parts after assembly: By eliminating unnecessary parts not attached to the connector, waste generation after assembly is reduced.

By satisfying these requirements, a lower failure rate of connector assembly will be expected even if workers do not have enough experience of assembling connectors in field. We introduced two types of connectors for different cord/fiber which equipped these features.

4. Field assembly connectors for cord

4-1 structure

We have developed a field assembly SC connector for ø3mm cord used for drawing fiber to a home in overseas FTTH access networks. The structure is shown in **Photo 1** and points of assembly procedure are shown in **Photo 2**. In our conventional connector assembly process for cord, a special crimp tool is required to fix aramid yarns existing inside the cord to the connector. In order to decrease special crimp tools, we adopted a screw mechanism to fix

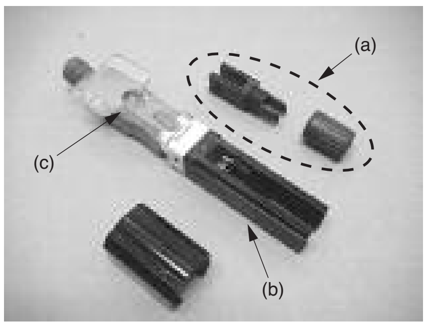

Photo 1. Field assembly connector for 3 mm cord

aramid yarns with two cable grip parts. (**Photo 1 (a), Photo 2 (1) and (2)**). This fixing method can fix not only aramid yarns but also cord sheath, so that we can assure cable retention and twist properties at the same time. We also equipped fiber length confirmation gauge on the outer housing, so that a worker does not need a rule or other gauge except the connector. The housing also performs as fiber inserting guide (**Photo 2 (3)**). After insertion of fiber and contact to built-in fiber, the cable grip parts can be fixed to the connector and fiber coating outside the connector is bent. The condition is kept in the process and leads to certain fiber contact.

In addition, we adopted a transparent material in mechanical splice which fixed fiber inside the connector and also in a wedge part. Through a given hole of outer housing, inside the connector can be checked. When a visible light source is introduced from the connector ferrule, a part of failure in the connector assembly, if any, will emit light, and thus, workers can judge his assembled connector is good or no good on site.

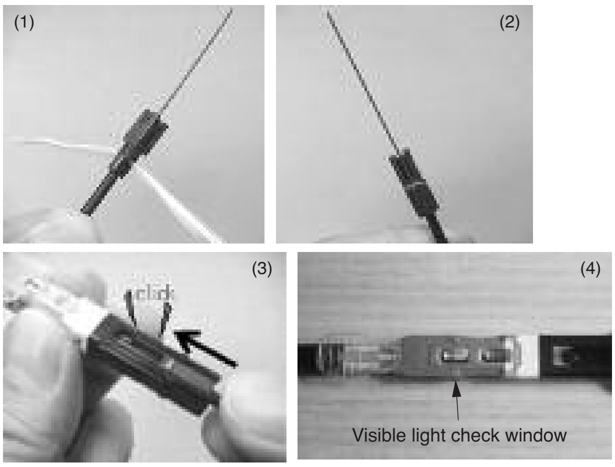

Photo 2. Outline of assembly procedure of field assembly connector for ø3 mm cord

4-2 Reliability test results

We measured assembly time of a field assembly connector for ø3 mm cord. Its average time was under 3 minutes and we confirmed that it was reduced by half compared with a conventional connector using a crimp tool.

We also conducted various tests on the connectors for ø3 mm cord. **Table1** shows the reliability test results. The maximum insertion loss is 0.42 dB, and mechanical and environmental characteristics are also good results. We assembled the connector with shorter cleaved fiber intentionally as the simulation of assembly failure, and introduced visible light source from the ferrule. We could see light emitting from the inside of the connector through the hole of the housing. As a results, we confirmed that a worker can judge if the connector is successfully assembled or not on site.

Table 1. Reliability test results of field assembly connector for ø3 mm cord (SM type)

Test Item	Test Condition	Results
Insertion loss	λ =1.55μm	Avg.0.24dB Max.0.42dB
Return loss	λ =1.55μm	Avg.51.9dB Min.48.3dB
Tensile	10N, 1min	⊿IL≦0.15dB
Flex	4.9N ±90° ×10cyc.	⊿IL≦0.15dB
Twist	4.9N @30mm ±90°×10cyc.	⊿IL≦0.15dB
Temperature cycle	-40~75˚C,12cyc.	⊿IL≦0.20dB
Damp heat	40˚C, 95%RH,96hr.	⊿IL≦0.20dB

5. Field assembly connector for ø0.9 mm fiber

5-1 Structure and assembly process

Under the same foregoing development concept, we have also developed a field assembly LC connector for ø0.9 mm fiber, which is highly demanded in the LAN market. ø0.9 mm fiber is stiffer than ø0.25 mm fiber. With our existing product, an inserting fiber can be broken in the assembly process when inexperienced workers assemble it pressing so hard. Therefore, we have focused on such failure aiming at reducing the failure rate even if amateur workers can manage in this process. In addition, to satisfy other requirements shown in 3-2, we also developed a new fiber holder. The holder and connector components are shown in **Fig. 4**. This holder is so simple and composed of plastic mold parts that it can be attached with connector products.

Photo 4 shows the assembly procedure. A connector is set to fiber insertion guide **(1)** and after stripping, set to the fiber holder **(2)** and cleaving **(3)**. After that, fiber length can be checked on the fiber insertion guide **(4)**. Throughout the process, the fiber is fixed to the holder with cover (a)~(c) in order to cleave a setting length without fluctuation. The fiber holder can slide along the insertion guide **(5)**.

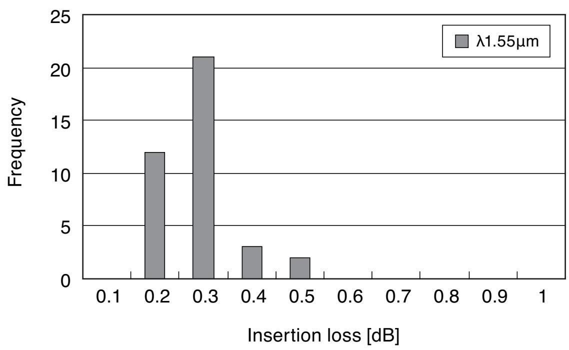

Fig. 4. Insertion loss distribution of field assembly connectors for ø3 mm cord (SM type)

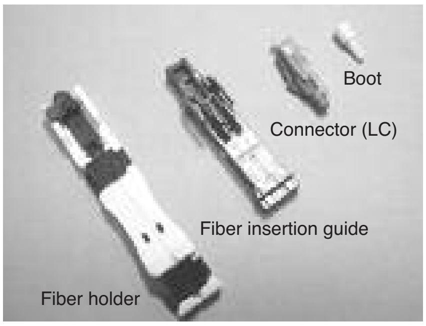

Photo 3. Composition of LC connectors for ø0.9 mm

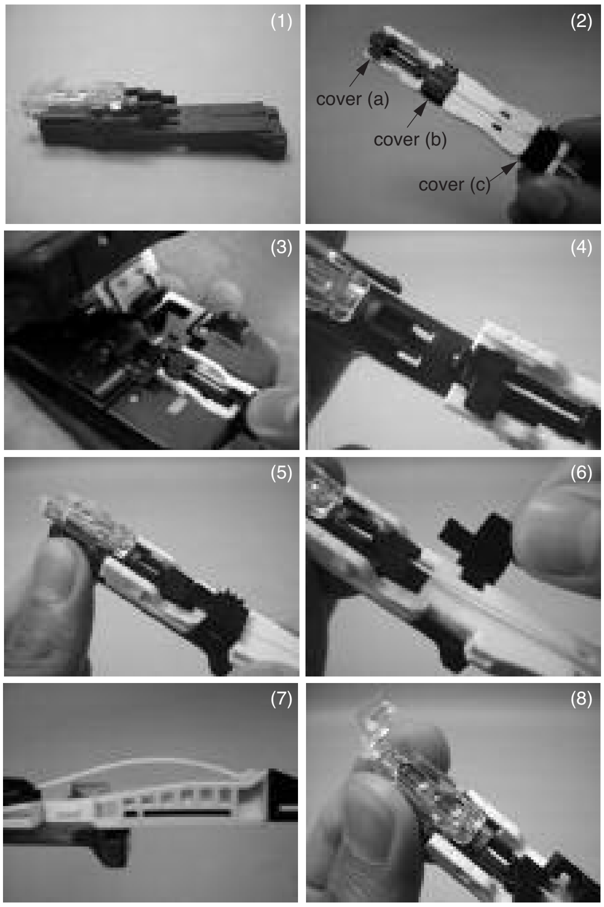

Photo 4. Outline of assembly procedure of LC connector for ø0.9 mm fiber

According to our examination, suitable fiber length and bending prevent fiber inside the connector from being broken. If the cover (a) and (b) are rigid, the fiber might be broken in assembly process because the fiber pressing force is too much. Therefore, we designed the fixation of cover (a) to be rough so that workers must remove cover (b) to assemble the connector.

The sequence is as follows. Firstly, a fiber holder stops once before the insertion fiber contacts the built-in fiber. And if cover (b) is not released, the holder does not move any more. Therefore, a worker must open cover (b) to finish the assembly process.

After that, the fiber holder can be moved forward and fiber contact is completed. The bending shape of fiber coating is like **(7)** and that is suitable for successful assembly. It can also be kept in that shape). By following this sequence, even amateur workers can assemble connectors successfully. The process is finished when a wedge is released and a boot is attached.

Like our ø3 mm cord connector, this product has also transparent parts and housing, and thus, a worker can judge if his assembled connector is good or not on site by using visual light source.

5-2 Reliability test results

We conducted an experiment in which 3 amateur persons assembled the connector and the insertion loss and working time are measured. The assembly time results are shown in **Photo 4** and insertion loss results in **Fig. 5**. Average time is less than 3 minutes and the maximum insertion loss is 0.18 dB. We considered that those results are sufficient for practical use.

We also conducted various test on LC connectors for ø0.9 mm fiber (MM50 type). **Table 2** shows the reliability test results.

6. Low return loss field assembly connector

6-1 Structure and performance

For the conventional field assembly connector com-

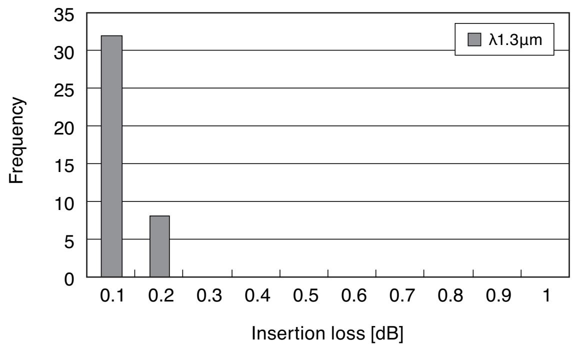

Fig. 5. Insertion loss distribution of assembled connectors for ø0.9 mm fiber by amateur worker

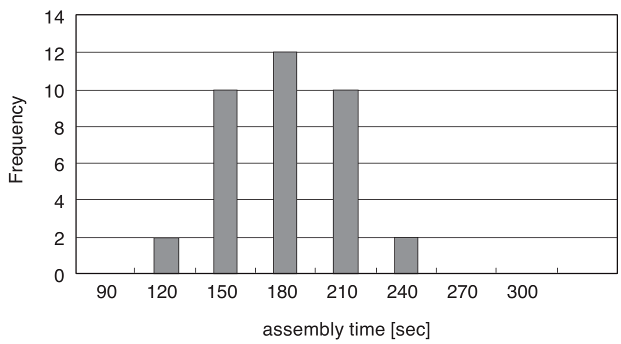

Fig. 6. Working time of connectors for ø0.9 mm fiber (MM50 type) by amateur worker

posed of a mechanical splice, insertion fiber and built-in fiber is cleaved at a right angle. For this reason, its return loss can not be expected less than 40 dB. Thus the connector is unlikely to be applied to the analogue transmission network of video service.

We developed a new APC polished field assembly connector that realized a low return loss. The built-in fiber is angle-cleaved and the insertion fiber is also angle-cleaved by an angle cleaver. This method compensates for slight index mismatching between the glass and gel, realizing a low return loss property. We conducted various test on the angled fiber splice connectors for ø0.9 mm fiber. **Table 3** shows the reliability test results. Minimum return loss is as low as 61.5 dB. Each mechanical and environmental characteristic shows a good result. The temperature property of return loss is especially stable with over 55 dB (**Fig 7**). This connector is expected to be adopted into a low return loss environment such as analog transmission network.

Table 2. Reliability test results of field assembly LC connector for Ø0.9 mm fiber (MM50 type)

Test Item	Test Condition	Results
Insertion loss	λ =1.3μm	Avg.0.08dB Max.0.18dB
Return loss	λ =1.3μm	Avg.40.2dB Min.32.9dB
Tensile	3N, 1min	⊿IL≦0.00dB
Flex	0.2N ±90° ×10cyc.	⊿IL≦0.00dB
Vibration	1.5mmp-p 10-55MHz	⊿IL≦0.05dB
Impact	100G 6ms 3-direction	⊿IL≦0.05dB
Temperature cycle	-10~65°C/93%RH 24hrs×10cyc.	⊿IL≦0.10dB
Dump heat	40°C, 95%RH, 96hr.	⊿IL≦0.10dB

Table 3. Test Results of field assembly angled polished SC connectors for Ø0.9 mm fiber (SM type)

Test Item	Test condition	Results
Insertion l loss	λ =1.55μm	Avg.0.22dB Max.0.59dB
Return loss	λ =1.55μm	Min.61.5dB
Tensile	3N, 1min	⊿IL≦0.15dB RL≧65dB
Vibration	1.5mmp-p 10-55MHz	⊿IL≦0.15dB RL≧65dB
Impact	1.5m free fall×5times	⊿IL≦0.15dB RL≧65dB
Temperature cycle	-25~70°C,12cyc.	⊿IL≦0.20dB RL≧55dB
Damp heat	40°C, 93%RH, 96hr	⊿IL≦0.20dB RL≧55dB

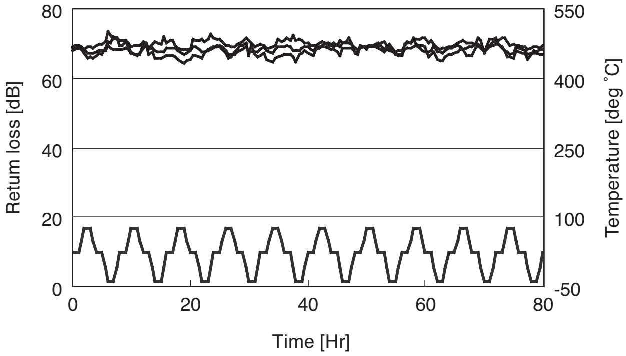

Fig. 7. Return loss properties of field assembly angled polishes SC connectors for 0.9 mm fiber at heat cycle test

7. Conclusion

The settings of the conventional field assembly connectors composed of mechanical splices depended on worker's skill. Therefore, we made the skill-free fiber butt-coupling method used for mechanical splice parts by adopting the structure which keeps a bending state. In addition, we enabled to visualize whether the assembly is successful or not by using visual light source. Furthermore, we developed high-performance connectors which realize a low return loss by angle splice technologies. They can be applied even to analog transmission systems. We confirmed the high reliability of these connectors and expect that they will contribute to the workability improvement and expansion of FTTH wiring and LAN wiring systems in the future.

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Contributors (The lead author is indicated by an asterisk (*)).

D. NISHIOKA*

- Assistant Manager, Fiber Management Products & Systems Department, Lightwave Network Products Division
  He is engaged in the development of optical connectors and other optical connection items.

T. YAMAUCHI
- Assistant General Manager, Fiber Management Products & Systems Department, Lightwave Network Products Division

Y. KIMURA
- Fiber Management Products & Systems Department, Lightwave Network Products Division

Y. YOKOMACHI
- Assistant General Manager, Fiber Management Products & Systems Department, Lightwave Network Products Division

M. HAMADA
- Manager, Fiber Management Products & Systems Department, Lightwave Network Products Division

K. SAITO
- General Manager, Fiber Management Products & Systems Department, Lightwave Network Products Division