History and Vision of Optical Fiber Fusion Splicing Technology

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Sumitomo Electric Industries, Ltd. released the TYPE-3 fixed V-groove optical fiber fusion splicer for multi-mode fibers in 1980. Over the years, optical fiber fusion splicing technology has been making steady progress with the advancement of optical fiber production technology and the development of new jointing methods. This paper looks back at the history of splicing technology and highlights the technology that marked a crucial turning point in the progress. We also discuss our perspectives on how the technology can make further headway in the future.

Keywords: optical fiber, fusion splicing, direct core monitoring, wireless LAN

1. Introduction

An optical fiber fusion splicer is an apparatus that instantly connects two fibers placed left and right on the apparatus by fusing the end surfaces of the fibers at a high temperature (approximately 1,800°C) created by arcing (Fig. 1).

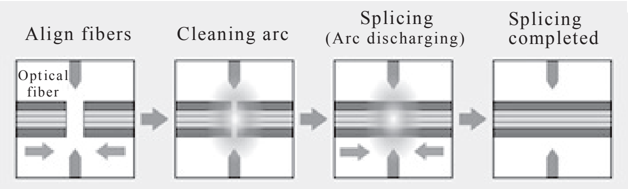

Fig. 1. Arc fusion splicing

Compared to many other countries, optical fiber cable installation in Japan is highly advanced. As data communication services for the home—Fiber-To-The-Home (FTTH)—become widely available, the people benefit from high capacity data transmission services for the Internet, television, and mobile communications. At the same time, optical fiber network construction is rapidly progressing across the world. This increases use of fusion splicers for installing backbone and FTTH networks, as well as in the assembly factories of fiber optic communication devices.

Sumitomo Electric Industries, Ltd. started sales of its first fusion splicer, the TYPE-3, in 1980, and at that time the fusion splicer was designed only for multi-mode fiber (MMF/ITU-T G.651)*1. With this type of splicer, operators needed to splice the optical fibers while observing them in the V-shaped groove of the splicer through an attached microscope in order to accurately align the outer diameters of the fibers. The splice loss therefore depended on the operator's skill and experience, yet the MMF could still deliver a low splice loss thanks to its large core diameter and splicing with the fixed V-groove method. In 1982, Sumitomo Electric developed a new fusion splicer, the TYPE-11, to support the splicing of single-mode fiber (SMF/ITU-T G.652)*2, which has a core diameter only one-fifth that of MMF. This splicer contributed to Japan's first installation of fiber optic relay systems. The TYPE-11 fusion splicer was equipped with a fiber aligning mechanism having a light source and a light receptor at the far ends of each of the fibers to be spliced. With this mechanism, the fiber core was aligned at the point where the receptor detected the maximum amount of light from the light source. However, since the light source and the power meter had to be set up at locations some hundred meters or even several kilometers apart, splicing required rather too much preparation and time. To work around such issues and achieve stable splicing, we developed the direct core monitoring technology whereby the core is aligned by directly monitoring the fiber core through a microscope. This technology was originally developed for submarine cable installation but further evolved for use in land network installations.

2. Optical Fiber Splicing Technologies

2-1 Optical fiber core direct monitoring technology

Sumitomo Electric first employed the technology to directly monitor the optical fiber core in the TYPE-33 fusion splicer, which was launched in 1984. The TYPE-33 utilized a microscope equipped with a high-precision and-

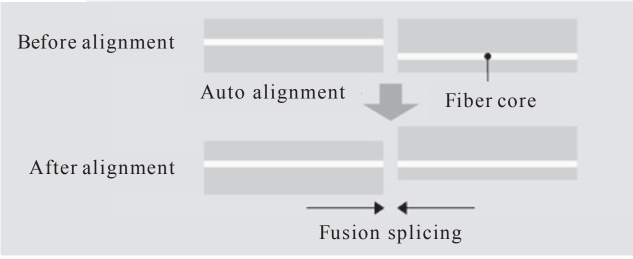

Fig. 2. Core alignment by direct monitoring

high magnification object lens to observe the core of the optical fiber. The succeeding TYPE-34 adopted a CCD camera*3 for such monitoring. The camera automated the monitoring and alignment of the core of the optical fiber (Fig. 2), enabling stable fusion splicing with low splice loss.

2-2 Downsizing and weight reduction

The TYPE-34 became larger in size and weight compared to its predecessors as it processed the image using a CCD camera, a circuit board, and a monitor.

At the same time, as optical fiber networks became more widespread in Japan, cable installation sites also became diverse. Installation used to take place only in station buildings and cable tunnels but installation in the available space within sewerage tunnels and aerial distribution became more common. Along with such changes in the installation environment, demand increased for fusion splicers to be smaller and lighter for better mobility.

To respond to such needs, Sumitomo Electric developed more compact and lighter products by employing a compact image sensor such as CMOS*4, dedicated LSI*5, and multi-layered high-density printed circuit board. In the latter half of the 1990s, the company started developing a battery-operated model to meet demand for usage in locations where an AC power supply was not available. From 2000 onwards, compact, light, and battery-operated fusion splicers became Sumitomo Electric's mainstream products.

2-3 Environmental durability

The spread of optical fiber networks accelerated across the world and from this came increased demand for fusion splicers that could be used in harsh environments. In Japan, the splicers were required to be windproof so that they could be utilized at a height, such as at the top of pylons and electricity poles. While in other countries, more diverse weather durability was required, such as protection against higher and lower external temperatures, differences in elevation, dust, water, and shock. Nowadays, fusion splicers are required to be compliant with a range of standard grades concerning operating environments, such as operating temperatures between -10°C and 50°C (storage temperatures between -40°C and 80°C), altitudes between 0 m and 5,000 m, and water and dust resistance. All of our fusion splicers meet such requirements. The shockproof capabilities of the splicers have been particularly improved through their size and weight reduction as well as the adoption of shock absorbers to reduce the impact transmitted to important components.

The following sections describe the features of Sumitomo Electric's optical fiber fusion splicer technologies and future prospects after 2000.

3. Features of Sumitomo Electric's Optical Fiber Fusion Splicer Technologies

3-1 Dual heaters

After the year 2000, with the increasingly widespread use of optical fibers, one of the issues associated with fusion splicing was the time needed to heat the splice protection sleeves used to reinforce the splice. At that time, splicing time was about 10 seconds, while the protection sleeve heating time required some 50 seconds. There arose demand to shorten the sleeve heating time for more efficient cable splicing work. The solution to this issue was the world's first dual heater mechanism, which was installed in our TYPE-39 splicer (Photo 1).

Photo 1. TYPE-39

Adoption of this dual heater mechanism eliminated the waiting time, which eventually led to the splicing technique adopted in China, where multiple operators handle different tasks using a single fusion splicer. At the same time, the dual heater mechanism presented a new requirement in fusion splicers: an increase in power capacity to operate the two heaters continuously. To work around this, Sumitomo Electric improved the heater structure to reduce the required heat capacity and increase thermal conducting efficiency to the splice protection sleeve. As a result, the protection sleeve heating time was reduced to 35 seconds. This in turn reduced the increase in the required power capacity to less than 20%, which also contributed to keeping fusion splicers compact in size.

3-2 Automatic fiber profiling detection

Towards 2010, a bend insensitive fiber (BIF/ITU-T G.657) was introduced for home optical fiber cable installation purposes. This fiber featured less optical power attenuation even when bent sharply. Fusion splicers were then required to handle this new fiber. Splice programs for BIF were different from those for single-mode fiber because the core of BIF is surrounded by holes and cladding with additional dopants*6. Thus, operators needed to vary splice programs depending on the type of optical fibers. The difficulty was that operators could not visually distinguish SMF and BIF as they appear identical, so the operators first needed to determine the fiber types using the attached specification documents. If they failed to identify the fibers and spliced them under the wrong program, the network quality was compromised due to increased splice loss and other defects. This prompted the need for fusion splicers to be able to detect the fiber type, set the optimum splice program, and then actually splice them all in an automated manner. Sumitomo Electric responded to this need with a new function that detects the optical fiber type from a processed image acquired through our exclusively high-magnification and high-precision object lens and camera technologies. When observing the profile of an optical fiber at an optimum focusing distance, a certain profile pattern of light and dark areas appears at the core. Sumitomo Electric's conventional fusion splicers identified the position of the core by processing an image of this pattern. Utilizing the fact that these light and dark profile patterns differ between SMF and BIF, an algorithm was developed to detect the optical fiber type and installed in a new model. This function enabled operators to deliver high-quality fusion splicing without having to manually confirm the optical fiber type.

3-3 The world's smallest and lightest splicers

Compactness and lightness of a fusion splicer are critical in FTTH installations where efficient work in a limited space, such as on top of a pole, is essential. Sumitomo Electric's TYPE-25 compact fusion splicer had already enjoyed popularity thanks to its compactness and efficiency. However, needs for even smaller and more efficient splicers, a low-profile model in particular, increased due to requirements to splice fibers within a fiber enclosure. The company then redesigned the splicer structure by integrating control circuits that had been separated according to functions in previous models, and also by downsizing the monitoring equipment such as the object lens and camera. This led to the release of the TYPE-201 compact fusion splicer series (Photo 2) in 2013, which boasted the world's smallest and lightest body.

Photo 2. TYPE-201 series

3-4 Improvement in operability

Around 2010, smartphones became even more popular in Japan as use of mobile devices accelerated thanks to their convenient touch screen operations. Accordingly, the user interface of various devices shifted from physical button operations to touch screen operations. This coincided with the time when fusion splicers' operations became more complex to support diversifying optical fibers, making it necessary to further improve operability. In 2011, Sumitomo Electric released the TYPE-71 series (Photo 3), equipped with the industry's first touch screen, shifting the user interface from the conventional button-based input to more intuitive panel operations.

Installing a touch screen to a fusion splicer faced difficulties in ensuring durability against weather, temperature, and shock, just as required by the splicer itself. We adopted reinforced glass, which is highly weather-proof and physically durable, as the panel surface, and designed the structure to be well sealed against dust and water. Thus, we created a touch screen that would withstand harsh outdoor use.

Photo 3. TYPE-71 series

Recent technological movements around Internet of Things (IoT) and Big Data have also influenced fusion splicers, creating a growing demand for the capability to record splicing work details, such as work dates, and splicing conditions and data. Furthermore, requirements for easy maintenance of data and functions for splicer operation management increased. In particular, ease in managing data on the fusion splicer as in a smartphone is becoming more important, and such data management functions include utilization of a massive volume of images and splice data, and batch update of software. To enable such data management operations, Sumitomo Electric released the TYPE-71C+ fusion splicer with a wireless LAN function in 2015.

3-5 Fusion splice management system

Due to advancement of the Internet and telecommunication technologies, IoT technologies are claiming society's attention. With this backdrop, Sumitomo Electric developed the SumiCloud system (Fig. 3), which enables management of fusion splicer data over the Internet. The system stores and manages data, such as fusion splicing work details and work locations, which are shared between fusion splicers connected to the cloud server.

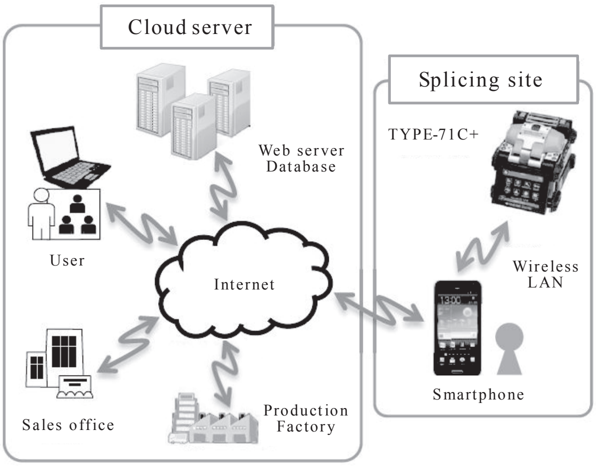

Fig. 3. SumiCloud system configuration

Using data management functions within the cloud server, managers of fusion splicing projects can remotely view the installation status and fusion splicer conditions, check the splicing quality, and manage installation schedules in a more efficient manner.

4. Future Prospects

To build high-speed telecommunication infrastructures, fiber cable installation will continue across the world. Various countries are competitively developing new generation technologies, such as multicore fibers and other types of fiber development towards 5th generation communications, and small-diameter super-multicore cables. It is important to establish fusion splicing technologies that can handle all types of optical fiber in order to realize more advanced optical communications. For this purpose, we continue our development of optical fiber direct monitoring technology and associated technologies.

5. Conclusion

This paper has followed the history of optical fiber fusion splicing technologies and introduced the key developments that have contributed to the evolvement of splicers. Sumitomo Electric continues to develop high-precision, high-performance, and highly-valued optical fiber fusion splicing technologies and offer them to the market.

- SumiCloud is a trademark or registered trademark of Sumitomo Electric Industries, Ltd.

Technical Terms

∗1 Multi-mode fiber/MMF: MMF is used for communication over short distance, such as LAN and datacenter. The core of MMF has a refractive index profile gradually changing from the center of the core to the cladding, which enables multiple of transmission light (mode) travel with nearly the same velocity.

∗2 Single-mode fiber/SMF: It is the most common optical fiber in the world. SMF is tuned to minimize the dispersion (which gives the deformation to the signal) around the wavelength at 1310 nm.

∗3 CCD camera: Charge Coupled Device camera.

∗4 CMOS: Complementary Metal Oxide Semiconductor

∗5 LSI: Large Scale Integration.

∗6 Dopant: Materials mixed to attain an optimum refractive index distribution.

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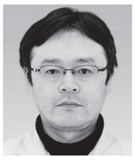

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