Development of 6912F Ultra-high Density Optical Cable with 200µm fiber Rollable Ribbon

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Abstract
In order to realize the ultra-high-density optical fiber cable demanded by the expansion of datacenters, we have developed a 6912F optical fiber cable using 12F rollable ribbon made from 200µm-diameter optical fiber. This cable achieves an external diameter under 30mm at 29mm, and it is possible to lay in 1.5-inch ducts. This cable has the worlds' highest core density at 10.5 cores/mm². The 12F rollable ribbon using 200µm fiber can be fusion spliced in the same way as conventional ribbons, and because of the small size ribbon and protection sleeve, high density, compact storage in the closures, cabinets, distribution frames and so on is also possible. We have confirmed that the cable we have developed shows favorable results in evaluations of various characteristics, and no problems occurred in its practical use.

Keywords: Optical fiber cable; Rollable ribbon; UHFC; 200µm.

1. Introduction
Global data traffic is increasing with the spread of internet services. Furthermore, datacenter traffic is also rapidly increasing with the swift increase in the use of the cloud applications. Demands of data centers are expected to expand in the future too with the increase of IoT (Internet of Things) applications (smart cars, smart cities, etc.).

In hyper-scale datacenters, multiple servers in multiple data centers are connected in parallel, and an architecture adopted in which a single, virtual, computer is constructed from these. In order to access remote servers and storage as though they were local, it is necessary to connect many cabinets and devices together using high-speed, high reliability optical fiber, and as such demand for ultra-high fiber count optical fiber cables is increasing.

From this background, in recent years, ultra-high fiber count optical fiber cable with rollable ribbon using 250µm-diameter optical fiber has been developed [1] and its deployment begun. However, because the outer diameter of optical cable laid inside ducts is restricted by the inner diameter of the duct, a breakthrough technology has been needed in order to achieve an ultra-high fiber count optical cable subject to a restricted outer diameter.

While basic studies [2] using multicore fiber as one method of achieving ultra-high fiber count optical cables have also begun, 200µm fiber has already begun to be used as a technology for achieving small diameter optical cables in micro-cable applications, chiefly installation in micro-ducts.

In this study, we developed a 6912F ultra-high fiber count optical cable by combining rollable ribbon and 200µm fiber technologies together with the technology for producing cable implementing these at high-density.

2. Cable Design

2.1 Rollable Ribbon
Figure 1 shows the structure of the ribbon used in this study. So-called rollable ribbon is constructed from 12 colored fibers intermittently bonded into a net structure. When rollable ribbon is sheathed within a cable its shape can be changed and can be rolled up. As a result, despite the cable being structured from ribbons, it is possible to achieve a cable with a high-density, small diameter and low weight equivalent to cable constructed from single fibers. Furthermore, because the ribbon shape of the rollable ribbon is restored when removed from the cable, mass fusion splicing using a fusion splicer is possible in the same way as for conventional optical fiber ribbon, and the duration of the splicing operation, a source of concern for ultra-high fiber count cables, can be greatly reduced. By printing barcodes on the ribbon, we have made it possible to identify ribbon numbers.

To date, investigation and commercialization of conventional rollable ribbon cabling constructed using 250µm fiber has mainly been advanced, however, in this study 200µm fiber was applied to rollable ribbons.

2.2 Bundled Unit
Figure 2 shows the structure of the bundled unit. The 6912F cable is constructed from 48 units, each unit consisting of 12 ribbons each with 12 fibers. In order to distinguish the 48 units, two strips of plastic tape were wrapped around 12 ribbons, and these intersections fastened with glue to make it difficult for the unit bundles to collapse. Adjusting the winding pitch of the plastic tape maintains cohesion and made it easy to distinguish from other units. Furthermore, by changing the color of the two strips of plastic tape, it was made possible to determine the unit number from the combination of colors.
2.3 Cable
Figure 3 shows the cable structure. The cable core was constructed by 48 144F units. The cable core was encased in water absorbent non-woven fabric for waterproofing, and two dielectric strength members and two rip cords were sheathed together in black polyethylene to form a cable. Because this is an entirely dry construction that does not use jelly inside the cable, workability during laying operations is favorable.

![Figure 3. Cable structure](image)

2.4 Cable Core Design
When designing cables, the density of the cable core is an important parameter. If the density is too high, the movement of the optical fiber within the cable core is impaired. As a result, this causes increases in transmission loss, especially under the condition of the expansion and contraction of the cable from thermal changes and external mechanical forces like bending, lateral pressure, impacts, etc. On the other hand, where density is too low, the flow of water cannot be stopped in the unlikely event the interior of the cable is flooded. This also leads to unnecessary enlarging of the cable. Cable core density was defined as follows:

\[
\text{Cable core density} = \frac{S_2}{S_1}
\]

\(S_1\): Cross sectional area of the inside of the water absorbent non-woven fabric
\(S_2\): Cross sectional area of the ribbons and the bundling tapes

Figure 4 shows the cable core density with respect to the cross-sectional area of the cable core we designed. A design utilizing 250µm fibers has already been achieved. The design used in this study is one utilizing 200µm fibers. Through prototyping and evaluation, it was understood that a density with a good balance of various characteristics is almost the same in cables using 200µm and 250µm fibers.

Based on the design described above, Figure 5 shows the outer diameter of the cable including the sheath. When compared with 3456F cable, rollable ribbon cable using 200µm fiber can reduce the outer diameter by about 16% compared to ribbon loose tube cable, however, using the 200µm fiber the outer diameter can be reduced by about 30%. The 6912F cable developed in this study achieved a diameter below 30mm at 29mm, and it is possible to lay this in a 1.5inch duct. The core density of this cable is 10.5 cores/mm², the world’s highest. Moreover, with a mass of 0.64kg/m, a reduction in weight was also achieved.

![Figure 4. Cable core density](image)

![Figure 5. Cable diameter](image)

3. Characteristics
3.1 Fusion splice of 200µm fiber rollable ribbon
We confirmed batch fusion splicing of 12F rollable ribbons comprised of 200µm diameter optical fiber. The following tools were prepared in order to splice the 200µm fiber rollable ribbons, which is thinner and narrower compared to 250µm fiber ribbons: A fiber holder and thermal stripper used to remove the coating, adjusted to the outer diameter of the ribbon; a conventional fiber cleaver was used. For the fusion splicer, the V-groove used to guide the fiber once the coating has been removed was changed to a new one with 200µm pitch. Figure 6 shows the steps of the fusion splicing process. The workability and working time of the 200µm fiber rollable ribbon is about the same when compared to the 250µm fiber rollable ribbon. Figure 7 shows the results of measurement of splice loss in various ribbons. These splice losses are almost the same, and it was confirmed that 200µm fiber rollable ribbon is as spliceable as 250µm fiber rollable ribbon.
3.2 Mechanical characteristics
Table 1 shows the results of testing the mechanical properties of the 6912F cable. Loss increasing during mechanical property testing was measured at a wavelength of 1550nm. Favorable results were obtained from various tests.

<table>
<thead>
<tr>
<th>Item</th>
<th>Condition</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile</td>
<td>IEC 60794-1-21 Load: 2700N</td>
<td>&lt; 0.10dB</td>
</tr>
<tr>
<td>Crush</td>
<td>IEC 60794-1-21 Load: 2200N/100mm Holding time: 1min</td>
<td>&lt; 0.10dB</td>
</tr>
<tr>
<td>Impact</td>
<td>IEC 60794-1-21 1N × 1m</td>
<td>&lt; 0.10dB</td>
</tr>
<tr>
<td>Repeated bending</td>
<td>IEC 60794-1-21 Sheave diam.: 20 × cable diam. Cycle: 10</td>
<td>&lt; 0.10dB</td>
</tr>
<tr>
<td>Torsion</td>
<td>IEC 60794-1-21 ±90 deg. / m Cycle: 3</td>
<td>&lt; 0.10dB</td>
</tr>
</tbody>
</table>

3.3 Temperature characteristics
Table 2 shows the results of conducting a 3-cycle temperature cycling test, holding the 6912F cable at temperatures of -30°C ~ 70°C for 6 hours. The maximum loss increasing was within 0.1dB/km, a favorable level posing no challenge to practical use.

<table>
<thead>
<tr>
<th>Item</th>
<th>Condition</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature cycling</td>
<td>IEC 60794-1-22 -30°C ~ 70°C Holding time: 6 hours for each temp. Cycle: 3</td>
<td>&lt; 0.10dB/km</td>
</tr>
</tbody>
</table>

4. Joint Closure
Comparing 200µm fiber rollable ribbon to conventional 250µm fiber rollable ribbon, because the width is narrower it is also possible to use the small protection sleeve that shields the fusion spliced section. Figure 8 shows an instance where 2 6912F cables are spliced and housed within a joint closure. We confirmed the possibility of splicing 6912F cable by modifying part of a joint closure designed to be used with 250µm fiber 3456F cable.

The ability to pack protection sleeves in high density and in a small form is regarded as further contributing to the miniaturization and high-density installation of OCEF (Optical cable entrance facility) and the distribution frames and so on.

5. Conclusions
We have developed a 6912F optical fiber cable which boasts the world’s highest core density using a 12-core rollable ribbon constructed from 200µm diameter optical fiber. The 200µm fiber 12F rollable ribbon has the same splicing characteristics as conventional ribbon, and the splicing segments can be packed at high density and in a small form. We confirmed that the developed cable shows favorable results when evaluating various characteristics, and that there are no problems in its practical application.
6. References


7. Pictures of Authors

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