ULTRA COMPACT INDOOR OPTICAL FIBER CABLES & APPLICATIONS

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Abstract
Demand for small diameter, but very high fiber count cables has exploded in recent years. This demand is due to the high connection design architecture of the datacenter expanding in a limited amount of internal real estate. The limitations exist in overloaded cable trays and in ducts between data halls and throughout the datacenter campus. This has sparked the demand for more compact, yet higher fiber count cables for the indoor environment. A new ribbon and cable design using pliable ribbons has greatly increased the density of previous cable designs. The new cable designs meet or exceed the industry standards and alleviate the issues with space in the indoor environment.

1. Introduction
Fiber rich fat tree network designs are the predominate architecture of the hyperscale datacenter. These networks may contain hundreds of thousands of fiber interconnections. Some of these connections may be across a hall, pod, campus or metro area. In addition, each of these network components may be geographically diverse.

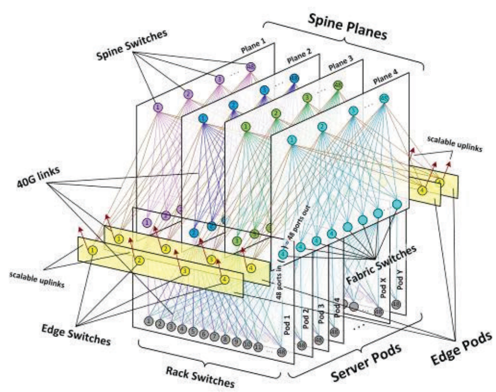

Figure 1. Schematic of Data Center Fabric [1]

Outside plant ultra high fiber count cables currently in use include fiber counts as high as 3456 fibers. [2] These cover the intra campus and outside plant ring needs, but once in the datacenter a companion indoor cable is needed.

The new problem created by this network topology is the density of cabling. Traditional conduits, ladder racks and trays easily become overloaded when conventional cable is used. Fiber density and small cable size become an important factor, especially in the situation where existing infrastructure is in place and upgrading would be very costly and disruptive.

The functional design goals of indoor cables are necessarily different from the outdoor cable for a number of reasons. The need for higher flexibility to route around tight bends and fire rating are examples of the differences in the cable classes.

2. Ribbon and Cable Design

Traditional flat fiber optic ribbons have been popular for many years due to their ability to be mass fusion spliced. They are also easily connectorized using factory finish or splice on connectors. One disadvantage of their flat structure is the inability to maximize packing density in round cables. This was the driving factor for the development of pliable ribbon technology. [2]

2.1 Pliable Ribbon Construction

The new pliable ribbon technology solves this issue allowing flat ribbons to fold and become round in a cable, but flatten when splicing. This is accomplished with intermittent slits in the ribbons. The spacing and length of these slits has been heavily optimized for both cable performance and splicing. [2,3,4].

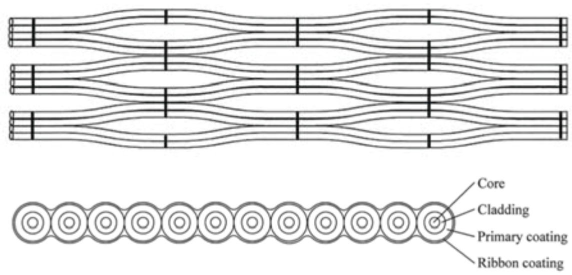

Figure 2. Pliable Ribbon Structure

2.2 Cable Design

The basic cable design resembles conventional indoor cable but it must also accommodate the pliable ribbons with acceptable packing density. An acceptable packing density is determined through a balance of the cable, ribbon and fiber design.

Indoor cables for datacenter use typically are designed using either a Poly Vinyl Chloride (PVC) or Low Smoke Halogen Free (LSHF) materials for the jacket and buffer tube. Strength elements are also used to provide both tensile and anti-buckling performance. Depending on the application a flame retardant tape may also be used if necessary.

The choice of jacket and buffer tube material is largely determined by the application and local safety code. For instance, in the United States where a NFPA 262 [5] Plenum rating is required a PVC sheath is necessary. For it is widely recognized that current generation LSHF materials have difficulty passing this strict test. However, in Europe, there has been a long-standing halogen free preference so LSHF materials are used.

This paper discusses an optimal cable design were the fiber density for a given cable outer diameter may increase dramatically. For instance, a 288 fiber conventional ribbon cable has an approximate outer diameter of 20.5 mm whereas the pliable ribbon version may be 15.7 mm or smaller.

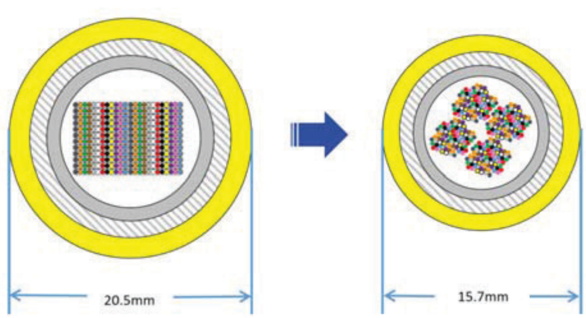

Figure 3. 288 Fiber Standard and Pliable Indoor Cable

In the case of higher fiber count cables, such as the 1728 fiber riser cable the density doubles. This cable holds 1728 fibers in the same cable diameter as a conventional 864 fiber cable using flat 36 fiber flat ribbons.

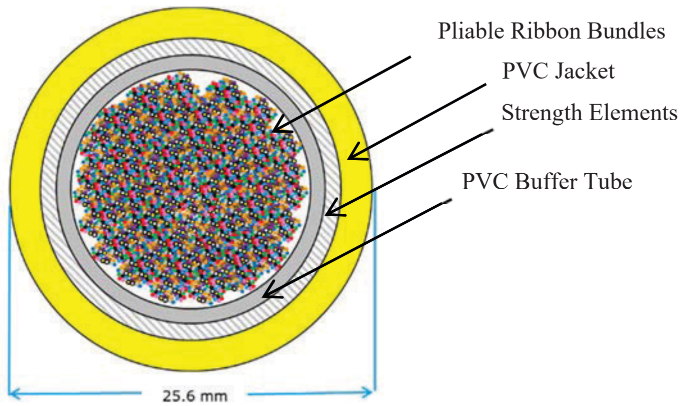

Figure 4. 1728 Fiber Pliable Indoor Cable

3. Cable Qualification

The predominant US standards for cable qualifications come from the International Cable Engineers Association (ICEA). The governing US body is the American National Standards Institute (ANSI) which approved the ICEA standards. The indoor cable standard is ANSI/ICEA S-86-596, Fiber Optic Standard for Indoor Cable. [6]

All pliable ribbon indoor cables meet or exceed ICEA 596, the 1728 fiber cable result is shown in the following table.

ANSI/ICEA 596 Cable Qualification Results

Test	Section	Conditions	Requirements	Test Procedure	Results
Material Compatibility and Cable Aging	7.14	Cable coils caped and aged at 85°C, 30 days	Buffer tube bending	ITM-9 FOTP-89	No evidence of splitting, cracking, or delamination of the aged tubes was observed.
Low and High Temperature Bend	7.16	20x Cable OD or 150mm (larger) for backbone	No visible cracks, splits or tears ≤ 0.40 dB at 1550 nm	FOTP-37	-10°C/+60°C No measureable change
Cable Temperature Cycling	7.18	2 cycles -20° to +70°	≤ 0.40 dB at 1550 nm	FOTP-3	-20°C/+70°C No measureable change
Cyclic Flexing	7.19	25 cycles, 180° arc 20x Cable OD or 150mm (larger) for backbone	No visible cracks, splits or tears ≤ 0.40 dB at 1550 nm	FOTP-104 I and IV	No measureable change No visible cracks, splits or tears.
Impact Test	7.20	2 impacts, 3 locations spaced 150mm apart Impact Energy: Backbone: 2.9 N-m	No visible cracks, splits or tears ≤ 0.40 dB at 1550 nm	FOTP-25	No Measureable change No visible cracks, splits or tears
Cold Impact	7.21	2 impacts, 3 locations spaced 150mm apart Backbone Riser: -10°C Impact Energy: Backbone: 2.9 N-m	No visible cracks, splits or tears	FOTP-25	No visible cracks, splits or tears in jacket
Long Tensile and Bending and Fiber Strain	7.22	Vertical Backbone: 1320N	Rated Installation Load: f ≤ 60% fiber proof strain Residual Load: f ≤ 20% fiber proof strain Residual Load & Release ≤ 0.40 dB at 1550 nm	FOTP-33	No Measureable change Fiber strain ≤ 20% fiber proof strain

Compressive Loading	7.23	Backbone: 100N/cm 10min hold, measurements after release of load	≤ 0.40 dB at 1550 nm	FOTP-41	No Measureable change
Cable Twist Test	7.24	10 cycles, ±180° Backbone: 1m Interconnect: 0.3m	≤ 0.40 dB at 1550 nm	FOTP-85	No Measureable change
Cable Fire Resistance	7.25	As defined by relevant body	As defined by relevant body. UL/ETL	UL1666, FT4	Pass
Ripcord Function Test	7.26	1 specimen at low & high installation temp	No breaks over 1 m. Repeat testing allowed if breaking occurs		No breaks over 1 meter over either installation temp.

Table 1. ANSI/ICEA 596 Cable Qualification Results

4. Ribbon Splicing

The efficiency of mass fusion splicing combined with the capability of pliable ribbon to fold and increase the packing density of the cable is a very desirable combination where space is limited. The previous section explained that the ribbon performs well through the rigors of installation and environmental testing but the splicing of pliable to pliable ribbon and also to standard flat ribbon must be evaluated.

The pitch and spacing of the matrix resin gaps have been optimized around two counter-prevailing objectives. On the one hand having very little attachment between fibers is desirable to aid in the ribbon folding. On the other hand the more attachment, the better alignment in the ribbon holders of a mass fusion splicer. [2,3,4]

Figure 5. Flat Ribbon and Pliable Ribbon

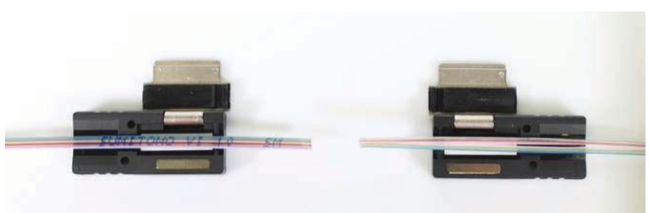

Figure 6. Ribbon Splice Holders (Open)

Figure 7. Ribbon Splice Holders (Closed)

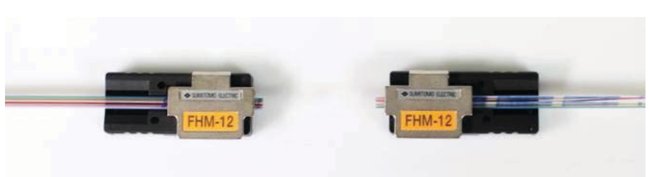

Figure 8. Ribbon Stripped and Cleaved

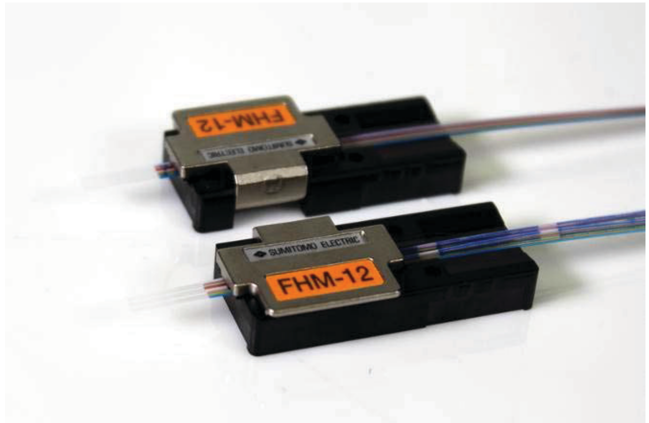

Figure 9. Pliable Ribbon Splice Preparation

Earlier splice studies have shown that splicing a pliable ribbon to a pliable ribbon and pliable to flat ribbon is easily accomplished. What differentiates this ribbon is that splicing is performed without any additional tape or preparation. Standard ribbon thermal strippers and mass fusion splice holders are used without modifications to the splicer settings.

5. Network Hardware

The ultra high fiber count indoor cables introduced in this paper must connect to outside plant high fiber count cables. The scale of the fiber count and connections has necessitated a new class of hardware. This includes splice enclosures and entrance facility exchange devices where splicing and cable transitions may occur.

A new device was developed for this application that can accommodate 41,472 fibers using a series of 48 sliding trays with 864 fibers spliced per tray.

Figure 10. Ultra High Fiber Count Exchange

Figure 11.Splice Work Platform for Ultra High Fiber Count Exchange

6. Conclusions

A new indoor cable design has been introduced effectively doubling the fiber density of previous cable designs. While this may be accomplished with loose fiber, this design utilizes pliable ribbons that may fold for cabling, but be laid flat for mass fusion splicing. High density pliable ribbon cables are in service now in the outside plant environment, but prior to the introduction of the pliable high density indoor cable introduced in this paper these outside cables must transition to lower count, less space efficient cable for the indoor. This new cable design complements the outside plant designs by bringing the splicing efficiency and packing density advantages to in the inside plant.

7. References

[1] A. Andreyev, "Introducing data center fabric, the next-generation Facebook data center network," https://code.facebook.com/posts/360346274145943/ (November, 2014).

[2] F. Sato, K. Ryan, Y. Nagao, T. Hirama, R. Oka, K. Takahashi, "Characteristics of Ultra-High-Fiber-Count and High-Density Optical Cables with Pliable Ribbons," (2017)

[3] F. Sato, K. Okada, T. Hirama, K. Takeda, R. Oka, K. Takahashi, "Ultra-High-Fiber_Count and High-Density Slotted Core Cable with Pliable 12-fiber Ribbons," IWCS Proceedings, pp.604-609 (2016)

[4] F. Satou, M. Takami, K. Yamamoto, T. Hirama, H. Satou, H. Miyano, S. Ishigami, "Design of Ultra-high-density Optical Fiber Cable with Rollable 4-fiber Ribbons for Aerial Deployment," pp.433-436 (2012)

[5] NFPA 262, "Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces," (2015)

[6] ANSI/ICEA S-83-596-2016, "ICEA Standard For Indoor Optical Fiber Cable," ANSI/ICEA (2016).

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