

MPO Pre-Terminated Multicore Fiber Trunk Cable

A. Inoue^(1,*), K. Haji^(1,*), Y. Saito^(1,*), T. Kikuchi^(1,*), T. Morishima^(1,*), K. Takeuchi⁽²⁾, S. Rikimi⁽¹⁾, J. Takano⁽¹⁾, T. Nagashima⁽¹⁾, K. Okabe⁽²⁾, Y. Shimoda⁽³⁾, F. Sato⁽³⁾, M. Tanaka⁽¹⁾, S. Mouri⁽¹⁾, H. Tazawa⁽¹⁾, T. Taru⁽¹⁾, and T. Hayashi^(1,*)

1: Optical Communications Laboratory, Sumitomo Electric Industries, Ltd., *t-hayashi@sei.co.jp

2: Sumitomo Electric Optifrontier Co., Ltd.

3: Optical Fiber & Cable Division, Sumitomo Electric Industries, Ltd.

#These authors contributed equally to this work

Abstract We present 288-core trunk cable with 3 break-out cords, each with 24 strands of 4-core fibers and pre-terminated with MPO connectors. The pre-terminated MCF trunk cable is considerably lighter and thinner compared to single-mode fiber trunk cables, and demonstrate satisfactory performance for short-reach optical interconnects. ©2024 The Authors

Introduction

Multicore fiber (MCF) has attracted attention for more than a decade as a promising solution [1–3] for coming capacity crunch [4,5] in ultra-high-capacity submarine transmission networks, and MCF has been finally commercialized for submarine/long-haul applications [6], with ultralow-loss uncoupled 2-core fiber [7,8].

Besides the submarine networks, hyperscale data center (DC) network is another strong potential application of MCFs [9], which requires a large number of optical fibers for connecting compute, storage, switching equipment [10]. Within a DC building, pre-connectorized (pre-terminated: preterm) optical fiber cables are widely used to avoid optical fiber splicing during cable installation and management. In hyperscale DCs, high-fiber-count MPO-preterm trunk cables (cable assemblies with multiple MPO-preterm cords) are adopted to support high bandwidth demands for short-reach interconnects, and recently emerging AI/ML applications would demand further high-density optical interconnects [11].

In this study, we fabricated and evaluated 288-core trunk cable with 3 break-out cords, each with 24 strands of 4-core fibers (4CFs) which were pre-terminated with MPO connectors. The fabricated MCF trunk cable realizes $\geq 60\%$ reductions in cable cross section and weight, compared to an SMF trunk cable with the same core count. We also fabricated 288-channel fan-in/fan-out (FIFO) rack panels and constructed an MCF link with the MPO-preterm MCF cable, which achieved optical and transmission performance suitable for short-reach applications.

Multicore Fiber for Cable Fabrication

We employed simple-structure uncoupled 4CF without refractive index trenches [12], which has sufficiently low crosstalk in C-band for short-/medium-reach bidirectional transmission use [13] (even applicable for long-haul bidirectional transmission in C-band with typical XT MCFs [14]). In this study, instead of step-index cores [12], we employed W-type cores with shallow depressed cladding (see Fig. 1), which is widely adopted for

standard SMFs and can increase light confinement without significant impact on manufacturability. Table 1 summarizes the characteristics of the fabricated simple structure 4CF. The mode field diameter (MFD), cable cut-off wavelength λ_{cc} , zero dispersion wavelength λ_0 , zero dispersion slope S_0 , and attenuation coefficients are compatible to ITU-T G.657.A1.

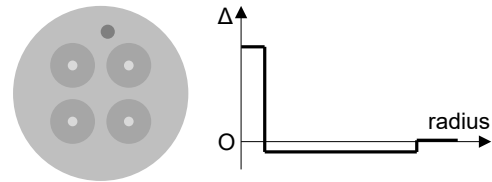


Fig. 1: Schematics of (left) cross section of simple-structure uncoupled 4CF with shallow depressed cladding, and (right) refractive index contrast (Δ) profile of its core.

Tab. 1: Characteristics of the simple-structure 4CF.

	λ [nm]	Targets	Fabrication results
MFD [μm]	1310	8.6 ± 0.4^a	8.5–8.9
Core pitch [μm]	-	40 ± 1	39.2–39.7
Cladding diameter [μm]	-	$125.0 \pm 0.7^{a,b}$	125.0 ± 0.3
Coating diameter [μm]	-	200 ± 20^b	206 ± 4
λ_{cc} [nm]	-	$\leq 1260^a$	1163–1224
λ_0 [nm]	-	1300–1324 ^a	1313–1316
S_0 [ps/(nm ² ·km)]	λ_0	$\leq 0.092^a$	0.086–0.087
Attenuation coefficient [dB/km]	1310	$\leq 0.40^a$	0.318–0.323
	1550	$\leq 0.30^a$	0.187–0.194
Macrobend loss [dB/10turns] at R=15mm	1550	$\leq 0.25^a$	<0.10
Macrobend loss [dB/turn] at R=10mm	1550	$\leq 0.75^a$	0.04–0.31
XT between neighboring cores [dB at 1 km] ^c	1310	≤ -50	-67 to -65
	1550	$\leq -26^d$	-34 to -33

a: compatible with ITU-T G.657.A1

b: compatible with IEC 60793-2-50:2018

c: co-propagating XT, 10 dB/decade length dependence.

d: sufficiently low for bidirectional transmission up to 2 km [13].

MCF Trunk Cable

We designed a 288-core trunk cable with the simple-structure 4CFs. Table 2 shows the comparison of design parameters of an SMF trunk cable and the MCF trunk cable, with the same core count. With 24-fiber break-out cords, the MCF trunk cable achieves 288 cores with 3 cords, whereas the SMF cable needs 12 cords to

achieve the same core count. This results in 37% reduction in outer diameter, 60% reduction in cross sectional area, and 62.5% reduction in weight, of the MCF cable compared to the SMF cable. Using the above design, we fabricated 1-km of the 288-core trunk cable using the simple-structure 4CFs whose fiber properties are already summarized in Tab. 1. All 72 fibers in the cable were fabricated from one MCF preform. The attenuation and XT of the cabled MCFs are summarized in Tab. 3. Although there are some measurement errors in the OTDR measurement of short MCF and in the XT measurement of short MCF using FIFOs, the results showed a negligible impact of cabling on the attenuation and XT.

Tab. 2: Comparison of SMF-based trunk cable and 4CF-based trunk cable with the same core count

	SMF trunk Cable	4CF trunk Cable (This work)
Schematic cross section		
# of cores / fiber	1	4
# of fibers / cord	24	24
Cord OD	2 mm	2 mm
# of cords / cable	12	3
# of fibers / cable	288	72
# of cores / cable	288	288
Cable OD	10 mm	6.3 mm
Cable weight	80 kg/km	30 kg/km

Tab. 3: Characteristics of the fabricated 1-km MCF trunk cable.

	λ [nm]	Specs	Results
Attenuation coefficient [dB/km] ^a	1310	≤ 0.40	0.295 ± 0.028
	1550	≤ 0.30	0.201 ± 0.016
XT between neighboring cores [dB at 1 km] ^b	1310	≤ -50	-65 to -51
	1550	≤ -26	-36 to -32

a: Measured using OTDR. Average $\pm \sigma$ of 288 cores. Short-fiber measurements induced measurement errors.

b: Measured using a FIFO pair. XT increase at 1310 nm was due to the FIFO pair in the measurement setup. At 1550 nm, FIFO XT is low enough compared to MCF XT, and we can confirm no significant impact of cabling.

Pre-termination of MCF Trunk Cable with MCF MPO Connectors

As emerging AI/ML applications demand high-density optical interconnects within 100-m range [11], we fabricated 100-m MPO-preterm MCF trunk cable using the MCF trunk cable. We cut 100 m of the MCF trunk cable from the drum, and stripped ~ 1.5 m of its cable jacket at each end for cord furcation. Each end of the cable jacket (furcation point) was protected with heat shrink tube. Each end of the break-out cords was terminated with an MCF MPO connector presented in [15]. Because we have to rotationally align the MCFs in each cord, we stripped ~ 0.3 m of the jacket at the ends of the break-out cords to hold individual MCFs for rotational alignment. After MCF

alignment and MPO assembly, the bare coated MCFs between the MPO and the cord jacket were covered and protected by a furcation tube with OD of 4.1 mm and length of 30 ± 0.5 cm, as shown in Fig. 2(left). This furcation tube is commercially used for protecting bare coated fibers between a splice-on connector [16] and cord/cable jacket. The fully pre-terminated MCF trunk cable is shown in Fig. 2(right). The insertion loss (IL) and return loss (RL) of MCF MPO connectors are discussed in the next section, which were measured with MCF FIFO rack panels.

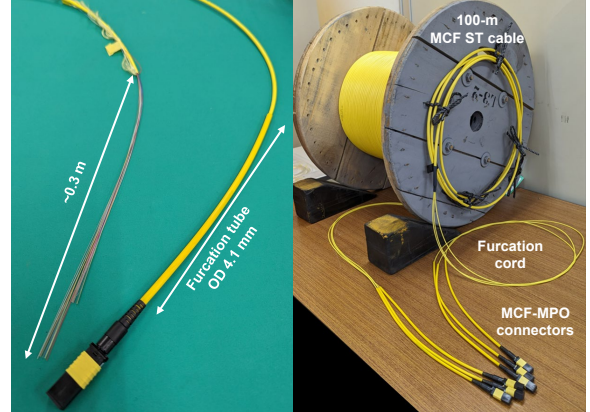


Fig. 2: (left) Jacket stripping for MCF rotation alignment and MCF MPO assembly with furcation tube for protecting MCF without cord jacket, and (right) appearance of MPO-preterm MCF ST cable.

MCF FIFO Rack Panel

Although native MCF transceivers (TRx) [17,18] would be useful for data center applications and eagerly anticipated, MCF-SMF conversion with FIFO is also necessary to connect MCFs to a SMF network. Therefore, we developed MCF FIFO rack panel that can convert the 288-core MCF trunk cable to 288 SMF LC connector termination. In this study, we fabricated 2 pieces of MCF FIFO rack panels for MCF trunk cable

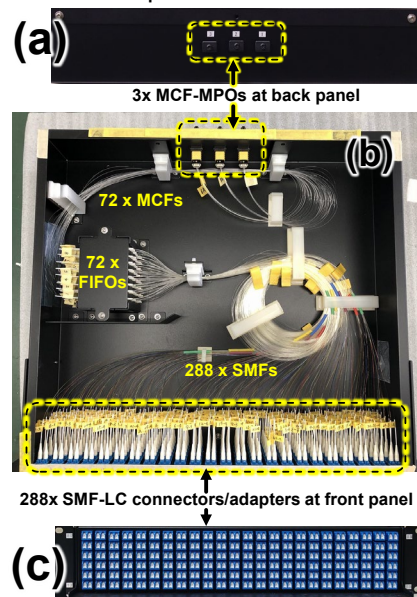


Fig. 3: 19-inch MCF FIFO rack panel for the ST cable: (a) back panel, (b) top view, (c) front panel.

evaluation. Fig. 3 shows the images of a constructed MCF FIFO rack panel, designed to fit within a standard 19-inch rack. The panel has 2U height to accommodate 288 adapters for SMF-LC connectors. Fig. 4 shows the IL characteristics of MPO connections between the trunk cable and FIFO panels. The measured IL distribution was relatively higher than our previous report [15], where MPOs were assembled using individual MCFs. This is because MCF rotational alignment process has not been optimized for cable pre-termination. However, by optimizing the alignment process, we believe the IL of an MPO connection to/between preterm MCF cables can be reduced to the same degree as we achieved with individual MCFs. Fig. 5 shows the IL characteristics of a FIFO panel, which are consistent with our previous report [19], by considering SMF LC ILs were included in Fig. 5 results.

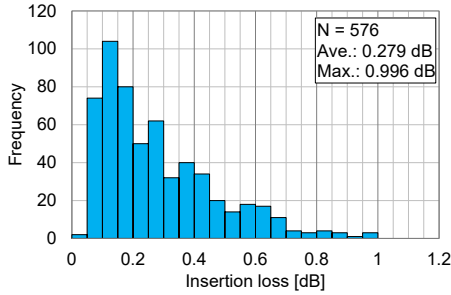


Fig. 4: IL histogram of an MPO connection between the MCF trunk cable and the FIFO panels at 1310 nm.

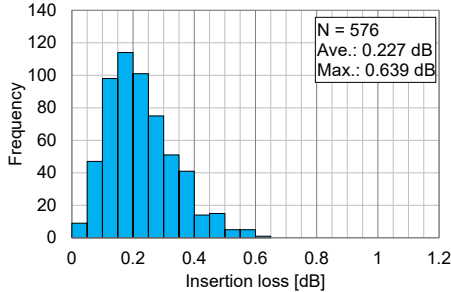


Fig. 5: IL histogram of a FIFO panel (including ILs of a FIFO and an SMF LC connection but excluding MPO connection) at 1310 nm.

MCF Trunk Cable Link Characteristics

We evaluated the IL and XT characteristics of the whole MCF link with the MPO-preterm MCF trunk cable and MCF FIFO rack panels, as shown in Fig. 6 and Fig. 7, respectively. The average value of the link IL can be mostly explained by the sum of the average ILs of 2 FIFO panels (FIFO+SMF LC) and 2 MCF-MPO connections (1.01 dB in average). Therefore, the IL reduction of these components will be the key for further reduction of the link IL. The XT values are mostly limited by the FIFO devices (in this 100-m cable configuration) and there is no significant difference between neighboring core pairs and diagonal core pairs.

We also examined transmission characteristics of the MCF link. We used two Viavi 800G Optical Network Tester (ONT-804D), each mounted

two InnoLight 400Gb/s QSFP-DD FR4 TRx. Total 4 TRx were used to simultaneously test all 4 cores of each MCF. Fig. 8 shows the pre-FEC bit-error rates of the 400GBASE-FR4 signals transmitted over an MCF link with the highest average XT in the constructed 288-core MCF trunk cable link with FIFO panels, which clearly shows the pre-FEC bit-error rate was sufficiently lower than the FEC limit of 2.4×10^{-4} . The power penalty of an MCF link at the FEC limit was also evaluated in several links (including the highest average XT link), and we confirmed negligible power penalty of an MCF link within the range of measurement error of ± 0.3 dB. The loss budgets (launch power – FEC-limit power) of 4 TRx were 8.7 to 9.7 dB, which are sufficiently higher than the MCF link IL in Fig. 6.

Together with the FIFO rack panels, the present MPO-preterm MCF trunk cable has demonstrated solid optical and transmission performance, paving the way for considerably lighter cabling solutions in short-reach applications such as optical interconnects for AI/ML.

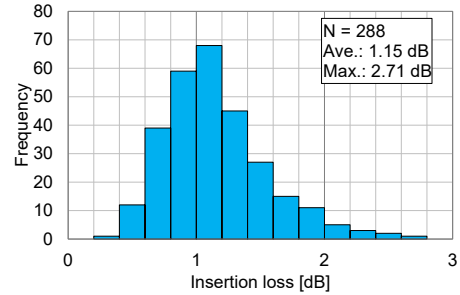


Fig. 6: IL histogram of the MCF trunk cable link with FIFO panels at 1310 nm.

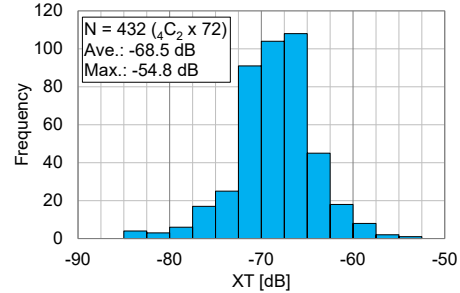


Fig. 7: XT histogram of the whole MCF trunk cable link with FIFO panels at 1310 nm.

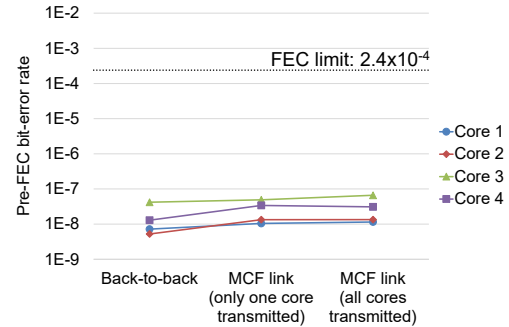


Fig. 8: Pre-FEC bit-error rate of 400GBASE-FR4 signals transmitted over an MCF link with highest average XT in the constructed 288-core MCF trunk cable link with FIFO panels.

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