

# Transmission Performance of OM3, OM4 and OM5 Multimode Fibers

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## ABSTRACT

50 Gbps PAM4 transmissions at 850 nm and 908 nm, and 100 Gbps SWDM4 transmissions over OM3/OM4/OM5 fibers were carried out. OM5 fiber can support 50 Gbps PAM4 transmission links of 500 m at 850 nm and 300 m at 908 nm. Another OM5 fiber can support an over 400 m link of 100 Gbps SWDM4 transmission, while the right-tilted OM3/OM4 fibers can only support 100 m and 150 m links, respectively, with similar EMB at 850 nm as the OM5 fiber.

**Keywords:** OM5, OM4, OM3, multimode fiber, PAM4, BiDi, SWDM, high speed transmission

## 1. INTRODUCTION

Laser optimized multimode fibers (MMF) combined with low-cost VCSELs are competitive in short reach fiber solutions for local area networks (LANs) and data centers (DCs). Currently 10GBASE-SR and 40GBASE-SR4 solutions are widely used. 100GBASE-SR4 has also been deployed. The IEEE 802.3bs standard has recently approved 400GBASE-SR16 on 25Gbaud lanes on OM3/OM4/OM5 fibers [1]. All these technologies are implemented by parallel transmissions. As the data transmission rate increases, more fiber pairs will be needed. Two wavelengths Bi-Direction (BiDi) and Shortwave Wavelength Division Multiplexing (SWDM) are promising techniques to reduce the fiber counts used in high-speed LANs and DCs. 100 Gbps BiDi solution takes advantages of both multiple lanes and quadrature-pulse-amplitude modulation (PAM4), utilizing two channels near 850 nm and 910 nm to save half the amount of fibers. SWDM4 technology targeting an operational window between 850 nm and 950 nm with VCSELs to support 4 wavelengths saves four times the amount of fibers [2, 3].

The Multisource Agreement (MSA) of SWDM has released specifications for 40G and 100G SWDM4 with OM3/OM4/OM5 fibers. However, it is worth noting that OM5 fibers are designed specifically for multi-wavelength applications, whose bandwidth peak is usually near 880 nm, taking account of the bandwidths at both ends of 850~950 nm. In production, effective mode bandwidths (EMBs) at 850 nm and 953 nm are under daily monitoring for OM5 fibers, to guarantee bandwidth performance for multi-wavelength applications. Differently, OM3/OM4 fibers' bandwidth is optimized only for 850 nm. EMBs at longer wavelength are not in production control for OM3/OM4 fibers.

In this paper, we carry out 50 Gbps PAM4 transmissions at 850 nm and 908 nm over OM3/OM4/OM5 fibers firstly. As a result, the OM5 fiber sample can support 500 m at 850 nm and 300 m at 908 nm employing IEEE standard KP4 FEC with a BER threshold at  $2E-4$ . Secondly, 100 Gbps SWDM4 transmissions over another OM5 fiber sample as well as two types of OM3 and OM4 fibers are studied. The BER performance of 400 m OM5 shows adequate margin to achieve error free transmission in data center systems applying IEEE standard KR4 FEC with a BER threshold at  $5E-5$ .

## 2. 400G OSFP SR8 TRANSMISSION

### 2.1 Experimental Setup

The experimental transmission link and back to back eye diagrams are shown in Figure 1. Two InnoLight 400G OSFP SR8 transceivers of 850 nm and 908 nm were used to conduct the experiment, which were tested separately. The 50

Gbps PAM4 optical signals at 850 or 908 nm was launched from Tx to the fiber samples. Each end of the transceiver was inserted with a MPO-FC jumper. The fibers under tested (FUT) were connected to the jumpers by FC-FC connectors. The eye diagrams were obtained at the fibers output directly, not through the Rx of transceivers. Signals were finally received by a bit error rate tester (BERT) to evaluate BER, with forward error correction (FEC) function disabled.

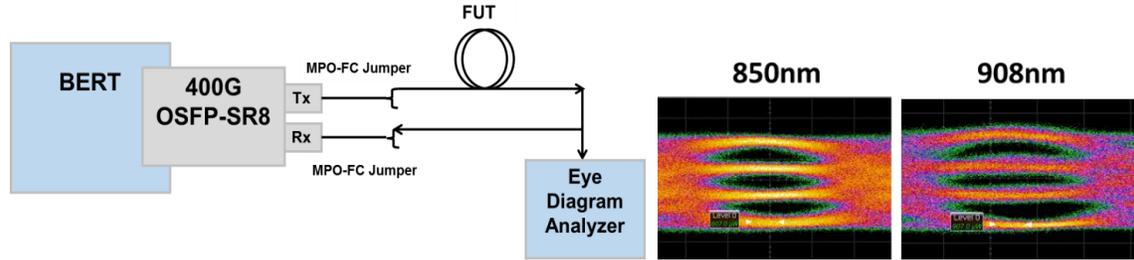


Figure 1. Schematic of experimental transmission link and back to back eye diagrams (850nm and 908nm).

## 2.2 Transmission Test Results

The InnoLight 400G OSFP SR8 transceiver (T-OS8FNS-N00) provides 50 Gbps PAM4 signals per lane. Table 1 reveals that, employing IEEE standard KP4 FEC with a BER threshold at  $2E-4$ , the OM5 fiber can support a 500 m link at 850 nm and a 300 m link at 908 nm with error free. It is also shown that OM4 fiber can support 500 m and 200 m transmissions at 850 nm and 908 nm, respectively. Besides, error free transmissions of OM3 fiber were achieved with both 300 m at 850 nm and 908 nm, respectively.

Table 1. BER test results over OM3/OM4/OM5 fibers of 50 Gbps PAM4 signals at 850 and 908 nm.

Sample length (m)		850 nm		908 nm	
		BER	Rx optical power (dBm)	BER	Rx optical power (dBm)
Back to back		0	0.30	$2.3E-11$	2.15
OM5	200	$5.0E-12$	-0.17	$4.0E-7$	2.28
	300	$2.7E-9$	-0.48	$3.2E-6$	2.06
	400	$4.6E-7$	-0.73	$7.0E-4$	1.87
	500	$1.2E-5$	-0.90	LOSS	-
OM4	200	0	-0.26	$2.3E-6$	2.24
	300	$1.4E-10$	-0.44	LOSS	-
	500	$1.4E-6$	-1.15	LOSS	-
OM3	100	0	0.09	$6.5E-10$	1.97
	200	$3.6E-10$	-0.18	$5.5E-9$	2.23
	300	$3.7E-6$	-0.51	$7.0E-6$	2.04

## 3. 100G SWDM4 TRANSMISSION

### 3.1 Sample characterization

The EMB performance is measured using a high resolution DMD bench with a tunable Titanium-Sapphire laser at various wavelengths. Figure 2 shows the DMD plots of 1# and 2# OM3/OM4 MMF at 850 nm. 1# OM3/OM4 samples are with left-tilted DMD plot, and 2# OM3/OM4 samples are with right-tilted DMD plot. EMB performances of selected OM5, OM4 and OM3 MMF over wavelengths from 850 nm to 953 nm are depicted in Figure 3.

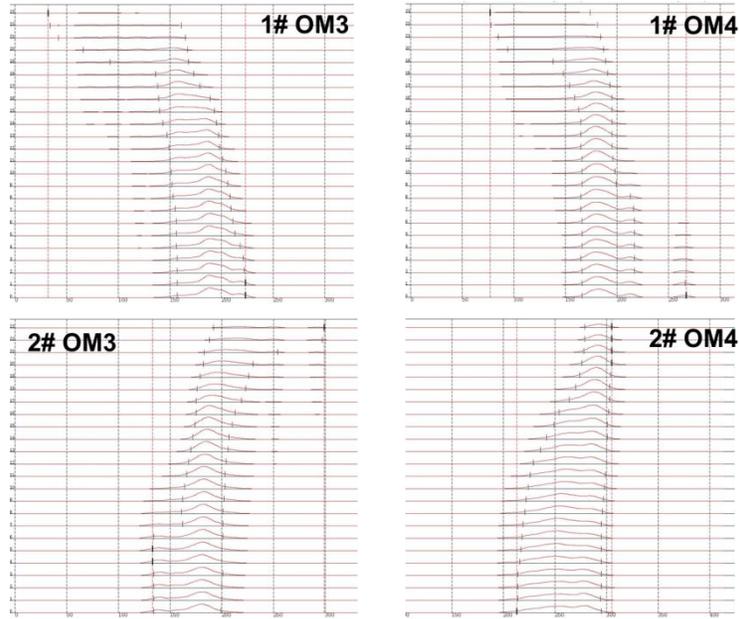


Figure 2. DMD plots of left-tilted OM3/OM4 (1#) and right-tilted OM3/OM4 (2#) MMF at 850nm.

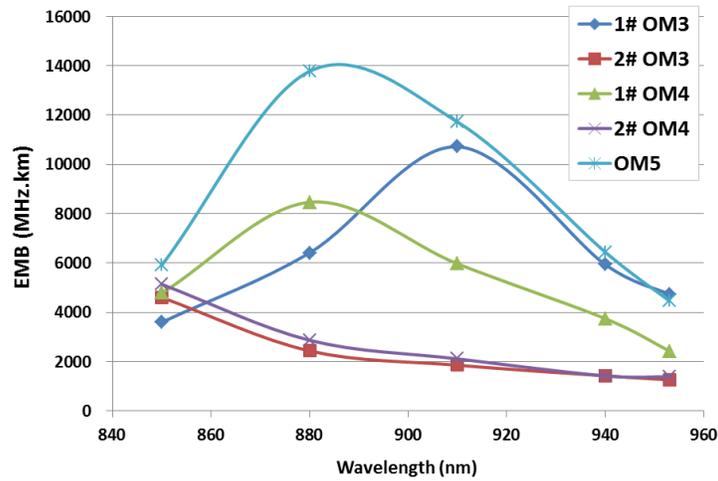


Figure 3. DMD plots of left-tilted OM3/OM4 (1#) and right-tilted OM3/OM4 (2#) MMF at 850nm

Five fiber samples with similar EMB of 850 nm were specifically selected. 1# OM3/OM4 samples are with left-tilted DMD plot, whose EMB peaks locate at wavelength longer than 850 nm. 2# OM3/OM4 samples are with right-tilted DMD plot, which are with peak EMB locating at wavelength shorter than 850 nm. Then two OM3 fiber samples were cut into 75 m, 100 m and 150 m, two OM4 fiber samples into 100 m, 150 m and 200 m, and OM5 fiber sample into 200 m, 300 m and 400 m for transmission test.

### 3.2 Experimental Setup

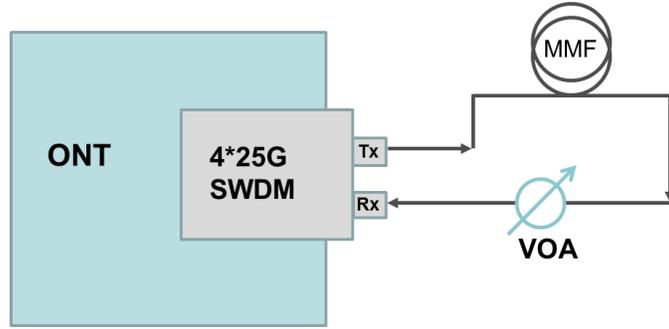


Figure 4. Schematic of 100G SWDM4 experimental setup

The 100G SWDM4 transmission experimental setup is shown in Figure 4. EXFO Optical Network Tester (ONT FTBx-88200NGE) was applied to conduct the transmission experiments. A Finisar 100GE SWDM4 transceiver was plugged into the EXFO ONT. Four streams of 25 Gbps NRZ signals at the wavelengths of around 850, 880, 910 and 940 nm were launched from Tx to the fiber samples. Each end of the transceiver was inserted with an LC pigtail. The fiber samples under tested were connected to the pigtails by splicing. The splicing losses are all below 0.03 dB. A variable optical attenuator (VOA) was inserted between the sample and Rx of the transceiver for BER waterfall curve testing. The forward error correction (FEC) function of the ONT was turned off during testing.

### 3.3 Transmission Test Results

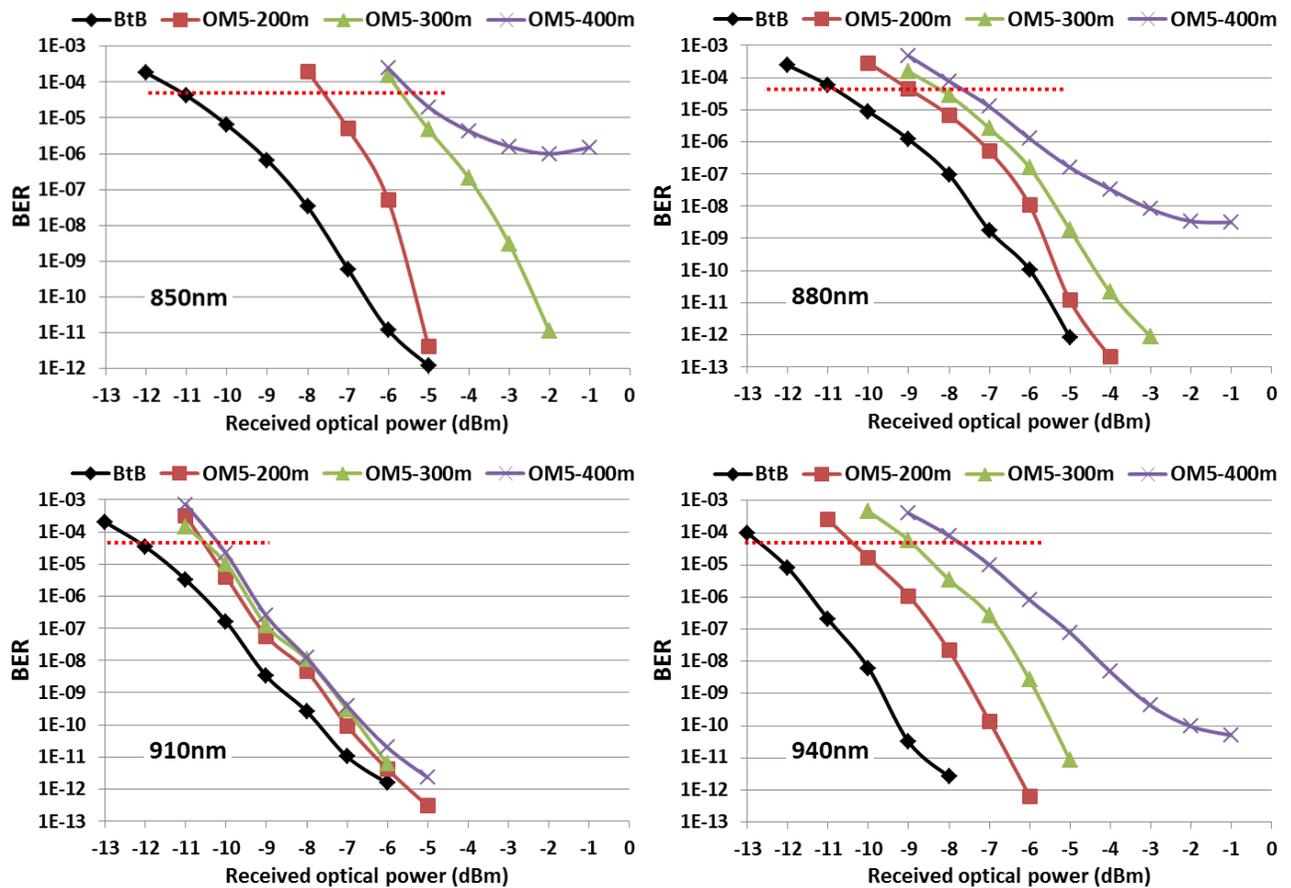


Figure 5. BER curves of 100G SWDM4 transmission over BtB and OM5 fibers

Figure 5 shows the measured BER curves for 4\*25 Gbps NRZ-SWDM transmissions over OM5 fibers as a function of

received optical power. BER waterfall curves were measured for back to back (black diamonds), after 200 m (red squares), 300 m (green triangles) and 400 m (purple crosses) transmission for each wavelength channel. The red dotted line in Figure 5 represents IEEE standard KR4 FEC of a BER threshold at  $5E-5$ . It reveals that, without FEC technology, the OM5 MMF with EMB of  $5904 \text{ MHz}\cdot\text{km}$  at 850 nm and  $4459 \text{ MHz}\cdot\text{km}$  at 953 nm can support a distance of over 400 m in 100 Gbps transmission. Accordingly, in 100 Gbps SWDM4 transmission systems, OM5 fibers can provide a stable and reliable link of distance over 400 m.

To study the SWDM4 transmission characteristics of OM3/OM4 fibers with different DMD plot tilt directions, the same experiments were conducted for 1# OM3, 2# OM3, 1# OM4 and 2# OM4 fiber samples with various lengths as OM5 samples. Their received optical power at KR4 FEC threshold for each wavelength channel is recorded in Table 2. Smaller received optical power means lower system sensitivity and larger transmission margin.

Table 2. Received optical power at KR4 FEC threshold using the 100Gbps SWDM4 transceiver.

	Length (m)	Rx sensitivity (dBm)			
		850 nm	880 nm	910 nm	940 nm
BtB		-11.2	-11.0	-12.2	-12.8
OM5	200	-7.7	-9.0	-10.6	-10.4
	300	-5.7	-8.4	-10.6	-9.0
	400	-5.4	-7.8	-10.2	-7.8
1# OM4	150	-8.8	-8.2	-10.6	-10.0
	200	-8.2	-9.3	-10.0	-7.0
2# OM4	150	-9.4	-7.0	-9.0	-4.8
	200	-4.4	Loss	Loss	Loss
1# OM3	100	-9.4	-9.9	-10.7	-11.4
	150	-6.4	-9.0	-10.0	-11.2
2# OM3	75	-9.6	-8.0	-9.0	-5.8
	100	-8.7	-6.0	-6.3	-1.7

Table 2 reveals that, in the 100 Gbps SWDM4 transmissions, the OM5 sample can provide a 400 m link with big margin; and left-tilted OM4 and OM3 samples can support 200 m and 150 m links, respectively, while the right-tilted OM4 and OM3 samples can only preserve 150 m and 100 m links with strain system margin, respectively.

Actually, in mass production, the vast majority of OM3/OM4 fibers get peak bandwidth occurring at wavelengths other than 850 nm. Herein the OM3/OM4 fibers with peak EMB longer than 850 nm are called left-tilted OM3/OM4, and the opposite are called right-tilted. The transmission test results show big differences on left-tilted and right-tilted OM3/OM4 fibers, although they are with similar EMB at 850 nm. Accordingly, it is unreliable to choose OM3 or OM4 fibers in WDM systems, such as SWDM4 and BiDi, because the EMB at other than 850 nm is not monitored.

#### 4. CONCLUSIONS

50 Gbps PAM4 transmissions at 850 nm and 908 nm, and 100 Gbps SWDM4 transmissions over OM3/OM4/OM5 fibers were carried out. OM5 fiber can support 50 Gbps PAM4 transmission links of 500 m at 850 nm and 300 m at 908 nm. It can be predicted that OM5 fiber can support a 300 m link in 100 Gbps BiDi transmissions with two wavelengths at 850 nm and 908 nm. In 100 Gbps SWDM4 transmissions, the OM5 fiber can support over 400 m link, while right-tilted OM3/OM4 fibers can only support 100 m and 150 m links, respectively, with similar EMB at 850 nm as the OM5 fiber. In general, OM5 fibers can provide a stable and reliable link of more than 300 m in 100 Gbps multi-wavelengths system, showing a great potential application in the evolution of transmission systems from 100 Gbps, 400 Gbps to higher transmission rates.

## REFERENCES

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