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Connectors Make A Difference in Optical Fiber Power Measurements*

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Optical fiber power meters (OFPMs) are one of the most common forms of test equipment for optical fiber communication networks, directly impacting every individual who makes a long distance phone call or uses the Internet. An OFPM is used to measure the optical power that exits an optical fiber. A typical OFPM consists of a sensor, a window, and a fiber adapter. Optical reflections among these components can introduce errors, which appear as offsets, into power measurements. (See Figure 1.) Common fiber connectors are shown in Figure 2.

We have measured OFPM offsets as high as 12 % when different fiber connectors are used to mate an OFPM and an optical fiber source or even when the same type of fiber connector, made by different vendors, is used to connect an OFPM and source. [1]. These offsets are due to multiple reflections from the OFPM window, detector and connector's ferrule. (See Figure 1.) These reflections may produce interference effects that will lead to an OFPM reading that is higher than expected with an unconnectorized source. Often, adapters are used to connect an OFPM and a source with different fiber connectors. However, the junction between the fiber connector and the adapter can contribute up to 4 % offset in OFPM measurement. More seriously, the magnitude of the connector-induced offsets in a function of wavelength of optical source. Thus, substituting either a different type of fiber connector or another vendor's connector for another can invalidate a calibration result.

To determine the magnitude of potential connector effects, NIST researchers conducted a study involving the calibration of OFPMs described in detail in [1]. Six popular connector types were selected for the study: FC/PC, biconic, SC, ST, FC/APC, and SMA (see Figure 2) from four vendors chosen randomly (the vendors are identified by letters A through D). These connectors were attached to single-mode fiber cables. Measurements were performed on four types of OFPMs (the meters are identified by numbers 1 through 4) at three wavelengths: 850, 1310, and 1550 nm. The four types of OFPMs were (a) Si and Ge remote sensors with angled window (OFPM #1), (b) InGaAs fiber-pigtailed sensor (OFPM #2), (c) Ge sensor with flat window (OFPM #3), and (d) windowless Ge sensor (OFPM #4).

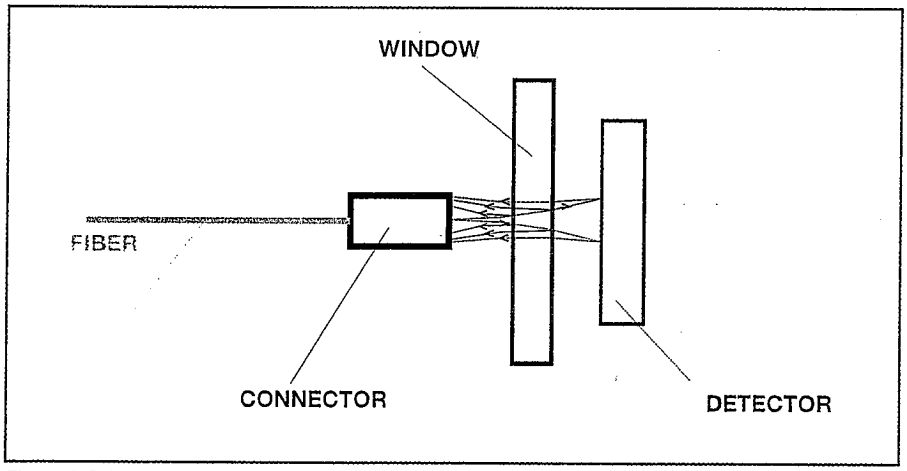

Figure 1. Schematic of OFPM showing possible interference effects between sensor, window and detector. Some OFPM models have fiber connectors integrated into their design.

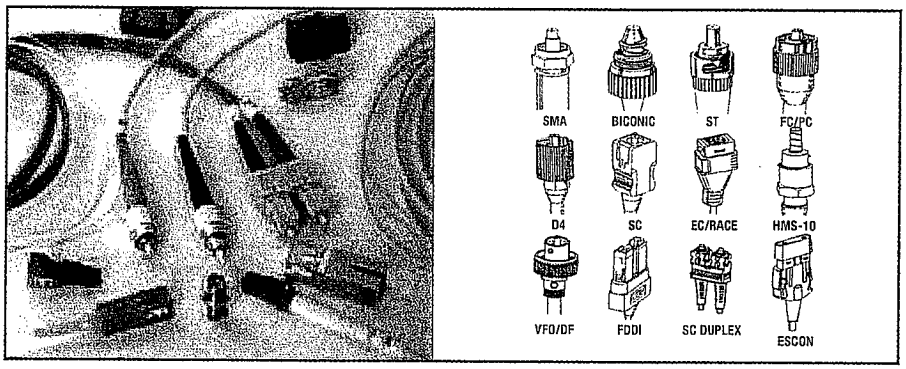

Figure 2. Common optical fiber connectors.

Same vendor, different connector type

All of the connectors in the study had ceramic ferrules, except the metallic connector ferrules from vendor B and the SMA from all vendors. Table 1 documents the results of measurements taken with four OFPMs from four different vendors at 1550 nm. The difference

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Table 1. Connector effects for OFPMs compared to FC/PC at 1550 nm

Power meter	OFPM #1				OFPM #2				OFPM #3				OFPM #4			
Connector/vendor	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
biconic	0.40	0.20	0.20	0.80*	-0.01	0.10	0.20	0.57*	-4.9	-11.7	-4.7	-5.2*	0.18	-3.5	0.70	0.68*
SC	0.01	-1.0	0.10	---	-0.10	-0.20	-0.41	---	-2.8	-3.7	-2.1	---	0.88	1.4	1.2	---
ST	-0.30	-0.30	-0.30	---	-0.58	0.70	-0.20	---	-0.66	0.58	-1.4	---	-1.8	-0.33	0.28	---
FC/APC	---	-0.70	-0.75	---	---	0.01	-0.10	---	---	-1.7	-0.01	---	---	-0.17	0.42	---
SMA	---	---	0.01	0.10*	---	---	0.80	0.97*	---	---	6.8	-1.2*	---	---	2.8	1.3*
Maximum offset	0.40	0.20	0.20	0.80	-0.01	0.70	0.80	0.97	-0.66	0.58	6.8	-1.2	0.88	1.4	2.8	1.3
Minimum offset	-0.30	-1.0	-0.75	0.10	-0.58	-0.20	-0.41	0.57	-4.9	-11.7	-4.7	-5.2	-1.8	-3.5	0.28	0.68

* compared to ST connector of vendor D
--- not available

Table 2. Connector effects for different vendors compared to vendor A at 1550 nm

Power meter	OFPM #1			OFPM #2			OFPM #3			OFPM #4		
Connector/vendor	B	C	D	B	C	D	B	C	D	B	C	D
biconic	0.10	0.20	0.40	0.10	0.20	0.01	-0.55	-0.25	-0.67	0.30	-0.01	0.10
ST	-0.10	-0.01	0.10	1.3	0.38	0.01	8.5	-1.1	0.29	2.9	-0.68	0.10

Table 3. Connector effects for vendor C used with 3 OFPMs compared to open beam

Power meter	OFPM #1			OFPM #3		OFPM #4	
Connector/vendor	852	1307	1550	1307	1550	1307	1550
FC/PC	0.77	0.20	0.20	5.7	4.9	1.5	3.9
biconic	0.42	0.30	0.40	1.2	-0.10	1.2	0.90
SC	0.45	0.40	0.30	3.3	2.7	1.3	2.7
ST	0.12	-0.30	-0.10	4.4	3.5	0.94	2.1
FC/APC	-0.14	-0.79	-0.55	6.7	4.9	0.11	0.96
SMA	0.41	0.20	0.20	12.2	12.0	2.7	4.4
Maximum offset	0.77	0.40	0.40	12.2	12.0	2.7	4.4
Minimum offset	-0.14	-0.79	-0.55	1.2	-0.10	0.11	0.90

between the values of maximum and minimum offset (expressed in percent) shows the range of possible offsets when a vendor's OFPM is used with different fiber connector type. The largest range of offsets was found for OFPM #3 when connectors of vendor B were used.

Same connector type, different vendor

Table 2 compares connectors of various vendors using a specific OFPM and connector type (biconic and ST). Table 2 shows the results of measurements taken with four OFPMs and compares the measurement results from three vendors to the reference connectors of vendor A at 1550 nm. The largest offsets at 1550 nm were found for OFPM #3 when ST connectors of vendor B were used.

Free space versus fiber-coupled laser beam

Table 3 documents results of measurements taken with both free space and fiber-coupled laser beams for three different OFPMs. The largest spans of offsets (from maximum to minimum were found for OFPM #3 when various connectors of vendor B were used.

Conclusion

In conclusion, the only way to ensure accurate measurements of optical fiber power is to have your OFPM calibrated in the configuration that you intend to use it. Users must consider the fiber connectors and adapters that they will use as well as the optical wavelength and power. There is no consistent methodology for predicting the magnitude of the offsets that occur when different fiber connectors and/or adapters are used with a calibrated OFPM. In addition, users should not assume that the calibration results obtained from fiber-connectorized measurements will be the same as those obtained with free space laser beams. NIST offers a suite of measurements services for comprehensive characterization of OFPMs. For more information, please visit to the NIST Optoelectronics Division calibration web page at www.boulder.nist.gov/div815/Calibrations/LPEC.htm ■

Reference

[1] I. Vayshenker, X. Li, and D. A. Keenan, "Connector-induced offsets in optical fiber power meters," *Appl. Opt.* 45, 24, 6163–6167, 2006.

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