Choosing a Mode Conditioner for Use with the Optical Backscatter Reflectometer in Diagnosing Multi-Mode Fiber

Contents

1 Introduction

Luna Technologies' Optical Backscatter Reflectometer (OBR) is ideally suited for troubleshooting both single mode and multi-mode optical networks.[1] Because the OBR operates on the principle of swept wavelength interferometry, fiber used in the instrument is single-mode in order to maintain optimum interferometer performance. The fiber under test however, may be multi-mode or single mode.

When the fiber under test is MMF there will be a SMF to MMF transition since the OBR uses SMF in its internal measurement networks. Choosing the most effective mode launch for a particular task will provide the best performance and ensure success.

This application note discusses three methods of mode conditioning, the advantages and disadvantages of each method, as well as when to use them. These methods are 1) direct launch method 2) full equilibrium mode launch 3) partial mode launch.

For an in depth discussion on launch conditions, and loss measurements in multi-mode fiber please see the Luna Technologies Engineering Note: "*Using the OBR with Multi-Mode Fiber*[1]*".*

2 Launch Conditions

2.1 Direct Launch versus Mode Conditioned Launch

A direct launch as in Figure 1, is achieved by connecting directly the multi-mode fiber device to the OBR. This type of launch tends to populate only lower order modes in the multi-mode fiber device because the numerical aperture of SMF is significantly lower than that of MMF. As such, most of the light will propagate in the center of the core and the so the OBR will be highly sensitive to core defects like bubbles, splices, cracks and breaks. However, since there will be little to no light propagating near the core- cladding interface, any defects here, such as barrel or waist splices, macro or micro bends, etc. may go unseen.

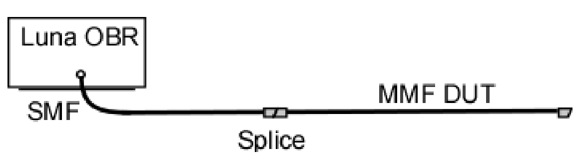

Figure 1: Direct launch measurement network. The bulkhead connector on Luna's OBR is FC/APC, therefore in a direct launch setup the multi-mode device should be connectorized with a FC/APC connector or spliced directly (as shown).

In order to locate defects near the core-cladding interface with the OBR, light must be propagating in higher order modes. This is achieved by using a mode conditioner or mode converter to redistribute light from the fundamental mode, which propagates near the center of the core, to higher order modes, which propagate near the core-cladding interface. As seen below in Figure 2, in practical use the Mode Conditioner is placed between the OBR and the multi-mode fiber device under test.

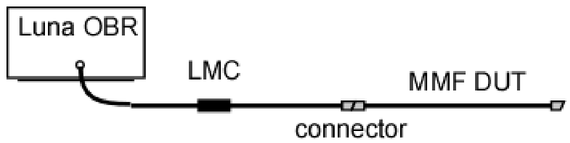

Figure 2: Example mode conditioned launch measurement network. The output of the Luna Mode Conditioner (LMC) is FC/APC so the MMF DUT should be connectorized with a FC/APC connector (as shown) or spliced directly.

One disadvantage to using a mode conditioned launch is that it induces more loss than a direct launch, taking away from the OBR's total insertion loss dynamic range. Luna offers a Mode Conditioner that by design has less insertion loss and return loss than other commercially available mode conditioners.

2.2 Which Mode Conditioner to Use

Luna provides two types of mode conditioners for use with the OBR family of products. One that achieves equilibrium mode fill and one that populates a few higher order modes. As discussed below, there are advantages and disadvantages to each type.

Various mode conditioners are available for various fiber types. Many of these mode conditioners aspire to achieve what is known as equilibrium mode fill, where there is equal power propagating in all modes. The advantage to using this type of mode conditioner is repeatable loss measurements in multi-mode fiber independent of the source. However, the closer to equilibrium mode fill, the more loss is induced; the less Insertion loss dynamic range is available to the OBR. Equilibrium mode conditioners typically impose 7-10 dB insertion loss.

The Luna Mode Conditioner is designed such that only a few higher order modes are populated. The result is a mode conditioner that allows the OBR products better sensitivity to defects that affect higher order modes, with significantly less loss than an equilibrium mode fill conditioner. Typical loss through a Luna Mode Conditioner is 5-6 dB. This allows maximum insertion loss and dynamic range while maintaining sensitivity to defects throughout the fiber cross section.

3 Correlating OBR and Power Meter Multi-Mode Loss Measurements

The Luna Mode Conditioner was designed as a low loss multi-mode *fault finder, not a multi-mode power meter*. Having said that, multi-mode loss measurements made using the OBR and Luna Mode Conditioner are closely correlated to loss measurements using standard power meters. This makes locating and discriminating non-critical loss points from “fail” loss points straightforward.

For the data summarized in Table 1, a Luna OBR 4600 was used with several 50/125 µm Luna Mode Conditioners to measure the insertion loss of various diameter loops in standard 50 µm OM2 fiber. This data was then compared to measurements made with an 850 nm multi-mode power meter; the source, detector and procedure compliant with TIA/EIA-455-20A. As can be seen in Table 1 and Figure 3 below, the Luna Mode Conditioner measurements correlate well with power meter results.

Table 1: Luna OBR 4600 was used with various 50/125 µm Luna Mode Conditioners to measure the losses of various diameter loops.

Mode Conditioner	4600 Loop Diameter (Inches) Loss (dB)					
	3/16	1/4	3/8	1/2	5/8	3/4
1	4	2.75	1.3	0.7	0.53	0.37
2	4.45	2.57	1.33	0.66	0.6	0.5
3	4.07	2.38	0.99	0.62	0.51	0.35
4	4.76	2.55	0.92	0.59	0.47	0.3
5	5.35	2.95	1.56	0.88	0.76	0.5
6	4.83	2.68	0.97	0.45	0.33	0.2
7	5.08	2.86	1.46	0.66	0.66	0.52
8	4.56	2.86	0.94	0.56	0.48	0.39
9	4.34	2.36	1.27	0.68	0.66	0.41
10	4.23	2.8	1.25	0.81	0.58	0.38
Average	4.57	2.68	1.2	0.66	0.56	0.39
St. Dev.	0.44	0.21	0.23	0.12	0.12	0.1
Power Meter	4.66	2.35	0.91	0.52	0.5	0.43

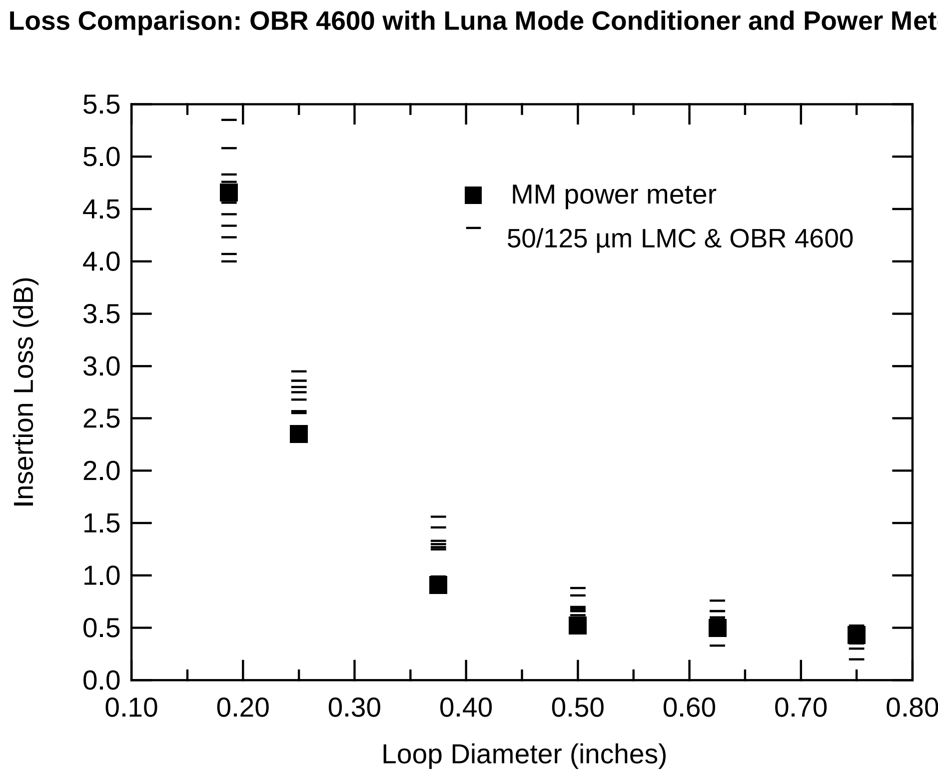

Figure 3: Plot of Table 1 data. The LMC results were compared with those of a TIA/EIA compliant, 850 nm wavelength, multi-mode power meter. Note increasing variance with higher loss, yet close correlation in the mean value.

4 Locating Faults in Multi-mode Fiber Using the Luna Mode Conditioner

With the Luna Mode Conditioner and OBR family of products, locating faults in multi-mode fiber is straightforward. Micro bends, macro bends, pinches, barrel and waist splices, offset splices, and a host of other defects will show up as a reflective event in most fiber types and as a drop in the scatter level (i.e. an insertion loss event) in all fiber types. For example, an OBR 4200 was used to locate a fault in a branch of a 62.5/125 µm multi-mode network, as seen in Figure 4.

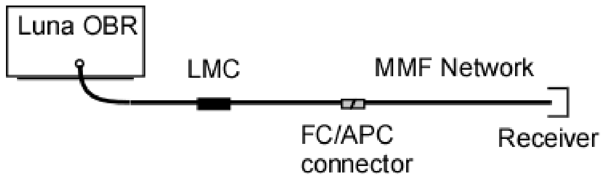

Figure 4. Measurement setup used to locate fault in MMF network branch

The resulting trace is seen below in Figure 5. The portable OBR 4200 with Luna Mode Conditioner located a 0.9 dB loss, 1.83 meters from the FC/APC connector. This same event measured with a standard power meter measured 0.7 dB loss.

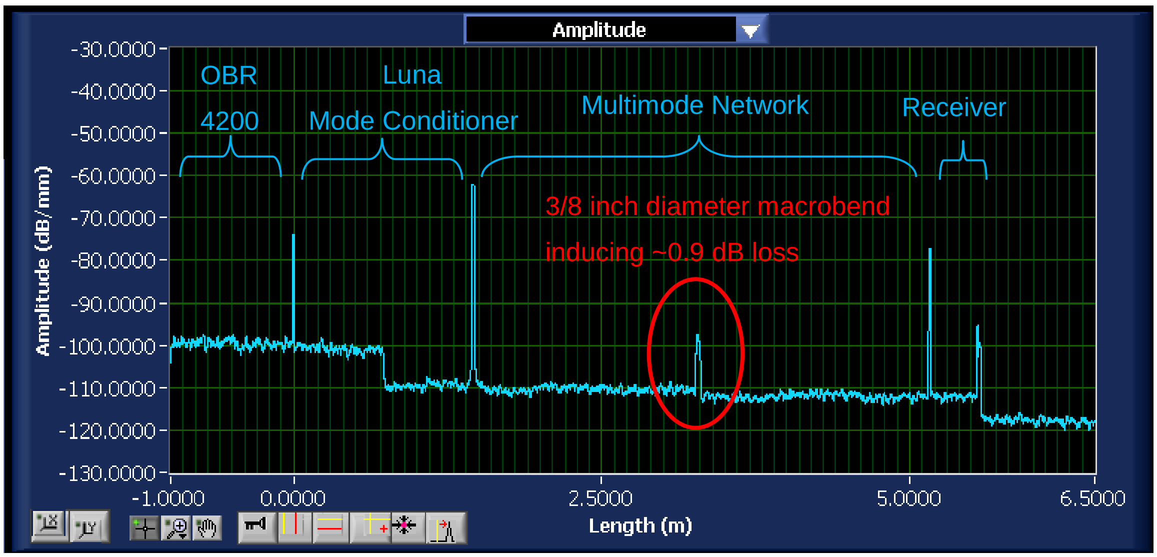

Figure 5. OBR 4200 scan of a multimode network branch using the Luna Mode Conditioner. Note the reflective signature at the fault makes locating it obvious since no reflections are expected between the input to the network and the receiver.

Summary

The OBR is a useful tool for locating and diagnosing faults in fiber networks and devices. While troubleshooting multi-mode fiber with an OBR, some consideration should be given to the launch condition between the OBR and the multi-mode device or network under test.

A direct launch can be used for greatest insertion loss dynamic range and sensitivity to core-center defects, but will not be sensitive to core-cladding interface defects. For a more complete OBR diagnosis, a mode conditioner is necessary to populate higher order propagation modes and inspect the entire fiber cross section.

Equilibrium mode conditioners typically have 7-10dB insertion loss which decreases the available OBR insertion loss dynamic range. The Luna Mode Conditioner has been designed specifically for use with the OBR to minimize insertion loss penalty (5-6dB) and optimize troubleshooting and fault finding utility. Since loss measurements made with an OBR and Luna Mode Conditioner correlate well with TIA/EIA standard power meter measurements, the user can be confident in locating and discriminating between critical and insignificant faults.

Using the Luna Mode Conditioner in combination with the Luna OBR gives the user the advantage of supporting both single mode and Multi-Mode testing with a single instrument, thus reducing the overall size, weight, complexity and cost of test equipment.

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1 Luna Engineering Note "Using the OBR with Multi-Mode Fiber, 2013"

2 B. Soller, D. Gifford, M. Wolfe and M. Froggatt, "High resolution optical frequency domain reflectometry for characterization of components and assemblies", Optics Express, Vol. 13, No. 2, 2005, 674.

3 B. Soller, M. Wolfe, M. E. Froggatt, "Polarization resolved measurement of Rayleigh backscatter in fiber-optic components," OFC Technical Digest, Los Angeles, March, 2005, paper NWD3.

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