Spectral testing of active systems in lab and manufacturing environments

white paper

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Introduction

Any optical transmitter, whether it is a 100 Gbit/s line card or a pluggable, such as an SFP or QSFP28, includes optical subassemblies to generate the optical signal. The most basic component—the laser—is integrated into increasingly complex assemblies, up to complete optical networking systems (WDM or other). Each optical source, with its specific level of complexity, must be carefully tested and qualified. Spectral analysis, or the measurement of optical power as a function of wavelength and related parameters, is a key part of thorough optical source qualification. This white paper outlines the recommended tests in laboratory and manufacturing environments for optical sources and optical amplifiers. First, it will show why spectral testing is fundamental in lab and manufacturing environments. Second, it will describe the different types of optical sources in order of increasing complexity and explain the relevant tests for each of them. And finally, it will present EXFO's spectral instruments for each type of source.

Why optical spectral testing matters

In laboratory and manufacturing environments, optical spectral testing helps to overcome a number of potential issues:

- It assesses the working condition of optical sources and amplifiers
- It prevents the use of a defective optical module, which would lead to errors in transmission and network downtime
- For manufacturers: it ensures that the products delivered to customers are top quality
- For service providers and end users: testing optical sources and amplifiers in the lab confirms that they are performing according to specifications, and reduces costly truck rolls

Types of optical sources

Distributed feedback (DFB) lasers and Fabry-Perot (FP) lasers

These are the most basic optical sources, usually offered in a very small form factor. While Fabry-Perot lasers feature several side modes, DFB lasers present a more narrowband spectrum thanks to a Bragg grating that precisely selects the desired wavelength.

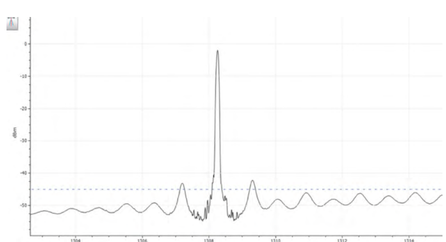

Figure 1. DFB optical spectrum

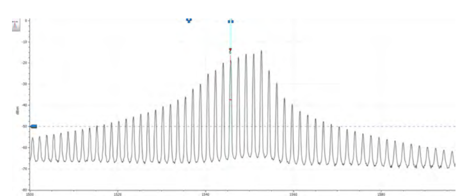

Figure 2. Fabry-Perot optical spectrum

Transmitter optical subassemblies (TOSAs)

TOSAs feature one or more lasers, a multiplexer and a laser driver in a metal or plastic housing. Depending on the application, they may also have additional components such as a photodiode monitor, cooling module, isolators, etc. TOSAs are used to couple the signal into an optical fiber.

Transmitters

Transmitters contain TOSAs as well as electronics to generate a meaningful optical data stream of a given protocol (OTN, Ethernet, etc.). These electronic components can condition and encode/decode the data into light pulses, manage the signal clock, and so on.

Optical systems

A full optical system, usually based on wavelength division multiplexing (WDM) technology, features several passive components and a length of optical fiber that transports the signal between transceivers (a combination of transmitter and receiver). In some longhaul networks, the span of fiber is so long that the signal requires amplifiers, often based on Erbium-doped fiber, to regenerate the signal without adding an excessive amount of optical noise to the system.

Testing the different types of optical sources

Spectral testing of lasers

The spectral testing of DFB and FP lasers is similar in some areas and different in others. In both cases, critical measurements include central wavelength and optical power. For DFB lasers, the side mode suppression ratio (SMSR) is a key pass/fail criterion in manufacturing, since it qualifies how effectively the laser eliminates unnecessary side modes. SMSR can be obtained by computing the power difference between the main mode and first side mode (Figure 3). Figure 4 shows the measurements provided by EXFO's OSA in DFB mode.

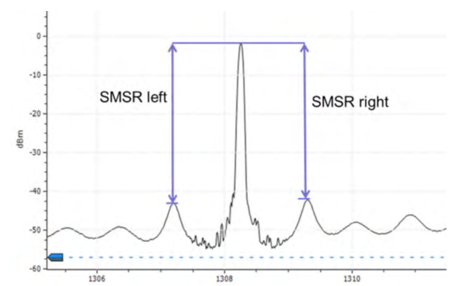

Figure 3. SMSR definition

Center wavelength:	1530,331 nm	Worst case SMSR:	51,45 dB
Peak power:	5,15 dBm	Worst case SMSR position:	1530,895 nm
Bandwidth at 3.00 dB:	0,031 nm	Left stopband:	0,443 nm
Bandwidth at 20.00 dB:	-	Right stopband:	0,564 nm
Left SMSR:	59,36 dB	Central offset:	-0,060 nm
Right SMSR:	51,45 dB	Fabry-Perot mode spacing:	0,675 nm

Figure 4. DFB mode display on EXFO's FTBx series of OSAs

In the case of FP lasers, the full width at half maximum (the spectral width of the main mode 3 dB below the peak) is another common key performance indicator.

Trace 1

Spectral Width Results		λ_{mean} Results		λ_{peak} Results	
λ_{center} (nm):	1560.9860	λ_{mean} (nm):	1561.3140	λ_{peak} (nm):	1562.3153
$Level_{center}$ (dBm):	-5.79	$Level_{mean}$ (dBm):	-5.47	$Level_{peak}$ (dBm):	-3.14
Δλ@20.00dB (nm):	5.3722	σ (nm):	1.1880	**Optical Power Results**	
Number of Modes:	17	**FWHM Results**		Total Power (dBm):	6.10
Mode Spacing (nm):	0.3339	Gaussian FWHM (nm):	3.3880	Total Power (mW):	4.07

Figure 5. FP mode display on EXFO's OSA20

As we move closer to system-level testing, optical characteristics become more relevant at the expense of opto-electrical parameters such as the threshold current.

Spectral testing of TOSAs

Best practices for characterizing TOSAs closely follow the measurements discussed in the laser section. The relevant measurements are:

- Center wavelength
- Power
- SMSR

Additionally, since TOSAs often contain a cooling module, a measurement of central wavelength as a function of temperature is often performed. The 20 dB linewidth, i.e., the spectral width of the main mode 20 dB down from the peak, can also be of interest in manufacturing.

Spectral testing of transmitters

As we move closer to system-level testing, optical characteristics become more relevant at the expense of opto-electrical parameters such as the threshold current. At the transceiver level, most vendors will focus on measuring:

- Central wavelength
- Power
- 20 dB linewidth
- SMSR

In addition, other protocol layer tests such as throughput, bit error rate and latency are carried out on transmitters.

Spectral testing of amplifiers

The amplifier is a key component of longhaul transmission systems. As such, most testing of amplifiers is performed as part of overall optical system testing, details of which we provide in the next section. However, testing amplifiers can also be performed independently, allowing for much better characterization of the instrument itself. In this regard, amplifier vendors will look to measure the performance of their instruments using the following keys parameters:

- Spectral coverage
- Gain and gain flatness as a function of the wavelength
- Noise figure

Gain defines the amount of amplification achieved by the amplifier, while the noise figure provides information about the quality of that amplification by quantifying the deterioration of the original signal caused by the noise arising from amplified spontaneous emission (ASE). This background noise degrades the OSNR and increases the bit error rate (BER).

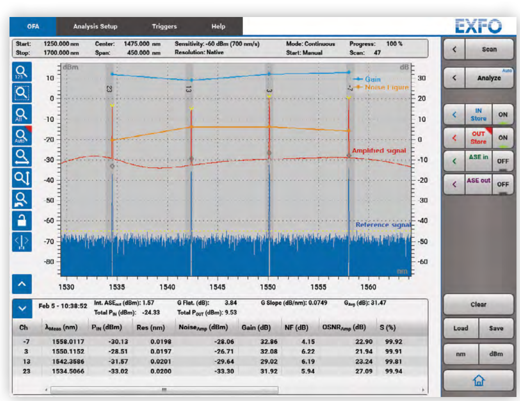

Figure 6. OFA (optical fiber amplifier) mode display in EXFO's OSA20

It should be highlighted that selecting the right OSNR methods, which depends on the data rate and the presence or not of ROADMs, is critical for obtaining an accurate OSNR reading.

Spectral testing of optical systems

This last level of optical source integration involves a lab simulation of transceiver behavior in an optical network that replicates the topology of real networks: long fiber spans, amplifiers, maybe some reconfigurable add-drop multiplexers (ROADMs), multiple channels, etc. As such, the spectral measurements carried out on optical systems in a lab setting, usually by verification groups, are very similar to those made in the field on actual networks.

Spectral testing at this level can be challenging and requires specific acquisition methods to provide meaningful results. For example, simulating longhaul networks involves a spectral measurement setup using a recirculating loop configuration, while passive optical networks (PON) require spectral acquisition of bursts of data, typical of this type of system.

The relevant parameters when testing WDM networks are:

- Channel identification
- Channel central wavelength
- Channel power
- Optical signal-to-noise ratio (OSNR)

A closer look at optical signal to noise ratio (OSNR)

Due to its greater complexity, OSNR deserves to be addressed independently. OSNR is the ratio of signal power to amplified spontaneous noise power, the latter being produced by amplifiers and ROADMs. OSNR reveals signal quality since receivers require a minimum OSNR value to operate error-free. The receiver OSNR threshold will vary according to the vendor and model, but is typically between 15 and 18 dB for 10G systems, between 12 and 15 dB for 100G QPSK-based systems, and around 19-20 dB for 16-QAM-based systems. It should be highlighted that selecting the right OSNR methods, which depends on the data rate and the presence or not of ROADMs, is critical for obtaining an accurate OSNR reading (Figure 6).

Data rate	ROADM	Modulation format	Baud rate	OSNR method
≤ 10 Gbit/s	No	OOK	10 GBd	IEC
≤ 10 Gbit/s	Yes	OOK	10 GBd	In-band
40 Gbit/s non-coherent	Yes or no	DPQSK or other	20 GBd	In-band
40 Gbit/s coherent	Yes or no	DP-QPSK or DP-BPSK	10 GBd or 20 GBd	Pol Mux / In-service Pol Mux
100+ Gbit/s coherent	Yes or no	DP-QPSK, DP-16-QAM	28 GBd	Pol Mux / In-service Pol Mux

Figure 7. The right OSNR methods for different situations

For an in-depth discussion of OSNR methods, please read "OSAs in next-generation networks" (www.exfo.com/umbraco/ surface/file/download/?ni=12838&cn=en-US), "40G/100G/200G OSNR measurements with a pol-mux OSA" (www.exfo. com/umbraco/surface/file/download/?ni=13240&cn=en-US) and "In-service Pol Mux OSNR measurements with an FTBx- 5255 optical spectrum analyzer" (www.exfo.com/umbraco/surface/file/download/?ni=13020&cn=en-US).

Also, verification engineers generally run spectral tests at different locations in the network. Tests at the receiver are paramount because they provide a complete picture of network behavior. If all spectral tests at the receiver pass, then tests elsewhere in the network become less critical. Spectral analysis at the transmitter or between the Tx and Rx also provides useful information about system performance, particularly if done over time to assess system stability. The drift mode in EXFO's OSA, which samples the signal at specific times for a duration specified by the user, is the ideal tool for this (Figure 8).

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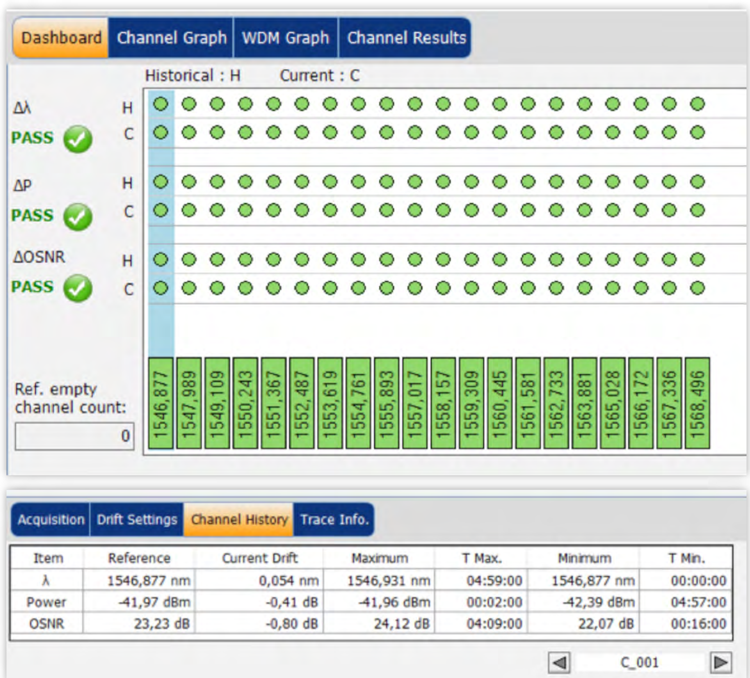

Figure 8. Drift mode in EXFO's OSA to evaluate the long-term spectral performance of an optical system

EXFO's spectral testing portfolio

EXFO offers a full range of high-performance OSAs for spectral testing in laboratory and manufacturing environments.

OSA model	Platform	Suitable environment	FB, DFB, EDFA, Transmittance	OSNR measurement method for non-coherent DWDM (10G, 40G)	OSNR measurement method for coherent DWDM (40G, 100G, 200G, 400G)	Special acquisition (RLT & Burst)
 FTBx-5243-HWA	FTB-4 Pro LTB-8	Manufacturing	✓	----	----	----
 FTBx-5245	 FTB-2/FTB-2 Pro  LTB-8 *	Field and manufacturing	✓	IEC interpolation	----	----
 FTBx-5245-P			✓	IEC interpolation and In-band	Pol-Mux	----
 FTBx-5255			✓	IEC interpolation and In-band	Pol-Mux and In-Service Pol-Mux	----
 OSA20	Benchtop instrument	Manufacturig and R&D Labs	✓	IEC interpolation	On/off	✓

The LTB-8 can host up to 8 modules including optical power meters, variable optical attenuators and switches. In addition, the EXFO Multilink feature connects multiple users to EXFO modules and LTB-8 platforms remotely through any web browser.

Abbreviations: FB=Fabry-Perot laser, DFB=Distributed FeedBack laser, EDFA=Erbium-Doped Fiber Amplifier, RLT=Recirculating Transmission Loop, INSPM=In-service Pol-Mux.

Learn more

Discover our complete range of OSAs for both laboratory and manufacturing environments.

EXFO serves over 2000 customers in more than 100 countries.
To find your local office contact details, please go to **www.EXFO.com/contact.**