NEW OSAs WITH IN-BAND OSNR CAPABILITIES–POWERFUL TOOLS FOR NEXT-GENERATION NETWORKS

By Marie-Hélène Côté, Sr. Product Manager, Spectral Solutions

Facing the Latest DWDM Testing Challenges

Dense wavelength-division multiplexing (DWDM) has emerged as a key strategic solution for telecom service providers. This technology provides scalable bandwidth, overcomes most fiber-exhaust scenarios, can handle different data formats and bit rates and is easily integrated into current network architectures at a reasonable cost. Recent technological advents, such as reconfigurable optical add/drop multiplexers (ROADMs) and new high-speed modulation formats for 40 Gbit/s or 100 Gbit/s, have changed the way that some tests need to be performed, e.g., optical signal-to-noise ration (OSNR). When assessing the ability of the spectral characterization tools to remain future proof, the previously listed capabilities need to be taken into consideration.

DWDM technology also requires that test-equipment manufacturers design instruments that are equally good in the field and lab. In addition to having superior specifications, field instruments must be easy to use, given that network managers have little time to master these new tools.

A portable optical spectrum analyzer (OSA) can measure the most important parameters in a DWDM system. The instrument is used during installation, commissioning, upgrading, maintenance and troubleshooting of a link in a network. An OSA may also be used to continuously monitor key parameters on the DWDM signal to verify the system stability; therefore, this instrument plays an essential role in ensuring proper DWDM system operation.

Measurement Principle

An OSA can divide a light wave signal into its constituent wavelengths, making it possible to see the spectral profile of the signal over a certain wavelength range. The profile is graphically displayed with the wavelength on the horizontal axis and the power on the vertical axis, as shown in Figure 1. In this way, the many signals combined on a single fiber in a DWDM system can be taken apart to perform per-channel analysis of the optical signal and its spectral interaction with the other wavelengths.

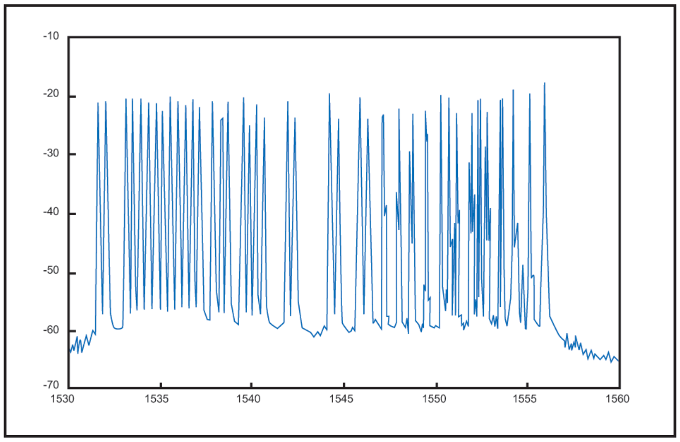

Figure 1. Typical OSA trace

In terms of field-testing applications, diffraction gratings are the preferred method for dividing the light wave into its components (colors). By definition, a diffraction grating is a dispersive element that, due to the multitude of the fine parallel lines on its surface, breaks up or diffracts a light signal into its optical spectrum. Once the signal is diffracted, it is possible to measure the power of any given wavelength by aligning a detector to a specific position on the diffracted spectra. To measure another wavelength, the detector must be realigned with another wavelength, and so forth.

Figure 2 illustrates the simplest OSA setup using a fixed detector–the single-pass monochromator. Today's OSA manufacturers have improved the basic design with new dispersive-grating arrangements, multipath schemes and impressive power-detection methods.

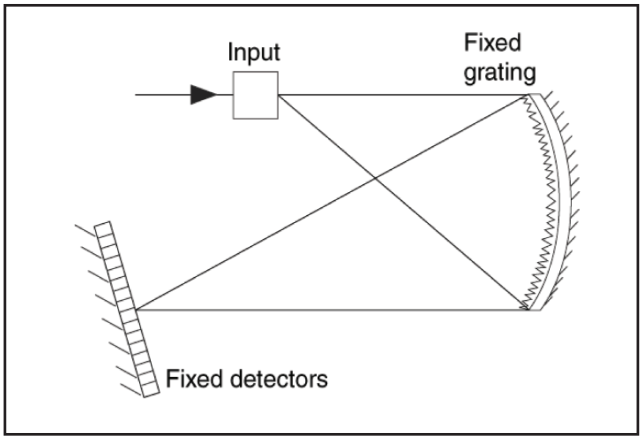

Figure 2. A simple OSA design

Key OSA Specifications

What is an acceptable dynamic range for an OSA? Why is a wide wavelength range an advantage? Why is resolution bandwidth important? The answers to these questions largely depend on the particular needs of the user, the rules dictated by the standardization bodies and the DWDM industry trends.

From the network operator's point of view, an OSA unit must be portable, rugged and easy to use. Furthermore, the optical performance must meet today's requirements and withstand foreseeable developments to avoid becoming quickly obsolete. Additionally, roll-out of next-generation networks–including ROADMs, 40 Gbit/s and even 100 Gbit/s modulation formats– requires new capabilities. If you are looking for a future-proof OSA, having in-band OSNR measurement capacity is a must.

Power Measurement Specifications	Wavelength Measurement Specifications	General/Performance Specifications
Optical rejection ratio (ORR)	Wavelength range	Field portability/ruggedness
Power dynamic range	Resolution bandwidth	Ease of use
In-band OSNR capability		

Optical Rejection Ratio

The optical rejection ratio (ORR) performance of an OSA determines its ability to measure low-level signals close to a peak; it is defined as the ratio (in dB) of the power at a given distance from the peak (Δλ) to the power at the peak of the OSA filter response for a given narrow input. In order to adequately measure OSNR with a desired accuracy, IEC 61280-2-9 suggests a required ORR at the noise measurement position (mid-channel) of at least 10 dB below the measured OSNR. For example, to measure an OSNR of 25 dB at 0.2 nm (0.2 nm around 1550 nm is 25 GHz and would be the mid-channel spacing for a channel set with a spacing of 50 GHz), the ORR of the instrument at 0.2 nm must be at least 35 dB to ensure an uncertainty below 0.42 dB on the OSNR measurement.

In Figure 3, two OSA traces are compared while measuring the same signal. The blue trace (upper trace) is from an OSA with a poor ORR specification, while the red trace (lower trace) is from an OSA with a better ORR. When many channels are closely spaced (i.e., 50 GHz), the importance of a good ORR is obvious.

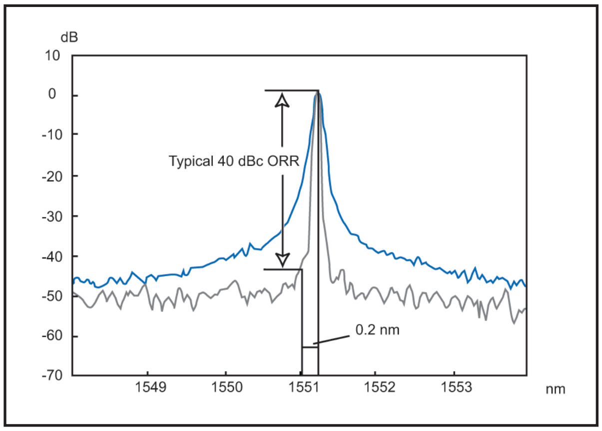

Figure 3. Optical rejection ratio

In Figure 4, it is clear that the ORR limitation of the upper trace hides most of the spectral details of the DWDM signal profile.

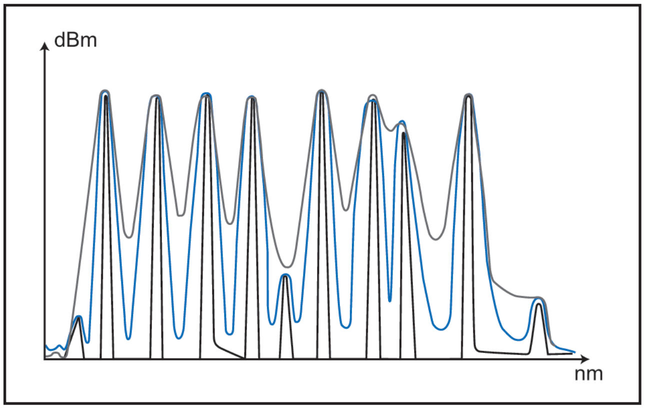

Figure 4. Impact of ORR on system identification

The main concern of the OSA user is to have a clear picture of the spectral profile. If the device's ORR is not higher than the system's optical signal-to-noise ratio (OSNR), the user will obtain a trace indicating the limitation of the test unit rather than the optical behavior of the signal.

It is clear that increases in channel count and smaller channel spacing are strong drivers for better ORR and power measurement specifications, but another important factor is the time-division multiplexing (TDM) bit rate on each of the system's channels.

System integrators and manufacturers have the responsibility of delivering a system that meets today's needs and that is also ready for future upgrades. Due to this responsibility, they use stricter standards for dynamic range and ORR, which allows for the required additional tolerance needed during the qualification of DWDM systems; in this way, they future proof the performance of their installation. On average, system integrators need to check OSNR levels from 21 dB up to more than 35 dB in different situations. A top-of-the-line OSA guarantees an ORR of at least 50 dBc at 0.4 nm (approximately -50 GHz) from the peak—allowing accurate characterization in all situations.

Wide-Power Dynamic Range

The wide-power dynamic range specification reflects the capacity of the optical detector in an OSA to effectively measure all the different power levels required for WDM applications. An instrument with wide dynamic range can accurately measure high power values and a low noise floor during the same acquisition, resulting in a clearer picture of the spectrum.

As the DWDM point-to-point link becomes increasingly long, higher power levels are used either to signal a launch or after amplifier points to reach longer distances. However, the signal peak power near the end of the link is very weak because of cumulative losses over a long distance. In this scenario, there is a need for measuring both high and low power values, depending on the point at which the DWDM system will be checked. There is also a need to measure low power when troubleshooting single system components. During this process, the test point must extract only a small percentage of the total power.

The capacity to measure the insertion loss of couplers, filters, optical multiplexer (MUX) and demultiplexer (DEMUX) paths, etc., requires low power sensitivity. As a result, an OSA with a wide dynamic range adds versatility, since it can be used for testing at both system and component levels. As WDM technology extends to the metro networks—and even to access networks—an increasing number of optical components are installed in the field, translating into an increasing need for reliable component testing outside the manufacturing plant and research labs.

In-band OSNR

Many high-bandwidth networks are currently being upgraded to include reconfigurable optical add/drop multiplexers (ROADMs) in order to improve efficiency and flexibility. Networks using ROADMs are somewhat different from standard systems: a simple glitch on a live network operating at many wavelengths and at high data rates can cause the system to lose a considerable amount of data, gravely affecting not only the overall quality of service (QoS) but costs as well, thus accentuating the importance of accurate measurement of OSNR.

Traditionally, the standard technique for measuring OSNR was to deduce it from a simple interpolation of the interchannel noise level between DWDM channels (as recommended in the IEC subsystem test procedure 61280-2-9); this is referred to as the "out-of-band" technique. However, the out-of-band technique is no longer valid in reconfigurable networks since the optical filtering in ROADMs removes the noise between channels. Therefore, in-band OSNR measuring techniques become essential to accurately measuring the OSNR in reconfigurable networks, and optical spectrum analyzers that base their measurements on the IEC 61280-2-9 procedure make critical errors.

Figure 5 presents a case where noise measured on channel 12 would have been underestimated by approximately 15 dB, using the traditional method. New OSAs made by EXFO are designed to enable accurate measurement of noise inside a channel (in-band noise) due to the polarization properties of noise (non-polarized) and signal (highly polarized) and our polarization diversity method. For more details, visit the *Library* section of our website.

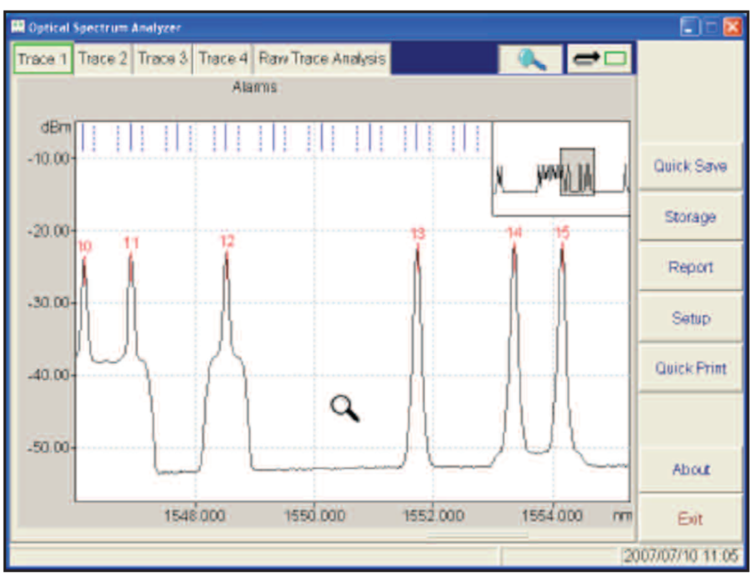

Figure 5. OSA trace acquired at the output of a ROADM, where channels 10, 11 and 12 clearly present the noise level that comes from filters ASE noise around -38 dBm, while channel 13 that traveled a different path presents much lower noise value (-53 dBm)

Wide Wavelength Range

An OSA wavelength range is its capacity to analyze signals over a defined section of the spectrum. It can be expressed in nanometers (i.e., 400 nm) or by indicating the initial and final wavelength of the range (i.e., from 1250 to 1650 nm). Many deployed WDM systems are designed to transmit their multiple channels in the C-band since this is the wavelength range for effective use of erbium-doped fiber amplifiers. This is the spectrum section from 1530 to 1565 nm, according to ITU-T Rec. G.692.

For high-channel count systems, the use of the L-band (L for long) for wavelengths above 1565 nm enables the number of channels in systems to increase to more than 160. The addition of channels in the S-band (S for short) at 1490 nm, for example, and around the 1310 nm region, justifies the need for the largest wavelength-range possible. New developments in the 1310 nm range for 40 Gbit/s and 100 Gbit/s—where four signals with 5 nm spacing (ITU G.694.1 specification: 1295.56, 1300.05, 1304.58 and 1309.14 nm) are multiplexed at the output of the transmitter module—are another reason why an OSA with a large wavelength range will be a clear requirement. Figure 6 shows the respective bands over the spectral attenuation profile of standard single-mode fiber.

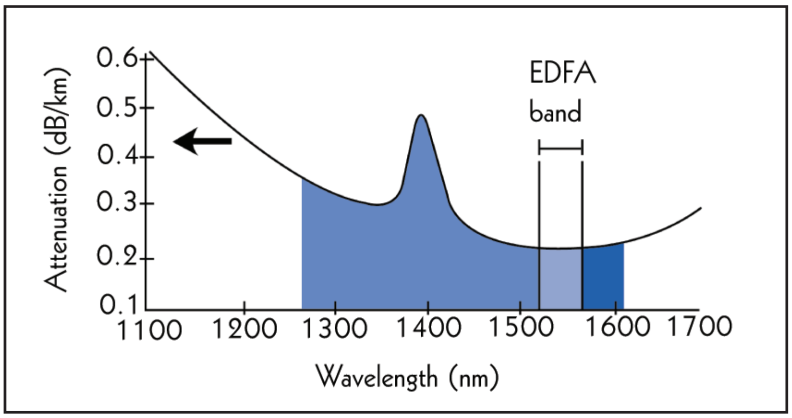

Figure 6. Spectral attenuation profile of standard single-mode fiber. The C-band is defined by the ITU while the S- and L- band ranges may change from one manufacturer to another

An OSA that can perform an analysis over all the bands (all single-mode wavelengths from 1250 to 1650 nm) is a future-proof and versatile instrument because it will be able to test under all the possible evolution scenarios in a system. Moreover, all optical supervisory channel (OSC) wavelengths can be tested with a wide wavelength range—the most common wavelengths for optical supervision are 1510 nm, 1625 nm and 1490 nm.

Small Resolution Bandwidth

Resolution bandwidth is the ability of an OSA to take apart two signals with close wavelength spacing. This specification is mainly determined by the optical filter behavior of the OSA's internal optics–the narrower the filtering, the better (smaller) the resolution bandwidth of the OSA. Top-of-the-line OSA units use a double-pass configuration together with high-quality diffraction gratings to achieve a good resolution bandwidth.

A very small resolution bandwidth of around 0.03 nm combined with a good ORR will increase the OSA's performance when measuring OSNR between closely spaced channels. The OSA will be capable of analyzing DWDM systems with channel spacing of 25 GHz (0.2 nm) or less. The ideal optical filter shape will have extremely sharp cutoffs (almost square). The filter shape is important when measuring the single-mode suppression ratio in DFB lasers or OSNR figures between high-power channels with small channel spacing. The more square the filter shape, the better the filter.

Field Ruggedness and Portability

The rapid increase in bandwidth demand is pushing WDM technology out of the laboratory at a record pace, creating a need for high-performance measurement instruments that are adapted to the outside-plant environment. An OSA is the workhorse instrument for the deployment and maintenance of DWDM networks; it is used in a wide range of situations, at different points in the network and eventually, in extreme environments–a reality that is far from the lab.

Most high-performance OSAs today are benchtop units designed for research installations. They are delicate units intended for controlled environments and experienced users. And, most field-portable OSAs decrease the optical performance to offer a practical testing solution.

Bulk optics and micrometer-precision mechanics are at the heart of an OSA. Any deviation in mechanical alignment between these components will directly degrade the optical specifications of the instrument. A portable OSA offers battery operation, which enables fast and convenient testing in many different situations. A field unit should also pass Belcore (Telcordia) drop tests without degrading its specifications.

Value-Added Features

As the technology for test and measurement on DWDM systems evolves, manufacturers are adding features to their portable, high-performance instruments. The relevance of these features is directly linked to their impact on productivity, test speed, data management and versatility.

Software for the Field

Traditionally, OSAs have complex software inherited from the lab. An OSA adapted for field testing offers a simpler user interface, including automatic testing and step-by-step simplified test procedures, pass/fail criteria and integrated reporting. This enables every operator to obtain the information needed–whether they are novices or DWDM experts. Features such as automatic discovery of existing channels, pre-loading of complete test parameters setup, pass/fail criteria and data saving and reporting ensure that even non-skilled operators get the best out of the instrument. Also, data transfer using a USB tool or an Ethernet link ensures easy troubleshooting or post-processing of data.

Conclusion

As digital networks migrate to optical technology, DWDM systems are everywhere. Therefore, there is a strong need for powerful, portable OSA units. The OSA is becoming a very important instrument for checking optical network quality at both the manufacturing and commissioning levels. By fully understanding the advantages and limitations of this instrument, OSA users can make an educated decision when choosing between units. For OSA manufacturers, understanding DWDM technology trends and the real needs of users means producing field-ready, future-proof and modular instruments. The new generation of OSAs will increase productivity and protect the user's investment, while delivering top-of-the-line testing capabilities for present and future systems.

EXFO Corporate Headquarters > 400 Godin Avenue, Quebec City (Quebec) G1M 2K2 CANADA | Tel.: +1 418 683-0211 | Fax: +1 418 683-2170 | info@EXFO.com

Toll-free: +1 800 663-3936 (USA and Canada) | www.EXFO.com

EXFO America	3701 Plano Parkway, Suite 160	Plano, TX 75075 USA	Tel.: +1 800 663-3936	Fax: +1 972 836-0164
EXFO Asia	151 Chin Swee Road, #03-29 Manhattan House	SINGAPORE 169876	Tel.: +65 6333 8241	Fax: +65 6333 8242
EXFO China	No. 88 Fuhua First Road Central Tower, Room 801, Futian District	Shenzhen 518048 P. R. CHINA	Tel.: +86 (755) 8203 2300	Fax: +86 (755) 8203 2306
	Beijing New Century Hotel Office Tower, Room 1754-1755 No. 6 Southern Capital Gym Road	Beijing 100044 P. R. CHINA	Tel.: +86 (10) 6849 2738	Fax: +86 (10) 6849 2662
EXFO Europe	Omega Enterprise Park, Electron Way	Chandlers Ford, Hampshire S053 4SE ENGLAND	Tel.: +44 2380 246810	Fax: +44 2380 246801
EXFO Service Assurance	285 Mill Road	Chelmsford, MA 01824 USA	Tel.: +1 978 367-5600	Fax: +1 978 367-5700

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