Choosing the Best Field-Based Optical Spectrum Analyzer for Analysis of 200G/400G and Flexgrid Signals

Jean-Sébastien Tassé, Product Manager, EXFO Inc.

INTRODUCTION

As the next generation of faster transponders operating at 200 Gbit/s and even 400 Gbit/s gradually become commercially available, optical spectrum analyzer (OSA) users might wonder what type of OSA will be required to analyze these signals; will traditional grating-based OSAs work, or will a new generation of OSAs be required? In this white paper, it will be demonstrated that traditional OSAs, with precise specifications for each application, are perfectly adapted to carry out the typical OSA measurements in the field, and that high-resolution OSAs are not required for field use.

CHARACTERISTICS OF 200G/400G CHANNELS

Signals operating at 200G and higher come with a number of technical novelties which include:

- Flexgrid
- Spectral shaping: root raised cosine or Nyquist filtering
- New modulation formats: mainly 16-QAM, but also 8-QAM, etc.
- Superchannels

Until recently, channels were always found on specific wavelengths, defined by ITU grids (50 GHz spacings or 100 GHz spacings). Flexgrid defines a new grid, where each channel width is a multiple of 12.5 GHz (n * 12.5 GHz, n being an integer), which allows for selecting variable channel width to best fit the signal width, as shown in figure 1. So far, 200G signals are found mostly on the ITU 50 GHz grid, while 400G signals will feature flexgrid superchannels.

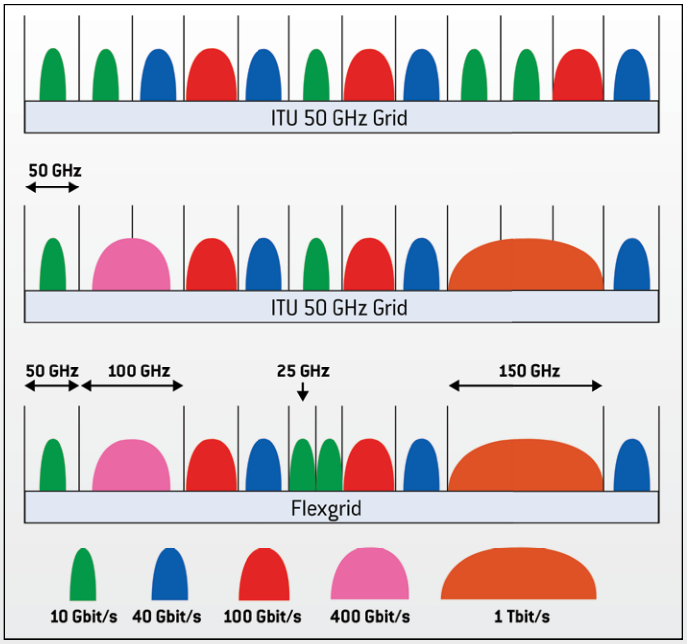

Figure 1. Flexgrid principle

Spectral shaping will also be everywhere for 200G/400G signals. It consists of applying a signal processing algorithm at the transmitter to obtain a flat-top signal, which reduces the spectral width occupied by the channel, increases spectral efficiency and decreases interchannel crosstalk (figure 2).

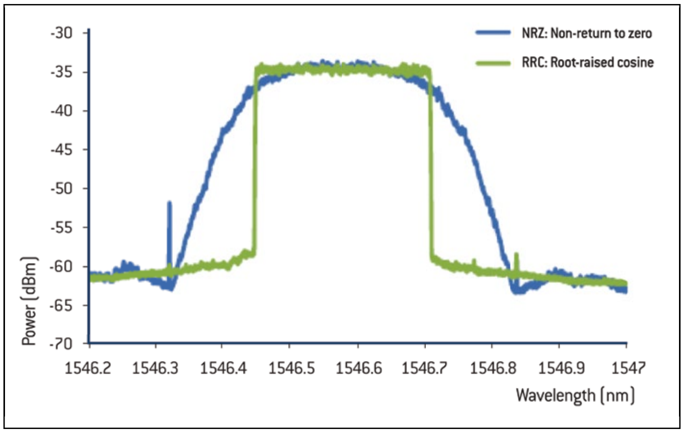

Figure 2. Comparison of a traditional signal (e.g. NRZ signal) and a spectrally-shaped signal (e.g. RRC signal).

Also, 200G+ will rely on a diversity of modulation formats. Quadrature phase shift keying (QPSK), the widespread 100G modulation format, will still be used in many cases, but the dominant modulation format, especially for <1000 km networks, will be 16 quadrature amplitude modulation (16-QAM).

The combination of flexgrid and spectral shaping opens the door to superchannels—a new type of signals consisting of several subcarriers. Common examples of a 400G superchannel include two closely spaced 16-QAM 200G signals or four 100G QPSK subcarriers. Most system vendors offer the flexibility of switching between modulation formats and data rates.

OSA TECHNOLOGIES

Currently, two OSA technologies exist: the traditional or grating based OSAs, and tunable optics or coherent OSA (sometimes called high-resolution OSAs). The former make use of a diffraction grating as the wavelength-selective device, while high-resolution OSAs rely on a tunable laser that sweeps the spectral range. As their name implies, high-resolution OSAs provide higher resolution bandwidth (RBW) than traditional OSAs, but this higher RBW is not always beneficial, as discussed in the next paragraph.

RESOLUTION BANDWIDTH (RBW) AND 200G/400G SIGNALS

Resolution bandwidth can be defined as the capacity of an OSA to separate closely spaced signals. Since flexgrid technology allows for smaller channel spacings, it makes sense to wonder what RBW is required for spectral analysis of these signals. Many OSAs have been labeled as “200G/400G compliant”, and the main specification that distinguishes them is the RBW. Let us have a closer look at the definition of RBW.

Simply stated, an OSA is a wavelength-dependent power meter. A filter, or slit, lets through a certain amount of light onto a detector, which takes the measurement. The OSA then displays the measured power associated with the central wavelength of the filter and, moving the filter across the entire wavelength band of interest, a graph is then generated showing power versus wavelength. Narrower slits will have higher resolution, as broad slits average the information from a broader range, which inhibits the view of closely spaced features. Therefore, one definition of RBW is the width of the slit inside the OSA. A smaller RBW will enable one to see finer details of a DWDM spectrum, such as clearly separating close channels, as shown in figure 3 below.

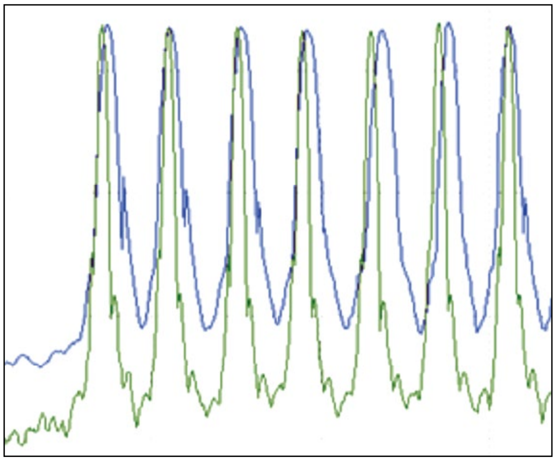

Figure 3. DWDM signals with 50 GHz spacings analyzed with an OSA with 65 pm RBW (blue) and 35 pm RBW (green)

Consequently, a smaller RBW is ideal to distinguish amongst closely spaced channels. But is a smaller RBW always better? Not necessarily, because the RBW must be wide enough to let through sufficient optical noise in a single scan, while at the same time avoiding crosstalk from neighboring signals. Thus, the ideal OSA slit would be a flat-top rectangular shape that is wide enough to encompass sufficient noise, and whose edges fall down to the instrument’s noise floor vertically from the peak’s maximum. **The best OSA for a given application is therefore the one that offers the best compromise between a smaller RBW to separate channels, and a larger RBW to provide good noise measurements.**

TYPICAL OSA MEASUREMENTS IN THE FIELD

To ascertain whether a certain type of OSA works for a certain application, it is important to remember which measurements are typically performed with an OSA. In the field, these measurements are:

- Channel power
- Channel central wavelength
- Optical signal-to-noise ratio (OSNR)
- Channel- or power- or signal flatness.

(Note that signal flatness, defined as the power difference between the most powerful channel and the weakest channel, can be calculated by measuring channel power.)

In R&D or manufacturing, other measurements might be performed, but these will not be covered in this paper.

Case 1: 200G 16-QAM

A single isolated 200G 16-QAM channel might be used when additional capacity must be added to an existing network, usually at 10G. Figure 4 compares the spectra of a root-raised cosine signal obtained with 3 OSAs: a 33 pm RBW OSA (EXFO’s FTB-5240BP), a 65 pm RBW OSA (EXFO’s FTB-5240S-P) and a high-resolution OSA. The power shown by the high-resolution OSA has been shifted upwards to facilitate comparisons. Note that it is normal that OSAs with different RBW give the same spectral shape, but shifted by several dB. This explains why channel power measurements are integrated values (i.e., integral of the area under the curve) which normalizes these measurements.

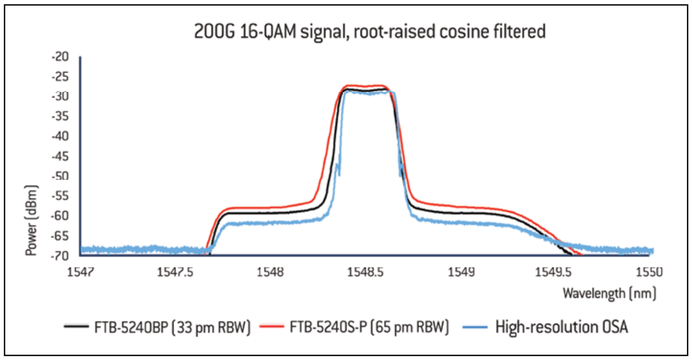

Figure 4. 200G signal analyzed with 3 different OSAs

Figure 4 displays a slight wavelength offset between the 65 pm RBW OSA and the two other ones, which stems from the slightly greater wavelength uncertainty of the 65 pm RBW OSA. This small wavelength offset is perfectly normal. **Therefore, figure 4 clearly shows that all three OSAs give, within their respective uncertainties, the same channel central wavelength, and the same channel power.** While the high-resolution OSA trace shows small features called side modes approximately half-way between the peak power and the noise floor, this does not affect the results of the four typical OSA measurements.

When looking at broadband optical noise, as seen in figure 4, the displayed noise floor on both sides of the signal depends on the RBW. This difference is actually quite normal and well-known by experienced OSA users, since as previously discussed, the smaller slit of higher RBW OSA lets through less light. This explains why OSNR measurements are always normalized to 0.1 nm RBW, as discussed in the IEC 61280-2-9 standard[1]. **Accordingly, all three OSAs provide similar results for the four typical OSA measurements, since channel power is the integrated power of signal, channel wavelength is a center of mass calculation and OSNR measurements are normalized to 0.1 nm RBW for comparison purposes.**

Case 2: 200G and 100G on the 50 GHz ITU grid

The second case is probably more representative of actual DWDM systems. It consists of a 100G QPSK signal on the left-hand side, and a 200G 16-QAM channel on the right-hand side, both with root-raised cosine spectral shaping. It can be observed that both 200G and 100G channels have similar spectral shapes.

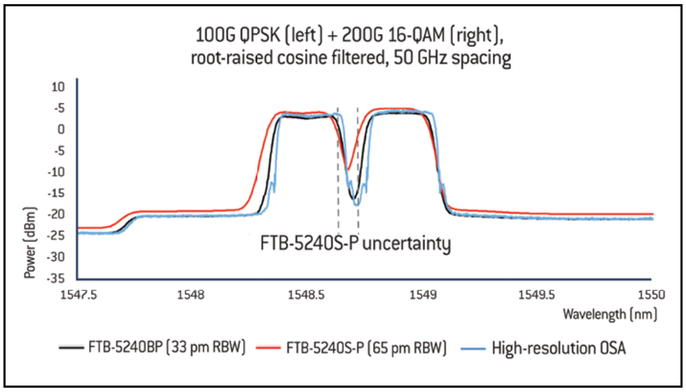

Figure 5. 100G and 200G signals analyzed with 3 different OSAs, 50 GHz spacing

First, all three OSAs can easily separate amongst the two channels, a key requirement to assess the suitability of an OSA for a given application. Also, the curves of the 33 pm RBW OSA and the high-resolution OSA match very closely. As in figure 4, the trace obtained with the 65 pm RBW OSA displays a slight wavelength offset versus the other two OSAs, but that offset is well within the instrument's wavelength uncertainty, as shown by the two vertical dotted lines. Accordingly, all three OSAs display similar channel wavelengths, within their respective uncertainties. The curve of the 65 pm RBW OSA features a more shallow dip between the two channels than the high-resolution OSA and the 33 pm RBW OSA, but that information has no significant impact on the four typical OSA field measurements. Therefore, all three OSAs deliver similar results for channel power, wavelength and OSNR, provided the right OSNR method is used. Note that the IEC 61280-2-9 interpolation method is not suitable for coherent channel OSNR measurements: the IEC 61282-12 (under revision) and CCSA YD/T 2147-2010 are suitable.

Case 3: 400G superchannel, flexgrid spacing

Figure 6 depicts an example of what future networks might look like: a superchannel consisting of two subcarriers, with flexgrid spacing of 37.5 GHz which is the common spacing for 400G superchannels with two 200G subcarriers. Although the channel on the left is QPSK, its spectral shape is almost identical to that of a 16-QAM signal, and this example is hence very representative of a 400G superchannel.

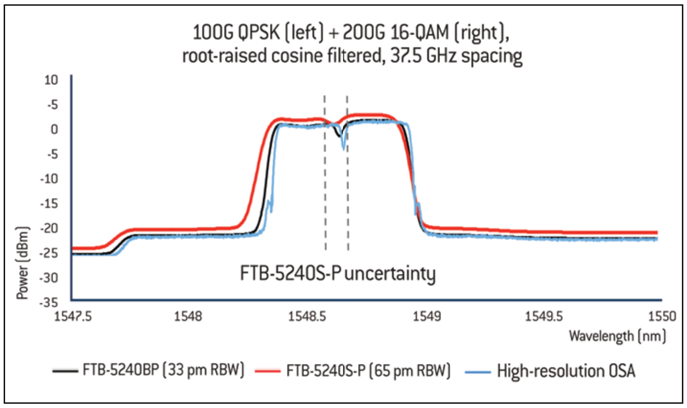

Figure 6. 100G and 200G signals analyzed with 3 different OSAs, 37.5 GHz spacing

Here, the 33 pm RBW OSA and the high-resolution OSA can distinguish amongst the two channels, while the 65 pm RBW OSA shows an interchannel dip that is too small to be attributed to the presence of two channels. However, the 65 pm RBW OSA trace features a dip that corresponds with the dip of the other two OSAs, within its wavelength uncertainty, as shown by the two vertical dotted lines. Just like in case 2, the 33 pm RBW OSA and the high-resolution OSA curves match very closely, and they accordingly deliver similar values for the four common OSAs field measurements. Therefore, for 400G spectral analysis, the FTB-5240BP and high-resolution OSAs are suitable, while the FTB-5240S-P is not recommended.

[1]*The IEC 61280-2-9 standard states that OSNR can be calculated with this equation :*

$$OSNR = 10\log\frac{P_i}{N_i} + 10\log\frac{B_m}{B_r}$$

where P_i is the signal power of channel i, N_i is the noise power of channel i, B_m is the bandwidth of the measurement, and B_r is the reference optical bandwidth. "Typically, the reference optical bandwidth is 0.1 nm."

Measurements of the OSNR of coherent 40G+ channels is covered by another standard, the IEC 61282-12.

THE RIGHT OSA FOR EACH APPLICATION

To summarize, selecting the right OSA depends on the application, as displayed in figure 7.

Data Rate	Spacing	Required RBW	Recommended models
10G to 400G	50 GHz	≤0.1 nm	FTB-5230S, FTB-5240S/S-P/BP
10G to 400G	Flexgrid (37.5 GHz)	≤ ~ 35 pm	FTB-5240BP, high-resolution OSAs

Figure 7. 100G and 200G signals analyzed with 3 different OSAs, 37.5 GHz spacing

In particular, a grating-based OSA with an RBW of 65 pm like the FTB-5240S-P is perfectly suitable to test 200G+ signals on the 50 GHz ITU grid, and a 33 pm RBW OSA like the FTB-5240BP is capable of analyzing superchannels, with flexgrid channel spacing. In addition, grating-based OSA have a number of benefits over most high-resolution OSAs: wider spectral range enabling testing of any type of network (i.e. DWDM, CWDM, DWDM over CWDM), in-band and Pol-Mux 40G/100G+ OSNR capabilities, faster scanning, and ruggedness for field use, to name a few.

EXFO Headquarters > Tel.: +1 418 683-0211 | Toll-free: +1 800 663-3936 (USA and Canada) | Fax: +1 418 683-2170 | info@EXFO.com | **www.EXFO.com**

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

WHITEPAPER064.1AN Printed in Canada 15/10