101 CWDM AND DWDM TESTING IN THE FIELD USING BROADBAND SOURCES AND AN OSA

APPLICATION NOTE

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Introduction

Most of today's CWDM and DWDM networks operate with a limited number of channels even though systems are generally designed for much higher channel count. But how do you know how many channels your system can actually support? This is an extremely important question if you are eventually planning to upgrade your system because, let's face it, the worst time to find out that components do not meet original specifications is during a system upgrade. Therefore, it is good practice to test multiplexers and demultiplexers before commissioning.

There are two preferred methods of doing this. The first is by taking a tunable source and a broadband detector (such as a power meter) and sweeping through the channels of the passive device, and the second is by taking a broadband source and an optical spectrum analyzer to perform the sweeping. This application note will essentially present the second configuration, explaining how and why such a test should be performed. This combination is ideal for measuring devices such as filters, isolators, circulators, attenuators, couplers and any other optical components with low or high loss. Used with an OSA, a broadband source (such as an amplified spontaneous emission (ASE) or super luminescent LED (SLED) source) will enable testing of bandwidth, central wavelength, ripple and insertion loss (see Figure 1).

Important Test Parameters

- ***Central Wavelength:*** As channel count increases, the spacing between the channels is reduced, and the linewidthis also decreased accordingly. If the central wavelength of the passive device's passband is not exactly the same as that of the transmitter, the device may block part of the signal and some data may be lost.
- ***Peak Power/Insertion Loss:*** Peak power is the main factor affecting the distance that the signal will travel. Passive components must minimize each channel's loss in order not to jeopardize the power budget.
- ***Power Flatness and Ripple:*** The optical amplifier's gain is related to the individual power carried by each signal. If all input wavelengths have similar power levels, they will all be amplified equally. Bad power flatness among the carriers will cause odd behavior in the amplifiers.
- ***Signal-to-Noise Ratio (SNR):*** The receiving end does not trigger on peak power level, but on SNR level. Distance and amplifiers degrade SNR; it is therefore crucial that the SNR degradation caused by passive components remain minimal.
- ***Channel Bandwidth and Channel Isolation:*** These parameters correspond to the amount of information from one channel that is present in neighboring channels. As spacing between channels is reduced, the channel bandwidth narrows, the neighboring channels get closer and closer, and crosstalk must be controlled tightly.

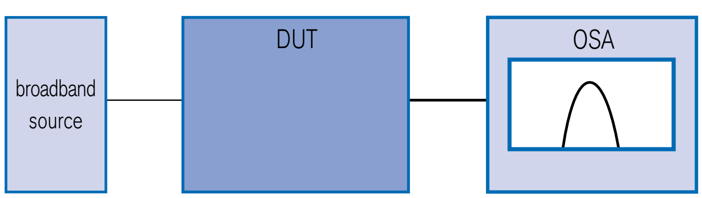


Figure 1. Typical setup for the characterization of a CWDM or DWDM in the field

Selecting the OSA

The discussions in this section refer to a double-pass grating-based OSA. The reason for using this type of instrument is that it is specifically built for field use, and offers the best optical rejection ratio (ORR), a low resolution bandwidth (RBW), excellent dynamic range and exceptional wavelength accuracy and repeatability.

- ***OSA Optical Rejection Ratio and Resolution Bandwidth***
  An OSA is a wavelength-agile power meter. The signal is divided into "slices" of light, determined by the filter shape. Ideally, the filter shape should look like a tall thin rectangle. The ORR specification of the OSA relates to the steepness of the filter, while the resolution bandwidth relates to its width.
- ***OSA Dynamic Range***
  Most CWDM and DWDM passive components have very little insertion loss in the passband, but it increases significantly directly outside this wavelength range. An OSA with a good dynamic range allows for testing of a broad range of components, regardless of whether the loss is high or not. For high-loss measurements, an OSA with a large RBW is preferred as it provides more light to the OSA detector, thus increasing the dynamic range of the test station.
- ***OSA Wavelength Accuracy***
  The central wavelengths of filters and passive components are defined by the ITU grid. To avoid crosstalk within the system, there is very little tolerance on this matter. The accuracy of a good OSA should be smaller than this tolerance to ensure proper testing.

When testing components or networks in the field, portability and ruggedness are also very important since the OSA will be used in many different test environments.

Selecting the Source

Having discussed the important OSA characteristics, here is a quick overview of the important source specifications to consider.

- ***Power Output***
  When using broadband sources, it is important to understand how the power spectral distribution affects measurement limitations. When looking at some broadband source power specifications, you might see the terms total power, peak power, and (power) spectral density:
  - ***Total power***, expressed in dBm or mW, is the total integrated power of the source, as is measured when connecting the output directly to a power meter.
  - ***Peak power***, expressed in dBm or mW, is simply the highest power level across the spectral distribution, as measured with an OSA. In order for this to be a meaningful value, you need to combine it with the resolution bandwidth of the OSA.
  - ***Spectral density***, usually expressed in dBm/nm, is the integrated power in a 1 nm slice of the spectrum. This is normally measured with an OSA whose resolution bandwidth is set to 1 nm. The power density will vary as a function of wavelength across the range of the source.

Spectral density will limit dynamic range when performing measurements with a grating-based OSA. As an example, let's say that we have a source that has a relatively flat power density of −10 dBm/nm and we want to take measurements with an OSA that has a resolution bandwidth of 0.1 nm. As this RBW setting is one-tenth of the 1 nm setting of the specification, the reference power is also one-tenth of what is measured in a 1 nm slice (~ −20 dBm). In our example, −10 dBm/nm is equivalent to −20 dBm/0.1 nm (see Figure 2). However, if we connect a DUT with 50 dB loss and measure it with the OSA, the power reaching the OSA in the 0.1 nm slice is now only −70 dBm, whereas it will reach −60 dBm in a 1 nm RBW. In that case and for high losses in general, the sensitivity of the OSA will limit the RBW that can be selected.

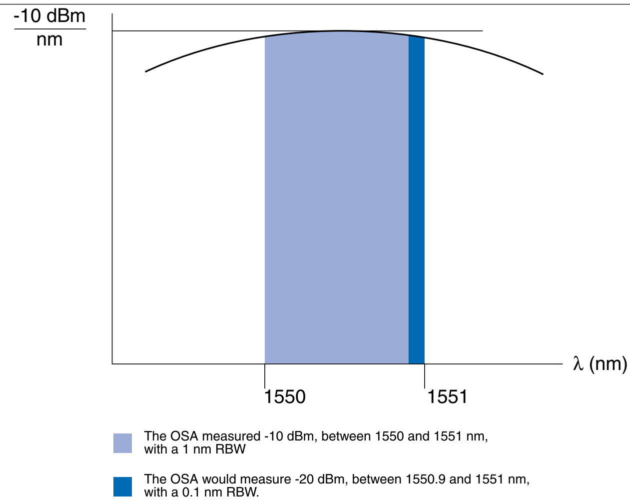


Figure 2. Resolution bandwidth of the OSA and the difference in spectral density, expressed in dBm/nm or dBm/0.1 nm

- ***Spectral Density Stability and Output Power Stability***
  The spectral density stability of a broadband source is the largest variation of the measured power in a spectral slice (over a certain period of time). Total power stability of a source is the variation over time of the total integrated power. It is relatively simple to design a sourthat has excellent total power stability; however, spectral stability is much more challenging and it is important to note how the pecifications are written. Because of the nature of ASE sources and even LED/SLED sources, transfer of energy from one wavelength to another often occurs. Sources are now available with a spectral density stability of ± 0.04 dB or better (you may want to refer to EXFO's FLS-2300B and FLS-2200 specification sheets, both optimized for spectral density stability).

  When characterizing DWDM components, we generally want to have measurements that are as precise and repeatable as possible. If the power in the spectral slice varies, this adds to the uncertainty of the measurement.

- ***Operating Wavelength Range***
  The operating wavelength range of the source is the maximum attainable wavelength range while achieving minimum detectable power density. An ASE source will provide a very powerful signal in the C and L bands, where erbium amplification occurs. An SLED source is certainly less powerful than the ASE source, but can cover a much wider selection of wavelength ranges. For example, the FLS-2200-SCL Broadband Source covers the 1460 nm to 1625 nm range with typically more than −29 dBm/nm.

Measurement Setup

The selected source must emit a spectrum broad enough to extend over the entire CWDM or DWDM wavelength range; otherwise, a few consecutive tests will have to be performed. When such a source is connected to the entry port of a CWDM or DWDM passive component, an accurate OSA can reveal the transmission characteristics of the component; i.e., its spectral response.

The quality of the measurement will be as good as the quality of the tool. An OSA with a 20 pm wavelength accuracy, a resolution bandwidth of less than 70 pm and an SNR of at least 45 dB ensures that the OSA is not limiting the characterization.

A typical measurement sequence would be as follows (see Appendix for illustrations):

1. First, the source is turned on and left to stabilize (warm up).
2. Next, a reference measurement is performed (source connected directly to the OSA via the patchcords to be used later).
3. Then, the DUT is inserted and the DUT measurement is performed.
4. Finally, loss is calculated by taking the difference between the measurement and the reference.

Results

Using this method has some advantages over the tunable laser source/power meter combo. Firstly, a broadband source can cover a very wide wavelength range, which enables testing components such as CWDM or DWDM devices, WDM couplers, switches and attenuators. In addition, the OSA offers very good power linearity, which is great advantage when measuring spectral ripple of filters. The high dynamic range and sensitivity of the OSA allows for a very high-performance test station, even for high-loss situations. And finally, no synchronization is necessary to provide a spectral response when using a broadband source and OSA. Today's high-end field OSAs offer several integrated applications to automatically calculate the device bandwidth, insertion loss, central wavelength and ripple.

On the other hand, the use of a tunable laser source and power meter combination allows you to test the component even while the network is active. Selecting the wavelength is an easy task (wavelength accuracy is most important) and transmitted power can be readily calculated through referencing of the signal. But there has to be some synchronization between the emitter and the detector in order to achieve spectral characterization of a device over a certain wavelength range.

When using the OSA, the output spectrum needs to be compared with the spectrum of the source itself. If the reference measurements are taken properly, and the OSA is properly calibrated, an accurate loss spectrum of the component is acquired. High-end field OSAs have an integrated function to automatically compare traces and determine the transmittance accordingly. Figure 3 presents the results of such an acquisition performed with EXFO's FLS-2300B ASE source (C and L bands), combined with an FTB-5240 OSA.

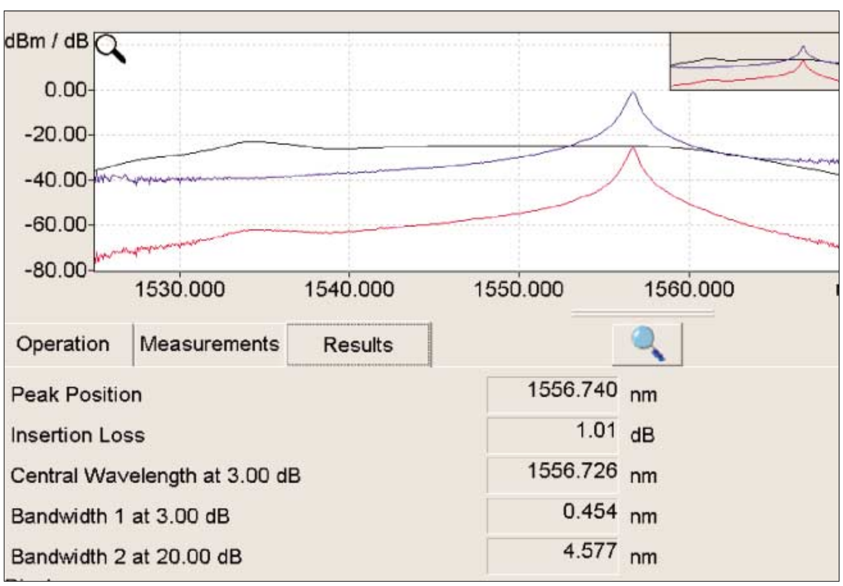


Figure 3. User interface of EXFO's FTB-5240 or FTB-5240B portable OSA (Broadband source used in this setup is the FLS-2300B)

If the components being tested are multichannel devices, the setup can include a switch to enable automatic testing of all the channels. Some modular field platforms can include both an OSA and a switch at the same time, thus enabling multichannel component testing with a single field-portable unit. Such platforms can also include a multiwavelength meter for accurate calibration of the OSA. Figure 4 presents EXFO's solution for testing multiplexers in the field.

Figure 4. EXFO'S FLS-2300B ASE Source, FLS-2200 Broadband Source (SLEDs) and FTB-5240B OSA

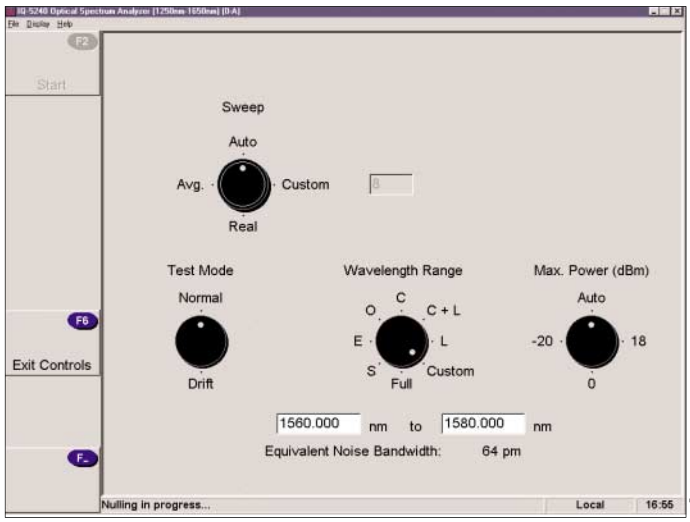
APPENDIX
Overview of Typical Test Sequence

Setting the Source

- First, turn on the source. For optimal performance, turn on the source as early as possible in order to let it stabilize (recommended warmup time for the FLS-2300B is two hours; 30 minutes for the FLS-2200).

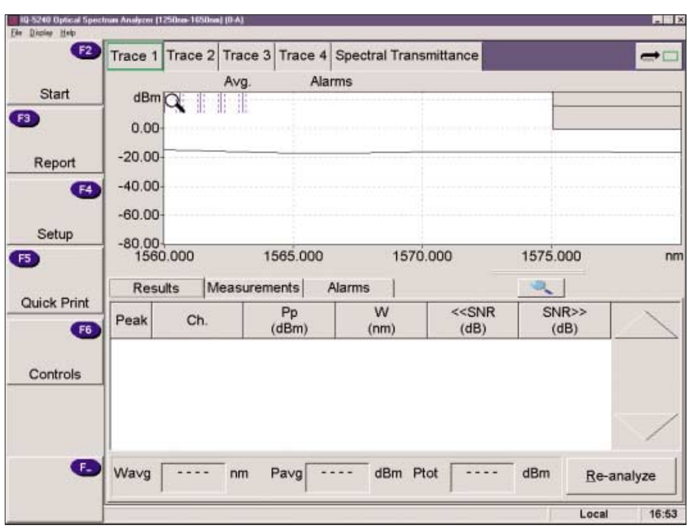
Setting the OSA

- Simply set the Sweep control to Auto and the Test Mode control to Normal; then set your wavelength range and power range, using corresponding controls.

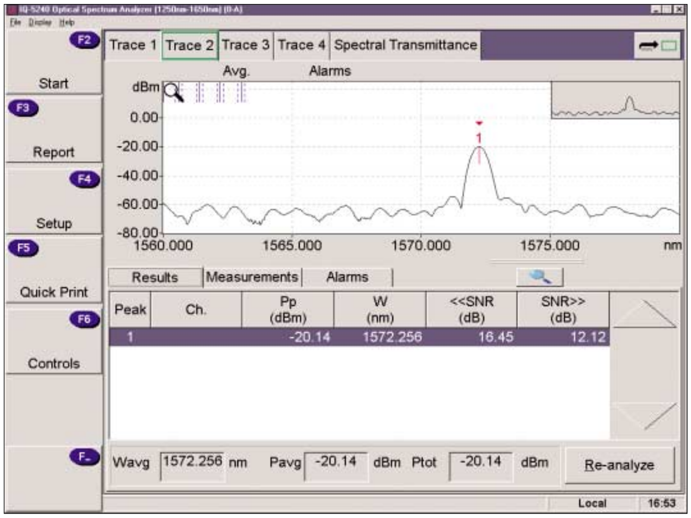


Testing the MUX

- First, from the Trace 1 tab, take a reference trace (with source connected directly to the OSA).

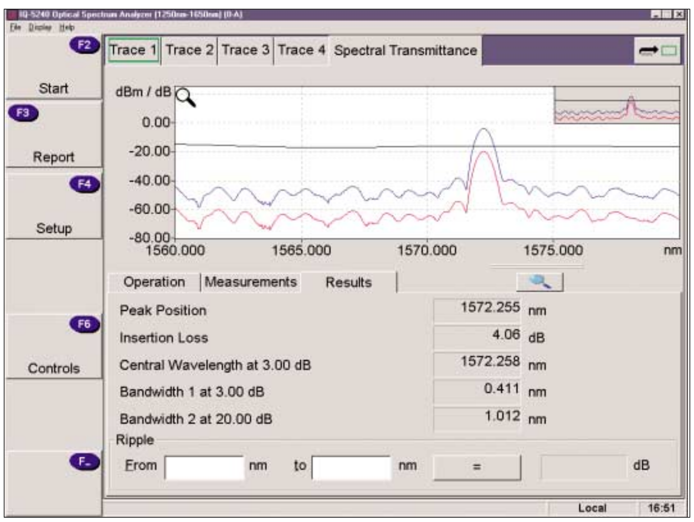


- Then, from the Trace 2 tab, acquire a second trace; this time, with the DUT between the source and OSA.



Results

- From the Spectral Transmittance tab, enter appropriate data in the Operation tab (trace 2 minus trace 1).
- Then, click on the Results tab, and results (blue line) will be displayed in dB.



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