The Power of Precision

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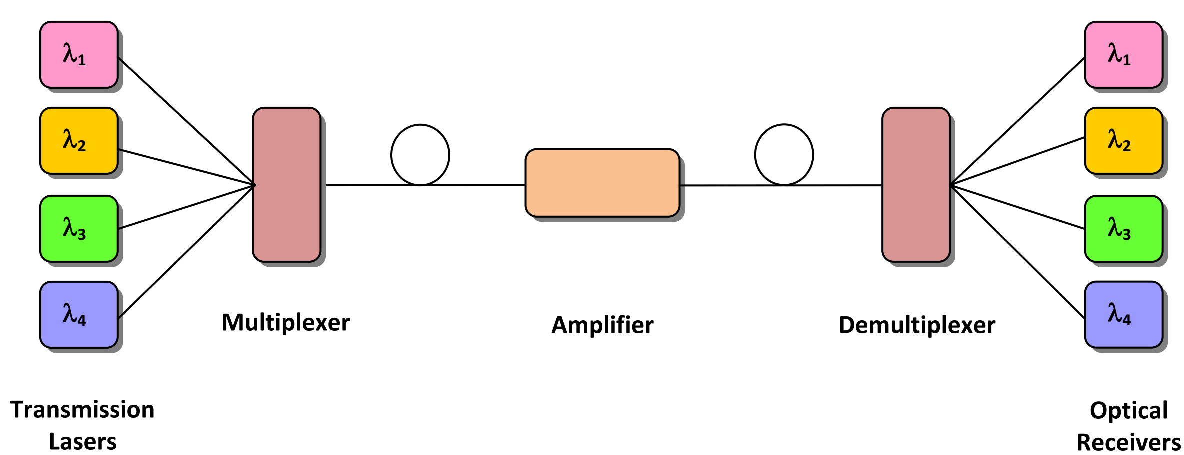
Wavelength Testing Solutions for DWDM Components and Systems

The demand for access to larger volumes of digital information continues to force telecommunications service providers to increase the capacity of their fiber-optic transmission systems. This is typically done by employing dense wavelength division multiplexing (DWDM) technology, a technique that couples multiple optical carrier signals onto a single optical fiber by using different laser wavelengths. DWDM technology requires stringent performance criteria be met in order to ensure quality, uninterrupted communications. In particular, the ability to accurately measure optical wavelength is necessary to characterize and optimize DWDM components, such as transmission lasers, and the optical signals from DWDM transmission systems.

A DWDM system employs several lasers at different wavelengths to simultaneously transmit separate streams of data along a single optical fiber. At the receiving end, the different wavelengths are optically separated and individually detected. A simple schematic representation of a point-to-point DWDM link with four channels is given below.

Four-Channel Point-to-Point DWDM Link



To ensure the compatibility of all DWDM transmission systems, the International Telecommunications Union (ITU) has defined a grid of central wavelengths, each separated by 100 GHz (0.8 nm), that identifies the channel wavelengths that must be used. Therefore, all wavelength dependent components must be accurately tested with respect to center wavelength and wavelength stability. In fact, wavelength characterization is even more critical today because current DWDM systems use a sub-divided ITU wavelength grid of 50 GHz (0.4 nm) and, in some cases, 25 GHz (0.2 nm).

Bristol Instruments has developed a family of optical wavelength meters specifically designed for DWDM testing applications. These optical wavelength meters are ideal for the precise wavelength characterization of DWDM laser transmitters. Bristol Instruments also offers a multi-wavelength meter product for testing DWDM signals with as many as 250 optical channels.

DWDM Laser Testing

All DWDM lasers must be tested with respect to absolute wavelength to ensure compliance with the ITU wavelength grid. The **228 Series Optical Wavelength Meter** measures the absolute wavelength of CW DWDM lasers, combining high accuracy with exceptional repeatability to achieve the most meaningful test results. In addition, features such as short measurement time, straightforward operation, and rugged design satisfy the needs of both the R&D scientist and the manufacturing engineer. In some cases, the wavelength testing of DWDM lasers will be done when they are modulated to mimic operation in DWDM transmission systems. The **328 Series Optical Wavelength Meter** is available for this application. This system is virtually identical to the model 228, except that it employs a fast Fourier transform analysis of the optical signal which results in the ability to measure the wavelength of both CW and modulated DWDM lasers.

Two versions of the model 228 and model 328 are available. The 228A and 328A systems are used for the most demanding applications, measuring wavelength to an accuracy of ± 0.3 pm. For less exacting test requirements, the 228B and 328B systems are lower-priced alternatives with a wavelength accuracy of ± 1.2 pm. The accuracy of these optical wavelength meters is maintained over long periods of time because they are continuously calibrated with a built-in HeNe laser wavelength standard. In order to achieve the highest accuracy, the 228A and 328A use a single-frequency HeNe laser that is stabilized using a precise balanced longitudinal mode technique. A standard HeNe laser is used as the wavelength reference in the 228B and 328B. The confidence level of these systems is 3-sigma which means that ≥ 99.6% of the wavelength measurements will fall within the specified accuracy limits. To verify this performance, every 228 and 328 system is rigorously tested with laser sources that are traceable to an NIST standard.

In addition to measuring center wavelength, the 228 and 328 Optical Wavelength Meters measure a laser's long-term wavelength stability. A convenient drift feature automatically monitors wavelength as a function of time. Current values and their deviation from the measurement starting point are displayed to provide real-time status of the laser. The maximum and minimum values are also reported to give the limits reached during the measurement period. And, for a more complete analysis of laser performance, the 228 and 328 systems measure the laser's optical power to an accuracy of ± 0.5 dB.

DWDM Signal Testing

In order to ensure that a DWDM transmission system is operating properly, it is imperative to verify that each channel is operating at its specified wavelength within safe margins. In addition, it is necessary to determine that channel power levels are acceptable and that various noise factors are low enough not to affect signal integrity. These general requirements can be met by measuring the following critical parameters.

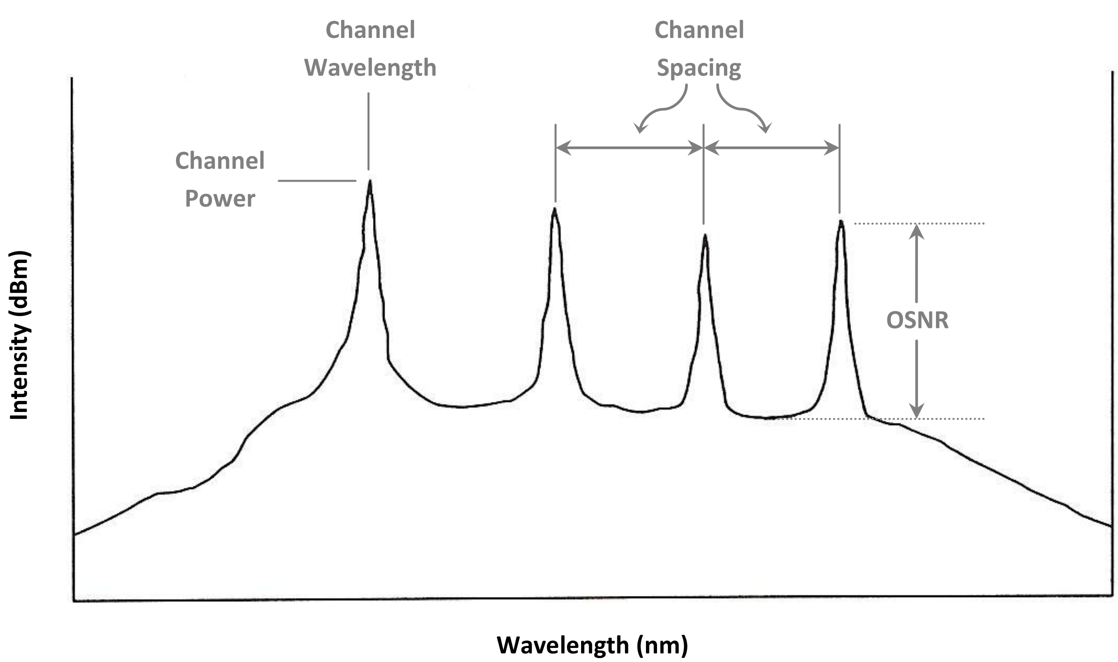
Absolute Channel Wavelength: In order to ensure compliance with the ITU wavelength grid, the absolute wavelength of each channel must be measured accurately. In addition, any drift in the channel wavelength must be studied to be certain that signals will remain within their assigned wavelength limits under all operating conditions.

Absolute Channel Power: This is a measure of the transmission signal and therefore must be of sufficient intensity to be detected at the end of a DWDM link. In addition, the power of each channel must be measured to verify that there is an equal distribution of power over all channels. This is of particular importance in systems that use cascaded optical amplifiers (Erbium-Doped Fiber Amplifiers, or EDFAs), where gain tilt has an important effect on the overall power transmitted in each channel.

Optical Signal-to-Noise Ratio: This parameter is a major determinant of the bit-error rate of a DWDM system, and thus of its performance and efficiency. It characterizes the optical noise level seen by the detector at the receiving end of the DWDM link. Optical noise is due mainly to amplified spontaneous emission in the EDFAs.

All three critical parameters are represented graphically in the following figure.

Four-Channel DWDM Signal



All three DWDM signal parameters can be measured by the **428 Series Multi-Wavelength Meter**. This system combines proven Michelson interferometer-based technology with fast Fourier transform analysis resulting in the ability to simultaneously measure the wavelength and power of 250 discrete optical signals. Wavelength is measured to an accuracy as high as ± 0.3 pm and power is measured to an accuracy of ± 0.5 dB. In addition, the 428 system automatically calculates optical signal-to-noise ratio (OSNR) to greater than 40 dB.

As with the 228 and 328 Optical Wavelength Meters, two versions of the 428 Multi-Wavelength Meter are available. The model 428A is used for the most demanding applications, measuring wavelength to the highest accuracy of ± 0.3 pm. For less exacting test requirements, the model 428B is a lower-priced alternative with a wavelength accuracy of ± 1.2 pm. The 428 system employs the same method of continuous calibration as the model 228 and model 328. A built-in wavelength standard is used to ensure a confidence level of 3-sigma. And, the performance of every 428 unit is verified via rigorous testing with laser sources that are traceable to an NIST standard.

Product Summary

228 Series Optical Wavelength Meter

- DWDM laser test
  - ✓ Single-wavelength and power measurement
  - ✓ CW optical signals

328 Series Optical Wavelength Meter

- DWDM laser test
  - ✓ Single-wavelength and power measurement
  - ✓ CW and modulated optical signals

428 Series Multi-Wavelength Meter

- DWDM signal test
  - ✓ Multiple wavelength, power, and OSNR measurement
  - ✓ CW and modulated optical signals