Testing DWDM
Passive Optical Components
This paper provides an overview of present and future requirements for testing passive optical components. Innovative new technology in DWDM passive optical components, used to meet the exploding bandwidth demand in fiber optic networks, creates new challenges in testing and measuring these components. They must be characterized over a wide range of parameters with the highest measurement resolution, accuracy and repeatability. This paper discusses the parameters tested, measurement theory and measurement techniques as well as solutions that satisfy both the demand for high accuracy and short measurement times.
The presentation begins with a short overview of DWDM passive optical components, how they are evolving, and the challenges in measuring them. A discussion of common tests is given, including details of the measurement techniques, followed by a look at specific problems and solutions in measuring the components quickly and accurately.
Wavelength Division Multiplexing (WDM) provides a means of utilizing the vast transmission capacity of an optical fiber beyond simply increasing the bit rate of a transmitter - receiver pair. In WDM, multiple transmitters, each at a different wavelength, are combined onto a single fiber by a WDM multiplexer (Mux). At the far end, a WDM demultiplexer (DeMux) separates the wavelengths into separate fibers to separate receivers. In this way, multiple transmitter - receiver pairs “share” the same fiber, much as radio broadcast stations (RF carriers) share the air.

The first and simplest WDM systems used 1310 and 1550nm wavelengths. Today's “dense” WDM (DWDM) systems use wavelengths more closely spaced in the 1550nm range. Optical amplifiers, primarily erbium doped fiber amplifiers (EDFA’s), play a critical role in facilitating long-distance DWDM links by amplifying all of the wavelengths in a single device. Without EDFA’s, long distance DWDM would be impractical.

DWDM also provides new possibilities in network architecture. Optical add / drop multiplexers (OADM’s) allow traffic on a particular wavelength to be separated out to a particular location while the rest of the traffic on the other wavelengths simply passes through. Traffic from that location is added back into the fiber by combining that wavelength with the others. This concept will be especially important in metropolitan networks where a large number of wavelength channels and OADM’s will handle a large number of subscribers.
The total capacity of a DWDM system can be increased in two ways. First, the bit rate of the individual channels can be increased. Current systems employ rates up to 10 Gbit/s, and 40 Gbit/s systems are under development. Second, the number of channels can be increased.

There are two ways to increase the number of channels. First, the channel spacing can be decreased to pack more into a given wavelength range. Channel spacings are moving from 100Ghz (0.8nm) to as small as 12.5 Ghz (0.1nm). The second way is to increase the useable wavelength range. Initially DWDM wavelengths were confined to the central or “C” band, which corresponds to the gain range of a standard EDFA, from about 1525 to 1565nm. Extension of EDFA gain into the long or “L” band now allows amplified channels up to about 1620nm. The next important wavelength window will likely be the short or “S” band, down into the 1400nm range.
The three common technologies for separating and combining wavelengths in DWDM components are fiber bragg gratings (FBG’s), dielectric thin-film filters (TFF’s) and phased arrays. Mux, DeMux and OADM components can be made by combining individual FBG’s or TFF’s or created as single component of silica waveguides on a single chip in a phased array configuration known as an arrayed waveguide grating (AWG).

Other important components for DWDM include dispersion compensators which can correct for fiber chromatic dispersion, optical cross-connects which are n x n optical switch fabrics, wavelength lockers which provide a wavelength error signal for wavelength control of a laser, optical circulators which are used to route the light in OADM’s and isolators used to protect lasers from reflections and to isolate EDFA’s at their input and output.
The next section discusses the tests commonly performed on DWDM components.
Tests of passive optical components can be divided into two broad categories - loss and dispersion. Insertion loss (IL), the loss in power of a signal through a device, is the most common test. Lower loss increases the potential distance of a transmission system or distance between amplifiers. As light travels down a fiber its state of polarization is constantly being transformed, so components in a system will usually receive light changing in polarization over time. If the insertion loss of a component varies with polarization, the power exiting will then vary over time. Since the light in a system will travel through many components, if their “polarization dependent loss” (PDL) is not kept small, the power finally arriving at the receiver will be unstable, potentially making the entire system unstable.

The last in the “all loss” set of tests is return loss (RL) which describes how much power reflects back from a device. Normally a high RL (low reflection) is desirable since reflections can upset the stability of unisolated transmitters, multiple reflections can create resonant cavities which cause wavelength dependent power fluctuations, and because they can create delayed images of the data arriving at the receiver.

In lower data rate systems, dispersion measurements are usually only important for the fiber itself, where the total dispersion increases with length. However, today’s 10 Gbit/s and especially the coming 40 Gbit/s systems often require even the small dispersion of the passive components be characterized.

This paper will focus on all-loss testing only, dispersion measurements will be covered in another paper.
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The evolution of DWDM components in the four approaches to extend transmission capacity create challenges in testing.

Decreasing channel spacing imposes a greater need for wavelength accuracy and resolution. On the way to all optical networks, optical switches and cross-connects with high port count are emerging, creating a need to test a large number of ports efficiently. The same is true for Multiplexers and Demultiplexers which are introduced with a constantly growing number of output ports.

Last, but not least, test and measurement solutions must follow the development and new technology trends in optical communication very closely. A good example is the hot 1400nm window, which will be used to extend the wavelength range and gained popularity because of the emerging Raman amplification technology.

Before starting a more detailed discussion about the requirements that optical test solutions face, general loss measurement principles will first be reviewed.
Loss is a stimulus-response measurement. A light source is used as the stimulus to launch light into the device. An optical receiver measures the response, the light exiting or reflecting from the device.

Non-DWDM devices, ones that have loss which does not vary significantly over wavelength, are usually tested only at one or two fixed wavelengths - 1310nm and 1550nm, for example. Fixed-wavelength Fabry-Perot lasers are used as the source and a simple power meter is used as the receiver. Connectors are an example of this type of device.

In DWDM devices where the loss usually is a function of wavelength, the loss must be measured over wavelength in a “spectrally resolved” loss measurement, often called a “swept” loss measurement. This requires that that either the source or receiver or both be wavelength selective or “tuned”. A tuned source, usually a tunable laser (TLS), can be paired with an untuned or “broadband” receiver, usually a power meter, which responds to a broad range of wavelengths. The opposite can also be done. A broadband source (BBS), such as one or more EELED’s or ASE from an EDFA, stimulates the device with a broad, continuous spectrum. Light leaving the device is shaped by its spectral loss and measured on a tuned receiver, usually an optical spectrum analyzer (OSA). Previously it was necessary to tune both the source and receiver, using a TLS and OSA, for certain types of devices. Today, advances in tunable laser technology have made this most expensive and complicated combination unnecessary for passive devices. The next slide compares these three possible measurement combinations.
Of the three swept loss measurement setups, the BBS - OSA (middle) has been the most commonly used. However, that combination has limitations in measuring today’s DWDM components where the TLS - PM (left) has several advantages. A major limitation of the BBS-OSA is its resolution. In order to analyze a device’s filter shape, the resolution bandwidth (RBW), the width of its sweeping filter, must be much narrower than the device’s, which is often impossible for today’s devices. Wavelength accuracy of OSA’s has improved, but relies on a pre-calibration and repeatability. The complexity of the sweeping filter in the OSA also limits its loss (power) accuracy. A strength of the BBS - OSA setup, its very fast sweep speed, is diminished when measuring devices with many outputs since a switch must be used and the outputs measured sequentially.

In comparison, resolution of the TLS - PM setup is limited only by the wavelength spacing of the samples on the power meter, which can be less than 0.001nm. The TLS’s equivalent of the OSA’s RBW is its linewidth, which is almost infinitely narrow (typ. 100kHz or 0.0000006 nm !). A high accuracy wavelength meter can be used to monitor the TLS during the measurement, ensuring high wavelength accuracy. Simple, low-cost power meters actually make the best loss measurement and allow all outputs to be measured in parallel, making this the fastest solution for multiple outputs.

The highest cost solution of TLS - OSA had been used to make up for deficiencies in TLS’s. New TLS technology makes this unnecessary, with the OSA’s filter actually adding error. Again a switch must be used for multi-output devices, slowing the measurement and adding additional uncertainty.
A loss measurement is a ratio type measurement meaning the ratio of two power levels must be determined. Insertion loss is the ratio of the power exiting the device, $P_{out}$, to the incident, $P_{inc}$, usually expressed in dB’s (IL is a positive number for passive devices). The measurement is done in two steps. In the insertion method (A), used for connectorized devices, the first or “reference” step is to connect a “reference” cable directly from the source to the power meter to measure $P_{inc}$. For a fixed laser this is a single measurement. For IL vs. wavelength with a TLS, it is a series of measurements while the TLS sweeps over wavelength (a “reference sweep”). The device is then connected between the source and power meter and $P_{out}$ is measured, again as a sweep for IL vs. wavelength. In this method the connector pair at the input of the device is part of the measured IL, there is no practical way to separate this connector loss from the actual loss of the DUT.

If the device has a bare fiber input, a reference cable with a bare fiber end is used and spliced to the device fiber. If the “cutback” technique (B) is used, it is possible to remove the splice loss from the measurement. In this technique the steps are reversed. First, the device is spliced in line and $P_{out}$ is measured. Next, the fiber is cut between the splice and the device (removing a few inches of the device’s input fiber) and $P_{ref}$ measured. Notice that the splice loss is part of the reference power, so it is not part of the measured IL. The cutback method could be used for a connectorized device, removing the connector loss from the measured IL. However, this would mean cutting off the input connector of the device, which is usually not practical.
From a spectral insertion loss measurement, filter characteristics can be deduced. Among the most important parameters are:

- Center wavelength
- Bandwidth
- Ripple
- Isolation

If the device consists of more than one filter, the interaction among the corresponding channels becomes of interest:

- Crosstalk
- Channel Spacing
- Flatness

Therefore, the spectral insertion loss contains the most information about the components filter behavior.

One of the biggest problems is that the definitions of such parameters may vary. For example, some prefer to specify the 3dB bandwidth of the filter, others need to determine the 1dB bandwidth. However, TIA FOTP 205 will give standardized definitions. Check the TIA website: www.tiaonline.org
The second common loss test is polarization dependent loss (PDL), which describes the maximum change in IL of a device over all states of polarization (SOP). There are two primary methods of measuring PDL in passive components. The first, shown here, is known as the “random polarization scanning technique”. If one were asked, “how can I know the total change in loss over over all states of polarization?”, one might answer “apply all states, measuring the loss at each one”. This is the basic idea of this technique. Actually, there are an infinite number of SOP’s, but the idea is to measure loss at enough SOP’s to find the minimum and maximum.

The measurement is done by using a stable, polarized source (most laser sources are highly polarized), a polarization controller with motorized fiber loops that will randomly vary the SOP without changing the power and a power meter with a low polarization dependent response. Measurements of the output power are taken over time as the polarization controller randomly varies (“scans”) the SOP. The p-p delta of the power samples is the PDL of the device.

To achieve the same accuracy, the larger the PDL, the more samples (more scanning time) are required. For small PDL’s of a few 0.1 dB’s or less, the PDL can be measured with about 3 seconds of scanning. This is fine if PDL is measured at one or a few wavelengths, since the total measurement time is on the order of the time to connect the device.
To measure PDL over the entire wavelength range of a device, to measure PDL vs. wavelength, possibly at 1,000’s of wavelengths, the polarization scanning technique would be too slow. Here a different technique which relies on polarization mathematics known as the Mueller Matrix can be used to greatly reduce the measurement time. This requires only four specific SOP’s be applied, which are all orthogonal on the Poincare sphere (a graphical representation of the SOP). To make known, rather than random, changes in SOP, a different type of polarization controller must be used. A controller containing a linear polarizer (to create linear SOP), and a quarter wavelength and half wavelength retarder plates, can “synthesize” any state of polarization by rotating the quarter and half wavelength plates.

Generating the four SOP’s and measuring the output through the device at each would take the same several seconds as the scanning technique. Speed is realized by taking a fast wavelength sweep at 1,000’s of samples per second in each of the four states, finishing the measurement in minutes, rather than the hours that would be required to stop and do polarization scanning at each wavelength. Because plate type polarization controllers tend to change the power as they change the polarization, a reference sweep in each of the four states is required. Even with that additional time, it is much faster than polarization scanning when PDL is to be measured over a large number of wavelengths.

For a complete description of the measurement and calculations, see the application brief on PDL in the References slide at the end of this paper. That brief is available from Agilent on request.
Because of the time involved, the polarization scanning technique is only practical for measuring PDL at a few wavelengths. For a bandpass filter, these would usually be taken in the passband, as shown in the left diagram.

The Muller Matrix method allows the PDL to be determined at all wavelengths in the sweep, giving a more complete analysis of the device’s PDL characteristics, as shown on the right.
The polarization scanning technique and the Mueller method are based on different approaches. However, both methods have one thing in common: they measure PDL. Ideally, both methods obtain equal values for the polarization sensitive transmission of a component.

Since there have been many concerns about the accuracy of the Mueller method, especially in conjunction with a continuous wavelength scan, a comparison to results obtained by the polarization scanning technique was done to validate the Mueller method approach.

As shown in the PDL measurement of a WDM filter, the PDL in the passband around 1534.2 nm is very small. Both methods demonstrate that they are capable of measuring low PDL values, and the results over wavelength are in very good agreement. The advantage of the Mueller method, again, is a much shorter measurement time.
The third common loss measurement is return loss (RL), which is the ratio of the (back) reflected power, $P_{\text{back}}$, and incident power, $P_{\text{inc}}$, usually expressed in dB's (RL is a positive number for passive devices). The most common method of measuring RL employs a laser source, 3 dB (50/50) directional coupler and a detector (power meter). Light launched into the coupler splits, with half going to a reflection-free termination and half to the device. Light reflected from the device travels back through the coupler, splitting in half to the source (which must be isolated) and to the detector which measures the reflected power.

A calibration of the setup is required for two reasons, done in two steps. First, RL is defined as the reflected to incident power ratio at the device plane (right side of the coupler), but the measurement is made on the other (left) side of the coupler. This first calibration step, measuring $P_{\text{REF}}$ with a known device, such as an open connector, effectively calibrates the incident power and loss from the device back to the detector. A second calibration step is required because there will be some unwanted power coming to the detector at all times. Terminating the fiber to the device leaves only the unwanted power at the detector, $P_{\text{Term}}$, which can then be subtracted from the total power at the detector when a device is measured, $P_{\text{MEAS}}$. 

$$RL = -10 \times \log \left( \frac{P_{\text{back}}}{P_{\text{inc}}} \right) (dB)$$

Reference Reflection
i.e. Open Connector $RL = 14.8$ dB
The two calibration steps shown in the previous slide, measuring $P_{REF}$ and $P_{Term}$, need only be done once as long as the source power remains the same. However, if the source power drifts, the measured RL values will drift by the same amount. The calibration steps would then need to be repeated to account for the change in source power. A general solution to this problem is to monitor the source power, which is done in Agilent RL modules.

The coupler, detector and termination on the bottom right in the diagram performs the RL measurement as in the previous slide. The upper left coupler and Monitor detector are added to monitor the source power. By taking the power ratio of the Monitor and RL detectors for the two calibration steps and the measurement step, rather than just the power of the RL detector, source drifts will cancel out in the final RL calculation, making the setup virtually independent of source power drift.
To verify that source monitoring in the RL setup, as shown in the previous slide, is effective, that setup was calibrated and a device connected and measured. The source power was then changed by 20 dB as RL readings were taken of the same device. The graph shows that the variation in the RL reading changed only 0.05 dB while the source power changed by 20 dB. Without source monitoring, the RL values would have changed by the same 20 dB as the source power.

In practice, source monitoring allows the RL setup to be calibrated once, and remain in calibration through an entire day of measurements.
The last section looks into the details of actual test systems including the problems which must be solved to make accurate and fast measurements of DWDM passive components.
As discussed in the comparison of test setups in the last section, the tunable laser - power meter solution has the best potential for meeting the test requirements of DWDM passive components. The very narrow linewidth of the TLS provides the highest resolution while power meters have the best power measurement accuracy. Since power meters are low-cost, the setup can include multiple power meters measuring in parallel to reduce the test time for devices with multiple outputs. For these reasons, this section will explore the important details of a TLS - PM measurements.

The diagram shows the TLS and multiple-PM setup. A plate type polarization controller is included to perform the PDL vs. wavelength measurement with the Mueller Matrix method as described in the previous section. The measurement is controlled by software on a PC using the GPIB bus to control the instruments.

For a TLS - PM setup to satisfy the measurement requirements listed, two critical performance limitations that TLS’s have traditionally had must must be overcome. The first is poor wavelength accuracy, which affects the wavelength accuracy requirement of the measurement. The second is spontaneous emission, which affects the dynamic range requirement. How these limitations affect a measurement and solutions to them are discussed next.
The basic concept of measuring IL vs. wavelength with a TLS and PM(s) is to have the laser move in wavelength while the PM(s) take samples (measurements) of the power exiting the device. The TLS can move either in a stepped or swept manner. In a stepped measurement, the laser moves a wavelength increment and dwells at that wavelength for a certain amount of time while the PM(s) take a power sample. This method is generally very slow. If the TLS can instead sweep at a constant velocity while the PM(s) take fast samples, the measurement will usually be faster by several orders of magnitude. A swept measurement requires proper synchronization of the TLS and PM(s). One way is to have the TLS generate triggers at the set wavelength interval (the “sample spacing”) to the PM(s) which take a sample at each trigger.

The power meters must be able to sample at a fast rate to achieve a small sample spacing at a reasonable sweep speed of the TLS. Usually this means that the PM(s) must have internal memory to store the results in during the sweep since transferring each sample individually over GPIB, especially from a large number of PM’s, would be too slow. Instead the complete set of samples is transferred at the end of the sweep.

Sample spacing is another part of the final resolution of the measurement. While the TLS linewidth may be very narrow, if a tight sample spacing cannot be achieved, details of the shape of the device will not be resolved.
Dynamic range is the difference between the largest and smallest loss value of a device that can be measured. In a TLS - PM setup one would normally assume that the dynamic range would be the difference between the TLS output power and the noise floor of the PM. However, the actual dynamic range of a TLS - PM can be limited to a much smaller value by a component of the output of the TLS known as source spontaneous emission (SSE). SSE is a continuous spectrum of light which surrounds the signal, usually over the entire tuning range of the TLS. In a standard TLS design, the total SSE power, represented by the entire area under the curve (shaded), is usually only 25 to 30 dB smaller than the signal power. That is, the Signal/Total SSE ratio is only 25 to 30 dB.

Consider measuring a device with a filter shape which is a narrow, deep notch, such as a fiber bragg grating. If the TLS signal power is 0 dBm, and the notch is 50 dB deep, when the TLS wavelength is in the area of the notch, signal power out of the device is: 0 dBm - 50 dB = -50 dBm. However, all the rest of the wavelength range of the device is low loss, so almost all of the SSE passes through the device to the power meter. The PM then receives the intended -50 dBm signal, but also the higher power -30 dBm of SSE. The power meter then measures the sum, which is approximately - 30 dBm. The dynamic range in this case is then limited to 30 dB and the true depth of the device cannot be measured.

The solution is a “low-SSE” TLS, one with a high Signal/Total SSE ratio. A TLS with a 60 dB Signal/Total SSE ratio can measure the true depth of a 50 dB deep notch filter as shown in the lower row.
Caution should be taken when observing the Signal/SSE ratio of a TLS on an OSA and when reading the specifications of a TLS. An OSA measures by sweeping a filter of settable width (the RBW) before a detector. Since the narrow TLS signal will fit into even the narrowest RBW's, its true power will be displayed. However, when an OSA measures a broadband signal, such as SSE, which is much broader than the RBW, the displayed power is only the SSE which passes through that RBW. If the RBW is 1nm and the displayed SSE level is -45 dBm, the density is -45 dBm/nm. If the RBW is reduced to 0.1nm, the displayed level of the same SSE will be -55 dBm, but this is the same density since -55 dBm/0.1nm = -45 dBm/nm. Neither is the total SSE, since it is typically 100nm or more wide. A TLS with a Signal / SSE ratio given as “45 dB/nm” or as “55 dB” with a footnote “measured in an 0.1nm RBW”, will likely have a Signal / Total SSE ratio of less than 30 dB. In fact, when SSE of a low-SSE TLS with a Signal/Total SSE of 60 dB is observed on an OSA, the SSE density, even in a wide RBW, is likely to be so low that it will be covered by stray light in the OSA optics. A test to determine if SSE is really being observed is to widen the RWB by a factor of two and seeing if the level increases by 3 dB, or by a factor of ten and an increase of 10 dB. If so, it is SSE. If the level stays fairly constant it is stray light.

This slide shows the results of measuring actual DWDM devices with both a standard and low-SSE laser. The difference is most pronounced in the notch measurement of a fiber bragg grating (upper), where almost all SSE is passed. SSE also affects the measurement of a bandpass TFF, even though only the SSE which passes through the bandpass is picked up by the PM.
A simplified diagram of the low-SSE cavity design used in Agilent TLS’s is shown. Like most TLS’s with a wide tuning range, this is an “external cavity laser” or “ECL”. Normally, a laser diode has a fixed wavelength determined by its cavity length, which is the length of the chip. In an ECL, an antireflection (a.r.) coating is applied to one end of the chip so that the chip is no longer the resonant cavity. The other end of the cavity is a diffraction grating which reflects different wavelengths at different angles (much like a prism refracts wavelengths at different angles). The resonant wavelength will depend on the angle of the grating and the distance from the chip. The grating is moved by a motor. In order to make the grating more selective and suppress adjacent resonances or “side modes” the light is made to pass the grating twice by use of the mirror. Normally, light from an ECL is taken from the front of the laser chip, as labeled “high power” here. SSE is produced in the gain material, which is the chip, so taking the light at this point results in the typ. 25 to 30 dB Signal/Total SSE ratio.

A low-SSE signal is created by taking the light directly from the grating by adding the beamsplitter, essentially taking the light where it is highly filtered by the grating - a simple idea, but one which dramatically increases the dynamic range of passive component measurements.

Before a low-SSE TLS was available, external filtering was used to attempt to remove SSE - either placing a “tracking” filter in front of the TLS or using an OSA as the receiver. In either case, the external filter adds a variety of problems to the setup including signal ripple due to mistracking and filter PDL. Solving the SSE problem with a better TLS design is a much better solution.
The second major performance problem in TLS - PM measurements is wavelength accuracy. Since ECL type TLS’s are mechanically tuned, their wavelength accuracy has been based on a positional calibration. The typical absolute accuracies achievable have been on the order of ± 100pm, which is not sufficient for measuring DWDM devices.

Wavelength accuracy can be divided into two types. First, absolute wavelength accuracy describes the accuracy of the TLS to produce a specific wavelength. For example, if the laser is set to 1550.120nm but the actual wavelength produced is 1550.220nm, the absolute error is 0.100nm (100pm). The ability of a TLS to make an accurate change or step in wavelength is known as the relative wavelength accuracy.

Absolute errors could result in measuring the wrong (absolute) center wavelength of a filter. Relative wavelength errors tend to distort the shape of a filter.
The common solution to the wavelength accuracy problem of TLS’s has been to couple some of the light from the TLS to an external wavelength meter. Wavelength meters have very high wavelength accuracy, but are usually very slow, taking on the order of 1 second to make a wavelength measurement. Since DWDM component measurements often require taking 1,000’s of samples over wavelength, using an external wavelength meter makes the measurement accurate, but extremely slow.

The solution is a high-speed wavelength meter. A block diagram of the built-in wavelength meter in Agilent TLS’s is shown. A portion of the light from the laser cavity is sent to a retarder or “birefringence” plate in which the refractive index in each axis is slightly different. The retarder plate acts as an etalon or resonator which will produce an interference pattern over wavelength. By launching light into both axis of the retarder, it acts as two etalons of slightly different optical lengths. This results in two interference patterns which are analyzed separately by splitting with a polarization beam splitter to two fast detectors. From the two patterns a series of possible, but exact wavelengths can be determined. Which wavelength of this series is determined from the mechanical calibration of the laser cavity. This wavelength meter allows wavelength to be measured continuously, in real-time, as the TLS makes a swept loss measurement, solving the speed / accuracy problem.
Since an external wavelength meter would be too slow to verify that the TLS with the internal, real-time wavelength meter is measuring correctly in a fast, swept measurement, a different strategy must be used. An alternative could be to measure a filter slowly by stepping the TLS and measuring the wavelength at each point with an accurate, external wavelength meter and then compare the results with the swept measurement. There is an even better way. NIST has done extensive work on gas absorption cells for use as wavelength references. They are available from NIST and from outside vendors. These gas cells, such as acetylene, have very narrow, stable absorption lines which have very well-known wavelengths. Relatively low in cost, these cells are a very handy tool for verification of TLS wavelength accuracy.

The results of measuring a NIST acetylene cell are shown. The agreement is generally within 1pm. NIST reports a two sigma uncertainty of most of the lines as +/- 0.6pm.
A low-SSE TLS, with a real-time internal wavelength meter and 8 dual-input power meter modules were used to make a swept IL measurement of a 16 output, TFF based DeMux. The channel spacing is 100Ghz (0.8nm).

Notice that details of the filter shapes can be seen more than 60 dB down due to the dynamic range provided by the low-SSE TLS.

Center wavelength accuracy is in the range of 3pm or less.

A sample spacing of 1pm, along with the narrow linewidth of the TLS, provides extremely high resolution.

This measurement took only minutes to complete.
Agilent offers test equipment for measuring all aspects of lightwave communication systems. Please come see the variety of equipment for DWDM component testing in our demonstrations.
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