State of the Art characterization of optical components for DWDM applications

Application Brief

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Abstract

Fiber optic network technology is taking a big step forward with the tremendous transmission capacity offered by dense wavelength-division multiplexing (DWDM). These developments bring new challenges to the testing of passive optical components.

This document provides guidance on the implementation of a test setup for loss measurement for a multi-channel DWDM component such as a multiplexer. The document describes some real-life measurement setups, to highlight differences and illustrate the use of certain features.

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Introduction

In recent years, the testing of fiber optic components for DWDM applications has become increasingly challenging. For example:

- Channel spacing has constantly reduced, so wavelength measurements must be increasingly accurate.
- New high-power EDFAs have triggered a need for optical detectors capable of measuring such high powers.
- The increasing length of fiber links has driven a demand for new test parameters such as 'polarization dependent loss', a type of signal distortion that can accumulate over distance.

In addition, the huge demand for fiber optic components, driven by the daily growth of bandwidth requirements, forced manufacturers to increase their throughputs dramatically. Thus, easy test setup and reduced test times are becoming essential drivers in the market.

Many of the parameters used to specify and characterize passive optical components can be derived from a rather small set of basic measurements. Since the specified performance of a certain parameter cannot be better than the uncertainty inherent in the test system, it is usually preferable to achieve the highest accuracy that test time and investment allows. This offers the possibility of balancing an improved specification for the parameter against an increase in yield.

The following sections describe several of the basic measurements. Finally some tools for implementing test systems are discussed.

Measuring absolute Power

Accuracy considerations

Accurate measurements of optical power are necessary for a variety of optical components, including:

- Characterization of Fiber Amplifiers, such as EDFAs,
- Characterization of optical sources, such as laser diodes,
- Determination of receiver sensitivity.

The suitability of an optical power meter for accurate absolute power measurements is determined by the *total uncertainty* characteristic. In contrast to the *uncertainty at reference conditions* characteristic, *total uncertainty* includes all variations in input parameters and influencing factors, such as:

- All wavelengths that the instrument is specified for
- The whole power range
- Temperature variations over the full operating range
- Every beam geometry (for example: fiber type) the instrument is designed for
- Aging (for the period of the recommended recalibration interval)

Unfortunately quite often the *total uncertainty* given is not as "total" as it should be. Some instrument manufacturer limit the parameter in order to have better figures in the spec sheet. For instance, sometimes "total uncertainty" is only specified for one single power level, or only at temperatures like 20°C ± 2°.

Closely related to the question of instrument uncertainty is the problem of repeatability. Often there are problems reported concerning the stability of power readings. In some cases, the stability of the readings is limited by noise. More often, problems with the measurement setup are responsible for weak stability. These setup problems include:

- Source variations because of back reflection
- Interference
- Polarization dependent loss.

Lasers show power fluctuations if part of the output power is reflected back into the source. A good laser source design can minimize the influence of such back reflections. Typical reasons for high backreflection include:

- Open straight connectors (glass - air junction),
- Bad connections (dirty or scratched connectors),
- Micro breaks in the fiber (often located next to the connector).

If there are multiple reflections within the setup, a cavity can be established. Depending on the length of that cavity, power fluctuations are noticed either:

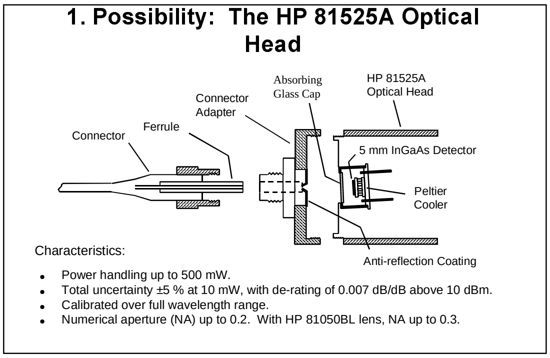
- When sweeping the wavelength,
- When tiny variations in optical path length occur (caused, for example, by small temperature changes).

If a device within the setup has a considerable amount of polarization dependant loss (PDL), variation of the state of polarization (SOP) will give rise to power fluctuations. The SOP of a standard single-mode fiber changes randomly over time and length of the fiber because changing environment conditions influence the birefringence of the fiber. Every small movement of the fiber changes the SOP, and therefore the loss, in the system. Even sound can cause a SOP change.

High power measurements

Special considerations have to be made when measuring high power levels, such as those produced by state-of-the-art EDFAs. Devices are available that deliver power levels of up to 10 Watt (+40 dBm). As no semiconductor-based power meter is able to accept such high powers directly, special measures have to be taken.

Picture 2/1 illustrates the Agilent Technologies solution for medium powers (up to 0.5 Watt, 27 dBm).



1. Possibility: The HP 81525A Optical Head

Characteristics:

- Power handling up to 500 mW.
- Total uncertainty ±5 % at 10 mW, with de-rating of 0.007 dB/dB above 10 dBm.
- Calibrated over full wavelength range.
- Numerical aperture (NA) up to 0.2. With HP 81050BL lens, NA up to 0.3.

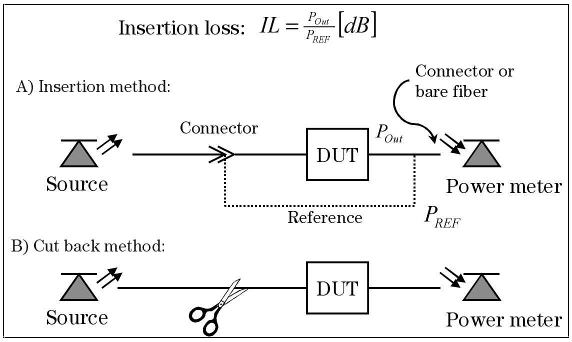
Figure 2/1: Power measurements up to 27 dBm with the Agilent Technologies 81525A Optical Head.

For powers > 27 dBm, an absorbing filter solution is not suitable because of the large amount of power that has to be dissipated in a relatively small volume. The goal is to distribute the power over as large a volume as possible. An example of this concept is the Agilent Technologies 81002AF Integrating Sphere, where power is dissipated over the wall of the whole sphere. This concept also allows the acceptance of emitters with high numerical aperture as well as with large emitting areas. For further information, refer to Agilent Technologies Product Note 5966-4844: "High power measurements using the HP 81002FF Integrating sphere". A disadvantage of the integrating sphere is speckle noise, caused by interference of the incident beam with itself by multiple reflections at the wall of the sphere. Typical speckle noise is of the order of 0.02 dB for a bandwidth of 50 MHz.

Insertion Loss

Measurement principle

Perhaps the most important characteristic for passive optical components is the insertion loss value. For wavelength division multiplexing (WDM) applications, the insertion loss must be determined as a function of wavelength. Some other device parameters can be determined using the results of an insertion loss measurement. For example, the crosstalk between different channels for a DWDM multiplexer can be calculated by comparing the insertion loss (IL) values at different wavelengths. The measurement principle for an IL measurement is shown in figure 2/2:



Insertion loss: $IL = \frac{P_{Out}}{P_{REF}} [dB]$

Figure 2/2: Principle of insertion loss measurement. Picture 2A) describes the so-called insertion method, 2B) explains the cut back method.

A loss measurement is the ratio of two power levels. Consequently there are two measurement steps:

1. The reference power, the power P_{REF} without the device under test (DUT) must be recorded. This is indicated with the dashed line in figure 2/2A.
2. Then the DUT is inserted and the output power P_{Out} after the DUT is measured.

The insertion loss is then given by P_{Out} / P_{REF} . Consequently, the measured DUT insertion loss includes the loss of one connector pair, and, because the same connector pair is not used again, there is a large uncertainty. Very often, these problems are solved by splicing the DUT into the signal path. Then the fiber is cut before taking the reference reading (figure 2/2B).

In contrast to absolute power measurements, the uncertainty of an IL measurement is not determined by the *total uncertainty* characteristic of the detector. The mathematical operation of dividing two absolute power values eliminates the wavelength dependence of the detector. Thus, the characteristic of interest is the detector's (power) *linearity*. The relation between the detector's influence on the IL measurement uncertainty and it's *linearity* is quite simple. A first-order approximation of the detector's contribution to the uncertainty is the specified *linearity* error; this holds as long as the SOP is kept constant during the measurement, or the detector has no Polarization Dependant Responsivity (PDR). In practical applications, the SOP cannot be kept constant so it is often important to use a detector with low PDR. Most of Agilent Technology's power sensors are specified for PDR.

Wavelength dependent measurements

Prior to the advent of *Wavelength Division Multiplexing* (WDM) the need for wavelength dependent testing was often at issue. WDM has made wavelength dependant testing mandatory; questions now focus on the accuracy of wavelength measurements required and the best method to do swept wavelength testing.

Basically, there are two options for doing swept wavelength testing as outlined in figure 2/3.

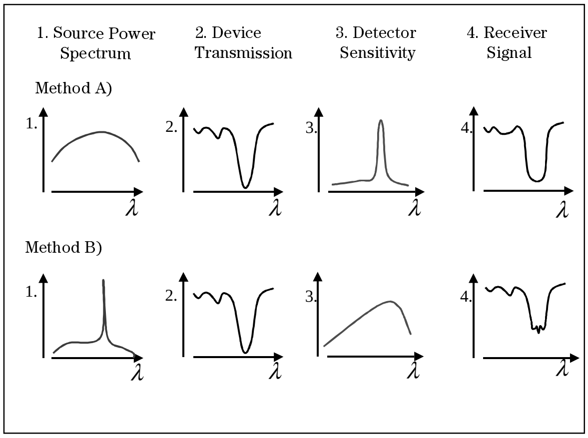


Figure 2/3: Explanation of the two most important methods used for swept wavelength testing: A) with broadband source and OSA, B) with TLS and power meter. Column 1 shows the emitted spectrum, 2 is the transmission characteristic of the device under test, 3 is the spectral sensitivity of the detector and 4 is the resulting receiver signal after the wavelength sweep.

In the example sketched above, the IL over wavelength of a filter device with a spectral transmission as indicated in graph 2 is to be measured. In method A) a broadband source with an emission spectrum as in picture 1 is used. As the stimulus spectrum is broad, the wavelength discrimination must be done in the detector. Thus a narrow band detector is used, and the pass band of the detector is swept over wavelength. This measurement principle is realized in an *optical spectrum analyzer* (OSA). The source used is either a white light source (halogen lamp), or one ore more EELEDs are used, depending on the wavelength measurement span and the output power needed. Method B) is based on a complementary principle: A narrow band tunable source is used to stimulate the DUT, the receiver is a non-selective detector, usually a semiconductor photo sensor. The different detector responsivity over wavelength is shown as 3rd picture in figure 2/3 Finally, the resulting receiver signal is shown in the 4th picture. Both signals show the typical limitations of their respective measurement method. In the case of the OSA Method, the most important limitation is usually the resolution bandwidth (typically $>=$ 50pm), so that small features of the DUT cannot be spectrally resolved. On the other hand, the typical limitation for Method B) (tunable laser source) is the so-called source spontaneous emission (SSE). This is indicated in B1 as the broad continuum below the stimulated emission peak. As the detector is broadband, this SSE gives rise to a receiver signal even in the stop band of the filter, so limiting the achievable dynamic.
Consequently, the best results are achieved with a combination of tunable laser source and OSA; that is, a combination of narrow source and a narrowband receiver. As this solution is rather expensive it is only used for the most demanding applications. In the second half of this paper we concentrate on solutions that use a tunable laser source, as this method is more flexible and instruments are now available that improve the SSE issue.

In addition to the uncertainty contributions mentioned above (detector linearity, PDL), interference effects have to be considered for swept wavelength measurements. This interference effect can be observed as a more-or-less periodic variation of loss over wavelength, superimposed on the loss of the device under test (DUT). This interference ripple is caused by at least two reflecting surfaces that are separated by a small distance (typically 0.1 to 0.01 mm). These reflecting surfaces set up a Fabry-Perot interferometer. A typical example of such a cavity is an open fiber end in front of the detector optics.

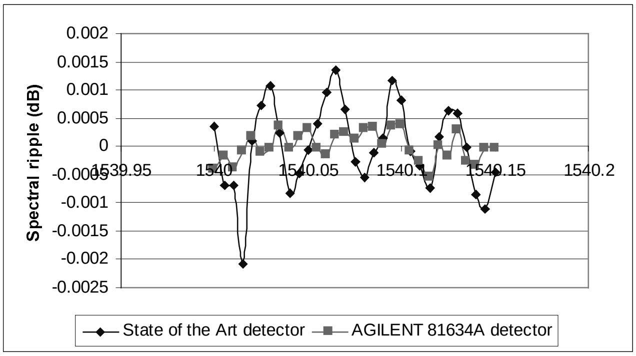
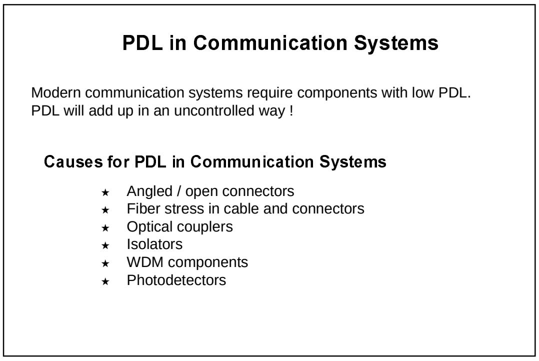


Figure 2/4: Interference effect for a state-of-the-art power meter and for the Agilent Technologies 81634A Detector module.

Figure 2/4 demonstrates the effect of interference for a swept wavelength loss measurement. The interference gives rise to loss variations that disturb the loss signal from the DUT. In the new Agilent Technologies Power Meters, special measures (such as anti-reflective coating) reduce the interference effects and also provide a high return loss.

Polarization dependant loss

Measuring polarization dependent loss has attracted enormous attention. The simple reason for this is that in a chain of optical amplifiers PDL effects add up in an uncontrolled way. The result may be complete failure of the system. Figure 3/1 lists the causes of PDL in communication systems.



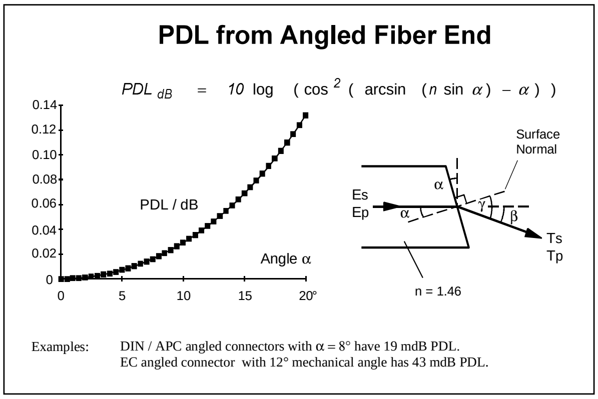
PDL in Communication Systems

Modern communication systems require components with low PDL.
PDL will add up in an uncontrolled way !

Causes for PDL in Communication Systems

- Angled / open connectors
- Fiber stress in cable and connectors
- Optical couplers
- Isolators
- WDM components
- Photodetectors

One well-known example of a PDL generator is an open, angled connector. Figure 3/2 shows the PDL dependence on the angle of the front surface. Only when this connector is brought in physical contact with a second connector will the polarization dependence be greatly reduced or eliminated.



PDL from Angled Fiber End

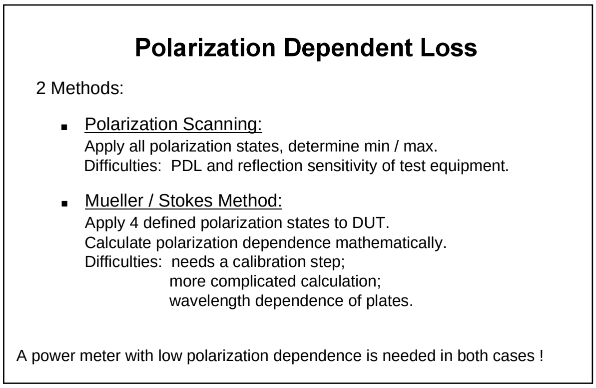
$$PDL_{dB} = 10 \log \left(\cos^2 \left(\arcsin \left(n \sin \alpha \right) - \alpha \right) \right)$$

Examples: DIN / APC angled connectors with α = 8° have 19 mdB PDL.
EC angled connector with 12° mechanical angle has 43 mdB PDL.

Figure 3/2: PDL for an angled fiber end.

The polarization state of optical signals traveling on a long fiber is subject to continuous and sudden environmental changes, and is completely statistical in nature. When the link consists of a number of concatenated amplifiers, these statistics may lead to changes of received power level, and even system failure. This is due to the fact that polarization-independent optical amplifiers do not exist. Typical polarization-dependent gains are in the order of 0.1 dB to 0.2 dB peak-to-peak.

Two methods are commonly used for PDL testing, as described in figure 3/3.



Polarization Dependent Loss

2 Methods:

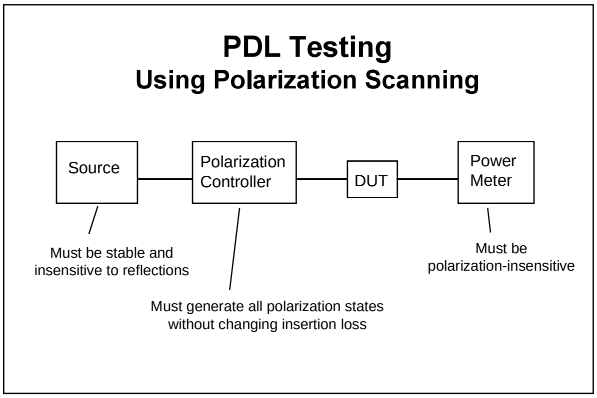
- Polarization Scanning:
  Apply all polarization states, determine min / max.
  Difficulties: PDL and reflection sensitivity of test equipment.
- Mueller / Stokes Method:
  Apply 4 defined polarization states to DUT.
  Calculate polarization dependence mathematically.
  Difficulties: needs a calibration step;
  more complicated calculation;
  wavelength dependence of plates.

A power meter with low polarization dependence is needed in both cases !

The Mueller / Stokes method will be discussed later, in conjunction with the testing of integrated optics. In the next section, we focus on the polarization scanning method.

PDL testing with polarization scanning

PDL can be tested by adding a polarization controller to an optical source. The source power (at the DUT) should be time-invariant and independent of the polarization state. The polarization controller should be able to generate polarization states which uniformly cover the entire Poincaré sphere; see figure 3/4.



PDL Testing
Using Polarization Scanning

Source
Polarization Controller
DUT
Power Meter

Must be stable and insensitive to reflections

Must generate all polarization states without changing insertion loss

Must be polarization-insensitive

Figure 3/4: Principle of a Polarization test.

Achieving high accuracy in this type of measurement is still difficult because:

- the polarization controller also manipulates the polarization state of any reflected waves, and non-isolated laser sources tend to generate power fluctuations upon these changes;
- optical power meters with very low polarization dependence are scarce.

On the other hand, this method offers some advantages, including:

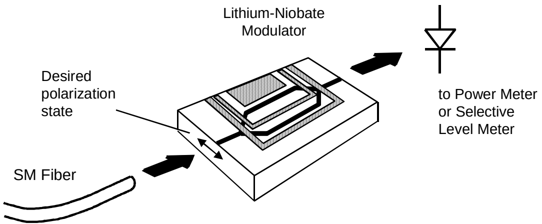
- speed
- ease of setup.

Testing Integrated Optical Devices

Fiber optics is becoming miniaturized. Optical modulators, switches, couplers, and other devices increasingly include implanted waveguides. Optical modulators need to be tested for their modulation transfer function. A frequent question in this context is: How can the desired horizontal and vertical polarization states be generated at the input of the device? Figure 3/5 illustrates this problem.

One possibility is to use polarization-maintaining fiber and mechanical rotators. However, the necessary rotation precision is very difficult to achieve. The alternative of using a polarization controller and conventional single-mode fiber, is usually not applicable because the polarization state at the end of the fiber is completely unpredictable. Is there an elegant solution, with electronic control?

Testing Integrated Optical Devices



How can you generate the horizontal or vertical polarization state ?

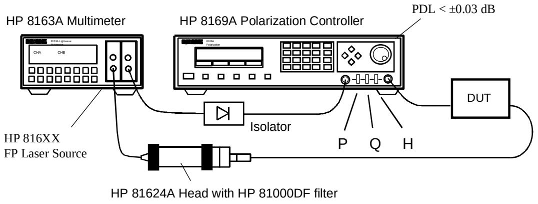
One possibility is based on the assumption that:

- The test device has sufficient PDL
- The maximum and minimum transmissions occur at the horizontal and vertical polarization states.

In this case, the Mueller method, originally a PDL test method, can be used to set the desired polarization states.

Figure 3/6 shows the measurement setup for PDL testing with the Mueller method.

PDL Testing (Mueller Method)



The HP 8169A polarization controller uses waveplates and polarizer.
The higher PDL of the HP 8169A can be eliminated by the Mueller method.

Additional benefit:
Sets the polarization state in a deterministic way.

The key element in this is the HP 8169A Polarization Controller, which is constructed from three rotatable plates: a polarizer, a quarter-wave retardation plate, and a half-wave retardation plate. The HP 8169A allows you to control the polarization state in a deterministic way, which is in contrast to polarization control using fiber-loops.

The use of the HP 8169A Polarization Controller for testing with the polarization scanning method is not advisable because of its internal PDL (±0.03 dB). Testing with the Mueller method eliminates this effect; the measurement procedure is outlined in figure 3/7.

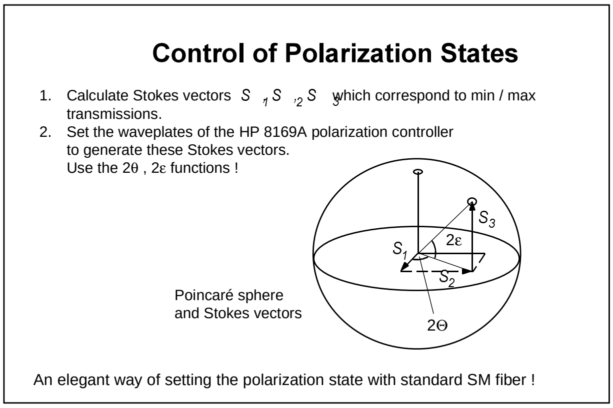
Mueller Method: Procedure

1. Maximize power throughput by adjusting polarizer (P).
2. Measure output power of PC at 4 different polarization states: horizontal, vertical, +45°, RH circular.
3. Insert test device.
   Measure output power again at the same polarization states.
4. Calculate max / min transmissions using the 8 measurement results and Mueller mathematics.
5. Calculate PDL:

$$PDL_{dB} \quad = \quad 10 \log \left(\frac{T_{\max}}{T_{\min}} \right)$$

Some of the preconditions for high accuracy are: fine and reproducible settings of the plates, and wavelength-independent retardation of the waveplates. The HP 8169A features a resolution of 0.18° and a repeatability of ±0.09°, with a settling time of less than 200 ms. The retardation is based on zero-order waveplates with small wavelength dependence. The specified wavelength range is 1470 to 1570 nm, which is well-suited to EDFA testing. However, operation outside of this range is still possible, although a correction of the retardation error is necessary.

The benefit of using the Mueller method and mathematics is that the polarization states (Stokes vectors), leading to minimum and maximum transmission, can also be calculated; see figure 3/8.



Control of Polarization States

1. Calculate Stokes vectors S_1, S_2, S_3 which correspond to min / max transmissions.
2. Set the waveplates of the HP 8169A polarization controller to generate these Stokes vectors.
   Use the 2θ , 2ε functions !

An elegant way of setting the polarization state with standard SM fiber !

After calculating the Stokes vectors, the circle application of the HP 8169A Polarization Controller can be used to generate the minimum and maximum polarization states. When this is accomplished, the modulator can then be tested for its modulation transfer function, its dependence on the input polarization state, and for other characteristics. Of course, the DUT's input fiber must be well-secured so that the polarization state remains constant.

It is advisable to write a computer program that will take the measurements and automatically control the polarization states. For more information, the Mueller method is discussed in detail in [1].

Multi-channel Loss Measurements of DWDM Components

Today, most DWDM component test systems are based on a tunable laser (TLS), tracking filter and power meter or an optical spectrum analyzer (OSA). The need for a wavelength selective receiver, such as an OSA, comes from the fact that the source spontaneous emission (SSE) of the tunable laser seriously limits the dynamic range of the measurement.
For the first time, a tunable laser with dramatically improved signal to source spontaneous emission ratio (SSE) is available. An SSE reduction of more than 20 dB – compared to typical SSE characteristics of modern tunable lasers – allows for elimination of the OSA from the test setup. As a result, the setup in Figure 4/1 is proposed. The setup shown in figure 4/2 can be extended to the actual channel count needed. The only limitation is the availability of GPIB addresses. In the following, the focus of the discussion lies on certain features for the tunable laser source, which enhance the performance shown in Figure 4/1.

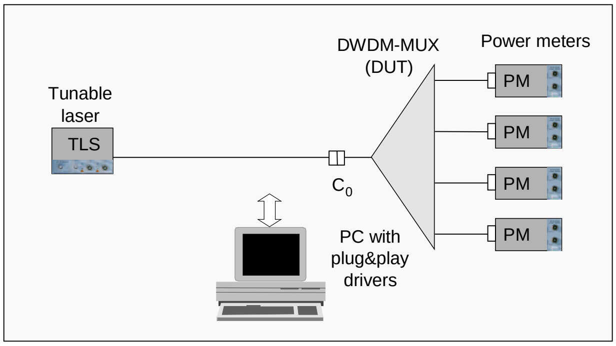


Figure 4/1 — Proposed test setup for DWDM components

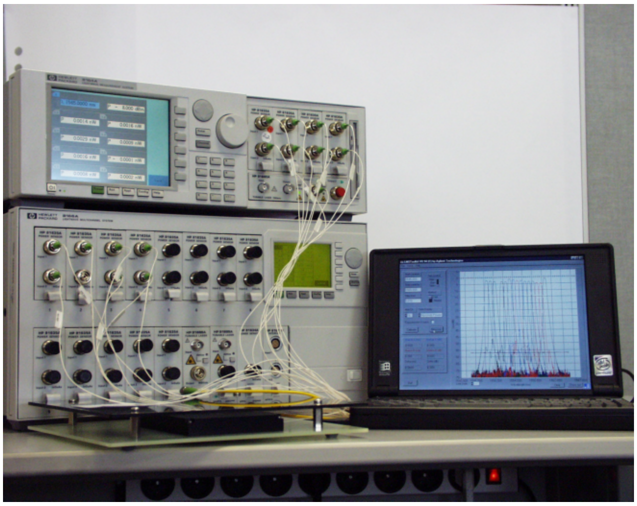


Figure 4/2 – Measurement setup used for a 40-channel device

Agilent816xVXI*plug&play* Instrument Driver

The Agilent 816x VXI*plug&play* instrument driver contains numerous functions to remotely control the HP816x mainframe series and related modules, such as power sensors or tunable laser sources. Each implemented function of the VXI*plug&play* library combines several GPIB commands. This results in less complex programs. The VXI*plug&play* driver is able to control a setup consisting of several HP816x mainframes. Particularly useful is the simplification of the logging and stability data acquisition functions (see following chapters), wavelength sweeping, and lambda scan (the co-ordination of wavelength sweeping and data acquisition from multiple power sensor channels).
A good example of the simplification that is provided by the VXI*plug&play* is the lambda scan application. The lambda scan can be prepared and performed with only two functions from the PnP library. A further function yields the measurement results (see last chapter). The functions deal with the necessary wavelength correction and power range stitching calculations (see following chapters).

The standard VXI*plug&play* interface allows you to build complicated test setups more quickly. Nearly all other complex test and measurement instruments provide VXI*plug&play* instrument drivers.
It is easier to program using VXI*plug&play* calls than by using individual GPIB commands because:

- you use fewer commands, allowing you to write programs more quickly, and there is no special need for error handling and parameter checking
- you make fewer mistakes, because the driver allows you to program without having an intimate knowledge of each individual GPIB command.

The Agilent 816x VXI*plug&play* instrument driver can be easily integrated with the HP/Agilent VEE and National instruments LabView graphical programming environments; or C, C++, and Visual Basic programming environments. An online help provides a description of all VXI*plug&play* functions. Sample programs demonstrate the ease of implementation.

Note:
All the integrated mainframes and modules must have firmware revision 2.02 or higher to operate with the 816x plug&play driver revision 2.05.

Description of Measurements

Power Calibration

The aim of the power calibration is to measure the wavelength-dependent input power, so that this uncertainty can be removed from the measurement result. Power flatness versus wavelength is typically
±0.1 dB.
The power calibration is carried out as follows:

- Connect the source output connector to the first power meter.
- Set the tunable laser to the center wavelength of the range of interest. Activate the laser.
- Take a reference trace for the first power meter. Use the same start wavelength, stop wavelength, and wavelength sampling interval as for the measurement.
- Store the trace as reference, associating it to the correct power meter.
- Connect the source output connector (C_0) sequentially to each of the power meters. Repeat the procedure for each power meter.

Such a power calibration should be done, for example, once per week.

Loss Measurement

To perform the insertion loss measurement,

- Connect the device under test to the test setup. Ensure the correct matching of the input and outputs the power meter channels.
- Take a trace simultaneously on all power meters using the plug&play driver function. Don't forget to set the correct stitching level for the expected loss dynamic range. Use double scan if you are unsure.
- Calculate the insertion loss of all channels using the stored reference values for each power meter channel.

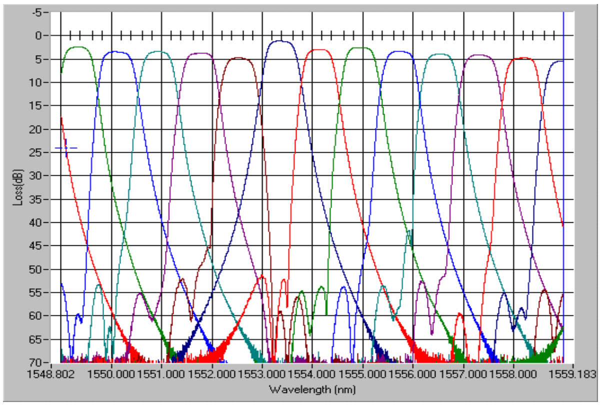


Figure 4/3 - Insertion loss of a 16 channel DEMUX

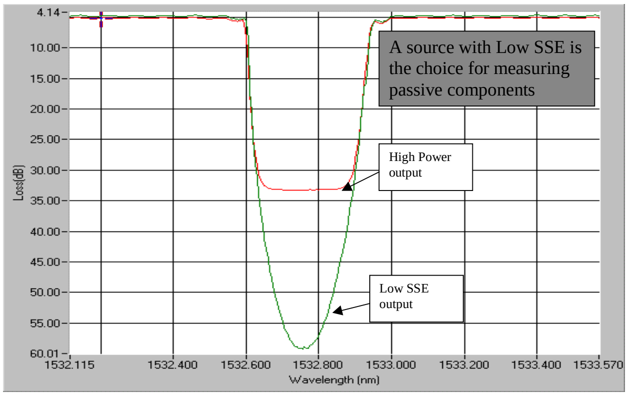
Comparison of Low SSE and High Power output

As mentioned earlier, for the first time, a tunable laser with dramatically improved SSE is available. SSE is the sum of all spontaneous transitions inside the laser diode. It has a broad spectral characteristic, but is weak compared to the laser line itself. A typical signal to SSE ratio of 30 dB is observed. This new approach reduces the SSE level by more then 20 dB (in comparison with typical SSE characteristics of modern tunable lasers) and allows you to eliminate the OSA from the test setup.
The signal to (SSE) ratio is specified to > 53dB/nm in the entire range 1460nm to 1580nm (Agilent 81680A). This ratio improves to > 63dB/nm in the range 1520nm to 1570nm.

Let us have a closer look on the effects of SSE when testing a Fiber Bragg Grating. If the tunable laser is sweeping over the filter's rejection band, the laser line is strongly attenuated, but the photo diode receives all spontaneous emission because the passbands do not attenuate these wavelength ranges.

Because a diode integrates over all wavelengths, this measurement can be described as a mathematical convolution of the source function and the filter response.

As a result, the power meter never detects the true filter shape, but a similar one, which is smeared over wavelength. The detected filter shape looks nice, but is misleading.



A source with Low SSE is the choice for measuring passive components

Figure 4/4 – Compared of the transmission characteristic of a Notch filter, measured either with low SSE or high power output

As shown in figure 4/4, the biggest impact by using a low SSE output is measuring a Notch filter. Nevertheless, the same argumentation is also valid for a bandpass filter. Although the spectral range with high transmission is not as broad as in the case of the notch filter, a higher dynamic range can be also be achieved by using the low SSE output. An example of a bandpass filter transmission measured both with standard and low SSE output is shown in figure 4/5.

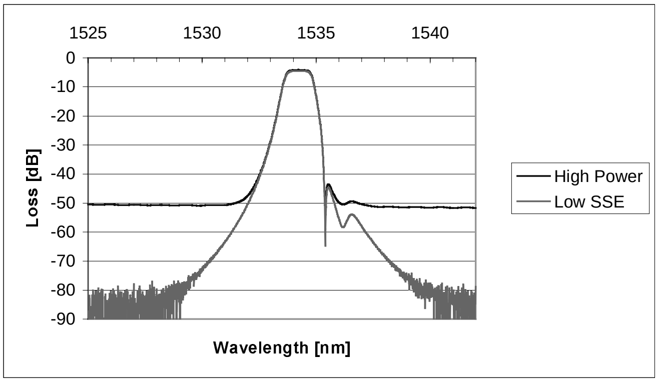
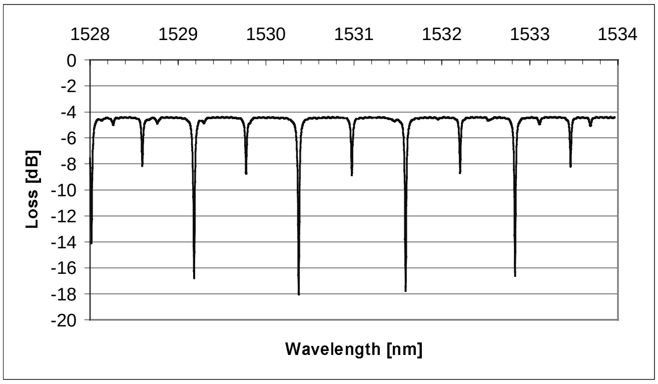


Figure 4/5 –Comparison of the transmission characteristic of a band pass filter measured once with the low SSE output and once with the high power output. Note that the absolute power was below 0 dBm in this measurement but the dynamic range is nevertheless high.

For more information, the impact of the source spontaneous emission is discussed in detail [see Reference 7].

Built-in wavelength meter

The wavelength logging function records the actual wavelength during a scan. To show how accurate the system works, a low pressure Acetylene gas cell is measured in a continuos scan. The absorbing lines of this wavelength standard are specified by NIST. The comparison is shown in Figure 4/6



P-Branch	NIST [nm]	Agilent[nm]
6	1528.5946	1528.5939
7	1529.1806	1529.1815
8	1529.7730	1529.7727
9	1530.3718	1530.3719
10	1530.9770	1530.9764
11	1531.5886	1531.588
12	1532.2067	1532.2064
13	1532.8312	1532.831
14	1533.4621	1533.4629

Figure 4/6- measurement of a low pressure Acetylene gas cell

For more information, the fast and accurate determination of a tunable laser wavelength and its application to DWDM components is discussed in detail [see Reference 6].

Power range stitching

Stitching is a smart way to extend the loss measurement range while maintaining the scale linearity. This is achieved by running the power meters at different sensitivity settings.

From the discussion above, it is clear that the Low SSE output offers a higher dynamic range. As the laser moves continuously from the start to the stop wavelength, all power channels are triggered to take a power measurement at the same time, whenever the TLS passes the selected step size. All connected power meters, and the internal wavelength meter of the TLS, will take a reading. All power readings are related to the measured wavelength at the trigger signal (wavelength logging). To improve the speed of the system, the upper power meter range limit is adjusted to the selected output power of the source. Changing the power meter range during the continuous sweep would limit the sweep speed. Therefore the power meter range is changed to different sensitivities for the second or third scan. The

816x plug&play driver stitches the data from the different scans together. This results in a higher dynamic range than possible for only one scan. The 816x plug&play driver performs the stitching. The only user-specified parameter is the number of scans, which depends on the overall dynamic range desired. Figure 4/7 shows the different dynamic range of a single, dual or triple scan.

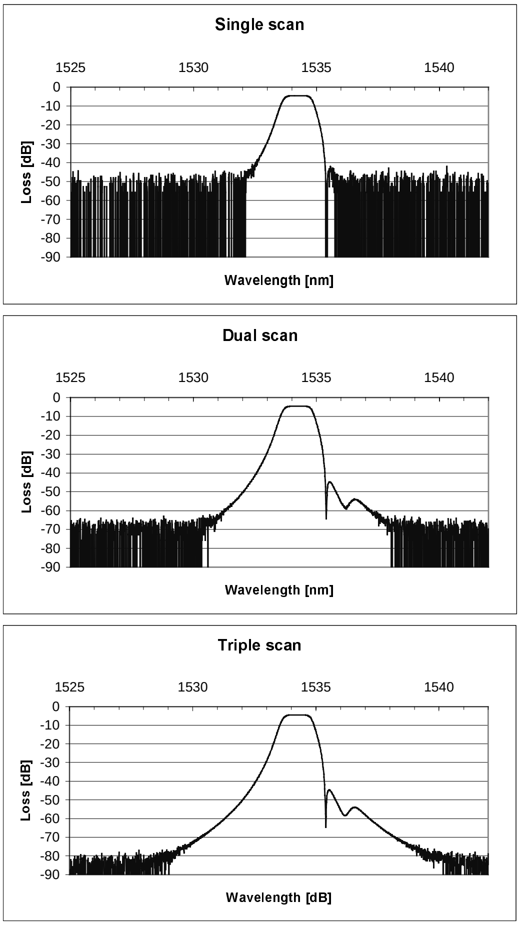


Figure 4/7- different dynamic range for a single, double or triple sweep

Resolution and wavelength range

The smallest possible resolution (step size) in a wavelength scan that can be selected from the 816x plug&play driver is 1pm. However, the power sensors limit the number of data points per channel. The maximum number of recordable data points is 12000 for the 816x power modules. Thus, for a resolution of 1pm, the wavelength range to be scanned is limited. Extended wavelength ranges can be scanned by coarsening the resolution (step size).

Measured times for a real life application

The time it takes for completion of a measurement depends on a number of parameters, such as: the wavelength range, the step size, the number of channels, and the number of scans. Therefore, it is impossible to state a general measurement time. Figure 4/8 shows some graphs, and indicate the expected measurement time. The measurements are done with the setup shown in Figure 4/2.
The first graph shows typical measurement times for a fixed wavelength range of 30nm and different resolutions (step sizes). As mentioned above, the smallest possible resolution (step size) is 1pm. However, the actual limitation is the maximum number of data points per power channel (12000 for 816x modules). Therefore no resolution of 1pm is shown over a 30nm range. The second graph shows a variation in the range of interest, with a fixed resolution (step size) of 50pm.

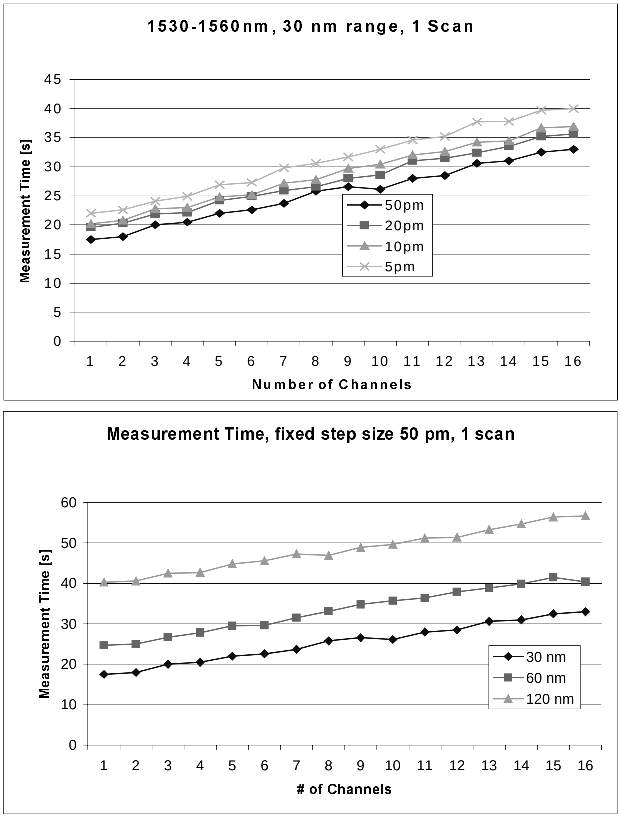


Figure 5 Indication of measurement times

Example Program using the 816x plug&play drivers

The following example in Agilent VEE shows a sample program for a multiframe lambda scan (That is: A wavelength scan for more than one mainframe). The functions deal with the necessary wavelength correction and power range stitching calculations.
The functions use input parameters such as: wavelength range, resolution (step size), number of scans, and the complete lambda scan.

The resulting transmission over wavelength already combines the power readings from each scan. Note that no additional modification, such as stitching or wavelength logging, is necessary!

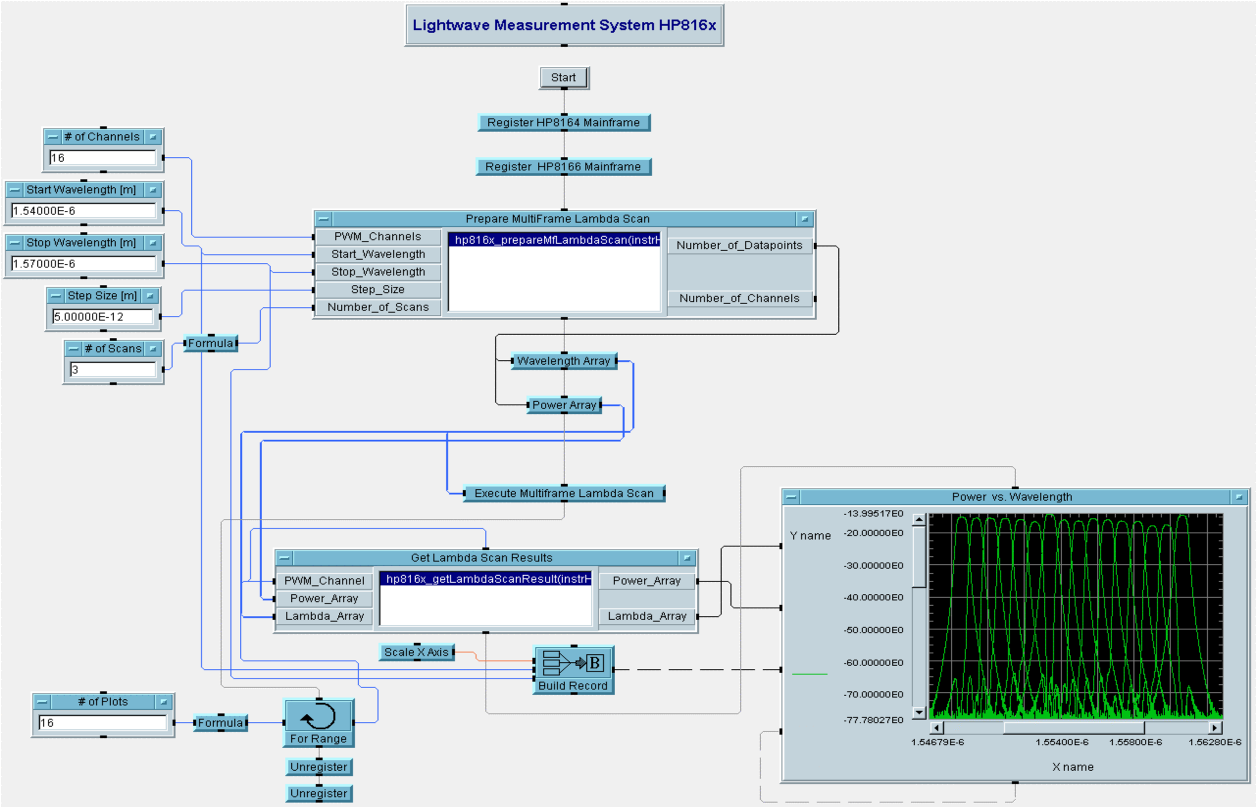


Figure 4/9 – example Program in HP VEE using the 816x plug&play driver

Related Agilent literature:

[1] Siegmar Schmidt, C. Hentschel
PDL Measurements using the HP 8169A Polarization Controller
p/n 5964-9937E

[2] 81002FF Integrating Sphere,
technical specifications,
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[3] High Power Measurements using the
81002FF Integrating Sphere,
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[4] 8164A Lightwave Measurement System,
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[5] 8164A Lightwave Measurement System,
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p/n 5968-3405E

[6] Müller, E., Rück, C., Born, T., Wagemann, E.U., Leckel, E.: "Fast and accurate determination of a tunable laser wavelength and its application to DWDM components", paper WB 2, Optical Fiber Conference, Baltimore, March 2000

[7] Leckel, E., Sang, J., Wagemann, E.U. and Müller, E.: "Impact of source spontaneous emission (SSE) on the measurement of DWDM components", paper WB 4, Optical Fiber Conference, Baltimore, March 2000

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