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Basic Test Methods for Passive Fiber Components

APPLICATION NOTE

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Basic Test Methods for Passive Fiber Optic Components

By: John Flower

Introduction

The ever increasing demand for telecommunications bandwidth is driving the market for the components that make up fiber-optic networks. This article presents basic principles of passive component testing and compares test methods. In particular, the benefits and drawbacks of broadband and narrowband sources measurements are discussed.

Since more detailed works have been published on this topic, our goal in this guide is to stimulate discussion of alternative approaches to help you in your test system design decisions. A list of suggested references is included at the back of this note.

For the purpose of this article a “passive” component is one that does not require electrical input to add energy to the information signal. Electrical input may be required for control. Examples include attenuators, fused couplers, multiplexers, circulators, splitters, taps, isolators, WDM filters, Bragg gratings, and waveguides.

Testing for Process Control

As manufacturing processes mature, the variables that need to be controlled become better understood, allowing changes in test methods. For example, during the early stages of product development, a full and detailed spectral scan of each unit’s performance might be appropriate. As the process becomes more stable you will begin to notice that all the scans look the same as long as the process remains in control. More importantly, experience with your processes teaches you what can go wrong and where to look for problems.

Efficient process control testing usually means testing specific points rather than a complete spectral scan. To make sure your process is remaining consistent, you can continue complete spectral scan testing on a smaller sample of your production.

Test Parameters

The parameters to be tested depend on the purpose of the particular Device Under Test (DUT). This section illustrates the most common test parameters you will consider in passive component testing.

Insertion Loss

The basic passive component test: if your DUT is expected to pass light, how well does it do that? Figure 1 illustrates one way to do this two-step test.

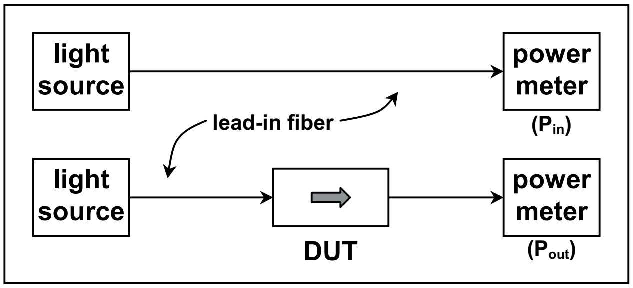


Figure 1: Insertion loss test

The first step of this test is to measure power though the same lead-in fiber that you will use in step two. This gives you the input power to the DUT. The output power from the DUT is measured in the second step. Insertion loss is then expressed as follows:

$$\text{Insertion Loss (dB)} = 10 \log \frac{P_{in}}{P_{out}}$$

Since this is a relative measurement, the meter's accuracy does not directly affect the results. Meter stability and linearity, plus connection repeatability, will primarily determine accuracy. Long-term meter stability will determine how often you need to take the lead-in fiber reference measurement.

Bare Fiber Measurements

Repeatable and accurate measurements from a bare fiber end require care. Use a properly adjusted fiber cleaver to prepare a clean 90° endface. After the fiber holder is in place on the detector, rotate it to see how much the reading changes. Also check how much the reading changes when you remove the fiber from the holder and put it back. These "repeatability" errors must be added (root-sum) to the meter's accuracy or stability. The detector will usually need an integrating sphere to do this well.

It is best to use a bare fiber holder that does not contact the endface. A holder that requires sliding the fiber through a ferrule can give good measurements. However there is usually some microscopic damage ("spalling") to the edges of the cleave. If your next step is a fusion splice, this damage will degrade its quality.

Automating this test with optical switches can be a problem if repeatability errors add too much measurement uncertainty to keep the result within your tolerance limits. Like many tests, the simplest form is often the most accurate. In some cases you will need to use fusion splices or connect to bare fiber ends.

Here are some examples of components that may require an insertion loss test:

- Connectors
- Splices
- Isolators, forward direction
- Circulators, appropriate path
- Lithium niobate modulators, on-state
- Switches, selected to this port
- Attenuators, set to minimum
- Filters, in the passband wavelength
- Waveguides, appropriate path and wavelength

Root-Sum Error Addition

To determine the total uncertainty of your measurement system, you need to add the error contributions of each part. However, errors are a statistical phenomenon, so if you just add them you will get a much larger error than is really happening. If the errors are random with respect to each other (one doesn't affect the other) you can use root-sum addition, the square root of the sum of the squares.

For example, the simple sum of 2 + 3 is 5. However, the root sum is 3.6, calculated as:

$$\sqrt{2^2 + 3^2} = \sqrt{4+9} = \sqrt{13} = 3.6$$

- Couplers

Isolation

If your DUT is required to block light transmission, how well does it do that? Isolation is simply an insertion loss test, except that a good result is a high-value loss, so you are measuring a very low signal level. Here are some examples of components that may require an isolation test:

- Isolators, reverse direction
- Circulators, reverse path
- Lithium niobate modulator, off state
- Switches, selected to another port
- Attenuators, set to maximum
- Filters, outside the passband wavelength
- Waveguides, adjacent path (crosstalk test)

Split Ratio

A splitter, or tap, divides light into two or more outputs without wavelength selection (all channels go to each output). Split ratio can vary from 50/50 to 99/1. A splitter with a high ratio (e.g., 99/1) is usually called a tap. Split ratio is a straightforward measurement. Figure 2 illustrates one way to do this test.

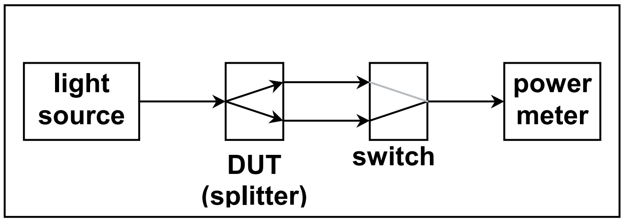


Figure 2: Split ratio test

In this test, you first measure light output through each DUT port, then compute the ratio. You can eliminate the switch by using two power meters or by simply reconnecting a patch cord. Some two-channel power meters have a ratio function to display this result directly. If the splitter has more channels, switching will probably make more sense.

Like the insertion loss test, split ratio is a relative measurement. Linearity, stability, and connection repeatability determine measurement uncertainty.

Wavelength Dependent Loss

Most components respond differently to light of different wavelength. Filters are designed to do just that. Figure 3 for example illustrates typical characteristics of a narrow passband filter.

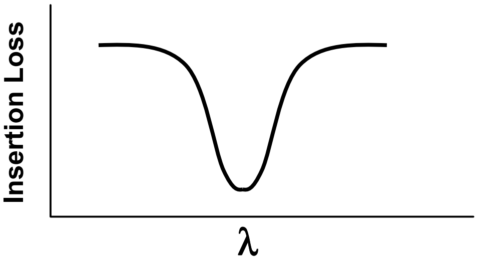


Figure 3: Narrow passband filter

For other components Wavelength Dependent Loss (WDL) is an undesirable effect to be minimized. One way to measure WDL is by multiple insertion loss measurements on small slices of the wavelength spectrum. Depending on your measurement method, there are

Polarization Dependent Ratio

Many splitters and couplers are manufactured by fusing fibers together. For this type of component, the splitting and coupling ratio can vary with polarization. So the simple split ratio test above may not be sufficient. See the discussion about PDL below.

tradeoffs in wavelength resolution, dynamic (power) range, measurement speed, and difficulty. Either the source or the measurement must be narrowband tunable. See Figure 4.

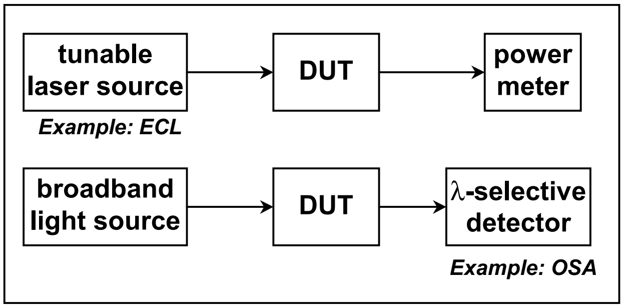


Figure 4: Wavelength dependent loss test

Refer to the discussion of sources and detectors that follows for some insight into these tradeoffs.

Polarization Dependent Loss

The way some components respond to light varies with polarization state. One example is a lithium niobate ($LiNbO_3$) modulator. The ratios of fused couplers and splitters can be polarization dependent. Other components are designed to pass or block light, depending on polarization.

To test Polarization Dependent Loss (PDL) you need to vary polarization without changing other test parameters. Figure 5 illustrates one way to perform this test.

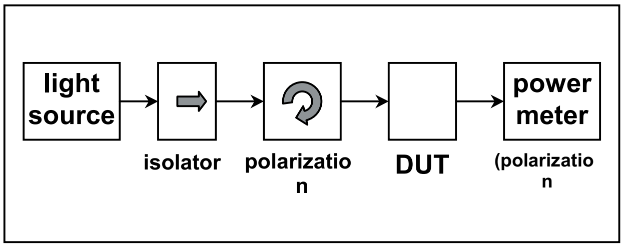


Figure 5: Polarization dependent loss test

In this test you measure how much light comes through the DUT as you vary input polarization. Since laser diode sources are highly polarized, a polarization controller can scramble this light into all possible polarization states. You can then measure the minimum and maximum power through the DUT. However this test requires care:

1. The polarization controller must produce nearly all polarization states within a reasonable time. The time required can be calculated.
2. Input power to the DUT must remain constant as polarization changes. Two issues affect DUT input power:
   - ✓ The polarization controller's PDL. Check the specifications. Some designs are *much* better.
   - ✓ Source stability. Light of varying polarization reflecting back from the controller to the source can destabilize it. An isolator helps prevent this.

$$PDL_{dB} = 10 \log \frac{P_{max}}{P_{min}}$$

3. The meter must be insensitive to polarization. This is often a problem for meters that couple the light directly to a detector surface. An integrating sphere is usually required to solve this problem.

From the minimum and maximum power readings, PDL is calculated as:

Notice that PDL is also a relative measurement because the result is calculated from a ratio.

Light Sources

In this section we will discuss and contrast the various light sources commonly used for testing passive components. Depending on your test method, you will choose either a broadband or narrowband source. And you will also have other choices to make.

Broadband Light Sources

An ideal broadband source would offer these characteristics:

- Uniform power over all wavelengths of interest; if not flat, very smooth spectral characteristics. (This means a spectral scan on an OSA would be smooth).
- The ability to couple all of its power into an optical fiber.
- Be unaffected by reflections from the test system, including the DUT.
- Random polarization.
- Low cost.

Figure 6 illustrates an optical power spectrum for an ideal broadband source.
Why is more power better? Why is smooth important? When you use a broadband source to measure wavelength dependent characteristics of your DUT, you will be slicing its spectrum into the smallest possible segments, to the resolution of your wavelength selective detector (e.g. OSA). There are two important issues to consider:

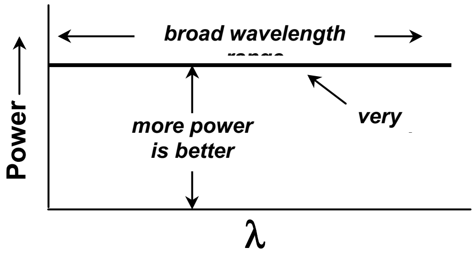


Figure 6: Ideal broadband source

1. You need enough power for a good measurement after slicing the spectrum into a small segment.
2. You need to know that the changes in power you record as you tune your detector are characteristics of the DUT, not the source.

These two concepts are known as:

1. Spectral Power Density
   Power per nanometer of wavelength (dBm/nm).
2. Spectral Stability
   Power stability as a function of wavelength (should be a smooth curve).

Unfortunately, we can't buy the ideal source in Figure 6. Let's examine some of the important tradeoffs of real sources by looking at tungsten lamps, edge emitting LEDs and Amplified Spontaneous Emission (ASE) sources.

Tungsten Lamp

A tungsten lamp source should be useful. Its power is flat over the entire infrared wavelength range used for optical fiber communications. It can be coupled to an optical fiber as shown in figure 7.

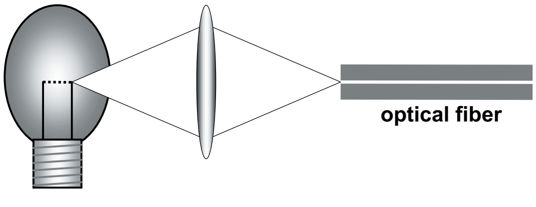


Figure 7: Tungsten lamp source coupled to a singlemode fiber

The main problem with a tungsten lamp source is that you cannot get enough light into the fiber for useful testing. And you can not solve this with a more powerful lamp. This is because tungsten lamps produce higher power by using a larger filament. Beyond a minimum size, the extra light arrives at the fiber at too great an angle to be accepted. Spectral power density, available into a 9µm singlemode fiber core, is less than -60 dBm. This is unfortunate, because tungsten lamps are cheap, have a broad flat spectrum, are unpolarized, and are unaffected by reflections.

Edge Emitting LEDs

An Edge Emitting LED (EELED) is similar to a Fabry-Perot laser except that the output facet is antireflection coated, precluding optical resonances and lasing. EELEDs can produce higher useful spectral power density, as illustrated in Figure 8.

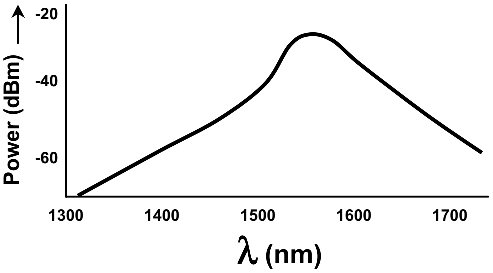


Figure 8: Spectral plot, 1550 nm EELED

As you can see from Figure 8, a 1550 nm EELED can produce spectral power density in the range of about -30 dBm, in the wavelength band of most telecommunications optical components. This is enough power for most test applications. A EELED can be a good choice. However its output can be as much as 60% polarized, limiting applications.

ASE Source

Erbium doped fiber produces a very useful gain profile when pumped with 980 nm or 1480 nm light. This characteristic is used to produce EDFA amplifiers. If no input signal is provided this spontaneous emission is amplified in the fiber to produce a useful broadband spectrum of 1500 nm to 1600 nm light. Figure 9 illustrates how this is done and Figure 10 shows a typical output spectrum.

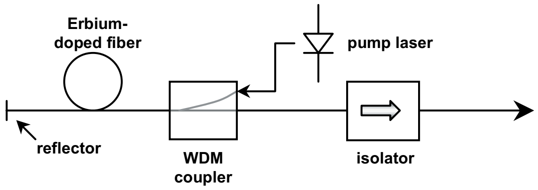


Figure 9: ASE source

As you can see from Figure 10, an erbium fiber based Amplified Spontaneous Emission (ASE) source has a narrower spectrum than an EELED. However, it produces spectral power density in the range of about -10 dBm over a useful range of about 40 nm. Filters are available to somewhat flatten its output. And some newer products are available that blend other dopant materials to broaden its spectrum.

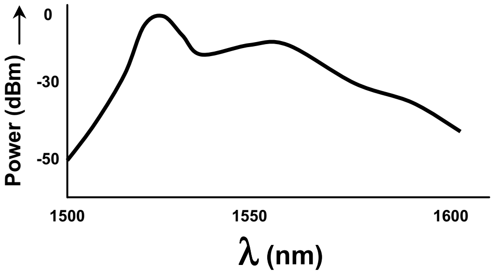


Figure 10: Spectral plot, ASE source

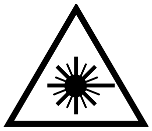
ASE sources are sensitive to reflections. If the reflections are strong enough, the source can begin lasing. Even at lower levels, reflected energy reduces output power because of gain saturation in the reverse direction. An isolator is then required.

ASE by its nature varies with wavelength, so spectral power stability can sometimes be a problem. Check this closely if you need to resolve very narrow features in your DUT.

All ASE sources have very low polarization. Provided it is properly isolated, an ASE is usually your best choice for a broadband source. However, like most “best” choices, it is also the most expensive.

Broadband Source Summary
Table 1 below summarizes our discussion of broadband sources:

Narrowband Light Sources



A narrowband light source allows you to measure DUT response at specific wavelengths with only a power meter. Narrowband sources are available at fixed wavelengths, hand tunable, or motorized tunable. Fixed narrowband sources provide an economical and fast way for monitoring passive component manufacturing processes. Manually tunable narrowband sources can be thought of as “reconfigurable-fixed,” allowing you to use the same workstation for various test requirements. Motorized tunable sources can automatically step across the test passband, stopping at each selected test point for a measurement.

Table 1. Comparison of Broadband Sources

	Tungsten Lamp	EELED	ASE
Cost	Low	Medium	High
Power into SM fiber	1µW	100µW	Up to 10mW
Spectral power density	-60 dBm	-30 dBm	-10 dBm
Spectral width	All IR	50 – 100 nm	40 – 50 nm
Polarization	Unpolarized	~50%	<5%
Reflection sensitivity	None	Problem	High OK if isolated

An ideal narrowband source would offer these characteristics:

- All power output in the desired passband, with no background emission in other wavelengths
- The ability to couple all of its power into an optical fiber
- Be unaffected by reflections from the test system, including the DUT
- Low cost

Figure 11 illustrates an optical power spectrum for an idealized narrowband source.

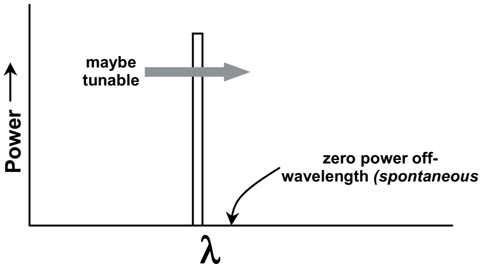


Figure 11: Ideal narrowband source

Since we cannot buy the source in Figure 11, let us examine some of the important tradeoffs of real-world narrowband sources. We will discuss Fabry-Perot lasers, Distributed Feedback (DFB) lasers, and both manually tunable and motorized external cavity lasers.

Fabry-Perot (FP) Lasers

A Fabry-Perot laser is a simple diode laser in which the optical resonator cavity is between two parallel reflective planes that are formed by the ends of the diode chip (see Figure 12).

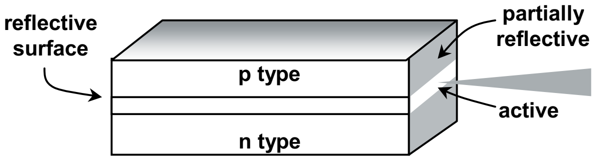


Figure 12: Fabry-Perot laser

At telecommunication wavelengths Fabry-Perot lasers typically have a multimode "comb" spectrum of many wavelengths. The height (power) of this comb is determined by the gain characteristics of the laser chip, essentially operating within the envelope you would see if the chip were operating as an LED (see Figure 13).

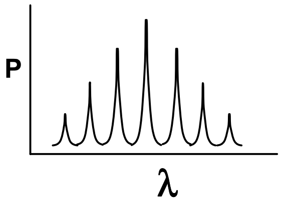


Figure 13: Typical Fabry-Perot laser multimode "comb" spectrum

Fabry-Perot lasers have significant advantages for passive component testing. The typical wavelength envelope (about the comb) is only 2-4 nm wide at 50% of its maximum power (FWHM). This is narrow enough for many tests. The multimode power level is generally unaffected by reflections from beyond its short coherence length of a few centimeters. Fabry-Perot lasers also usually cost less.

Distributed Feedback Lasers

Distributed feedback is a method of concentrating the lasing energy into the center highest mode, producing a narrow-line, single mode output (see the FP laser spectrum in Figure 13). This is achieved by a periodic corrugation in the active layer that distributes optical feedback in both directions, creating a condition that approaches single-mode oscillation (see Figure 14).

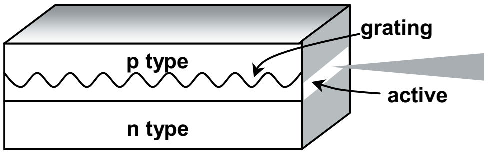


Figure 14: Distributed feedback laser

At telecommunication wavelengths DFB lasers typically have a narrow, single-line output spectrum (see Figure 15).

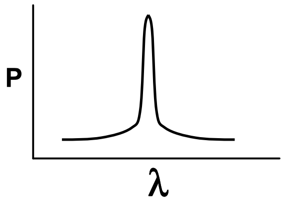


Figure 15: Typical DFB laser spectrum

DFB lasers are the most common transmitter used in fiber telecommunication networks today. Available on ITU-standard wavelength channels, DFBs are the right sources to use when your test must emulate "real" conditions in both wavelengths and linewidths. A good quality DFB laser can usually be directly modulated through its drive current to GHz levels, without excessive chirp. In test applications, multi-channel DFB source systems are the preferred input for testing active components such as EDFAs. DFBs are also useful as fixed sources for testing components that separate or route telecommunication channels such as waveguides.

External Cavity (ECL) Lasers

An External Cavity Laser (ECL) is a diode laser with an external resonator cavity. The external components are usually movable, so the ECL's wavelength is tunable (see Figure 16).

Coherence Length

In fiber telecommunications, coherence length is the distance down the fiber that light from a coherent source (laser) remains in phase with the source. Within the coherence length, reflections back to the laser source will be in phase with it (this usually destabilizes it).

Reflections can be generated from connectors and other components in the system. You can minimize connector reflections by using angled connectors (e.g., FC/APC).

The narrower the source linewidth, the longer the coherence length. Some technologies, such as external cavity lasers (ECLs), produce such narrow linewidths that their coherence limit is several tens of meters.

While an isolator can help, if you are using narrow linewidth lasers, look for a selectable on/off coherence control to broaden linewidth and reduce coherence length.

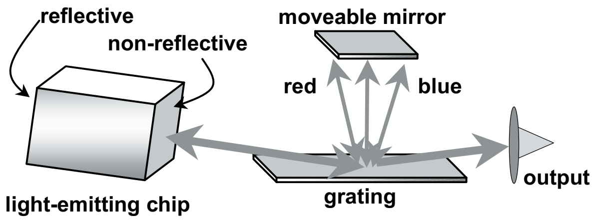


Figure 16: Tunable external cavity laser

A resonant cavity is formed between the mirror and the back of the chip. The grating selects only one of the resonating modes of the cavity to ensure single mode operation. Varying the mirror or grating position tunes the cavity length and the selected resonant wavelength. The longer cavity length results in an extremely narrow linewidth.

ECLs are expensive because they require careful alignment of parts to small free-space beams, which must then be lens-coupled into an output fiber. However, ECLs are a very useful test source for two reasons:

1. Tunability
2. Narrow linewidth

Tunable ECLs are available with either manual or motor-driven tuning. (Think of a manually-tuned ECL as a re-configurable fixed source.) A small number of manually-tuned ECLs are ideal for a fixed-wavelength passive component test system, because you can easily reset the system for different component requirements without requiring more source channels. This is the process control testing mentioned early in this note.

A motorized, tunable ECL allows you to construct a system that scans a component across its spectrum. Narrow linewidth gives the ECL a decided advantage over a spectrum analyzer in measuring characteristics that

Table 2. Comparison of Narrowband Sources

	FP Laser	DFB Laser	ECL
Cost	Low	Medium	High
Fixed/Tunable	Some	Slightly	50+ nm
Spectral width	2 – 4 nm	<1 nm	<1 pm

change with very small wavelength changes. An example of this is a narrow (single-channel) notch filter.

An ECL's narrow linewidth will cause more reflection problems than the other sources discussed here. See the box above about "coherence length".

Narrowband Source Summary
Table 2 above summarizes our discussion of narrowband sources:

Measurement

Broadband Measurement

A broadband meter measures all wavelengths of interest equally, yet cannot give you any wavelength information. An ideal broadband meter would offer these characteristics:

- Uniform (flat) response over all wavelengths of interest; if not flat, very smooth spectral response.
- The ability to couple all input power into its detector.
- Fast reading speed for automated test systems.
- Low cost.

For telecommunications applications practical power meters use semiconductor detectors: for reading speed and sensitivity to low power levels. Germanium and InGaAs (indium gallium arsenide) detectors respond well to telecommunications wavelengths. Germanium is the less expensive technology. However, InGaAs responsivity is fairly flat around 1550 nm, while germanium responsivity is falling steeply in this region (see Figure 17).

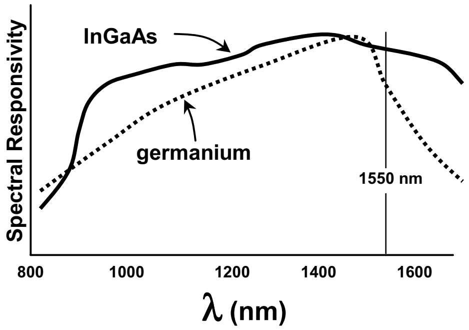


Figure 17: Spectral responsivity, germanium and InGaAs detectors

For a germanium detector, the steep responsivity curve at 1550 nm results in a wavelength dependent error of ~1%/nm. This error an InGaAs detector is less than 0.1%/nm. InGaAs detectors are usually preferred for testing passive fiber optic telecommunication components.

Narrowband Measurement

A narrowband meter measures only a narrow passband of wavelengths. This gives you power level as a function of wavelength. An ideal narrowband meter would offer these characteristics:

- Adjustable passband width. Wider passband for low power sources, narrower for resolving narrowband DUT characteristics.
- Respond only to the desired passband
- Respond uniformly (flat) over all wave

lengths as the passband is tuned.

- Have the ability to couple all input power into its detector
- Provide fast reading speed for automated test systems
- Low cost

Narrowband measurement can be accomplished through a narrowband filter in front of a power meter, or you can use an optical spectrum analyzer (OSA). We will discuss here the differences between the three types of OSAs, depending on their method of tunable narrowband input: interferometers (two types) and diffraction gratings.

A *Fabry-Perot interferometer* is used in the input of some OSAs. It is a simple design based on two parallel mirrors that form a resonant cavity. Its advantages are narrow resolution and simplicity. However, an FP interferometer has repeating passbands that you have to bring closer together in order to maximize resolution. Filters can resolve this, but they add complexity and reduce measurement sensitivity.

A *Michelson interferometer* is also used in some OSAs. This design splits the light into two paths that are then recombined, one fixed and the other variable in length. The resulting combination of the input signal and a delayed version of itself creates an interference pattern that can be measured. Properly calibrated, a Michelson interferometer measures wavelength to a high degree of accuracy: to a picometer level at 1550 nm. A Michelson interferometer also measures coherence length directly, something other OSAs cannot do.

Detector Spectral Responsivity
A detector spectral responsivity graph shows variation in detector response with wavelength. Since most semiconductor detectors are current devices, responsivity is normally given in amperes per watt: amperes of detector current per watt of light input.

Diffraction gratings are the most common input filter used in OSAs for telecommunication wavelengths. The grating separates incoming light into its wavelengths, similar to what a prism does to visible light. The resulting pattern then passes through a movable slit to pass only a portion of the spectrum on to the detector. Light input to the grating also needs to be restricted, so this approach is well suited to fiber input.

In summary, for fiber optic applications:

- An FP interferometer delivers the best resolution;
- A Michelson interferometer delivers the best wavelength accuracy;
- Diffraction gratings are most common in OSAs for telecommunications.

Test Scenarios

We will now contrast the applications of four possible test scenarios, using a broadband and narrowband source, and a broadband and narrowband detector.

Broadband Source and Measurement

A broadband source through the DUT, then into a broadband power meter, is a common method of measuring insertion loss. Simple in concept, this method does not provide wavelength dependent information. Figure 16 shows how this broadband test can miss a process problem, because the overall loss will be similar for each DUT.

Narrowband Source, Broadband Measurement

Referring back to Figure 16, assume you have learned through experience that process problems can increase losses at longer wavelengths. A simple test might consist of checking loss specifically at I_1. A fixed, narrow band source such as a Fabry-Perot or a DFB laser source could serve as a process control check. If you do a lot of this at different wavelengths, a manually-tuned ECL would be reconfigurable for each different component.

Point Testing

You can gain a lot in both efficiency and lower test cost by using fixed laser sources to check losses at specific wavelengths. This approach is often called “edge testing”, or “multipoint testing”, depending on how many points you decide to monitor. See figure 19.

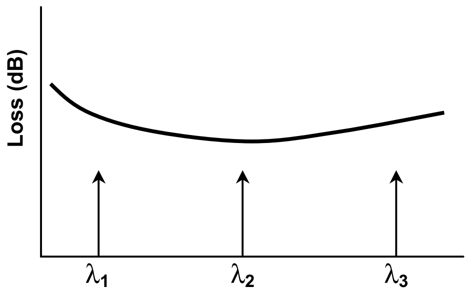


Figure 19: Three-point testing

If you are doing point testing, you may want to select a small sample for a complete scan. This will limit your losses if a new problem begins to affect your process.

Motorized TLS

With a motorized tunable laser source, such as an ECL, you can design a system that scans a component across its full spectrum. (This can be an appropriate test for the sample-check mentioned above). The ECL’s narrow linewidth allows you to identify narrow-wavelength features such as notch filter pass-band characteristics.

Broadband Source, Narrowband Measurement

A common way to do a spectral scan on passive components is to use a broadband source with a tunable narrowband meter. Although you can do this with a tunable notch-filter and a power meter, the most common instrument for this purpose is an optical spectrum analyzer (OSA). OSAs are common in passive component manufacturing test for two reasons: 1) Versatility; OSAs are a general purpose instrument, and 2) Automation; nearly all OSAs are designed for automated testing under computer control.

This is a good approach for low volume and production startup. However, as you build more test workstations, the high cost of a good OSA becomes less justifiable for each station. (That is when you start developing process control testing).

Narrowband Source, Narrowband Measurement

Some OSAs can be linked to track a motorized, tunable laser. Why would you use an expensive Tunable Laser Source (TLS) for this? After all, the OSA already gives you a l-scan. The answer is increased dynamic range. To see the problem, look at a typical ECL spectral scan in Figure 20.

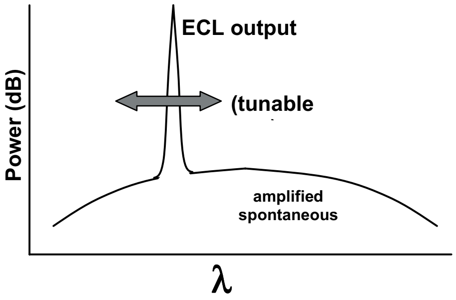


Figure 20: Typical ECL spectral scan

Unless it includes a narrowband tracking filter, a typical ECL output can include a significant amount of background ASE energy. This background adds to the meter reading, causing errors and limiting dynamic range. The narrow filtering of the OSA's input interferometer or diffraction grating eliminates the ASE background.

References

As you get into the detailed decisions of your passive component test plan, you will need more technical depth than this discussion note. Here are some recently published works that we find useful:
Fiber Optic Test and Measurement, published by Prentice-Hall. (ISBN 0-13-534330-5)
Optical Networks, published by Morgan Kaufmann. (ISBN 1-55860-445-6)
Handbook of Fiber Optic Data Communication, Academic Press. (ISBN 0-12-437162-0)

Discuss Your Test Needs

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The following publications are available for download on at www.ilxlightwave.com.

White Papers

- A Standard for Measuring Transient Suppression of Laser Diode Drivers
- Degree of Polarization vs. Poincaré Sphere Coverage
- Improving Splice Loss Measurement Repeatability

Technical Notes

- Attenuation Accuracy in the 7900 Fiber Optic Test System
- Automatic Wavelength Compensation of Photodiode Power Measurements Using the OMM-6810B Optical Multimeter
- Bandwidth of OMM-6810B Optical Multimeter Analog Output
- Broadband Noise Measurements for Laser Diode Current Sources
- Clamping Limit of a LDX-3525 Precision Current Source
- Control Capability of the LDC-3916371 Fine Temperature Resolution Module
- Current Draw of the LDC-3926 16-Channel High Power Laser Diode Controller
- Determining the Polarization Dependent Response of the FPM-8210 Power Meter
- Four-Wire TEC Voltage Measurement with the LDT-5900 Series Temperature Controllers
- Guide to Selecting a Bias-T Laser Diode Mount
- High Power Linearity of the OMM-6810B and OMH-6780/6790/6795B Detector Heads
- Large-Signal Frequency Response of the 3916338 Current Source Module
- Laser Wavelength Measuring Using a Colored Glass Filter
- Long-Term Output Drift of a LDX-3620 Ultra Low-Noise Laser Diode Current Source
- Long-Term Output Stability of a LDX-3525 Precision Current Source
- Long-Term Stability of an MPS-8033/55 ASE Source
- LRS-9424 Heat Sink Temperature Stability When Chamber Door Opens
- Measurement of 4-Wire Voltage Sense on an LDC-3916 Laser Diode Controller
- Measuring the Power and Wavelength of Pulsed Sources Using the OMM-6810B Optical Mutlimeter
- Measuring the Sensitivity of the OMH-6709B Optical Measurement Head
- Measuring the Wavelength of Noisy Sources Using the OMM-6810B Optical Multimeter
- Output Current Accuracy of a LDX-3525 Precision Current Source
- Pin Assignment for CC-305 and CC-505 Cables
- Power and Wavelength Stability of the 79800 DFB Source Module
- Power and Wavelength Stability of the MPS-8000 Series Fiber Optic Sources
- Repeatability of Wavelength and Power Measurements Using the OMM-6810B Optical Multimeter
- Stability of the OMM-6810B Optical Multimeter and OMH-6727B InGaAs Power/Wavehead
- Switching Transient of the 79800D Optical Source Shutter
- Temperature Controlled Mini-DIL Mount
- Temperature Stability Using the LDT-5948
- Thermal Performance of an LDM-4616 Laser Diode Mount
- Triboelectric Effects in High Precision Temperature Measurements
- Tuning the LDP-3840 for Optimum Pulse Response
- Typical Long-Term Temperature Stability of a LDT-5412 Low-Cost TEC
- Typical Long-Term Temperature Stability of a LDT-5525 TEC
- Typical Output Drift of a LDX-3412 Loc-Cost Precision Current Source
- Typical Output Noise of a LDX-3412 Precision Current Source
- Typical Output Stability of the LDC-3724B
- Typical Output Stability of a LDX-3100 Board-Level Current Source
- Typical Pulse Overshoot of the LDP-3840/03 Precision Pulse Current Source
- Typical Temperature Stability of a LDT-5412 Low-Cost Temperature Controller
- Using Three-Wire RTDs with the LDT-5900 Series Temperature Controllers
- Voltage Drop Across High Current Laser Interconnect Cable
- Voltage Drop Across High Current TEC Interconnect Cable
- Voltage Limit Protection of an LDC-3916 Laser Diode Controller
- Wavelength Accuracy of the 79800 DFB Source Module

Application Notes

- App Note 1: Controlling Temperatures of Diode Lasers and Detectors Thermoelectrically
- App Note 2: Selecting and Using Thermistors for Temperature Control
- App Note 3: Protecting Your Laser Diode
- App Note 4: Thermistor Calibration and the Steinhart-Hart Equation
- App Note 5: An Overview of Laser Diode Characteristics
- App Note 6: Choosing the Right Laser Diode Mount for Your Application
- App Note 8: Mode Hopping in Semiconductor Lasers
- App Note 10: Optimize Testing for Threshold Calculation Repeatability
- App Note 11: Pulsing a Laser Diode
- App Note 12: The Differences between Threshold Current Calculation Methods
- App Note 13: Testing Bond Quality by Measuring Thermal Resistance of Laser Diodes
- App Note 14: Optimizing TEC Drive Current
- App Note 17: AD590 and LM335 Sensor Calibration
- App Note 18: Basic Test Methods for Passive Fiber Optic Components
- App Note 20: PID Control Loops in Thermoelectric Temperature Controllers
- App Note 21: High Performance Temperature Control in Laser Diode Test Applications

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