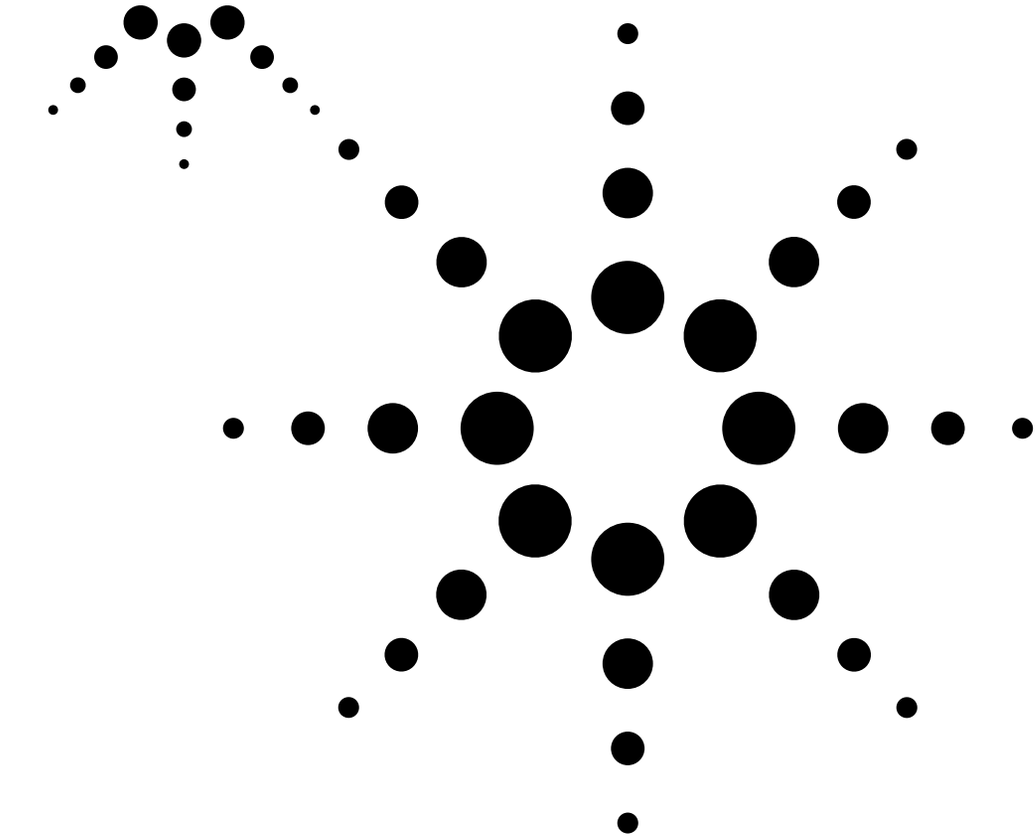
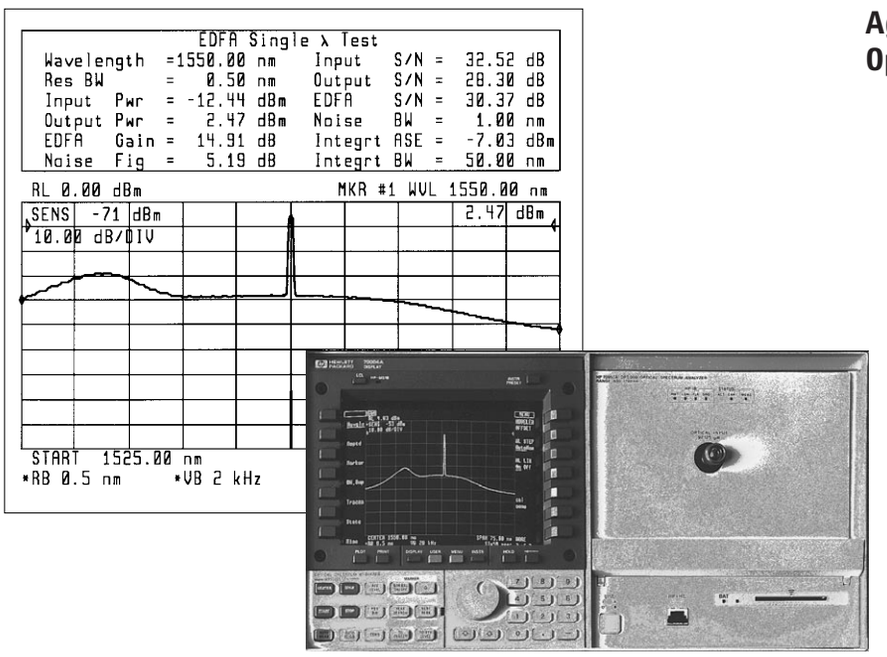
# EDFA Testing with the Interpolation Technique

Product Note 71452-1






**Agilent 71452B**
**Optical Spectrum Analyzer**

**Agilent Technologies**
Innovating the HP Way

# Table of Contents

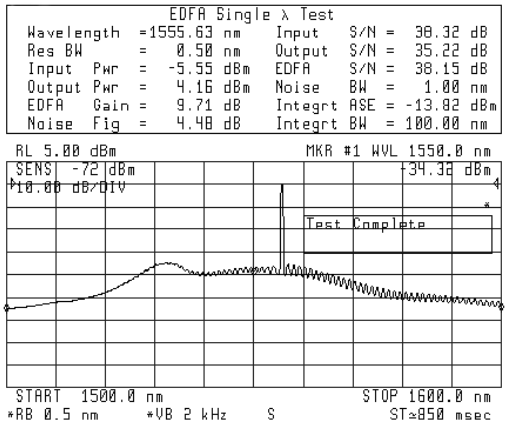
## Introduction

Erbium-doped fiber amplifiers (EDFAs) play a key role in modern telecommunication and CATV systems. Accurate measurements of amplifier performance are critical to the integrity of these communications links.

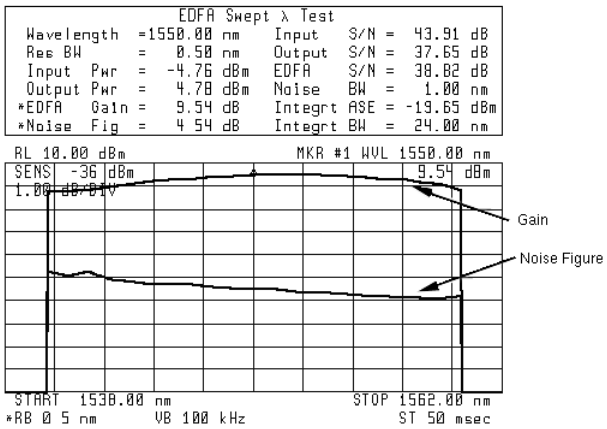
The Agilent 71452B Optical Spectrum Analyzer (OSA with polarization sensitivity and scale fidelity specifications of ±0.05 dB, and a built-in EDFA test personality) provides a quick and easy way to accurately measure a variety of EDFA parameters in three different measurement setups. Each of the three tests provides a display of EDFA parameters which is updated at the end of each OSA sweep. This product note describes the measurement of EDFAs using the interpolation measurement technique, the calculation of measurement accuracy, and the operation of the EDFA test personality.

Typical results from two of the tests are shown below. The *single wavelength test* allows characterization of an EDFA at a single wavelength. This is typically used with a distributed feedback (DFB) laser as the source. The measured parameters include wavelength, gain, noise figure, power levels, noise levels, signal-to-noise ratios, and integrated amplified spontaneous emission (ASE). The *swept wavelength test* makes the same measurements over a range of wavelengths. This requires a tunable laser source such as the Agilent 8168A*. The third test is the *output test* that provides several useful characteristics of the output spectrum of either a single or series of EDFAs. This test measures the signal wavelength, power, output signal-to-noise ratio (or noise level), and integrated ASE.

*Note: the measurements described in this product note work with the Agilent 8168B or Agilent 8168C as well.




**Single wavelength test result**



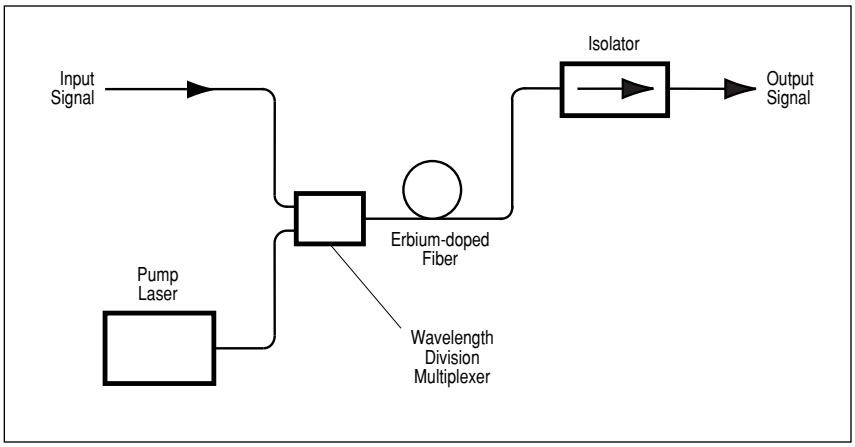

**Swept wavelength test result**

## Erbium-Doped Fiber Amplifier Operation

A block diagram of a single-stage co-directionally pumped EDFA is shown below. The pump laser (typically either 980 nm or 1480 nm) is coupled to the erbium-doped fiber with a wavelength division multiplexer. The erbium-doped fiber is highly absorptive at the pump wavelengths, and is a good emitter of light in the 1550 nm region.

The energy from the pump laser boosts the erbium ions in the fiber from the ground state to a higher, metastable energy level. Once in the metastable state, the ions are stimulated by the signal propagating along the erbium-doped fiber, causing them to decay back to the ground state. This results in the emission of a photon in phase with the signal, thus amplifying the signal by stimulated emission.

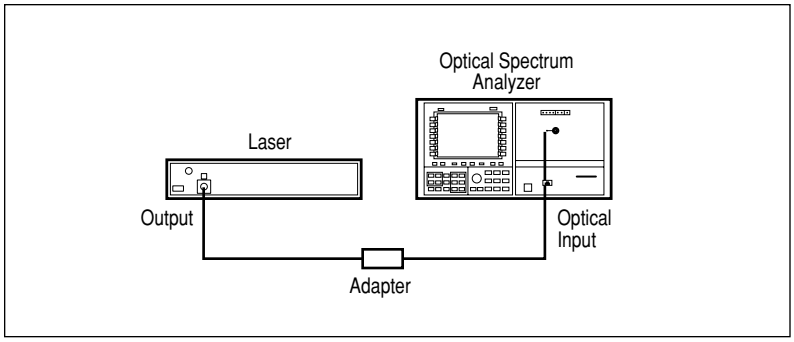
If stimulated emission does not occur, erbium ions in the metastable state will eventually decay spontaneously to the ground state, radiating photons of random phase and direction. Some of the spontaneously emitted photons will travel along the length of the fiber. These photons are subsequently amplified, and result in amplified spontaneous emission (ASE). This ASE, or noise, has important consequences on the performance of a system using EDFAs. In an optical communication system, the noise generated by an EDFA will degrade the signal-to-noise ratio at the optoelectronic receiver thus increasing the bit error ratio. Additionally, in systems with cascaded amplifiers, the ASE power contribution of each EDFA is amplified by subsequent amplifiers, increasing the impact on system performance. As a result, ASE power and noise figure are important EDFA figures of merit, in addition to gain and output power.



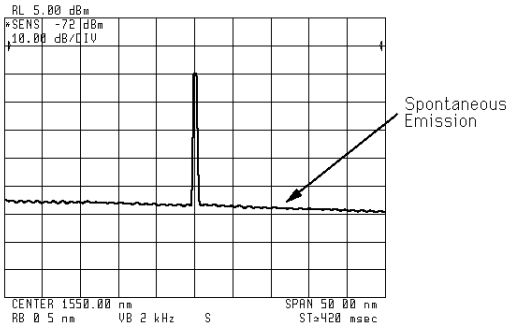

**Erbium-doped fiber amplifier block diagram**

## Measurement Technique

Erbium-doped fiber amplifiers can be characterized with a stable laser source used as the input signal and an optical spectrum analyzer for spectral measurements. A distributed feedback laser works well for single wavelength testing and a tunable laser source works well for performing tests as a function of wavelength. Spectral measurements of the laser source and the EDFA output are required to determine the EDFA parameters. The configuration for measuring the laser spectrum, and a typical spectrum measurement are shown below. The spectrum of the laser shows that there is spontaneous emission coming from the laser source. This must be measured and accounted for in the calculation of EDFA parameters.

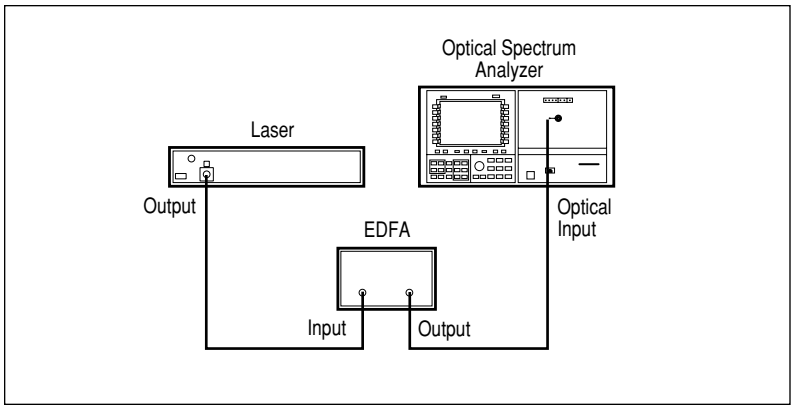



**Equipment configuration for source measurement**

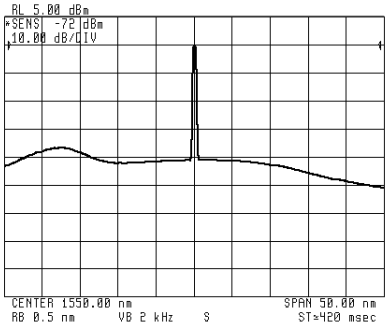



**Typical laser spectrum**

The output spectrum of the EDFA is measured by connecting the laser output to the EDFA input and the EDFA output to the optical spectrum analyzer input. This configuration, and a typical spectrum measurement are shown below.



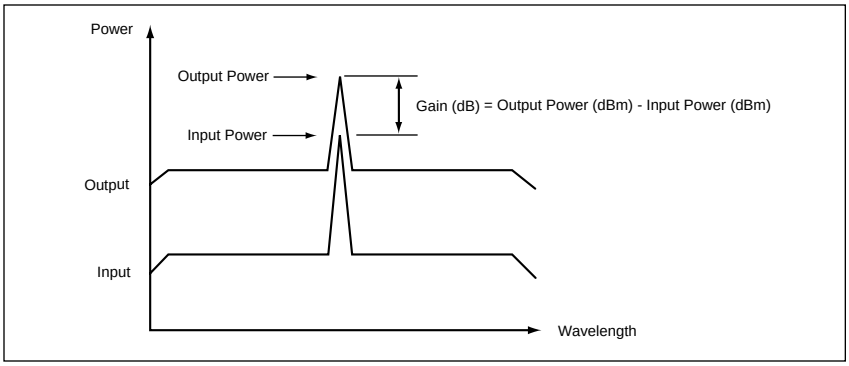

**Equipment configuration for EDFA measurement**




**Typical EDFA spectrum**

## Gain

The purpose of the EDFA is to provide gain, which is defined as the ratio of the output signal power to the input signal power. When these power levels are measured on a logarithmic scale, with units of dBm (decibels relative to 1 milliwatt), the gain is calculated as the difference between the two signals, as shown.

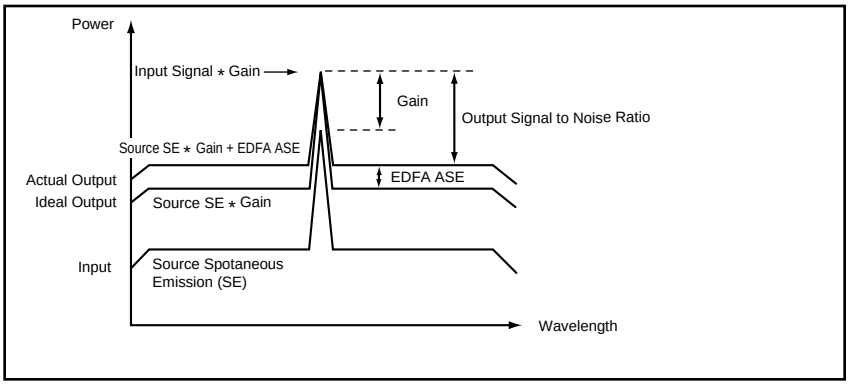



**Spectral measurements used to determine EDFA Gain**

The input and output power levels measured are actually the sum of the signal power and the small amount of spontaneous emission power within the optical spectrum analyzer's resolution bandwidth at the signal wavelength. This additional measured power usually has a negligible impact on the gain calculation, but it can be a factor when high spontaneous emission levels are present. This is corrected for by subtracting, from each of the power measurements, the spontaneous emission power in the measured spectrum at the signal wavelength. The method to determine the spontaneous emission power levels is discussed below.

### Amplified Spontaneous Emission

Ideally, an EDFA would amplify the input signal by its gain and produce no additional output. However, the EDFA also produces amplified spontaneous emission, which adds to the spontaneous emission produced by the source. Because the output spectrum contains spontaneous emission from both the source and the EDFA under test, the EDFA ASE cannot be determined directly from the output spectrum measurement. The calculation of EDFA noise figure requires that the portion of the output ASE level that is generated by the EDFA is known. This is calculated as the difference between the output spontaneous emission power and the equivalent source spontaneous emission power at the amplifier output.




**EDFA input and output spectra showing signal and spontaneous emission levels**

### Noise Figure

The noise figure of the EDFA is calculated from the measurements of signal and ASE levels using the following equation:

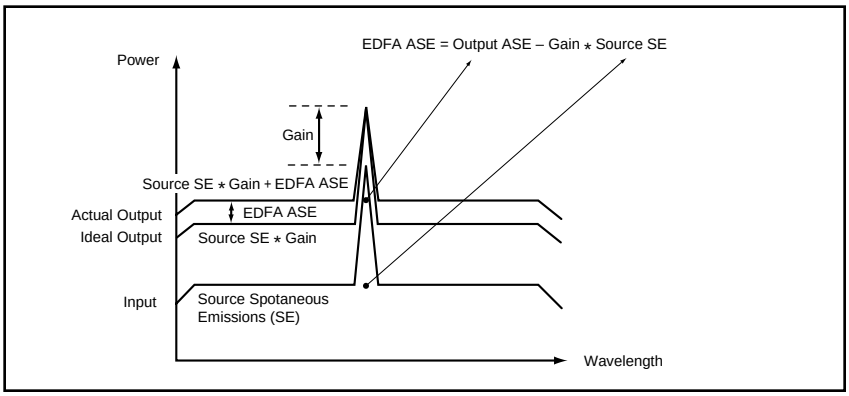
$$\textit{Noise Figure} \stackrel{\Delta}{=} \frac{N_{\mathrm{EDFA}}}{h\nu G B_{\mathrm{W}}} + \frac{1}{G} = \frac{N_{\mathrm{out}} - N_{\mathrm{in}} G}{h\nu G B_{\mathrm{W}}} + \frac{1}{G}$$

where:

- $N_{out}$ = output noise power (within the OSA bandwidth).
- $N_{in}$ = source noise power (within the OSA bandwidth).
- G = amplifier gain.
- $N_{EDFA}$ = portion of $N_{out}$ that is generated by the EDFA .
- $B_W$ = optical spectrum analyzer's noise bandwidth expressed in Hertz.
- h = Plank's constant, which is equal to $6.626 * 10^{-34}$ Watt seconds$^2$.
- $\nu$ = signal frequency in Hertz (speed of light divided by signal wavelength).

The noise figure equation contains two terms that contribute to noise at the electrical output of a photodetector used to detect the optical signal. The first term is due to mixing, at the photodetector, of the signal and the amplified spontaneous emission at the same wavelength. The second term represents the level dependent shot noise produced at the photodetector. This calculation assumes that a third noise term, the mixing of spontaneous emission with itself, is negligible in the determination of noise figure. This tends to be the case when either the signal power level is large enough to drive the amplifier into compression, or the output of the amplifier is passed through a narrow bandpass filter prior to the photodetector, or both.

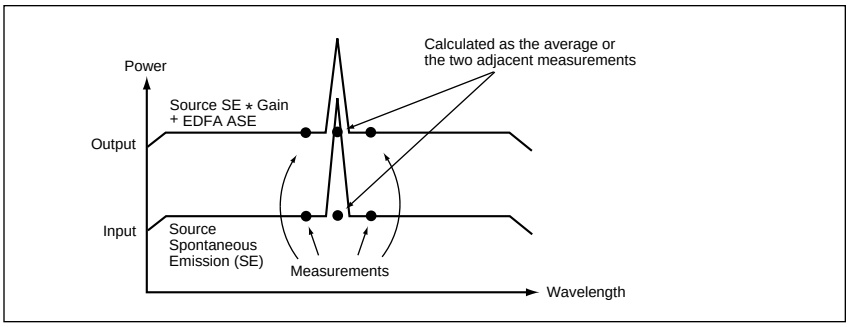
In order to correctly determine the noise figure, the ASE level must be determined at the signal wavelength. Unfortunately, this cannot be measured directly because the signal power level masks the ASE level at the signal wavelength.




**Spectral Information required for the determination of EDFA ASE level**

The noise figure measurement made by the EDFA test personality is based on the interpolation technique. It is so called because the amplified spontaneous emission of the EDFA at the signal wavelength is determined by measuring the ASE level at a wavelength just above and just below the signal, and then interpolating to determine the level at the signal wavelength. This technique works well for the measurement of one or a few EDFAs because it requires a linear ASE spectrum in a narrow wavelength region (typically ±1 nm) about the signal. Alternative techniques are required for determining the ASE level at the output of many EDFAs in series because, in that case, the ASE spectrum is typically not linear over a narrow wavelength range, and non-linear properties of the fiber cause spectral broadening. For example,one available technique utilizes a modulated source and Agilent's patented time domain extinction technique (see product note 71452B-2).

The spontaneous emission of the source is first determined by measuring its level at a specified offset (typically 1 nm) above and below the signal wavelength and then taking the average of the measurements. The same procedure is then used to determine the spontaneous emission at the output of the EDFA. From these two measurements and the calculated gain, the EDFA ASE and noise figure can be calculated.




**Use of linear interpolation to determine the spontaneous emission levels.**

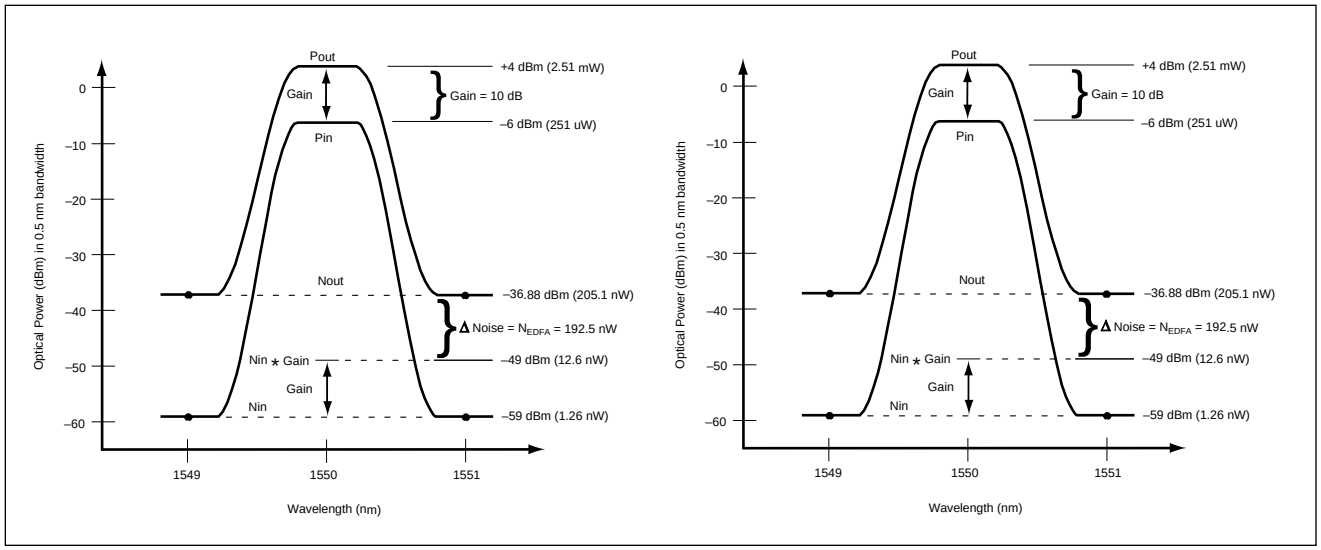
### Integrated Amplified Spontaneous Emission

Although noise figure is calculated based on the ASE level at the signal wavelength, it is useful to know the total output ASE power over a given wavelength span. This is especially true for simulating the optical bandwidth of a receiver and determining the total spontaneous emission power that will reach the photodetector. This is determined from the measurement of the output spectrum by integrating the spectral power over the wavelength range of interest, replacing the output signal power with the interpolated spontaneous emission at that wavelength.

## Determination of Measurement Accuracy

The gain and noise figure measurement uncertainties for a particular measurement can be calculated based on the measurement technique and the specifications of the equipment used. In this section, the significant gain and noise figure uncertainty terms are described and values are determined for example measurements using the interpolation technique. This analysis assumes that the EDFA ASE spectrum is linear in a region of ±1 nm about the signal wavelength, allowing the interpolation technique to be used effectively. These example uncertainty calculations are based on the use of an Agilent 71452B Optical Spectrum Analyzer (which has been calibrated as described in Appendix A). In order to illustrate the effects of the source spontaneous emission and swept wavelength vs. single wavelength testing, example uncertainties will be calculated for two measure-ment situations. One is a single wavelength example that uses a DFB laser with an output power of –6 dBm and a source spontaneous emission level of –56 dBm/nm at the interpolation offset wavelengths.

For best accuracy, the interpolation wavelengths should be carefully selected (the default is ±1 nm from the signal) to avoid laser sidemodes. The other is a swept wavelength example that uses a tunable laser source with an output power level of –6 dBm and a source spontaneous emission level of –43 dBm/nm. For both examples, the amplifier under test has a gain of 10 dB and a noise figure of 4 dB. Measurements should be made after the optical spectrum analyzer has been allowed to warm up for one hour and the auto-align routine has been run. The following figure shows the input and output spectra for the two measurement examples.




a) b)

**Input and output spectral levels of amplifier under test for a) single wavelength measurement example and b) swept wavelength measurement example**

Amplifier gain is calculated as the ratio of the output power ($P_{out}$) to the input power ($P_{in}$). For these examples:

$$Gain = \frac{P_{out}}{P_{in}} = \frac{2.51mW}{251\mu W} = 10\ (10dB)$$

An uncertainty of a given magnitude affecting the measurement of either $P_{out}$ or $P_{in}$, but not both, will result in a gain uncertainty of the same magnitude. For example, a 2% error in the measurement of $P_{out}$ only will result in a 2% error in the calculated gain. As a result, the gain uncertainty can be determined directly from the individual uncertainties for the measurements of $P_{out}$ and $P_{in}$. Because this is a relative measurement, those uncertainties that affect both measurements equally will cancel out and have no affect on the gain uncertainty. Prior to the gain calculation, the power measurements

are corrected for the small amount of spontaneous emission power within the optical spectrum analyzer's resolution bandwidth when the signal power levels are measured. These corrections are very small, and the gain uncertainty due to errors in the correction factors tend to be insignificant.

Amplifier noise figure is calculated based on the amplifier gain (G) and the amplified spontaneous emission produced by the amplifier ($N_{EDFA}$). The value of $N_{EDFA}$ is equal to the amplifier's output noise level ($N_{out}$) minus the equivalent source spontaneous emission level at the amplifier output ($N_{in}*G$).

$$NF = \frac{\Delta N_{EDFA}}{h\nu B_W G} + \frac{1}{G} = \frac{N_{out}}{h\nu B_W G} - \frac{N_{in}}{h\nu B_W} + \frac{1}{G}$$

For simplicity, the three terms on the right hand side of the equation will be referred to as A, B, and C in this analysis. The impact of an error in the measurement of gain, $N_{out}$ or $N_{in}$ on the overall noise figure error depends on the relative magnitude of the term (A, B, or C) or terms that it affects, and how that error mechanism affects the other measurements.

In the example using the DFB laser with a source spontaneous emission level of –56 dBm/nm, the source noise ($N_{in}$) in the optical spectrum analyzer's 0.5 nm resolution bandwidth is –59 dBm or 1.26 nW. For a wavelength of 1550 nm, a gain of 10 and a bandwidth of 0.5 nm, $h\nu$ (plank's constant multiplied by the laser frequency) is equal to $1.28*10^{-19}$ Watt seconds and $B_W$ is equal to 62.4 GHz. With a noise figure of 2.51 (4.0 dB), $N_{EDFA}$ is equal to 192.5 nW and $N_{out}$ is equal to 205.1 nW. Solving the noise figure equation for the measurement with the DFB laser source yields:

$$NF = \frac{205.1nW - 1.26nW*10}{(1.28*10^{-19}Ws)*(10)*(62.4*10^{9}Hz)} + \frac{1}{10} = 2.57 - 0.16 + 0.1 = 2.51$$

In this case, the noise figure calculation is dominated by the A term (2.57) which contains the measured values of $N_{out}$ and G. An uncertainty of a given magnitude in the measurement of either $N_{out}$ or G will result in a noise figure uncertainty of a similar magnitude. For example, a 2% error in the measurement of $N_{out}$ will result in a (2.57/2.51) ∗ 2% error in the calculated noise figure (assuming this error mechanism does not affect the other terms). On the other hand, a 2% error affecting only the determination of $N_{in}$ would have a small impact on the noise figure uncertainty (2% ∗ 0.16/2.51 = 0.13%). In a case such as this, with large gain and a low source spontaneous emission level, a simplified approximation of the measurement uncertainty could be made by assuming that all the errors are a result of the A term, and that the B and C terms are insignificant.

In the example using a tunable laser source with a higher source spontaneous emission level of –43 dBm/nm, the source noise ($N_{in}$) in the optical spectrum analyzer's 0.5 nm resolution bandwidth is –46 dBm or 25.1 nW. $N_{EDFA}$ is still equal to 192.5 nW but $N_{out}$ is equal to 443.7 nW, much greater than in the first example. Solving the noise figure equation for the measurement with the tunable laser source yields:

$$NF = \frac{443.7nW - 25.1nW * 10}{(1.28 * 10^{-19} Ws) * (10) * (62.4 * 10^{9} Hz)} + \frac{1}{10} = 5.55 - 3.14 + 0.1 = 2.51$$

In this case, the noise figure calculation is dominated by the difference between two large terms, A and B, and some of the measurement errors result in larger contributions to the noise figure uncertainty. For example, a 2% error affecting only the measurement of $N_{out}$ will result in an error of 4.1% [(5.55/2.51)*2% = 4.1%] in the calculated noise figure (assuming this error mechanism does not affect the other terms). The following analysis addresses each of the error terms individually.

As the difference between the two example measurements show, the source signal-to-noise ratio should be as large as possible for best accuracy. When using a laser with an adjustable bias level for power control, it is best to set the bias for a high power level and use an optical attenuator to achieve the desired source power level. This usually produces the greatest source signal-to-noise ratio.

### Sources of Measurement Uncertainty

This analysis takes the conservative approach of treating all of the individual measurement uncertainties as systematic - that is, uniform probability distribution within the specified limits. An error contribution is determined for each of the uncertainty terms described below. The total uncertainties are then calculated using the following equation:

$$uncertainty = 2\sqrt{\sum \frac{U^2}{3}}$$

where "U" is the uncertainty of each individual term. All uncertainties are expressed as peak values. That is, an uncertainty of ±0.04 dB will be written as 0.04 dB.

***Connector uncertainty***

When a fiber connection is made, either with a connector or splice, there is an amplitude uncertainty associated with it. Three connections contribute to the gain uncertainty. They are the source to optical spectrum analyzer connection during the source measurement ($P_{in}$), and the source to EDFA and EDFA to optical spectrum analyzer connections during the output measurement ($P_{out}$).

In order to determine the connector uncertainty in the noise figure measurement, the noise figure equation can be rewritten expanding the definition of gain:

$$NF = \frac{N_{out}P_{in}}{P_{out}h\nu B_W} - \frac{N_{in}}{h\nu B_W} + \frac{1}{G}$$

The ratio $N_{out}/P_{out}$ in the A term will not be affected by connector uncertainties since the two terms are measured with the same connections. As a result, both the A term ($P_{in}$) and B term ($N_{in}$) have the connector uncertainties associated with the absolute measurement of the input signal. The input measurement contains two connector uncertainties; the source to OSA connection during the calibration and source measurement, and the source to EDFA connection during the amplifier test. Assuming the noise figure is much greater than 1/G, the difference between the A and B terms is much greater than the C term and the noise figure uncertainty can be approximated as containing two connector uncertainties.

With Connectors: If good quality physical-contact fiber-optic connectors are used and maintained to have 35 dB minimum return loss and 0.25 dB maximum mismatch uncertainty, the contribution to the gain uncertainty is 3 x 0.25 dB, and the contribution to the noise figure uncertainty is 2 x 0.25 dB.

With Fusion Splices: Assuming a maximum mismatch uncertainty of 0.05 dB per connection, the contribution to the gain uncertainty is 3 x 0.05 dB, and the contribution to the noise figure uncertainty is 2 x 0.05 dB.

***Source stability***

Gain is calculated as the difference between two power measurements. Any change in the source power level between these measurements will directly affect the measurement accuracy. The 1 hour stability specification for the Agilent 8168A Tunable Laser Source is 0.05 dB (Agilent 8168B, 8168C is 0.03 dB), and this will be used for the gain measurement uncertainty.

The gain uncertainty affects the A and C terms in the noise figure equation. The impact of this term depends on the ratio of A+C to the total noise figure. For the single wavelength measurement example, the contribution to the noise figure uncertainty is 0.05 dB * (2.57+0.1)/2.51 = 0.053 dB. For the swept wavelength measurement example, the contribution is 0.05 dB * (5.51+0.1)/2.51 = 0.112 dB.

***Source repeatability***
When making swept wavelength measurements, the tunable laser source is stepped through all wavelengths two times. The source amplitude repeatability will affect swept wavelength measurements just as the source stability. This term is not a factor for single wavelength measurements. The amplitude repeatability specification of 0.04 dB for the Agilent 8168A Tunable Laser Source will be used for the gain measurement uncertainty. The contribution to the noise figure measurement uncertainty is 0.04 dB * (5.51+0.1)/2.51 = 0.089 dB.

***Source spontaneous emission repeatability***
When swept wavelength measurements are made with a tunable laser source, the tunable laser is tuned to other wavelengths between the source measurement and the amplifier output measurement. It is possible for the spontaneous emission level of a source to change after tuning away from and back to a given wavelength. Any change in the spontaneous emission level will result in inaccuracies in the calculation of the EDFA ASE level and therefore the noise figure. This term only applies to swept wavelength measurements and the spontaneous emission variation can be assumed to be no greater than 0.1 dB. In most cases, the actual variation will be less than this amount, however when retuning a tunable laser source back to a given wavelength, it is possible that it will lock on a different cavity mode than in the original case, and the resulting spontaneous emission level can be significantly different. On the rare occasions of a large change, the resulting plot of noise figure can be seen to have one value significantly different than the rest. Repeating the test will show if it was an erroneous reading.

The source spontaneous emission repeatability can be treated as an error in the measurement of the input noise level ($N_{in}$). The contribution to the swept wavelength noise figure measurement example is 0.1 dB * B/NF = 0.1 dB * 3.14/2.51 = 0.125 dB.

***OSA absolute amplitude accuracy***
The measurement of the input and output noise levels are absolute amplitude measurements. The gain calculation is based on a relative measurement and this term is not a factor in the gain uncertainty.

The absolute amplitude accuracy (see Appendix A) contains two error terms; the power meter transfer accuracy (0.1 dB), and the uncertainty of the OSA connection made during the calibration. The connection uncertainty has already been taken into account and does not need to be included again.

The power meter transfer accuracy affects the A and B terms equally. For the single wavelength and swept wavelength examples, this term is 0.1 dB * (A-B)/NF = 0.1 dB * (2.41/2.51) = 0.096 dB.

***OSA polarization sensitivity***

The input signal, output signal, and source spontaneous emission (of the tunable laser source) are highly polarized and the polarization sensitivity of the optical spectrum analyzer will add to the uncertainty of their measurement. The amplified spontaneous emission produced by the EDFA is not significantly polarized. The Agilent 71452B Optical Spectrum Analyzer provides a polarization sensitivity of 0.05 dB from 1542 nm to 1562 nm. Since the gain calculation involves two measurements of polarized signals, the gain uncertainty term is 2 ∗ 0.05 dB.

The contribution of the gain uncertainty to the noise figure measurement is equal to 2 ∗ 0.05 dB ∗ (A+C)/NF = 2 ∗ 0.05 dB ∗ (2.67/2.51) = 2 ∗ 0.053 dB for the single wavelength measurement. For the swept wavelength measurement, the contribution is 2 ∗ 0.05 dB ∗ (5.61/2.51) = 2 ∗ 0.112 dB.

The spontaneous emission produced by the tunable laser source ($N_{in}$) is polarized and that measurement is affected by the polarization sensitivity of the OSA. The measurement uncertainty of 0.05 dB for $N_{in}$ will contribute 0.05 dB ∗ B/NF = 0.05 dB ∗ 3.14/2.51 = 0.063 dB for the swept wavelength measurement. The measurement of the output noise ($N_{out}$) is partially affected by the polarization sensitivity because the amplified spontaneous emission produced by the EDFA ($N_{EDFA}$) is not significantly polarized, but the portion of the output noise ($N_{out}$) that is equal to the input noise ($N_{in}$) multiplied by the gain is polarized. This results in the same uncertainty for the measurement of $N_{out}$ as for $N_{in}$, so that the uncertainty calculated for $N_{in}$ is counted twice.

The source spontaneous emission produced by a typical DFB laser is not highly polarized, so this term is assumed to be zero for the single wavelength measurement example.

***OSA scale fidelity***

Scale fidelity reflects the accuracy with which the optical spectrum analyzer can be used to make relative amplitude measurements. The gain calculation is based on a relative measurement and the absolute noise level measurements can be considered as relative measurements with the calibration source. The optical spectrum analyzer's scale fidelity specification is either 0.05 dB or 0.07 dB, depending on the optical spectrum analyzer settings and the amplitude range covered. This analysis will use the worst case condition of 0.07 dB. The contribution to the gain uncertainty is 0.07 dB. This gain uncertainty will contribute to the noise figure uncertainty by 0.07 dB ∗ (A+C)/NF = 0.07 dB ∗ 2.67/2.51 = 0.075 dB for the single wavelength measurement, and 0.07 dB ∗ 5.65/2.51 = 0.157 dB for the swept wavelength measurement.

This uncertainty affects the A ($N_{out}$) and B ($N_{in}$) terms of the noise figure equation, but not necessarily equally, so they are treated as separate terms. For the single wavelength measurement, these two factors are 0.07 dB * A/NF = 0.07 * 2.57/2.51 = 0.072 dB and 0.07 dB * B/NF = 0.07 * 0.16/2.51 = 0.001 dB. For the swept wavelength measurement, these two factors are 0.07 dB * A/NF = 0.07 * 5.55/2.51 = 0.155 dB and 0.07 dB * B/NF = 0.07 * 3.14/2.51 = 0.088 dB.

***OSA flatness***

The spontaneous emission levels ($N_{in}$ and $N_{out}$) at the signal wavelength are estimated by measuring at 1 nm offsets from the signal wavelength and then interpolating. The worst case uncertainty for these measurements is equal to the OSA flatness (variation in OSA amplitude response with wavelength) specification of 0.2 dB. This uncertainty is a fixed amplitude error as a function of wavelength and will affect the input and output noise measurements equally. This term will contribute 0.2 dB * (A-B)/NF = 0.2 dB * 2.41/2.51 = 0.192 dB for both the single wavelength and swept wavelength measurements.

***OSA resolution bandwidth accuracy***

The measured spontaneous emission levels are a function of the optical spectrum analyzer's resolution bandwidth. This bandwidth is taken into account in the calculation of noise figure and, as a result, the accuracy with which the resolution bandwidth is known affects the noise figure accuracy. The actual bandwidth of the 0.5 nm resolution bandwidth filter is known to within 3%, which corresponds to a 0.13 dB uncertainty in the noise measurements. This uncertainty will affect each noise measurement equally, so the contribution to the noise figure uncertainty will be 0.13 dB * (A-B)/NF = 0.13 dB * 2.41/2.51 = 0.125 dB for both the single wavelength and swept wavelength measurements.

***OSA internal etalons***

Internal etalons in the optical spectrum analyzer can cause an amplitude uncertainty when measuring narrow linewidth laser sources. The measurement of a broadband signal, such as spontaneous emission, is not affected by this mechanism. This term adds a maximum uncertainty of 0.03 dB to the gain measurement, but has no affect on the noise measurements. The contribution of the gain uncertainty to the noise figure measurement is equal to 0.03 dB * (A+C)/NF = 0.03 dB * (2.67/2.51) = 0.032 dB for the single wavelength measurement. The contribution to the swept wavelength measurement is 0.03 dB * (5.61/2.51) = 0.067 dB.

***OSA dynamic range***

The measurement of the source spontaneous emission level and the EDFA output spontaneous emission level, at one nanometer offsets from the signal, are affected by the dynamic range of the optical spectrum analyzer. The Agilent 71452B Optical Spectrum Analyzer is specified to have a minimum dynamic range of 60 dB at a one nanometer offset from a signal. This means that when the optical spectrum analyzer is tuned one nanometer away from a large signal, it will detect a portion (up to –60 dBc) of that nearby signal in addition to the spontaneous emission level to be measured.

The magnitude of this effect can be determined based on the total error in the $N_{EDFA}$ term (A-B) multiplied by the ratio of the $N_{EDFA}$ term to the noise figure. The maximum error in the measurement of $N_{in}$ is equal to the input power level (–6 dBm) minus the dynamic range (–60 dB) resulting in an error of up to -66 dBm, or +251 nW. When multiplied by the gain (10), this represents a maximum error of +2.51 uW referred to the output. The maximum error in the measurement of $N_{out}$ is equal to the output power level (+4 dBm) minus the dynamic range (–60 dB) resulting in an error of up to –56 dBm, or +2.51 uW. If the dynamic range performance is the same for both measurements, the error terms (+2.51 uW for $N_{out}$ and + 2.51 uW for $N_{in}*G$) will cancel out in the calculation of $N_{out}$-$N_{in}*G$. Unfortunately this is not always the case, as the actual dynamic range performance can vary based on signal parameters such as state of polarization. Given that the dynamic range effect can be different for the two measurements, the worst case noise figure uncertainty will be when one measurement has the greatest offset (2.51 uW in this example) and the other has no offset. In the general case, this maximum error in the determination of $N_{EDFA}$ can be calculated as:

$$N_{\mathrm{EDFA}}\ \textit{dynamic range error} = 10 * \log\left[1+\frac{P_{\mathrm{OUT}} * \text{OSA DR}}{N_{\mathrm{EDFA}}}\right]$$

Where OSA DR is equal to the dynamic range of the optical spectrum analyzer (at a 1 nm offset) expressed as a linear ratio (in this case $1*10^{-6}$ for a 60 dB dynamic range). For these examples:

$$N_{\mathrm{EDFA}}\ \textit{dynamic range error} = 10 * \log\left[1+\frac{2.5*10^{-3}W*10^{-6}}{192.5*10^{-9}W}\right] = 0.056\ dB$$

The contribution to the noise figure uncertainty is equal to 0.056 dB * (A-B)/NF = 0.056 dB * 2.41/2.51 = 0.054 dB for both the single wavelength and swept wavelength measurement examples.

**Calculation of Total Measurement Uncertainties**

The following table summarizes the error terms calculated for the example measurements in the previous section and shows the total measurement uncertainties. The total uncertainties are calculated as $2\sqrt{\sum \frac{U^2}{3}}$ , where "U" is the uncertainty of each individual term. These uncertainty calculations are based on the use of linear interpolation measurements, as described herein, with an Agilent 71452B Optical Spectrum Analyzer, calibrated as described in Appendix A. For these example measurements, the source power is -6 dBm, the EDFA under test has a gain of 10 dB and a noise figure of 4 dB, and the source SE level is -56 dBm/nm for the single wavelength measurement source and -43 dBm/nm for the swept wavelength measurement source.

| | Single Wavelength Meas. | | Swept Wavelength Meas. | |
|---|---|---|---|---|
| | Gain | Noise Figure | Gain | Noise Figure |
| Connector Uncertainty | 3 x 0.05 (splice) or 3 x 0.25 (conn) | 2 x 0.05 (splice) or 2 x 0.25 (conn) | 3 x 0.05 (splice) or 3 x 0.25 (conn) | 2 x 0.05 (splice) or 2 x 0.25 (conn) |
| Source Stability | 0.050 | 0.053 | 0.050 | 0.112 |
| Source Repeatability | —— | —— | 0.040 | 0.089 |
| Source SE Repeatability | —— | —— | —— | 0.125 |
| OSA Absolute Accuracy | —— | 0.096 | —— | 0.096 |
| OSA Polarization Sensitivity | 2 x 0.05 | 2 x 0.053 (gain) | 2 x 0.05 | 2 x 0.112 (gain)<br>2 x 0.063 (noise) |
| OSA Scale Fidelity | 0.070 | 0.075 (gain)<br>0.072 ($N_{out}$)<br>0.001 ($N_{in}$) | 0.070 | 0.157(gain)<br>0.155 ($N_{out}$)<br>0.088 ($N_{in}$) |
| OSA Flatness | —— | 0.192 | —— | 0.192 |
| OSA Res BW Accuracy | —— | 0.125 | —— | 0.125 |
| OSA Internal Etalons | 0.030 | 0.032 | 0.030 | 0.067 |
| OSA Dynamic Range | —— | 0.054 | —— | 0.054 |
| Totals | | | | |
| w/ Splices: | +/- 0.17 dB | +/- 0.35 dB | +/- 0.17 dB | +/- 0.52 dB |
| w/ Connectors: | +/- 0.52 dB | +/- 0.53 dB | +/- 0.52 dB | +/- 0.65 dB |

# Performing Measurements

This chapter gives the measurement procedure for performing EDFA measurements with the Agilent 71452B Optical Spectrum Analyzer. The procedure is given for three separate testing modes. The first is the *single wavelength test*, which characterizes an EDFA at a single wavelength. The second is the *swept wavelength test*, which characterizes an EDFA over a range of wavelengths. The third is the *output test* that provides several useful characteristics of the output spectrum of either a single or series of EDFAs.

The input and output signal power levels, spontaneous emission levels, gain, noise figure, and integrated ASE are measured as described in the *Measurement Technique* chapter. Other parameters displayed by the EDFA test personality are *Res BW*, which is the corrected value of the OSA's resolution bandwidth used in determining the spontaneous emission levels, *Noise BW*, which is a user-definable bandwidth that the noise measurements are normalized to, and *Integrt BW*, which is a user-definable wavelength range used for the integrated ASE measurement.

### Displayed Signal-to-Noise Ratios and Noise Levels

The input, output, and EDFA noise levels can be displayed in two ways. The default is a display of signal-to-noise ratios. *Input S/N* is the ratio of the source signal level to the source SE, *Output S/N* is the ratio of the output signal level to the output ASE, and *EDFA S/N* is the ratio of the output signal level to the portion of the output ASE generated by the EDFA. For each ratio, the noise level used is the noise power in a bandwidth of *Noise BW* at the signal wavelength.

The other display option is to display the three spontaneous emission power levels in place of the three signal-to-noise ratios. Also note that in the *output* test only, when integrated ASE measurements are made, *EDFA S/N* becomes the ratio of the output signal to the integrated ASE.

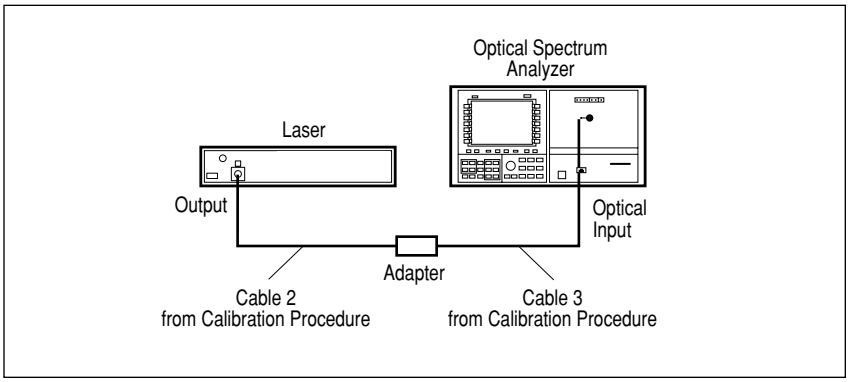
### Key Convention

The notation used to describe keys is that keys shown as [Front-panel key] are physically located on the optical spectrum analyzer and keys shown as Softkey are softkeys located next to the softkey labels, which appear as annotation on the optical spectrum analyzer display.

### Single Wavelength Test

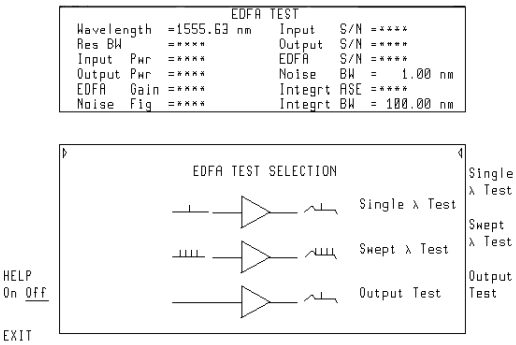
This test is for the characterization of an EDFA at a single wavelength and requires a single-line laser source at the wavelength of interest. First, the laser spectrum is measured in order to determine its power and spontaneous emission level. Then, the EDFA is connected between the laser and the optical spectrum analyzer and the output signal, ASE, and integrated ASE are measured. The EDFA characteristics are calculated from these measurements. For best accuracy, a *user calibration* should be performed on the OSA prior to making EDFA measurements. The required equipment and procedure for calibrating the OSA are given in Appendix A.

Connect the output of the laser to the optical spectrum analyzer as shown in the following figure. The adapter allows the use of the same cables that were used in the calibration procedure. For best accuracy, do not disconnect these cables from the laser or OSA during the test.



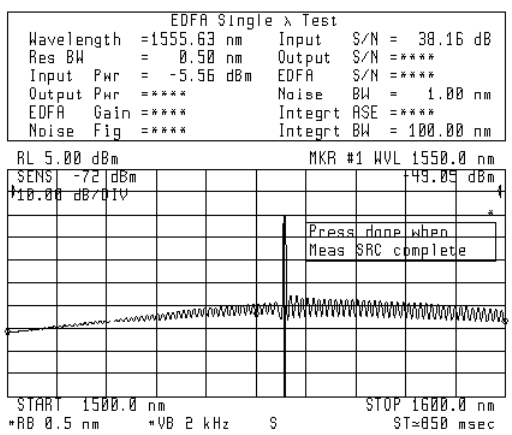

**Equipment configuration for the single-wavelength source-spectrum measurement**

Press USER and then EDFA to start the EDFA test personality. The test selection screen will appear as shown below.



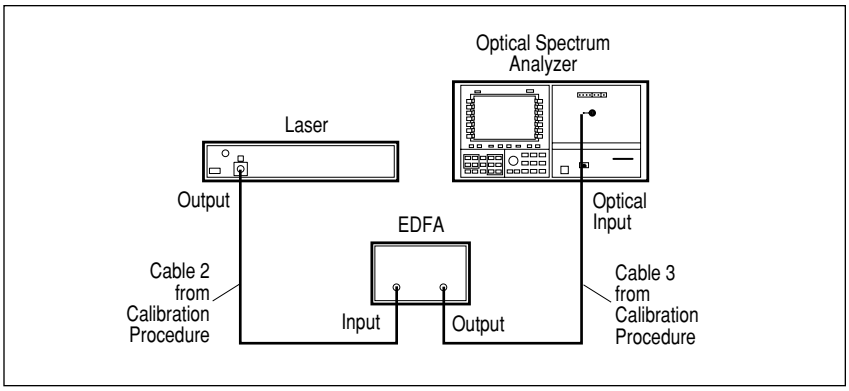

**Display of test selection screen**

Press **Single λ Test** to select the desired test. If necessary, adjust the tuning range of the OSA: press START, and enter the starting wavelength, press STOP, and enter the ending wavelength. The wavelength range should be selected to cover the desired portion of the ASE spectrum for integrated ASE measurements. The OSA span must be set to cover a minimum range of at least the *interpolation offset* value (default is 1 nm) on each side of the signal. If it is necessary to set the span greater than 130 nm, the OSA trace length should be increased from the default of 800 trace points such that there are at least 3 trace points/resolution bandwidth. For example, set the number of trace points to 1200 for a 200 nm OSA span with an 0.5 nm resolution bandwidth. The **trace length** function is found under the **Traces** menu and can be set to a maximum of 2048 points. Adjust the OSA reference level so that it is at the expected output power level of the EDFA (the laser signal power level plus the expected EDFA gain). To adjust: press REF LEVEL and enter the expected output power level. If the noise floor of the OSA is limiting the measurement of the spontaneous emission, adjust the sensitivity: press SENS, and enter a value at or below the lowest spontaneous emission level to be measured so that the display of the laser's spontaneous emission is free from noise. A properly displayed signal should appear as shown below. Press **Measure Source** and the EDFA test personality will measure the signal and noise levels at the end of the sweep. Allow at least one complete sweep to occur and then press **DONE**.



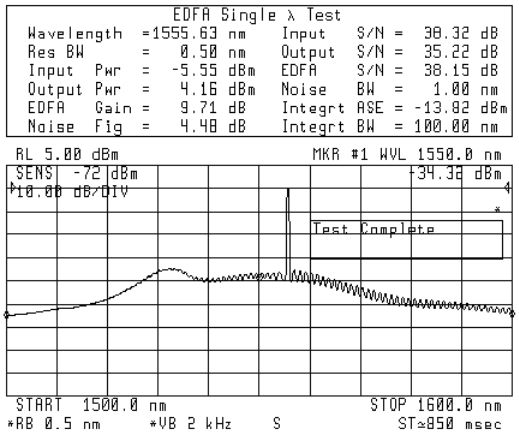

**Properly displayed signal for source-spectrum measurement**

Remove the adapter, and connect the EDFA as shown below.




**Equipment configuration for the single-wavelength amplifier measurement**

Press **Measure Amplfr** . After the first complete sweep occurs, the display lists all the measurement results at the top of the screen. At the end of each sweep, the parameters are recalculated. When you have finished measuring the amplifier, press **DONE** . This stops the sweeping of the OSA.




**Measurement results for single wavelength test**

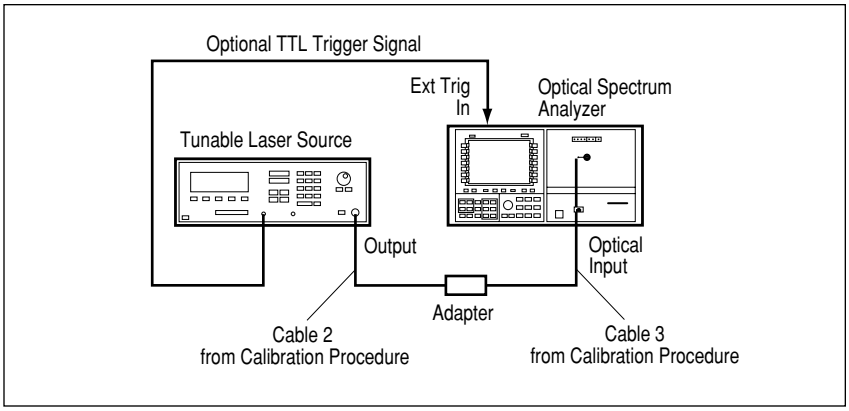
Press **EXIT** to exit the EDFA Test Personality and return to normal OSA operation.

**Swept Wavelength Test**

This test is for the characterization of an EDFA as a function of wavelength and requires a tunable laser source. First, the laser spectrum is measured over a range of wavelengths in order to determine its power and spontaneous emission level. Then, the EDFA is connected between the laser and the optical spectrum analyzer and the output signal, ASE, and integrated ASE are measured over wavelength. The EDFA characteristics are calculated from these measurements. For best accuracy, a *user calibration* should be performed on the OSA prior to making EDFA measurements. The required equipment and procedure for calibrating the OSA are given in Appendix A.

This procedure is defined specifically for use with an Agilent 8168A Tunable Laser Source. Other tunable laser sources can be used as explained below. Connect the output of the tunable laser source to the optical spectrum analyzer's input as shown in the following figure. The adapter allows the use of the same cables that were used in the calibration procedure. For best accuracy, do not disconnect these cables from the laser or OSA during the test.

Connect the laser's **Modulation Output** signal to the rear-panel **EXT TRIG IN** connector on the Agilent 70952B Optical Spectrum Analyzer module using a BNC (m) to SMB (f) cable. This cable can be ordered from Agilent as part number 85680-60093. This connection provides external triggering, which requires a TTL-compatible signal with a minimum level of 0V and a maximum level of +5V.




**Equipment configuration for the swept-wavelength source-spectrum measurement**

Press USER and then **EDFA** to start the EDFA test personality. In this example, the EDFA is characterized from 1540 nm to 1560 nm with a step size of 1 nm and a laser output power of 200 uw. These values are for example only.

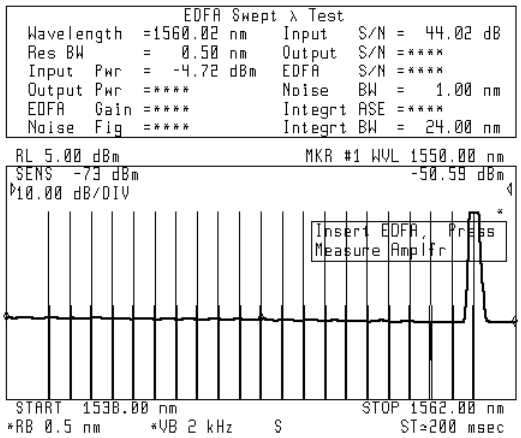
On the Agilent 8168A, press **λ-Sweep** , and enter the following settings: Start = 1540 nm, Stop = 1560 nm, and Step = 1 nm. On the optical spectrum analyzer, press **Swept λ Test** and enter the following start and stop wavelength settings: START 1538 nm and STOP 1562 nm. Note that the OSA wavelength range is set slightly wider than the tunable laser wavelength range. The OSA's range must be increased on both sides by at least the interpolation offset value. (The default interpolation offset value is 1 nm). Additional offset is added to allow for any wavelength discrepancy between the tunable laser source and OSA.

Press **Setup, MORE 1 of 2** , and then **TRIGGER EXT INT** so that EXT is underlined. This selects external triggering. *(If you are using a laser other than the Agilent tunable laser, leave* ***TRIGGER EXT*** ***INT*** *set to* ***INT****).*

Prior to measuring the source, the OSA's reference level and sensitivity may need to be adjusted. Adjust the reference level so that it is at the expected output power level of the EDFA (the signal laser power level plus the expected EDFA gain). To adjust: press REF LEVEL and enter the expected output power level. Adjust the sensitivity so that the OSA noise floor does not limit the measurement of the source spontaneous emission. To adjust the sensitivity: press SENS , and enter a value at or below the lowest spontaneous emission level to be measured.

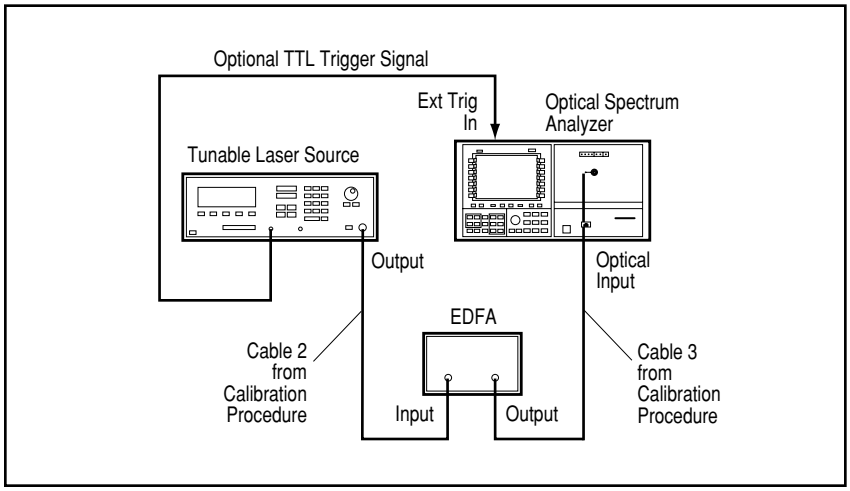
On the OSA, press **HP 8168 DWELL** to display the minimum dwell time required between laser wavelength changes. Then, on the Agilent 8168A, enter the dwell time listed on the OSA display. This number is the minimum time required for the OSA to collect and process the measurement data and it can be rounded up if desired. If any settings that change sweep time or trace length are modified, this key should be pressed again to check if the required dwell time has changed.

Press the **Measure Source** softkey on the OSA. On the Agilent 8168A, press **Auto** to begin stepping the source. *(If a laser other than the Agilent tunable laser is used, press* ***SINGLE SWEEP*** *on the OSA. Then, repeat the following steps for each wavelength to be measured: manually tune the laser to the desired wavelength and press* ***SINGLE SWEEP*** *on the OSA).* Press **DONE** after the final sweep has been completed and all the wavelengths are captured. You can restart testing at any time by resetting the laser and pressing **Measure Source** . This clears any previously measured data points. The figure below shows the source measurement. The two vertical lines at each signal wavelength represent the signal power level and the interpolated spontaneous emission power level.




**Display of source measurement at each wavelength**

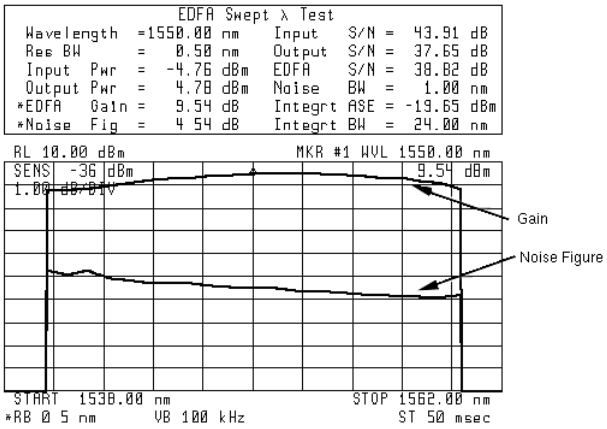
Remove the adapter and connect the EDFA as shown in the following figure.




Equipment configuration for the swept wavelength amplifier measurement

Press **Measure Amplfr** on the OSA. Press **Auto** on the Agilent 8168A to begin stepping the source. *(If a laser other than the Agilent tunable laser is used, press **SINGLE SWEEP** on the OSA. Then, repeat the following steps for each wavelength to be measured: manually tune the laser to the desired wavelength and press **SINGLE SWEEP** on the OSA).* Press **DONE** after the final sweep has been completed and all the wavelengths are captured. You can restart testing at any time by resetting the laser and pressing **Measure Amplfr** . This clears any previously measured amplifier data points but not the source measurements. Multiple amplifiers can be tested using the same source measurement data.

Press **Display Data** , and then **data select** to select the results to be displayed. Choose from one of the displayed softkeys to view a trace of measurement data versus wavelength. For this example, press **GAIN and NF** . Press **AUTO SCALE** to automatically scale the traces. Notice that the measurement values change color to match the corresponding displayed trace. Typical results are shown below.



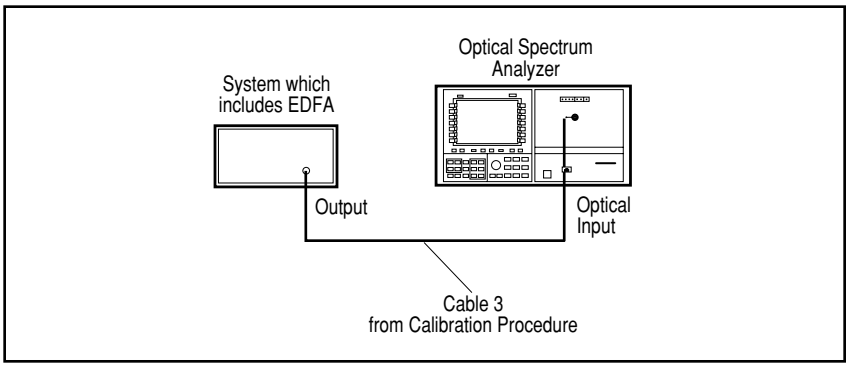

**Measurement results for swept wavelength test showing gain and noise figure as a function of wavelength**

If you want to manually scale the display, use REF LEVEL or **LOG dB/DIV** and the front-panel knob, step keys, or numeric keypad to enter a new value. Press HOLD to blank the display of the prompt. In order to activate and move the marker, press NORMAL ON/OFF and turn the front-panel knob. The display shows the data measured at the marker wavelength. Press **EXIT** to exit the EDFA Test Personality and return to normal OSA operation.

### Output Test

This test is for the characterization of the output spectrum of an EDFA-amplified telecommunications system with one or more EDFAs and sections of fiber. The laser source is considered to be part of the system under test and a single measurement is made at the output of the system. For best accuracy, a *user calibration* should be performed on the OSA prior to making EDFA measurements. The required equipment and procedure for calibrating the OSA are given in Appendix A.

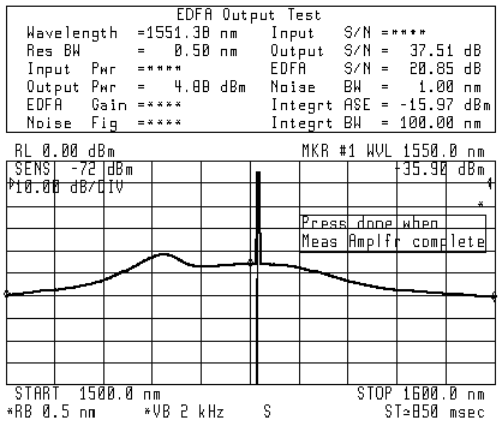
Connect the system under test to the optical spectrum analyzer as shown in the following figure.




**Equipment configuration for the amplifier output measurement**

Press USER and then **EDFA** to start the EDFA test personality. Press **Output Test** to select the desired test. If necessary, adjust the tuning range of the OSA: press START, and enter the starting wavelength, press STOP, and enter the ending wavelength. The wavelength range should be selected to cover the desired portion of the ASE spectrum for integrated ASE measurements. The OSA span must be set to cover a minimum range of at least the interpolation offset value (default is 1 nm) on each side of the signal. If it is necessary to set the span greater than 130 nm, the OSA trace length should be increased from the default of 800 trace points such that there are at least 3 trace points/resolution bandwidth. For example, set the number of trace points to 1200 for a 200 nm OSA span with an 0.5 nm resolution bandwidth. The **trace length** function is found under the **Traces** menu and can be set to a maximum of 2048 points. Adjust the OSA reference level so that the signal power level is near the reference level: press REF LEVEL and enter the signal power level. If the OSA noise floor is limiting the amplified spontaneous emission measurement, adjust the sensitivity: press SENS, and enter a value at or below the lowest amplified spontaneous emission level to be measured so that the display of the laser's spontaneous emission is free from noise.

Press **Measure Amplfr** . After the first complete sweep occurs, the display lists all the measurement results at the top of the screen. At the end of each sweep, the parameters are recalculated.




**Measurement results for output test**

When you are finished with measuring the system, press **DONE** . This stops the sweeping of the OSA. Press **EXIT** to exit the EDFA Test Personality and return to normal OSA operation.

### Configuring the Program

This section explains some of the features available in the **Setup** menu which allow the configuration of various measurement parameters.

***Signal wavelength calculation***

The signal wavelength value is calculated as the average of the two wavelengths that correspond to a displayed power level a specified amount, called the peak excursion value, below the signal's peak. The peak-excursion value can be set by using the **PEAK EXCURSN** softkey.

***Interpolation offset used for determining noise level***

The noise value at the signal wavelength is interpolated from noise values that are measured on either side of the signal. A straight-line (average) interpolation is used. The default interpolation offset is 1 nm. This value can be changed with the **INTERP OFFSET** softkey. For best accuracy, the interpolation wavelengths should be carefully selected to avoid laser sidemodes.

***Adjusting the ASE integration range***
The *Integrt ASE* measurement is the result of integrating the noise between the start and stop integration wavelengths. These two wavelengths are identified by trace markers. The default integration points are set to the optical spectrum analyzer's start and stop wavelength settings. These wavelengths can be changed using the **INTEGRT START λ** and **INTEGRT STOP λ** softkeys. Integration can be turned on or off using the **INTEGRT On Off** softkey. If integration is turned off, asterisks are displayed in place of measurement values.

***Selecting the noise bandwidth for normalized measurements***
Noise values used for *Input S/N, Output S/N, EDFA S/N, Input Noise, Output Noise, and EDFA Noise* calculations are measured in the optical spectrum analyzer's resolution bandwidth and then normalized to a specified noise bandwidth. This noise bandwidth can be set by using the **Noise BW** softkey.

***Correcting for actual resolution bandwidth***
Noise measurements are dependent on the optical spectrum analyzer's resolution bandwidth, and the accuracy of normalized noise level calculations are dependent on how accurately the true resolution bandwidth is known. Resolution bandwidth variations from nominal can be broken down into two parts: one is a predictable variation as a function of wavelength and the other is due to unit to unit variations in the optical spectrum analyzer's optical components.

For all Agilent 7145XB, both of these potential error terms are automatically corrected for. No addition resolution bandwidth correction factors are required. The *Res BW* value, shown in the measurement table, gives the optical spectrum analyzer's corrected resolution bandwidth.

For those OSAs that do not meet the above condition, the variation with wavelength is automatically corrected for, but the unit to unit variation is not. The **RES BW CORRECT** softkey can be used to enter the additional resolution bandwidth correction factor. The default value is 1.0 which corresponds to no additional correction. For example, for a nominal resolution bandwidth of 0.51 nm (including wavelength dependent effects) that is measured to be 0.48 nm, the appropriate correction factor to enter is 0.94. (0.94 = 0.48/0.51)

***Selecting the display of signal-to-noise ratios or noise power levels***
The input, output, and EDFA noise levels can be displayed in two ways. Press **DISPLAY NoiseSN** so that **NOISE** is underlined in order to calculate and display the *Input Noise* power, *Output Noise* power, and *EDFA Noise* power. Press **DISPLAY NoiseSN** so that SN is underlined in order to calculate and display the *Input S/N* ratio, *Output S/N* ratio, and *EDFA S/N* ratio.

# Appendix A: OSA User Calibration Procedure

This procedure requires a laser source, a wavelength meter, an optical power meter (such as the Agilent 8153A with the appropriate power sensor module), and a polarization state controller (such as the Agilent 11896A).

Performing a *user calibration* on the optical spectrum analyzer ensures maximum wavelength and amplitude accuracy for EDFA measurements. User calibrations require a stable (amplitude and wavelength) single-frequency laser within the 600 to 1700 nm range. For optimum results, perform the calibration at a wavelength that is within the range of the amplifier you are testing. You can access the *calibration* menu from the OSA's **Amptd** menu. (Press **MENU** and then **Amptd** .)

The OSA's maximum calibration adjustment range is about 2 nm in wavelength and 5 dB in amplitude. If a larger adjustment is attempted, error 2023, *Illegal Cal Signal* will be displayed.

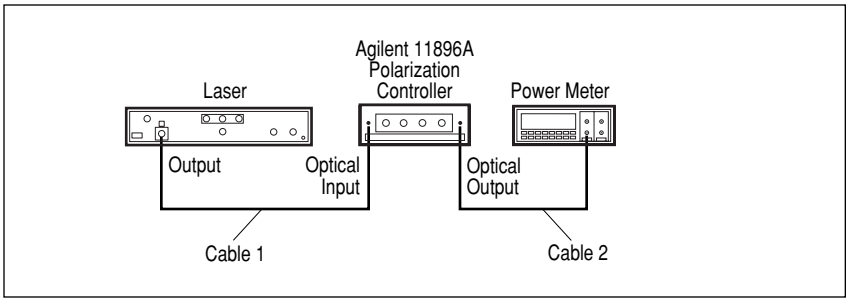
Because the OSA is slightly polarization sensitive, this calibration should be performed by persons knowledgeable on the effects of polarization on optical power measurements. During the calibration, the light source's output power is first measured with a power meter. Then, the fiber-optic cable is disconnected from the power meter and connected to the OSA. Because moving fiber-optic cables changes polarization, the measured value of the output power may vary. To ensure amplitude accuracy, move the fiber-optic cables as little as possible during this procedure.

### Measure the Source Wavelength

Measure and record the wavelength of a precision single-mode laser using a wavelength meter.

### Measure the Average Power

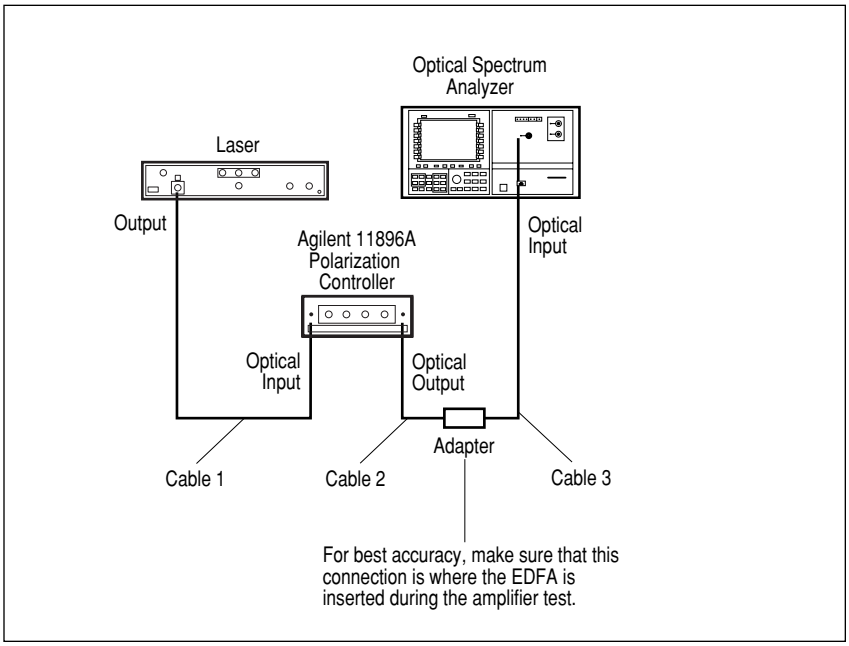
Connect the laser, polarization controller, and power meter as shown in the following figure. Do not disconnect cable 1 or cable 2 from the laser or polarization controller during the calibration procedure. Maintaining this connection ensures the greatest measurement accuracy.




**Equipment configuration for the measurement of the source power level**

Adjust the polarization controller to achieve the maximum power reading on the power meter and record the power level in dBm. Adjust the polarization controller to achieve the minimum power reading on the power meter and record the power level in dBm. Calculate the average of the two power readings and record the result in dBm.

In the test setup, replace the power meter with the OSA as shown. Be sure to use two cables and an adapter to connect the OSA to the polarization controller. For accurate measurements, do not disconnect cable 3 from the OSA during or after the calibration procedure. Maintaining this connection ensures the greatest measurement accuracy, because your OSA will be calibrated at the free end of cable 3. For fusion splice measurements, the adapter is replaced with a fiber splice.




**Equipment configuration for the optical spectrum analyzer measurements**

### Determine Correction Factor for Source Spontaneous Emission

Press AUTO MEAS to display the laser's response. When the auto-measure routine is completed, press AUTO ALIGN to align the OSA. Press INSTR PRESET, USER and then **EDFA** to start the EDFA test personality. Press **Output Test** and then adjust the wavelength span so that the lowest displayed source spontaneous emission level is more than 10 dB below the peak of the source spontaneous emission. (Use the START and STOP keys along with the front-panel knob to change the span.)

Press **Setup**, and then **INTEGRT START λ** and use the front-panel knob to move the left-integration marker to the left edge of the display. Press **INTEGRT STOP λ**, and use the front-panel knob to move the right-integration marker to the right edge of the display.

Press **Measure Amplfr** and record the displayed **Output Pwr** and **Integrt ASE** measurements (in dBm). Subtract the **Integrt ASE** from the **Output Pwr** to determine the power ratio expressed in dB. Use the following equation to calculate the correction factor for the broadband power meter measurement to the narrow band OSA measurement:

$$\textit{Correction Factor} = 10 \log \left[ 1 - \frac{1}{10^{\frac{x}{10}} + 1} \right]$$

where "x" is the difference (in dB) of the two power levels calculated above. This correction factor (in dB) is the source spontaneous emission correction factor. Press **EXIT** to exit the EDFA test personality.

### Calculate the Total Correction Factor

Power meters generally are calibrated with an open beam of light. The optical power in the beam emerging from the fiber end is lower than the power in the fiber by 3.6%, or 0.16 dB (use the CAL function in the Agilent 8153A). If your power meter has already accounted for this factor, ignore this term. Add this term (+0.16 dB), if appropriate, to the source spontaneous emission correction factor. Be sure to keep track of the sign of each number. This is the total correction factor.

### Calculate Corrected Power Level

Add the total correction factor to the average power measured with the optical power meter and record this corrected power level (in dBm).

### Measure the Average Power on the OSA

On the OSA, press PEAK SEARCH , TO CENTER , and SPAN , and then enter a wavelength span of 1 nm. Then press PEAK SEARCH and TO CENTER to place the signal at the center of the display. Press SPAN , and enter a wavelength span of 0 nm. Press MENU , the left-side **Amptd** softkey, **LOG dB/DIV** , 1 , and dB to select a 1 dB logarithmic amplitude scale. Press the left-side **BW,Swp** softkey, **SWPTIME AutoMan** , 1 , 0 , and then **s** to enter a ten second sweep time.

Adjust the polarization controller to “peak” the trace displayed on the OSA. This sets the polarization for a maximum power reading. Press PEAK SEARCH , and record the power level indicated by the marker (in dBm). Press Δ to activate the delta marker. Adjust the polarization controller to “dip” the trace displayed on the OSA to a minimum power value. Record the absolute value of the delta marker’s power ratio (in dB). Calculate and record the average displayed power (in dBm) as the maximum measured power minus one half the absolute value of the delta power reading.

Press the left-side **Amptd** softkey. Press **MORE 1 of 4** , **MORE 2 of 4** , and then **A METER On Off** so that On is underlined. Adjust the polarization controller to achieve a displayed Amplitude Meter power level equal to the average displayed power recorded above.

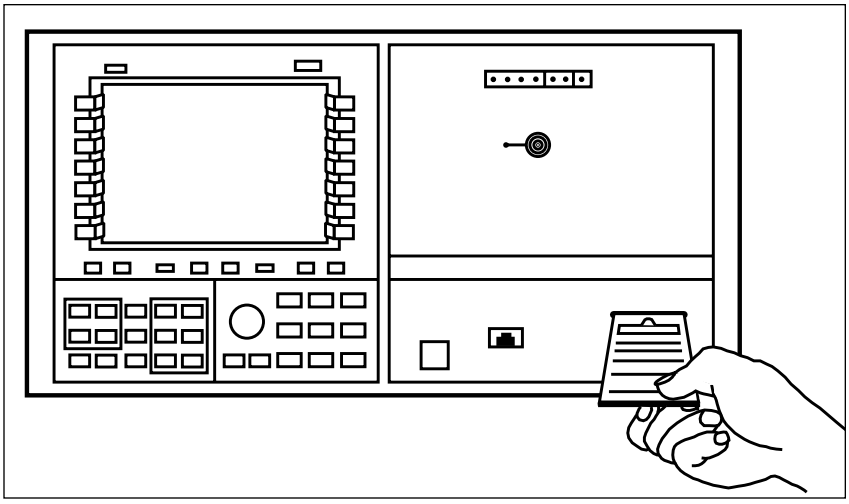
In order to ensure amplitude accuracy, it is very important not to move the fiber-optic cables during the remaining steps of this procedure.

### Enter the Calibration Power and Wavelength

Press the left-side **Waveln** softkey. Then, press **MORE 1 of 2** , **cal menu** , **Cal setup** and then **POWER FOR CAL** . Use the numeric keypad to enter the corrected power level calculated above. Press **WAVELEN FOR CAL** and enter the wavelength recorded from the measurement with the wavelength meter. Then, press **prev menu** and then **CAL POWER** and then **CAL WAVELEN** .

## Appendix B: Loading the Program from the Memory Card

Press the USER key on the optical spectrum analyzer. If the **EDFA** softkey appears, then the EDFA test personality is already installed. If not, locate the memory card containing the EDFA test personality program. Insert the card into the Agilent 70004A display's front-panel card slot, matching the card's arrow with the arrow printed above the card slot.



**Inserting the EDFA test personality memory card into the Agilent 70004A display**

Press DISPLAY, the left-side **Mass Storage** softkey, **msi**, and then **MEMORY CARD** to specify the memory card as the mass storage device. Following that, press MENU, the left-side **Misc** softkey, **More 1 of 3**, **catalog & MSI**, and then **HP-MSIB CARD** to display all files, and their file number, contained on the memory card.

Press the **LOAD FILE** softkey and, using the numeric keypad, enter the EDFA file number (normally 1) followed by **ENTER**. The front panel LED next to the card slot will light, indicating that the EDFA file is being loaded into the OSA memory. (If there is not sufficient memory to load the program, a memory overflow error will appear. In that case, refer to the Test Personality User's Guide.)

After the program has been loaded, it can be accessed by pressing the USER key followed by the **EDFA** softkey.

**For more information about Agilent Technologies test and measurement products, applications, services, and for a current sales office listing, visit our web site,**

**www.agilent.com/comms/lightwave**

**You can also contact one of the following centers and ask for a test and measurement sales representative.**


**United States:**
Agilent Technologies
Test and Measurement Call Center
P.O. Box 4026
Englewood, CO 80155-4026
(tel) 1 800 452 4844

**Canada:**
Agilent Technologies Canada Inc.
5150 Spectrum Way
Mississauga, Ontario
L4W 5G1
(tel) 1 877 894 4414

**Europe:**
Agilent Technologies
Test & Measurement
European Marketing Organization
P.O. Box 999
1180 AZ Amstelveen
The Netherlands
(tel) (31 20) 547 2000

**Japan:**
Agilent Technologies Japan Ltd.
Call Center
9-1, Takakura-Cho, Hachioji-Shi,
Tokyo 192-8510, Japan
(tel) (81) 426 56 7832
(fax) (81) 426 56 7840

**Latin America:**
Agilent Technologies
Latin American Region Headquarters
5200 Blue Lagoon Drive, Suite #950
Miami, Florida 33126, U.S.A.
(tel) (305) 267 4245
(fax) (305) 267 4286

**Australia/New Zealand:**
Agilent Technologies Australia Pty Ltd
347 Burwood Highway
Forest Hill, Victoria 3131, Australia
(tel) 1-800 629 485 (Australia)
(fax) (61 3) 9272 0749
(tel) 0 800 738 378 (New Zealand)
(fax) (64 4) 802 6881

**Asia Pacific:**
Agilent Technologies
24/F, Cityplaza One, 1111 King's Road,
Taikoo Shing, Hong Kong
(tel) (852) 3197 7777
(fax) (852) 2506 9284




Printed in U.S.A. 9/00
5963-7146E


**Agilent Technologies**
Innovating the HP Way