User's Guide

EDFA Noise Gain Profile Personality for HP 71450B/1B/2B

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1400 Fountaingrove Parkway,
Santa Rosa, CA
95403-1799, USA

Regulatory Information. The specifications and characteristics chapter of the *HP 71450B/1B/2B Optical Spectrum Analyzers Reference* contains regulatory information.

EDFA Analysis with the EDFA Noise Gain Profile Personality

The EDFA Noise Gain Profile Personality characterizes erbium-doped fiber amplifiers (EDFAs) for signal gain, noise gain, noise figure, and noise gain peak. The personality uses the time domain extinction (TDE) measurement technique. The measurement technique used takes advantage of the fact that, immediately after turning off the input signal, an EDFA's amplified spontaneous emissions (ASE) has a slow recovery to the undriven state.

Because of its measurement speed, the EDFA Noise Gain Profile Personality is ideal for use in manufacturing production lines.

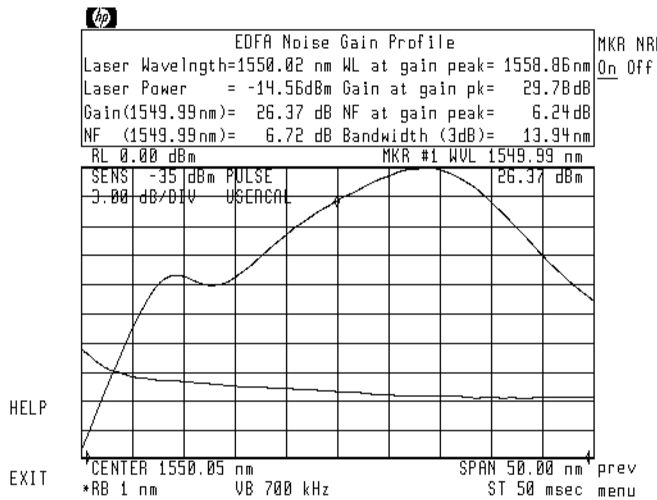
The following paragraphs describe three of the measurements performed by the personality:

Term	Definition
signal gain	Gain provided by the EDFA amplifier to the large (traffic) signal driving the amplifier into saturation.
noise gain	Gain of a small signal (such as noise) while a large signal is driving the amplifier into saturation. Its dependence on wavelength is called the **noise gain profile** which describes how the noise gain depends on wavelength over a certain range.
noise gain peak	Indicates the wavelength where the noise gain profile reaches its maximum amplitude.

These essential measurements are often used to match optical amplifiers in long-haul telecommunication systems.

Measurement results are displayed graphically

As shown in the following figure, the personality graphically displays swept measurement results. The top trace shows gain versus wavelength; the bottom trace shows noise figure versus wavelength.



Gain and noise figure measurement results.

Required equipment

The personality is included with the HP 71452B and provided as an option on is available for HP 71450B/1B Option 053 optical spectrum analyzers. It can also be used on HP 71450A/1A optical spectrum analyzers that have had the HP 70953A upgrade kit installed.

The personality requires the following equipment:

- HP 8168A/B/C Tunable Laser (Option 003 recommended).

  The tunable laser's modulation output triggers measurements and sweeps on the optical spectrum analyzer. Another laser can be used provided it can be modulated at 25 kHz and has an external trigger output signal that is TTL compatible.

- An HP 83424A Option H37 or C25 edge-emmitting LED (EELED).

  Because the HP 83424A Option H37 or C25 can be externally modulated by a TTL compatible signal, it is the recommended model. However, a manual test mode is available for using an EELED (or ASE from another EDFA) that cannot be externally modulated. Option H37's output is available through a connector. Option C25's has a pigtail output.

- A 3 dB coupler to couple the outputs from the laser and noise source together.

If not already installed, install the program as described in Chapter 1. Once installed, you can start the program by pressing (USER) and then the EDFA_NG softkey.

Ensuring the greatest accuracy

To ensure the greatest possible accuracy, observe the following:

- Maintain a resolution bandwidth $\geq$ 0.5 nm for best amplitude accuracy.
- Perform a user calibration of the optical spectrum analyzer as described in Chapter 2.
- Optical isolator reduces reflections.

  Inserting isolators at the input and output of the erbium-doped fiber amplifier reduces the effect of external reflections on amplifier performance.

- Clean connections are required for best accuracy. When connecting fiber-optic cables, do the following steps:

  1. Clean the connectors as described in Chapter 1 of the *HP 71450B/1B/2B Optical Spectrum Analyzers User's Guide*. Dry connections are recommended.
  2. Align connectors so that the fiber end does not touch the outside of the mating connector. Do not rub the fiber end against any other surfaces.
  3. After the ferrule is properly seated inside the connector, use one hand to keep it straight and finger-tighten it with the other hand. Refer to the manufacturer's data sheet for torque recommendations. Overtightening or undertightening connectors can result in misalignment and nonrepeatable connections.

- Fusion splices reduce measurement uncertainty.

  The largest source of measurement uncertainty in EDFA measurements is repeatability of fiber-optic connections. Fusion splices reduce typical connector uncertainties of $\pm$0.25 dB to a $\pm$0.05 dB splice uncertainty.

Control program using softkeys or programming commands

The EDFA Noise Gain Profile Personality can be controlled either via softkey menus or remote programming commands. Softkeys are the seven buttons located on each side of the screen. The functions of softkeys change according to the menus displayed on the screen. Generally, left-side softkeys access major menus. Refer to Chapter 3 for a definition of the programming commands.

Use the following three front-panel keys on the HP 70004A display to select the available softkey menus:

- Press (USER) to view EDFA Noise Gain Profile Personality menus. The personality must first be installed as described in Chapter 1.
- Press (MENU) to view optical spectrum analyzer menus.
- Press (DISPLAY) to view HP 70004A display menus.

Key Conventions

The following key conventions are used in this guide:

(Front-panel key)	Text shown like this represents a key physically located on the spectrum analyzer.
`Softkey`	Text shown like this represents a softkey. (The softkeys are located next to the softkey labels, and the softkey labels are the annotation on the right or left side of the spectrum analyzer display.)
`Screen Text`	Text printed in this typeface indicates text displayed on the instrument's screen.

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Warranty Service

Warranty service may be obtained from the nearest Hewlett-Packard sales office or other location indicated in the owner's manual or service booklet.

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1

Installing the Personality

Installing the Personality

Use the procedures in this chapter to install the personality. Copies of the program are included in the following forms:

- Memory card.
- 3.5-inch diskette. *(HP-LIF format)*

Do you have an HP 70004A display?

YES Install the personality from the memory card. Refer to "To install from the memory card" in this chapter.

NO Install the personality directly from the an external HP-IB disk drive. Refer to "To install from a 3.5-inch dikette drive" in this chapter.

Battery Power

Once installed, the program is stored in battery-powered memory. If the internal battery loses power, the program is erased from memory. With normal use, the internal battery lasts for several years. To replace the internal battery, return the optical spectrum analyzer to a Hewlett Packard service center.

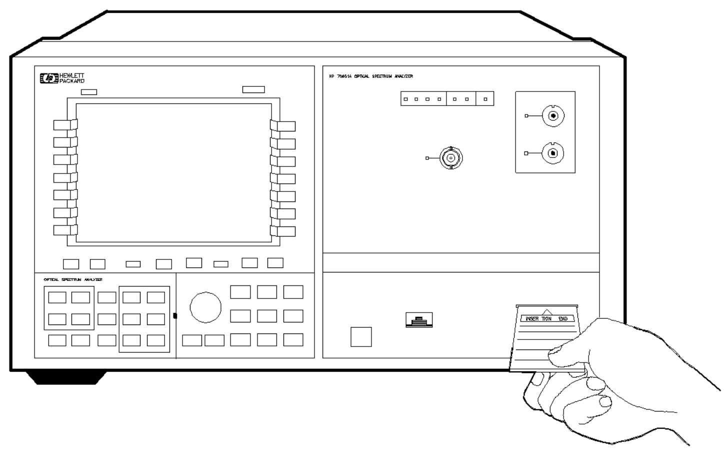
Installing on HP 71450A/1A optical spectrum analyzers

The EDFA Noise Gain Profile Personality can be installed in HP 71450A/1A optical spectrum analyzers if the HP 70953A upgrade kit is installed.

Chapter Contents

To Install From the Memory Card

1. Press (USER). If the softkey EDFA_NG appears, the personality is already installed. Continue with Chapter 2 to learn how to perform measurements.
2. Locate the memory card containing the program.
3. Locate the arrow printed on one end of the card.
4. Insert the card into the HP 70004A display's front-panel card slot. Match the card's arrow with the arrow printed above the card slot.



pkb1

5. Press (DISPLAY) and then the left-side Mass Storage softkey.
6. Press msi and then MEMORY CARD .
7. Press (MENU) and then the left-side Misc softkey.
8. Press MORE 1 of 3 and then catalog & MSI .

9. Press HP-MSIB CARD to display all files contained on the memory card.

   If 2053 Storage device error is displayed, either the card is missing or the card's HP-MSIB address is listed incorrectly. The HP-MSIB address for the card is the same address as the display's HP-IB address and is normally set to 4. If the address is not correct, enter the correct address using the numeric keypad.

10. Press the LOAD FILE softkey.

11. Use the numeric keypad to enter the EDFA_NG file number. (Normally, this means pressing 1 and then ENTER.)

    The front-panel LED next to the card slot lights indicating that the file is being copied into the USER menu.

12. If the error message 2011 Memory overflow is displayed, there is not enough free memory in the optical spectrum analyzer to load the program. Refer to "If a memory error is displayed" in this chapter.

To Install From a 3.5-inch Diskette Drive

When copying programs directly from an external diskette drive, the drive must be a 3.5 inch, CS80-compatible drive, such as an HP 9122. The diskette containing the EDFA advanced-measurement program uses the LIF format.

1. Press USER. If the softkey `EDFA_NG` appears, the EDFA Noise Gain Profile Personality is already installed. Continue with Chapter 2 to learn how to perform measurements.
2. Connect a 3.5-inch diskette drive to the MMS mainframe that contains the optical spectrum analyzer module. Use an HP-IB cable.
3. Insert the diskette containing the program into the diskette drive.
4. Press DISPLAY and then the left-side `Mass Storage` softkey.
5. Press `msi` and then `HPIB DISK`. Ignore any message such as `Unable to read device.`
6. Press MENU and then the left-side `Misc` softkey.
7. Press `MORE 1 of 3` and then `catalog & MSI`.
8. Press `HPIB DISK`, and use the numeric keypad to enter the diskette drive's address.

   New addresses are entered in the following form: *A.UV*

   where:

   A is a digit from 0 to 7, representing the drive's HP-IB address.

   U is a digit from 0 to 9, representing the unit number. The unit number is typically 0 or 1 and refers to an individual disk drive slot. The default value is 0.

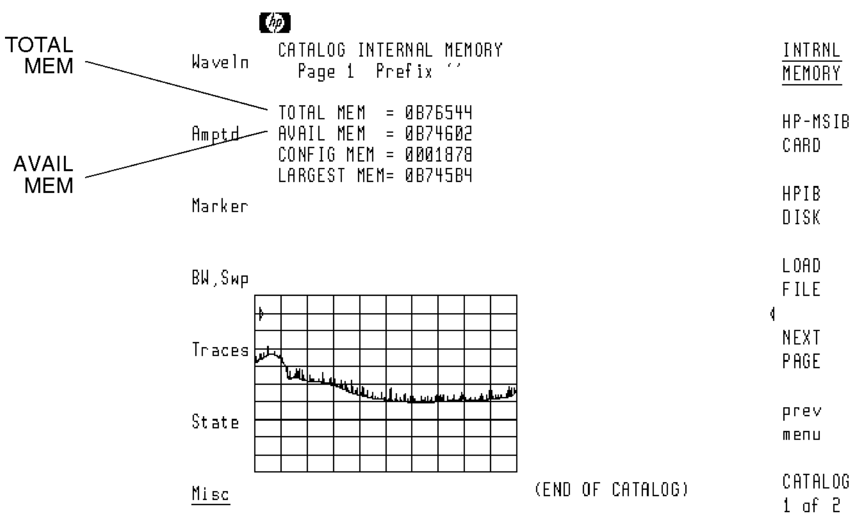
   V is a digit from 0 to 9, representing the volume number. Volume numbers are used for hard disk drives. So, for reading diskettes, the volume number should be 0. The default value is 0.

   For example, entering *3.00* indicates an address of 3, a unit number of 0 and a volume number of 0. This accesses a diskette in the left drive of an external diskette drive at HP-IB address 3.

9. Press the ENTER softkey.
10. Press the LOAD FILE softkey.
11. Use the numeric keypad to enter the EDFA_NG file number. (Normally, this means pressing 1 and then ENTER.)
12. If the error message 2011 Memory overflow is displayed, there is not enough free memory in the optical spectrum analyzer to load the program. Refer to "If a memory error is displayed" in this chapter.

If a Memory Error is Displayed

1. Press (MENU) and then the left-side **Misc** softkey.
2. Press **MORE 1 of 3** and then **catalog & MSI** .
3. Press **INTRNL MEMORY** . The following figure shows a typical display. Notice the **TOTAL MEM** and **AVAIL MEM** listings. You must increase **AVAIL MEM** (available memory) by deleting existing files to free additional memory. Or, if you have an HP 71450A/1A optical spectrum analyer, you may need to install additional memory; if **TOTAL MEM** is approximately 131000 bytes of memory, a 1 MB memory assembly can be installed by qualified service personnel. Order the HP 70953A upgrade kit.



smallmem

Optical spectrum analyzer memory configuration.

2

Performing Measurements

Performing Measurements

Chapter Contents

To ensure accurate measurements . . .

During calibrations and measurements, lightwave instrumentation and test setups are sensitive to vibration and movement. To ensure accurate measurements avoid bumping, moving, or otherwise jarring the instrument, test equipment, and supporting structure.

Calibrating the Optical Spectrum Analyzer

Performing a user calibration on the optical spectrum analyzer ensures maximum wavelength and amplitude accuracy for your EDFA measurements. User calibrations require a stable (amplitude and wavelength) single-frequency laser within the 600 to 1700 nm range. You can access the Calibration menu from the optical spectrum analyzer's `Amptd` menu. (Press (MENU) and then `Amptd`.)

The optical spectrum analyzer's maximum calibration adjustment is about 2 nm in wavelength. If a larger adjustment is attempted, error 2023, `Illegal Cal signal` is displayed.

Guard against changes due to polarization

Because the optical spectrum analyzer 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 optical spectrum analyzer. Because moving fiber-optic cables changes polarization, the measured value of the output power may vary.

Use a wavelength within the amplifier's range

For optimum results, perform the calibration at a wavelength that is within the range of the amplifier you are testing.

During a calibration, the optical spectrum analyzer defaults expect a signal within the following limits:

Power . . . . -5 dBm ±5 dB
Wavelength . . . . 1300 ±2 nm

You must enter the wavelength and amplitude of your calibration source if it is different from these values.

To calibrate the optical spectrum analyzer

Ensuring amplitude accuracy

During this procedure, avoid moving the fiber-optic cables whenever possible. Moving fiber-optic cables changes the polarization of the light which affects power measurements.

The following procedure requires a power meter and a polarization controller. The HP 11896A is the suggested polarization controller. For HP 71450A/1A optical spectrum analyzers perform the steps listed in "To calibrate an HP 71450A/1A" in this chapter.

Measure the source wavelength

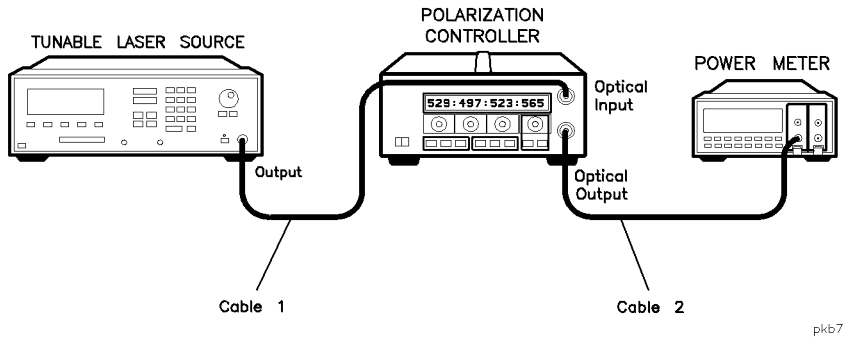
1. Measure the wavelength of a precision single-mode laser using a wavelength meter. Enter the wavelength in the space provided below.

   The laser must have a wavelength between 600 to 1700 nm. Because the optical spectrum analyzer's monochromator is air filled, measure the wavelength as in air.

   wavelength:______________nm

Measure the average power

2. Connect the laser, polarization controller, and power meter as shown in the following figure.



For accurate measurements

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.

3. Adjust the polarization controller to achieve the maximum power reading on the power meter. Record the power level on the following line:

maximum power:______________dBm

4. Adjust the polarization controller to achieve a minimum power reading on the power meter. Record the power level on the following line:

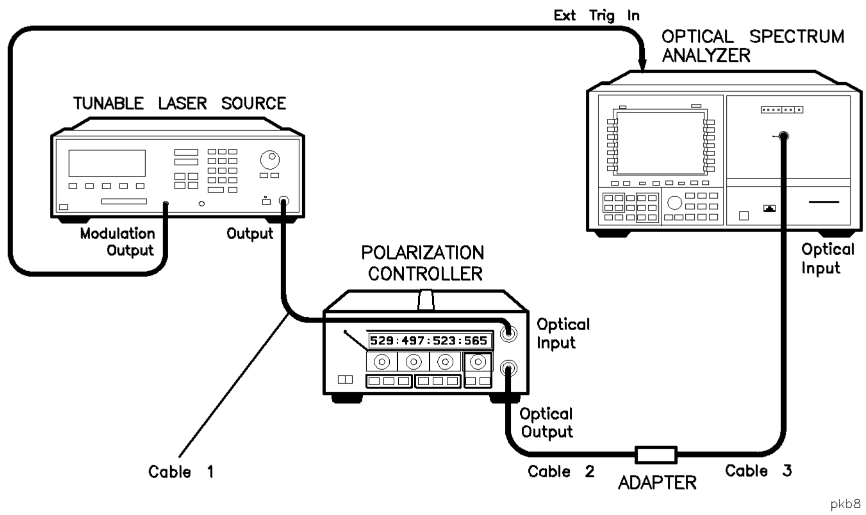
minimum power:______________dBm

5. Calculate the average of the two power readings recorded in steps 3 and 4 using the following equation. Record the result below:

$$average\ power = \frac{minimum\ power + maximum\ power}{2}$$

average power:______________dBm

6. In the test setup, replace the power meter with the optical spectrum analyzer as shown in the following figure. Be sure to use two cables and an adapter to connect the optical spectrum analyzer to the polarization controller.
7. Turn the laser on.



For accurate measurements

Do not disconnect cable 3 from the optical spectrum analyzer during or after the calibration procedure. Maintaining this connection ensures the greatest measurement accuracy, since your optical spectrum analyzer will be calibrated at the free end of cable 3. For fusion splice measurements, the adapter is replaced with a fiber splice.

Determine correction factor for source spontaneous emission

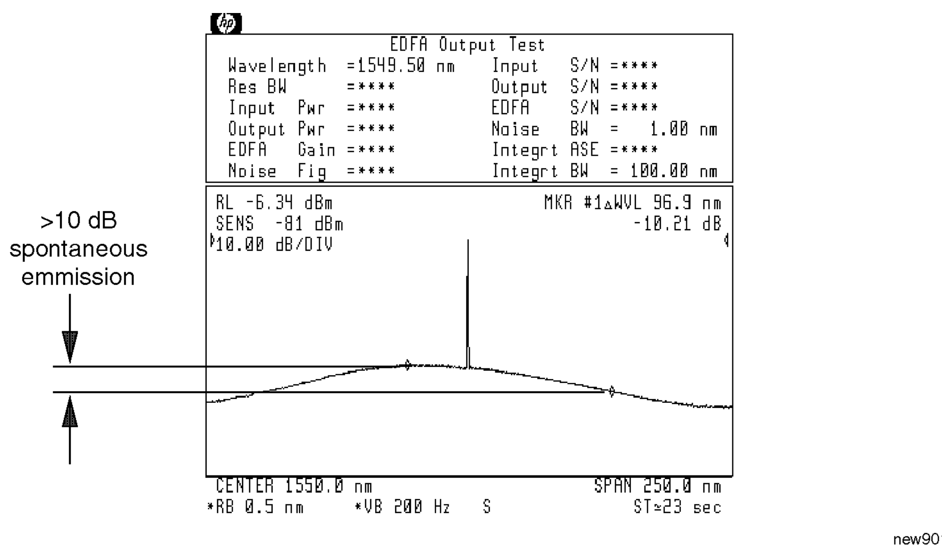
8. Press (INSTR PRESET).
9. Press (AUTO MEAS) to display the laser's response.
10. Press (AUTO ALIGN) to align the optical spectrum analyzer.
11. If the instrument you are calibrating has the Option 051 personality, perform the following steps:

    a. Press (USER) and then EDFA to start the EDFA test personality.

    b. Press Output Test.

    c. Locate the peak of the spontaneous emission. Adjust the wavelength span so that, on either side of this peak, 10 dB of spontaneous emmision is visible.

    Use the (SPAN) key along with the front-panel knob to change the span.

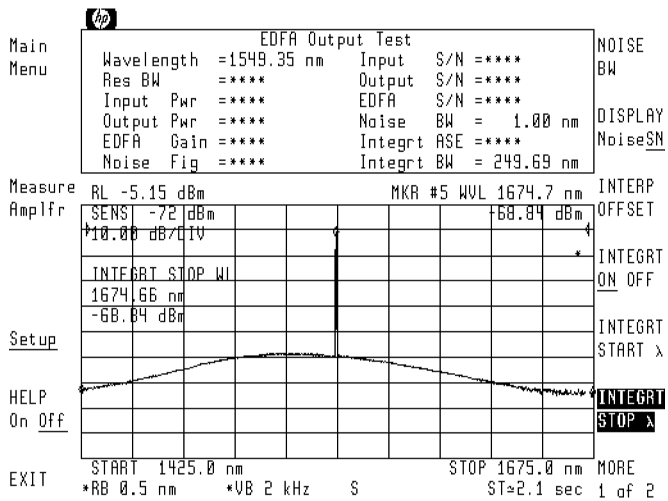


Span adjusted for proper spontaneous emmission levels.

    d. Press Setup and then INTEGRT START λ.

e. Use the front-panel knob to move the left-integration marker to the left edge of the display.

f. Press `INTEGRT STOP λ`, and use the front-panel knob to move the right-integration marker to the right edge of the display.



g. Press the left-side `Measure Amplr` softkey.

h. When the measurement is complete, record the displayed `Output Pwr` and `Integrt ASE` measurements on the following lines:

`Output Pwr`:_______________dBm
`Integrt ASE`:_______________dBm

i. Subtract the `Integrt ASE` from the `Output Pwr` to determine the ratio of the two power levels. Record the result on the following line:

$$\Delta\ power\ (dB) = Output\ Pwr\ (dBm) - Integrt\ ASE\ (dBm)$$

Δ power:_______________dB

12. If the instrument you are calibrating does not contain the Option 051 personality, perform the following steps:

a. Record the value of the signal peak on the following line:

Output Pwr:_______________dBm

b. Press NORMAL On/Off, and use the front-panel knob to place the marker on the maximum level of the spontaneous emission spectrum.

c. Press Marker, MORE 1 of 4, and then MKNOISE On Off so that On is underlined.

d. Record the marker value on the following line:

MKR_{noise}:_______________dBm/nm

e. Press MKNOISE On Off so that Off is underlined.

f. Press MORE 2 of 4, mkr bw/ zoom bw, and then MKR BW On Off so that On is underlined. Make sure that the marker bandwidth is set to −3 dB.

g. Record the displayed Marker Bandwidth value:

MKR_{BW}:_______________nm

h. Calculate the ASE using the values recorded above, and record the ASE on the line below:

$$ASE\ (dBm) = MKR_{noise} + 10\ log\,(MKR_{BW})$$

Integrt ASE:_______________dBm

i. Subtract the Integrt ASE *(step 12h)* from the Output Pwr *(step 12a)* to determine the ratio of the two power levels. Record the result on the following line:

$$\Delta\ power\ (dB) = Output\ Pwr\ (dBm) - Integrt\ ASE\ (dBm)$$

Δ power:_______________dB

j. Press MKR BW On Off so that Off is underlined.

13. Use the following equation to calculate the correction factor for the broadband power meter to the narrow band optical spectrum analyzer measurement:

$$factor = 10\ log\left(1 - \frac{1}{10^{\frac{x}{10}} + 1}\right)$$

where **x** is the Δ power recorded in step 11i or 12i.

source spontaneous emission correction factor:______________dB

Total the correction factors

14. Power meters generally are calibrated with an open beam of light. By simply using a fiber adapter, they will measure the optical power in the beam emerging from the fiber end. This is lower than the power in the fiber by 3.6%. If you wish to have power measurements relative to open-beam power emerging from the fiber, enter a correction factor of +0.16 dB. If you wish to have power measurements relative to power in the fiber, enter 0 dB.

    correction factor:______________dB

15. Add the values from steps 13 and 14. Be sure to keep track of the sign of each number.

    total correction factor:______________dB

Calculate corrected power level

16. Add the value recorded in step 15 to the average power recorded in step 5. Record the result on the following line.

    corrected power level:______________dBm

Measure the average power on OSA

17. Press (PEAK SEARCH) and then (TO CENTER).
18. Press (SPAN), and enter a wavelength span of 1 nm.
19. Press (PEAK SEARCH) and then (TO CENTER).
20. Press (SPAN), and enter a wavelength span of 0 nm.
21. Press (MENU).
22. Press the left-side `Amptd` softkey.
23. Press `LOG dB/DIV`, (1), and `dB` to select a 1 dB logarithmic amplitude scale.
24. Press the left-side `BW,Swp` softkey.
25. Press `SWPTIME AutoMan`, (1), (0), and then `s`.
26. Adjust the polarization controller to "peak" the trace displayed on the optical spectrum analyzer.

    This sets the polarization for a maximum power reading.

27. Press (PEAK SEARCH), and record the power level indicated by the marker:

maximum power:______________dBm

28. Press (Δ).

29. Adjust the polarization controller to "dip" the trace displayed on the optical spectrum analyzer to a minimum power value.

30. Record the absolute value of the Δ marker's power ratio on the following line:

Δ power: ______________ dBm

31. Use the values recorded in steps 27 and 30 to calculate the average displayed power as shown in the following equation. Record the result below:

$$average\ power = maximum\ power - \frac{\Delta\ power}{2}$$

average power: ______________

32. Press the left-side `Amptd` softkey.

33. Press `MORE 1 of 4`, `MORE 2 of 4`, and then `A METER On Off` so that `On` is underlined.

34. Adjust the polarization controller to achieve a displayed Amplitude Meter power level equal to the power level recorded in step 31.

Ensuring 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

35. Press the left-side `Waveln` softkey. Then, press `MORE 1 of 2`, `cal menu`, `cal setup`, and then `POWER FOR CAL`.
36. Use the numeric keypad to enter the corrected power level calculated in step 16.
37. Press `WAVELEN FOR CAL`. Enter the wavelength recorded in step 1. Then, press `prev menu` and then `CAL ALL`.

To calibrate an HP 71450A/1A

Ensuring amplitude accuracy

During this procedure, avoid moving the fiber-optic cables whenever possible. Moving fiber-optic cables changes the polarization of the light which affects power measurements.

The following procedure requires a power meter and a polarization controller. The HP 11896A is the suggested polarization controller.

The optical spectrum analyzer's ROM version is used to select which calibration procedure should be performed on the instrument.

Determine the ROM version

1. Press the left-side `Misc` softkey to enter the Miscellaneous menu.
2. Press the `MORE 1 of 3` and then `service` softkeys.
3. Press the `ROM VERSION` softkey. The version of the ROM is displayed in the upper right corner of the display.
   - If the ROM version is `B.05.00` or above, do not perform this procedure. Instead, perform the steps in "To calibrate the optical spectrum analyzer" in this chapter.
   - If the ROM version is `B.04.04` or below, continue with this procedure.

Measure the source wavelength

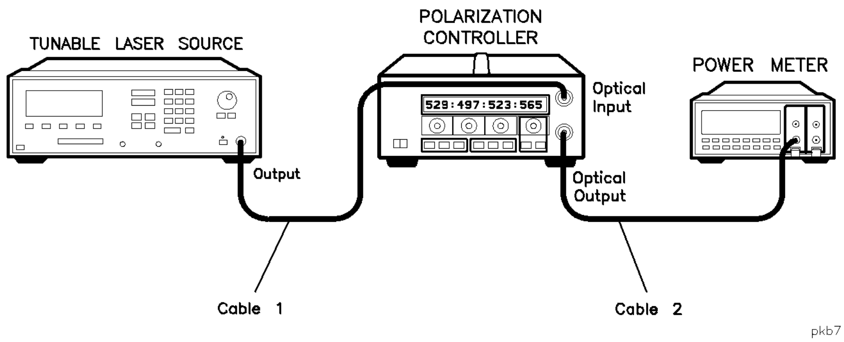
4. Measure the wavelength of a precision single-mode laser using a wavelength meter. Enter the wavelength in the space provided below.

   The laser must have a wavelength between 600 to 1700 nm. Because the optical spectrum analyzer's monochromator is air filled, measure the wavelength as in air.

   wavelength:_______________nm

Measure the average power

5. Connect the laser, polarization controller, and power meter as shown in the following figure.



For accurate measurements

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.

6. Adjust the polarization controller to achieve the maximum power reading on the power meter. Record the power level on the following line:

   maximum power:______________dBm

7. Adjust the polarization controller to achieve a minimum power reading on the power meter. Record the power level on the following line:

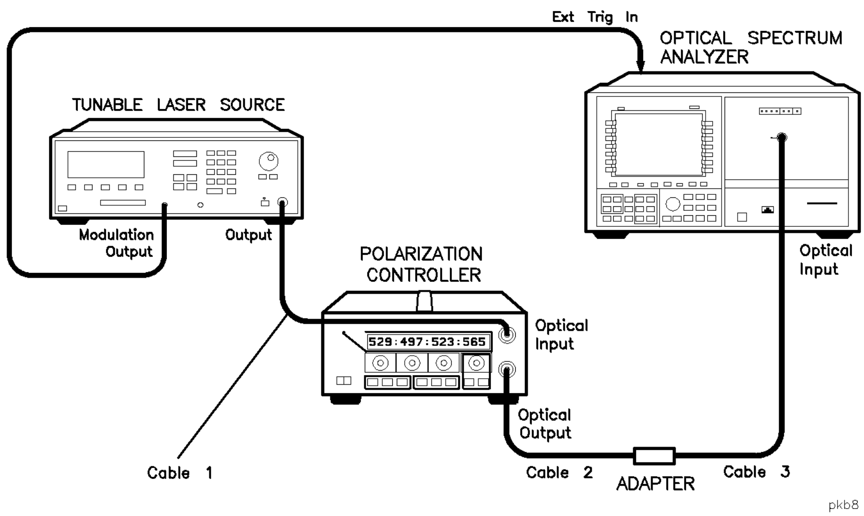
   minimum power:______________dBm

8. Calculate the average of the two power readings recorded in steps 6 and 7 using the following equation. Record the result below:

$$average\ power = \frac{minimum\ power + maximum\ power}{2}$$

average power:______________dBm

9. In the test setup, replace the power meter with the optical spectrum analyzer as shown in the following figure. Be sure to use two cables and an adapter to connect the optical spectrum analyzer to the polarization controller.
10. Turn the laser on.



For accurate measurements

Do not disconnect cable 3 from the optical spectrum analyzer during or after the calibration procedure. Maintaining this connection ensures the greatest measurement accuracy, since your optical spectrum analyzer will be calibrated at the free end of cable 3. For fusion splice measurements, the adapter is replaced with a fiber splice.

Determine correction factor for 0.2 nm RBW

11. Press AUTO MEAS to display the laser's response.
12. Press AUTO ALIGN to align the optical spectrum analyzer.
13. Press RES BW, and enter a 0.2 nm bandwidth.
14. Record the source amplitude on the following line:

    power (0.2 nm RBW):__________dBm

15. Press RES BW, and enter a 0.5 nm bandwidth.
16. Record the source amplitude on the following line:

    power (0.5 nm RBW):__________dBm

17. Subtract the reading in step 16 from the reading in step 14 and record the result on the following line:

$$correction\ factor = POWER_{step\ 14} - POWER_{step\ 16}$$

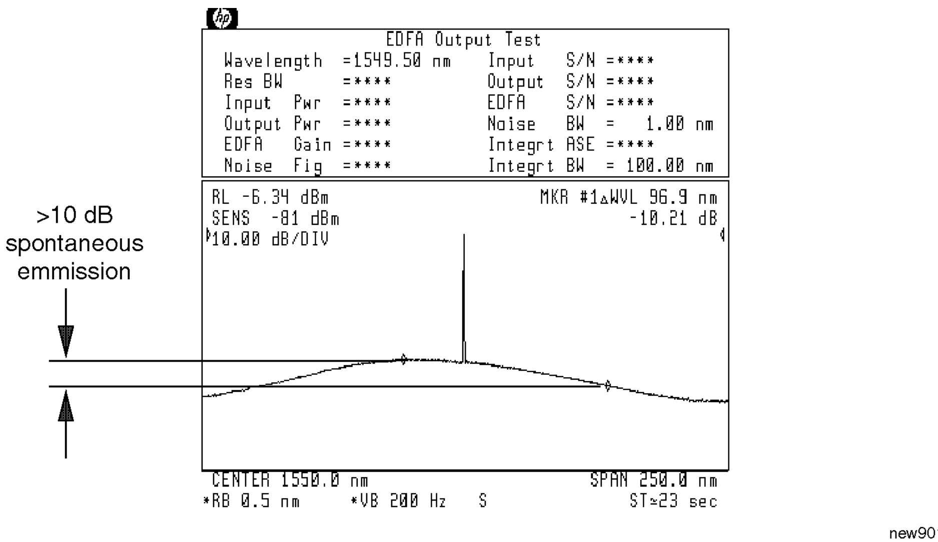
0.2 nm RBW correction factor:__________dB

> **NOTE**
>
> This number should be between 0 dB and −0.2 dB.

Determine correction factor for source spontaneous emission

18. Press INSTR PRESET.
19. If the instrument you are calibrating has the Option 051 personality, perform the following steps:
    a. Press USER and then `EDFA` to start the EDFA test personality.
    b. Press `Output Test`.
    c. Locate the peak of the spontaneous emission. Adjust the wavelength span so that, on either side of this peak, 10 dB of spontaneous emmision is visible.

Use the (SPAN) key along with the front-panel knob to change the span.

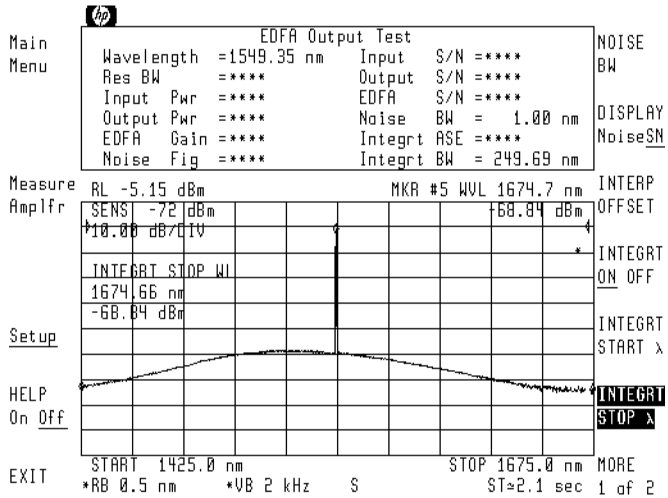


Span adjusted for proper spontaneous emmission levels.

d. Press `Setup`, and then `INTEGRT START λ`.

e. Use the front-panel knob to move the left-integration marker to the left edge of the display.

f. Press `INTEGRT STOP λ`, and use the front-panel knob to move the right-integration marker to the right edge of the display.



g. Press **Measure Amplr** .

h. When the measurement is completed, record the displayed `Output Pwr` and `Integrt ASE` measurements on the following lines:

`Output Pwr`:______________dBm
`Integrt ASE`:______________dBm

i. Subtract the `Integrt ASE` from the `Output Pwr` to determine the ratio of the two power levels. Record the result on the following line:

$$\Delta\ power\ (dB) = Output\ Pwr\ (dBm) - Integrt\ ASE\ (dBm)$$

Δ power:______________dB

20. If the instrument you are calibrating does not contain the Option 051 personality, perform the following steps:

a. Record the value of the signal peak on the following line:

`Output Pwr`:______________dBm

b. Press (NORMAL On/Off), and use the front-panel knob to place the marker on the maximum level of the spontaneous emission spectrum.

c. Press `Marker` , `MORE 1 of 4` , and then `MKNOISE On Off` so that `On` is underlined.

d. Record the marker value on the following line:

MKR_{noise}: ______________ dBm/nm

e. Press `MKNOISE On Off` so that `Off` is underlined.

f. Press `MORE 2 of 4` , `mkr bw/ zoom bw` , and then `MKR BW On Off` so that `On` is underlined. Make sure that the marker bandwidth is set to −3 dB.

g. Record the displayed **Marker Bandwidth** value:

MKR_{BW}: ______________ nm

h. Calculate the ASE using the values recorded above, and record the ASE on the line below:

$$ASE\ (dBm) = MKR_{noise} + 10\ log\,(MKR_{BW})$$

Integrt ASE: ______________ dBm

i. Subtract the **Integrt ASE** *(step 12i)* from the **Output Pwr** *(step 12a)* to determine the ratio of the two power levels. Record the result on the following line:

$$\Delta\ power\ (dB) = Output\ Pwr\ (dBm) - Integrt\ ASE\ (dBm)$$

Δ power: ______________ dB

j. Press `MKR BW On Off` so that `Off` is underlined.

21. Use the following equation to calculate the correction factor for the broadband power meter to the narrow band optical spectrum analyzer measurement:

$$factor = 10\ log\left(1 - \frac{1}{10^{\frac{x}{10}} + 1}\right)$$

where **x** is the Δ power recorded in step 19i or 20i.

source spontaneous emission correction factor: ______________ dB

Total the correction factors

22. Power meters generally are calibrated with an open beam of light. By simply using a fiber adapter, they will measure the optical power in the beam emerging from the fiber end. This is lower than the power in the fiber by 3.6%. If you wish to have power measurements relative to open-beam power emerging from the fiber, enter a correction factor of +0.16 dB. If you wish to have power measurements relative to power in the fiber, enter 0 dB.

    correction factor:______________dB

23. Add the values from steps 17, 21, and 22. Be sure to keep track of the sign of each number.

    total correction factor:______________dB

Calculate corrected power level

24. Add the value recorded in step 23 to the average power recorded in step 8. Record the result on the following line.

    corrected power level:______________dBm

Measure the average power on OSA

25. Press (PEAK SEARCH) and then (TO CENTER).
26. Press (SPAN), and enter a wavelength span of 1 nm.
27. Press (PEAK SEARCH) and then (TO CENTER).
28. Press (SPAN), and enter a wavelength span of 0 nm.
29. Press (MENU).
30. Press the left-side `Amptd` softkey.
31. Press `LOG dB/DIV`, (1), and `dB` to select a 1 dB logarithmic amplitude scale.
32. Press the left-side `BW,Swp` softkey.
33. Press `SWPTIME AutoMan`, (1), (0), and then `s`.
34. Adjust the polarization controller to "peak" the trace displayed on the optical spectrum analyzer.

    This sets the polarization for a maximum power reading.

35. Press (PEAK SEARCH), and record the power level indicated by the marker:

maximum power:______________dBm

36. Press (Δ).
37. Adjust the polarization controller to "dip" the trace displayed on the optical spectrum analyzer to a minimum power value.
38. Record the absolute value of the Δ marker's power ratio on the following line:

Δ power: ______________ dBm

39. Use the values recorded in steps 35 and 38 to calculate the average displayed power as shown in the following equation. Record the result below:

$$average\ power = maximum\ power - \frac{\Delta\ power}{2}$$

average power: ______________

40. Press the left-side `Amptd` softkey.
41. Press `MORE 1 of 4`, `MORE 2 of 4`, and then `A METER On Off` so that `On` is underlined.
42. Adjust the polarization controller to achieve a displayed Amplitude Meter power level equal to the power level recorded in step 39.

Ensuring amplitude accuracy

It is very important not to move the fiber-optic cables during the remaining steps of this procedure.

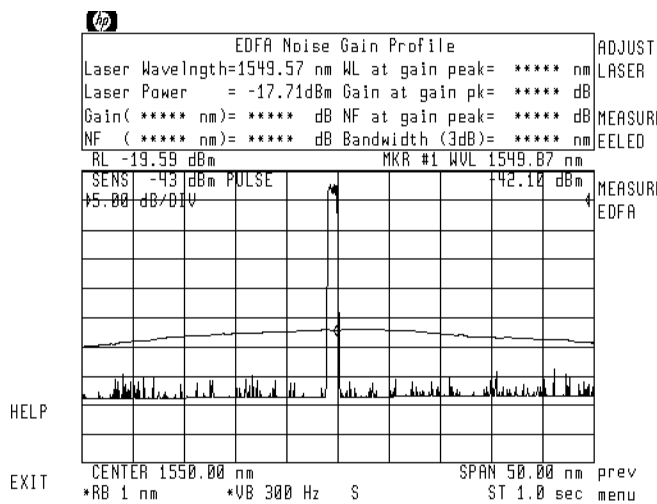
Enter the calibration power and wavelength

43. Press the left-side `Waveln` softkey. Then, press `MORE 1 of 2`, `cal menu`, `cal setup`, and then `POWER FOR CAL`.
44. Use the numeric keypad to enter the corrected power level calculated in step 24.
45. Press `WAVELEN FOR CAL`. Enter the wavelength recorded in step 4. Then, press `prev menu` and then `CAL ALL`.

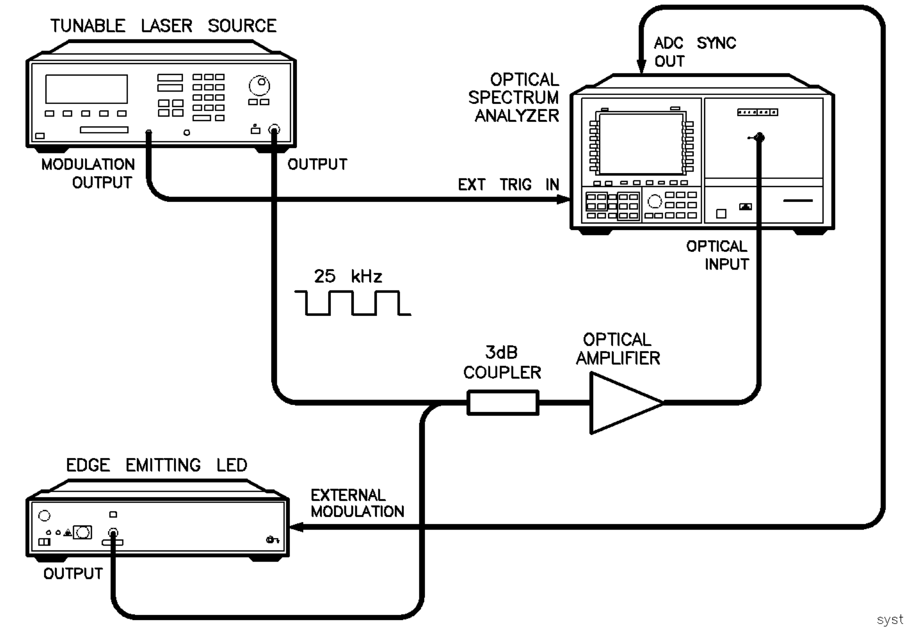
Running a Test

After you've calibrated the optical spectrum analyzer (as explained in the previous section), you're ready to make measurements. Two testing modes are available: automatic and manual. Although both testing modes perform the same measurement, the manual mode allows you to use EELED noise sources that can not be externally modulated by a TTL signal. Manual mode pauses the program so that you can manually turn on or off the EELED noise source.

The softkeys in both the "auto" and "manual" menus are displayed in the order that the testing should be done—from top to bottom. For example during "auto" testing, the operator adjusts the laser, measures the EELED, and then the measures the EDFA. During testing, display messages show the progress of the measurement.



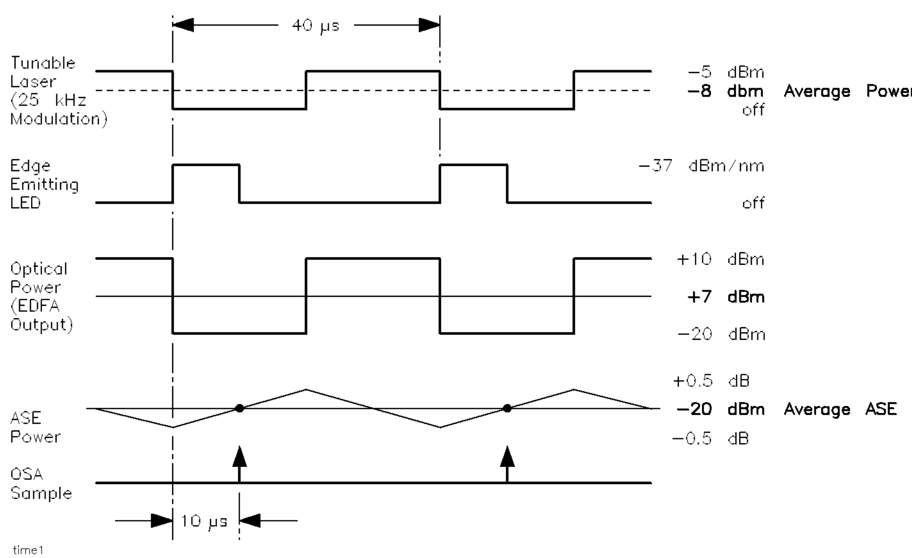
EDFA testing requires the following test setup.



Set the laser for the desired average power level

The EDFA TDE personality measures the average ASE power level resulting from a modulated laser's average power. Before you begin testing an EDFA, determine the average power level of the laser input desired for your application. Next, set the test laser's unmodulated power level 3 dB higher than this level. For example, if the modulated laser's power into the amplifier is −10 dBm, set your test laser's output power to −7 dBm. When modulated at the 50% duty cycle, the test laser's power will be equal to the level used in your application.

The following figure shows the timing required to measure the average ASE value from an input laser saturating the EDFA. The laser is modulated at a 25 kHz rate and 50% duty cycle. In this example, the laser's average power is −8 dBm (−8 dBm = −5 dBm −3 dB). The optical spectrum analyzer samples the data 10 μs after the laser is turned off. This point is half way through the laser's off cycle and in the region where the ASE varies linearly. As you can see in the figure, the ASE power level increases when the laser is turned off and decreases when the laser turns on. Measuring the ASE at 10 μs provides the average ASE level for the given average input power of the modulated laser.

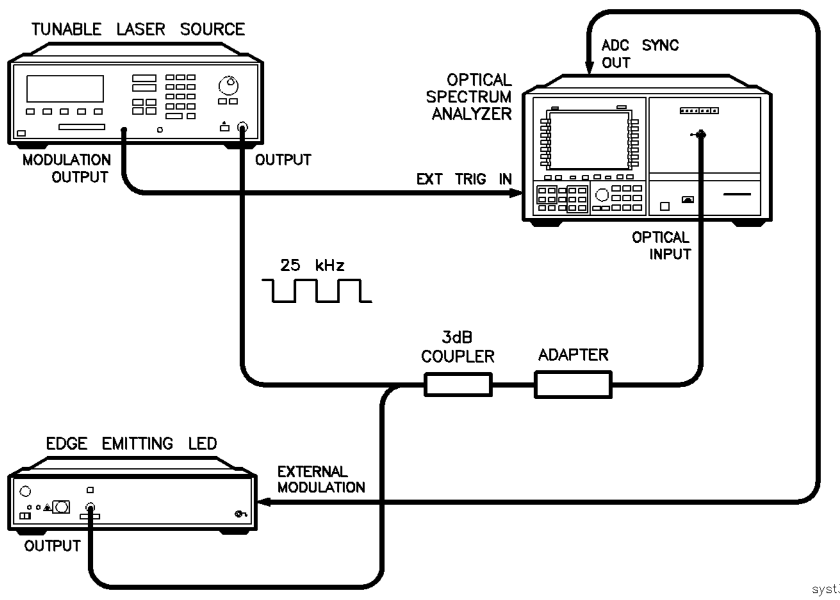


Timing diagram showing EELED noise source.

To automatically test an amplifier

Connect the equipment

1. Connect the equipment as shown in the following figure.



2. Turn on the equipment.
3. Do the following steps to modulate the HP 8168A/B/C laser at a 25 kHz rate:
   a. Press the front-panel (WAVELENGTH) key, and enter the desired wavelength.
   b. Press the (OUTPUT POWER) key, and enter the source power.
   c. Press `Mod/CW` to turn the modulation on.
   d. Toggle the `Freq`/`Power` softkey so that `FREQ:` is selected.

The softkey label reads Power.

e. Enter a modulation value of 25 kHz.

4. Turn the laser on.

Adjust the laser for the desired drive level to the EDFA

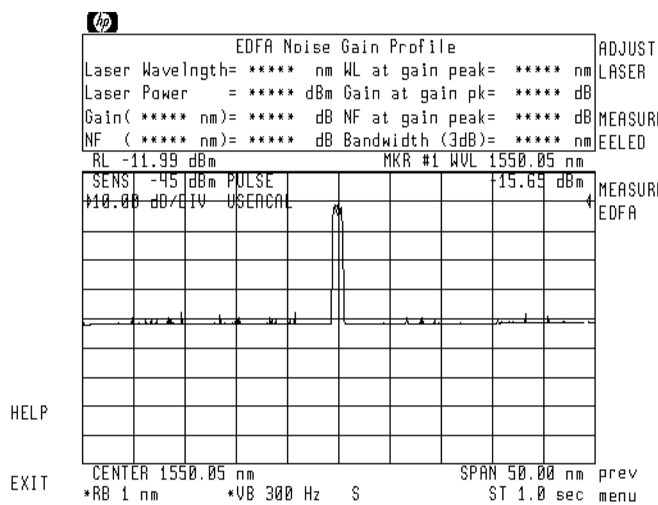
5. On the optical spectrum analyzer, press the front-panel (AUTO MEAS) key.

6. Press (USER), EDFA_NG, and then setup.

7. Perform the following steps if you need to change the optical spectrum analyzer's tuning range:

   a. Use the (CENTER) and (SPAN) keys to change the range.

   b. Press (HOLD).

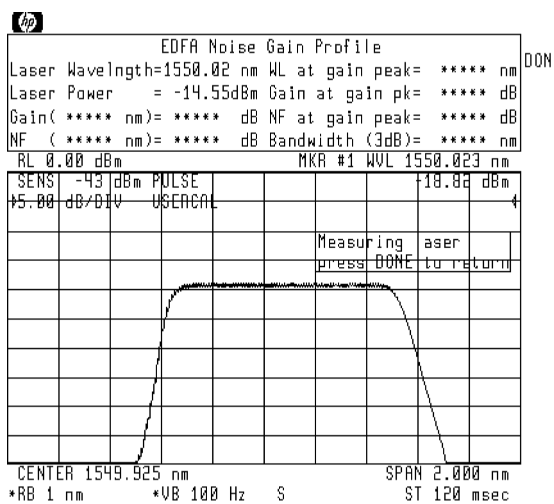


8. Press auto.

9. Press ADJUST LASER and then ZOOM.

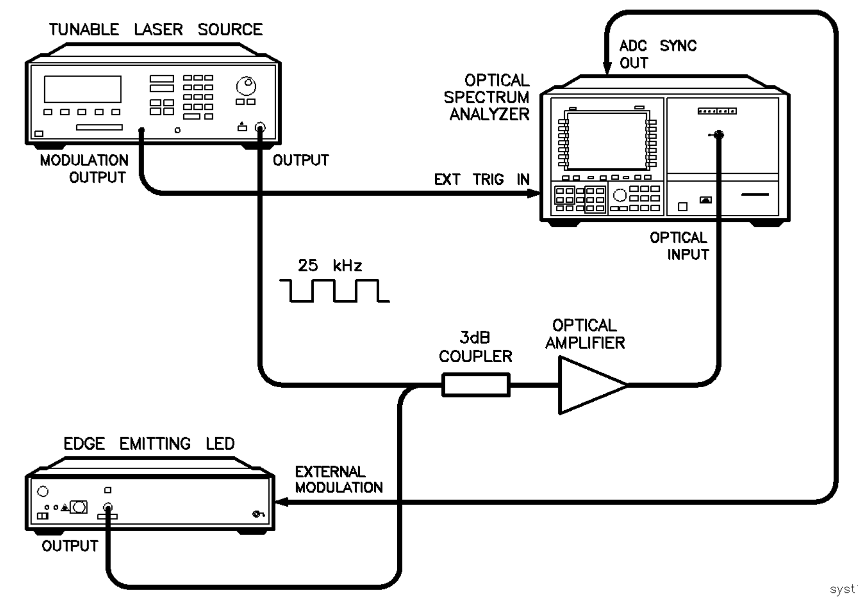
10. Adjust the laser power for the desired drive level. Then, press DONE .

> **NOTE**
>
> The laser power measured by the personality is the average power of the laser at the adapter. This will be less than the power setting on the tuned laser source by typically 7 dB (3 dB for average versus peak power and 4 dB loss in the coupler).



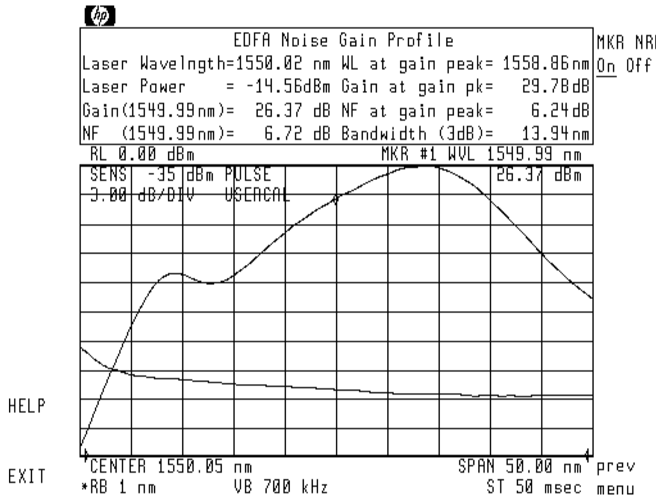
Measure the EELED

11. Press `MEASURE EELED`.
12. Wait until the message `Noise source measurement complete` is displayed.
13. Remove the adapter, and insert the EDFA as shown in the following figure.



14. Press `MEASURE EDFA`.
15. Wait approximately one minute for the measurement to complete.

    The gain and noise figure traces are displayed as shown in the following figure. The gain and NF markers are positioned at the laser wavelength for convenience. To move the markers to any position on the screen, press (NORMAL ON/OFF), and enter the desired wavelength or use the knob or step keys.

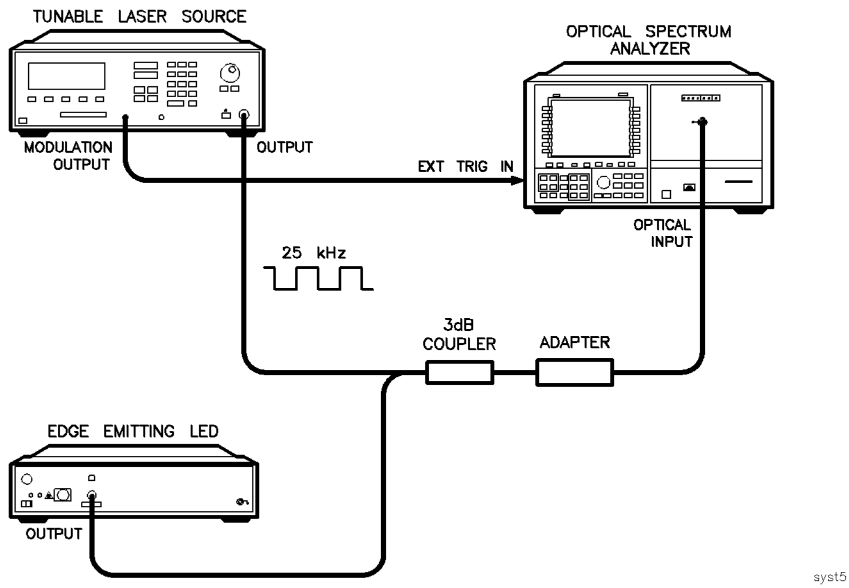


Gain and noise figure measurement results.

To manually test an amplifier

Connect the equipment

1. Connect the equipment as shown in the following figure.



2. Turn on the equipment.
3. Do the following steps to modulate the HP 8168A/B/C laser at a 25 kHz rate:
   a. Press the front-panel (WAVELENGTH) key, and enter the desired wavelength.
   b. Press the (OUTPUT POWER) key, and enter the source power.
   c. Press `Mod/CW` to turn the modulation on.
   d. Toggle the `Freq`/`Power` softkey so that `FREQ:` is selected.

The softkey label reads Power .

e. Enter a modulation value of 25 kHz.

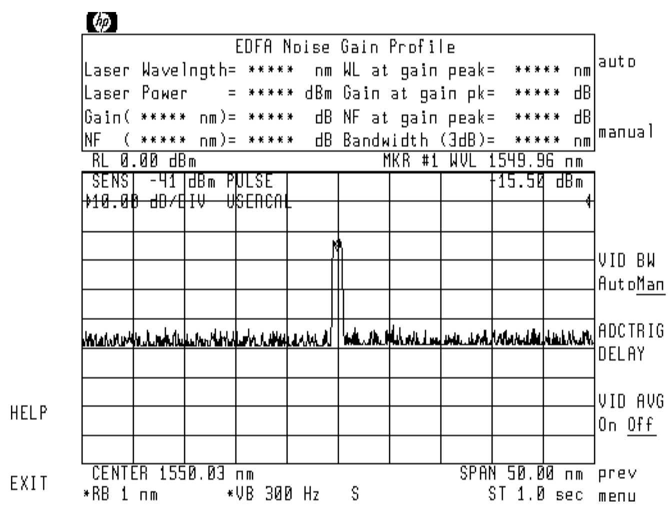
4. Turn the laser on.

Adjust the laser for the desired drive level to the EDFA

5. On the optical spectrum analyzer, press the front-panel (AUTO MEAS) key.
6. Press (USER), EDFA_NG , and then setup .
7. Perform the following steps if you need to change the optical spectrum analyzer's tuning range:

   a. Use the (CENTER) and (SPAN) keys to change the range.

   b. Press (HOLD).



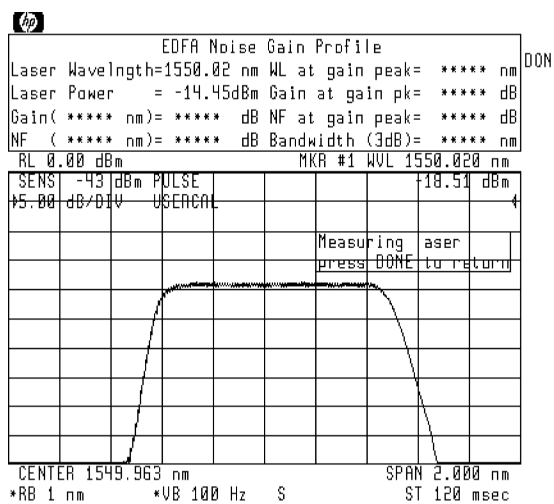
8. On the optical spectrum analyzer, press manual .

9. Press ADJUST LASER and then ZOOM.

10. Adjust the laser power for the desired drive level. Then press DONE.

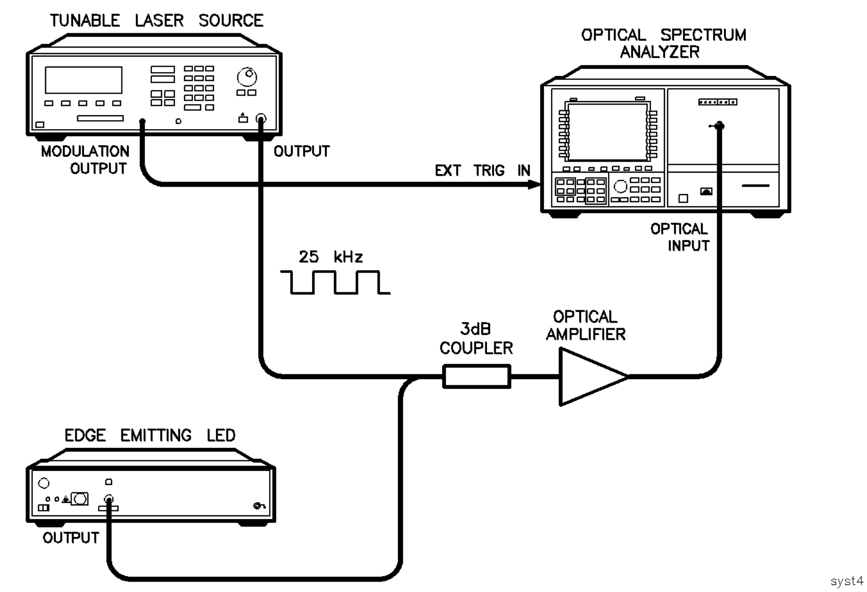
NOTE

The laser power measured by the personality is the average power of the laser at the adapter. This will be less than the power setting on the tuned laser source by typically 7 dB (3 dB for average versus peak power and 4 dB loss in the coupler).



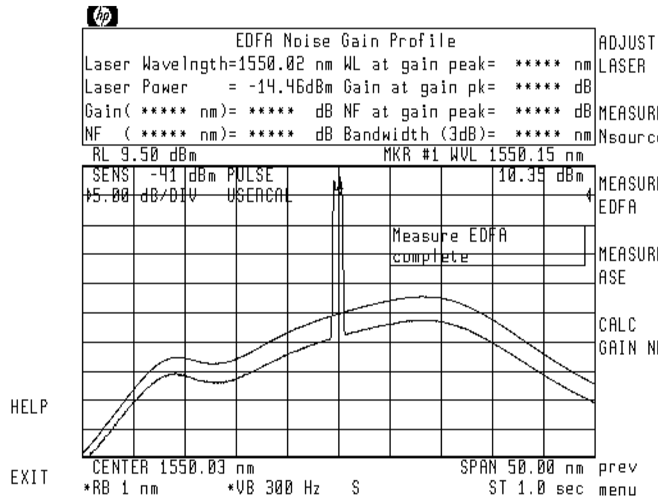
Perform the measurement

11. Turn on the EELED noise source.
12. Press `MEASURE Nsource`.
13. Wait until the message `Noise source measurem't complete` is displayed.
14. Remove the adapter, and insert the EDFA.

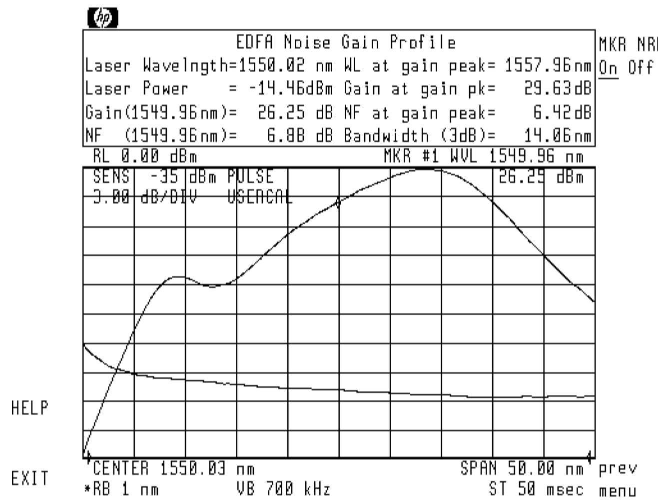


15. Turn on the amplifier.
16. Press `MEASURE EDFA`.

17. Wait until the message `Measure EDFA complete` is displayed.



18. Turn off the EELED noise source.
19. Press `MEASURE ASE`.
20. Wait until the message `Measure ASE complete` is displayed.
21. Press `CALC GAIN NF`.
22. After approximately 30 seconds, the gain and noise figure traces are displayed as shown in the following figure.


EDFA Noise Gain Profile
Laser Wavelngth=1550.02 nm WL at gain peak= 1557.96nm
Laser Power = -14.46dBm Gain at gain pk= 29.63dB
Gain(1549.96nm)= 26.25 dB NF at gain peak= 6.42dB
NF (1549.96nm)= 6.88 dB Bandwidth (3dB)= 14.06nm
MKR NRM
On Off
RL 0.00 dBm
MKR #1 WVL 1549.96 nm
26.25 dBm
SENS -35 dBm PULSE
3.00 dB/DIV USERCAL
HELP
EXIT
CENTER 1550.03 nm
SPAN 50.00 nm
*RB 1 nm
VB 700 kHz
ST 50 msec
prev
menu

Configuring the Program

This section explains several instrument settings that can be changed from the Setup menu. Unless you are knowledgeable about measurement theory, it is best to leave these settings alone—they are already set to optimum values. The Setup menu allows you to configure the following parameters:

- Change the video bandwidth.
- Set the ADC trigger delay.
- Set the number of video averag for the measurements.

Use the `VID BW AutoMan` softkey to change the video bandwidth. The default setting is "manual" with a setting of 300 Hz.

The `ADCTRIG DELAY` softkey allows you to specify the time delay from turning off the laser to measuring the ASE. Because the laser is modulated at 25 kHz, the default ADC trigger delay is set to 10 μs. This ensures that measurements are made midway in the "off" cycle which results in average ASE values.

Use the `VID AVG On Off` softkey to set the video averaging number. The default condition is a value of 10 which means that the values of ten traces are averaged together for the three traces used to calculate the gain and noise figure. Although decreasing video averaging reduces the measurement time, the accuracy of the noise measurements is affected.

Configuring the Program

3

Programming

Programming

This chapter documents the programming commands for the EDFA test personality. EDFA commands can be called from programs in the same manner as any optical spectrum analyzer command. For information on building and running programs, refer to the *HP 71450B/1B/2B Optical Spectrum Analyzers Programmer's Guide*.

Successful programs will follow the following recommended algorithm:

1. Start the personality with the `edfa_ng` command.
2. Use spectrum analyzer commands to set the center wavelength and span.

   Refer to the *HP 71450B/1B/2B Optical Spectrum Analyzer Programmer's Guide*.

3. Use EDFA personality command listed in this chapter to perform a measurement.

Send commands as ASCII strings

EDFA commands are sent to the optical spectrum analyzer as ASCII strings. The method used depends on the programming language and environment. Using an HP Vectra computer with the HP-IB Interface and Command Library (and programming in *C*), send a command as follows:

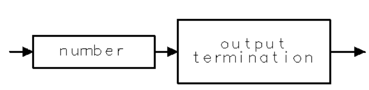
```
iooutputs(723L, "edfa_ng", 7);
```

Using an HP 9000 Series 300 technical computer with the HP-BASIC language, the same command would be sent as follows:

```
OUTPUT 723;"edfa_ng", 7
```

Query responses

Some EDFA commands can be issued as a query. A query causes data to be returned to the computer from the optical spectrum analyzer. The data is returned as an ASCII string. For example, the `ngpgpw?` query might return the string `1.550000E-006` representing 1550 nanometers. The following syntax diagram shows the form of a query response.



Some optical spectrum analyzer commands are used

The following table lists EDFA functions that should be controlled using optical spectrum analyzer commands. These functions have no equivalent EDFA programming command. Refer to the *HP 71450B/1B/2B Optical Spectrum Analyzers Programmer's Guide* for information on these commands.

Optical Spectrum Analyzer Commands

OSA Command	EDFA Softkey	Definition
ADCTRGDLY	ADCTRIG DELAY	Delays ADC triggering.
CENTERWL	—	Sets the center wavelength value.
CONTS	CONT SWEEP	Selects continuous sweep mode.
SNGLS	SINGLE SWEEP	Selects single sweep mode.
SP	—	Sets the wavelength span.
STARTWL	—	Sets the start wavelength value.
STOPWL	—	Sets the stop wavelength value.
LG	LOG dB/DIV	Changes logarithmic amplitude scale.
MKPX	PEAK EXCURSN	Sets marker peak excursion value.
VAVG	VID AVG On Off	Turns on video averaging.
VB	VID BW AutoMan	Select video-bandwidth filter.

Programming commands

The following tables list the programming commands. Some entries refer to the term smooth factor. The smooth facter indicates the number of adjacent measurement points averaged together to obtain a measurement value. It is mathmatically defined by the following equation:

$$smooth\ factor = \frac{0.8\,(trace\ length)\,(resolution\ bandwidth)}{span}$$

Commands by Functional Group

Function	Softkey/Function	Programming Command
Starting and Exiting		
Starts EDFA test personality.	EDFA	edfa_ng
Exits program.	EXIT	ngpexit
Menu Selection:		
Startup menu.		ngpset
Setup menu	setup	ngpseta
Auto menu *(ngp=1)*.	auto	ngpae
Manual menu *(ngp=0)*.	manual	ngpme
Return to auto menu	prev menu.	ngpa
Return to manual menu.	prev menu	ngpm
Exit results menu.		ngprep
Exit adjust laser procedure.	DONE	ngpsatr
Making Measurements:		
Displays laser adjust menu.	ADJUST LASER	ngpsata
Zoom to 2 nm span at laser wavelength.	ZOOM	ngpsatb
Measure probe source.	MEASURE EELED *(auto)*	ngpx
Measure probe source.	MEASURE Nsource *(manual)*	ngpx
Measure EDFA and calculate gain/nf.	MEASURE EDFA *(auto)*	ngpedfa
Measure output Nsource "on".	MEASURE EDFA *(manual)*	ngpy
Measure output Nsource "off".	MEASURE ASE	ngpz
Calculate gain/nf and extract results.	CALC GAIN NF	ngpw
Measure laser/probe source.		ngpsrce
Display and Update Data:		
Display results.		ngpres
Refresh display values.		ngpval
Resets displayed values.		ngpvalr
Refresh display text.		ngpdisp

Commands by Functional Group (continued)

Function	Softkey/Function	Programming Command
Measurement Parameters:		
Calculate gain/nf raw data.		ngpgain
Query Data:		
Queries laser wavelength	`Laser Wavelngth`	ngpsatw?
Queries laser power	`Laser Power`	ngpsatp?
Queries gain at marker wl	`Gain ( nm)`	ngpmkg?
Queries noise figure at marker wl	`NF ( nm)`	ngpmkn?
Queries wavelength at gain peak	`WL at gain pk`	ngpgpw?
Queries gain at gain peak	`Gain at gain pk`	ngpgpg?
Queries noise figure at gain peak	`NF at gain pk`	ngpnf?
Queries 3dB bandwidth of gain curve	`Bandwidth (3dB)`	ngpbw?
Queries mode: 1 auto, 0 man, 2 prog		ngp?
Queries measurement centerwl		ngpcwl?
Queries measurement span		ngpspan?
Queries measurement video bandwidth		ngpvb?
Queries marker wavelength		ngpmkw?
Queries rbw / span		rbspan?
Queries scale factor for gain peak wl		ngpscale?
Queries smoothing factor.		smfactor?

Softkeys versus Commands

Softkey	Equivalent Programming Command	Definition
ADCTRIG DELAY	ADCTRGDLY	Refer to OSA Programmer's Guide.
ADJUST LASER	ngpsata	Displays laser adjust menu.
auto	ngpae	Enter auto menu *(ngp1)*
CALC GAIN NF	ngpw	Calculate gain/nf and extract results.
CONT SWEEP	CONTS	Refer to OSA Programmer's Guide.
DONE	ngpsatr	Exit adjust laser procedure.
EDFA_NG	edfa_ng_	Starts personality.
EXIT	ngpexit	Exits personality.
HELP	ngphelpa	Displays auto menu help.
HELP	ngphelpm	Displays manual manu help.
HELP	ngphelpr	Displays help for results.
HELP	ngphelps	Displays setup menu help.
HELP	ngphelp	Display help for start.
manual	ngpme	Display manual menu *(ngp0)*.
MEASURE ASE	ngpz	Measure output with noise source "off".
MEASURE EDFA (auto)	ngpedfa	Measure EDFA and calculate gain/nf.
MEASURE EDFA (manual)	ngpy	Measure output with noise source "on".
MEASURE EELED	ngpx	Measure noise source. *(auto)*
MEASURE Nsource	ngpx	Measure noise source. *(manual)*
prev menu	ngpm	Display manual menu.
setup	ngpseta	Display setup menu.
SINGLE SWEEP	SNGLS	Refer to OSA Programmer's Guide.
VID AVG On Off	VAVG	Refer to OSA Programmer's Guide.
VID BW AutoMan	VB	Refer to OSA Programmer's Guide.
ZOOM	ngpsatb	Zoom to 2 nm span at laser wavelength.

Commands in Alphabetical Order

Programming Command	Definition	Softkey
edfa_ng_	Starts EDFA Noise Gain Profile personality.	EDFA_NG
ngp?	Queries mode: 1 auto, 0 man, 2 prog.	
ngpa	Displays auto menu.	prev menu
ngpae	Displays auto menu *(ngp = 1)*.	auto
ngpbw?	Queries displayed `Bandwidth (3dB)` value.	
ngpcwl?	Queries measurement center wavelength.	
ngpdisp	Refresh display text.	
ngpedfa	Measure EDFA and calculate gain/nf.	MEASURE EDFA *(auto)*
ngpexit	Exits program.	EXIT
ngpgain	Calculate gain/nf raw data.	
ngpgpg?	Queries displayed `Gain at gain pk` value.	
ngpgpw?	Queries displayed `WL at gain peak` value.	
ngphelp	Display help for start.	HELP
ngphelpa	Display help for auto.	HELP
ngphelpm	Display help for manual.	HELP
ngphelpr	Display help for results.	HELP
ngphelps	Display help for setup.	HELP
ngpm	Displays manual menu.	prev menu
ngpme	Displays manual menu (ngp = 0).	manual
ngpmkg?	Queries displayed `Gain ( nm)` value.	
ngpmkn?	Queries displayed `NF ( nm)` value.	
ngpmkw?	Queries marker wavelength.	
ngpnf?	Queries displayed `NF at gain peak` value.	
ngprep	Exit results to measurement menu.	
ngpres	Display results.	
ngpsata	Displays laser adjust menu.	ADJUST LASER
ngpsatb	Zoom to 2 nm span at laser wavelength.	ZOOM
ngpsatp?	Queries displayed `Laser Power` value.	

Commands in Alphabetical Order (continued)

Programming Command	Definition	Softkey
ngpsatr	Exit adjust laser procedure.	DONE
ngpsatw?	Queries displayed `Laser Wavelngth` value.	
ngpscale?	Queries scale factor for gain peak wavelength.	
ngpset	Dispay startup menu.	
ngpseta	Display setup menu.	setup
ngpspan?	Queries measurement span.	
ngpsrce	Measure laser/probe source.	
ngpval	Refresh display values.	
ngpvalr	Resets displayed values.	
ngpvb?	Queries measurement video bandwidth.	
ngpw	Calculate gain/nf and extract results.	CALC GAIN NF
ngpx	Measure probe source.	MEASURE EELED and MEASURE Nsource
ngpy	Measure output Nsource “on”.	MEASURE EDFA *(manual)*
ngpz	Measure output Nsource “off”.	MEASURE ASE
rbspan?	Queries rbw / span.	
smfactor?	Queries smoothing factor.	

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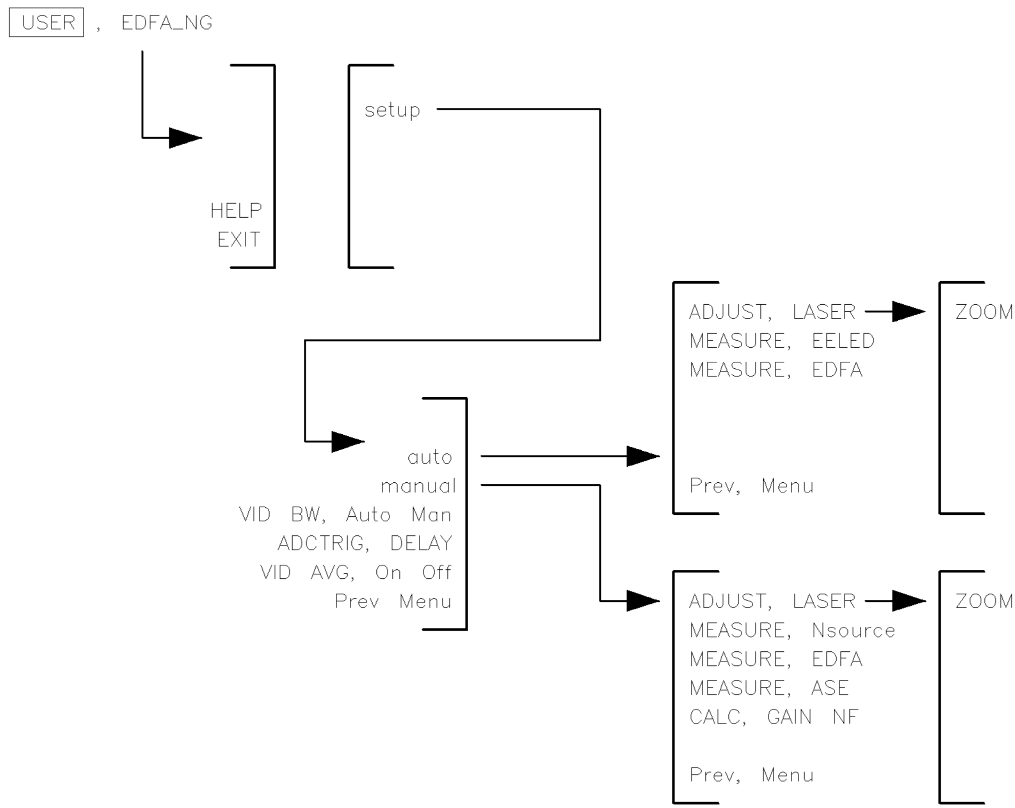
Reference

Reference

Chapter Contents

Menu Map



menumap6

Error Messages

This section defines error messages for the EDFA test personality. Error messages not defined in this section originate with the HP 70950B/1B/2B module and are documented in the *HP 71450B/1B/2B Optical Spectrum Analyzers Reference*.

Error messages can result from incorrect operating procedures, illegal programming commands, or hardware failures. Normally, the optical spectrum analyzer removes error messages from the screen as soon as the error conditions are corrected. If you have a computer, error messages can be retrieved via HP-IB by executing the `ERR?` command. Refer to the *HP 71450B/1B/2B Optical Spectrum Analyzers Programmer's Guide* for information on the `ERR?` command.

error 111

`EDFA Memory Error:` The program has run out of free memory. To free memory, perform the following:

- Erase objects of the following types from memory: saved traces, limit lines, user menus, and downloadable programs. Refer to the chapter on managing memory in the *HP 71450B/1B/2B Optical Spectrum Analyzers User's Guide* to learn how to erase these objects.

error 112

`EDFA Noise Figure < 0 Error:` Invalid data has resulted in a noise figure calculation less than zero. Valid noise figure results are always positive values.

error 116

`EDFA Command Error:` An unrecognized argument has been used with the programming command. Refer to Chapter 3 for the correct use of the command.

Measurement Calculations

The following calculations describe the process for obtaining the resultant traces for gain and noise figure, as well as each measurement result shown at the top of the display. A special `typeface` is used in this chapter to indicate displayed quantities. For example when the laser wavelength is referenced, it is printed as `Laser Wavelngth`.

Gain and Noise Figure Traces

The Gain and Noise Figure traces are calculated from the three measurement traces as follows:

$$trace\ A\ (measurement) = ASE = EDFA\ output\ (noise\ source\ off)$$

$$trace\ B\ (measurement) = (G)(N) + ASE = EDFA\ output\ (noise\ source\ on)$$

$$trace\ C\ (measurement) = N = noise\ source\ spectrum$$

All three traces are converted from dBm to watts (floating point and corrected for resolution bandwidth variation with wavelength) For each trace point, wavelength, a value for gain is calculated as:

$$G = gain = \frac{(B - A)}{C}$$

$$NF = \frac{ASE}{hvGain} + \frac{1}{Gain}$$

$$Gain\ (displayed) = smoothed\ Gain$$

$$NF\ (displayed) = smoothed\ NF$$

$$Smoothingfactor = greatest\ odd\ integer\left(0.8 * Trace\ length * \frac{Res\ BW}{Span}\right)$$

Laser Wavelngth and Power

The laser power and wavelength determine the saturation condition for the EDFA. The Noise Gain Profile routine measures and records the laser wavelength and power level referenced to the input of the EDFA. Since the laser is modulated, the desired power level is the average power of the source. The OSA measures the average power and wavelength accurately by ZOOMing in on the signal. This allows more measurement time on the signal to enhance the measurement repeatability. From the ZOOMed trace, the power and wavelength are extracted using the following calculations.

$$laser\ PWR = peak\ (smoothed\ trace)$$

$$laser\ WL = peak\ (double\ smoothed\ trace)$$

$$Smoothingfactor = greatest\ odd\ integer\left(0.8 * Trace\ length * \frac{Res\ BW}{Span}\right)$$

WL at gain peak

The exact wavelength is calculated for the gain peak using the following algorithm :

The gain and noise figure calculations return traces in an unsmoothed form. Before the traces are displayed, the gain trace is expanded to enhance the amplitude resolution.

1. The trace maximum gain value is determined.
2. The trace is multiplied by 325/max gain up to a maximum of 10.
3. The expanded trace is smoothed and the new maximum point is determined.
4. The wavelength of the maximum point is recorded as wavelength at gain peak.
5. The smoothed trace is un-scaled and displayed as the gain trace.

Gain at gain peak

The gain at gain peak is the gain value from the displayed gain trace at the wavelength at gain peak.

NF at gain peak

The NF at gain peak is the value of the noise figure trace at the wavelengh at gain peak.

Bandwidth (3dB)

The bandwidth (3dB) value is calculated from the gain peak using the OSA marker bandwidth function set to −3dB. It is the wavelength difference between the gain trace points which are 3dB down from the peak on either side.

Characteristic Measurement Uncertainty

This section is a guide for understanding the various sources of measurement uncertainty for `EDFA Gain` and `Noise Figure`. The actual uncertainty depends on the equipment you are using. This section takes the conservative approach of treating all of the individual measurement uncertainties as systematic, that is, uniform probability distribution within the specified limits. The uncertainty calculations assume the following points:

- An HP 71452B optical spectrum analyzer is used.

  This optical spectrum analyzer has improved polarization sensitivity from 1542 to 1562 nm.

- The uncertainty values apply from 1542 to 1562 nm.
- The source is an HP 8168B/C tunable laser source.
- 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 optical spectrum analyzer has been recently amplitude calibrated using an optical power meter with ±0.1 dB absolute accuracy.
- The optical spectrum analyzer has been recently wavelength calibrated with either the HP 8168B/C tunable laser source or another wavelength reference.
- All total uncertainties are calculated as shown in the following equation:

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

  where "U" is the uncertainty of each individual contributor.

Uncertainties

	With Splices[1]	With Connectors[2]
Gain Uncertainty[3]	0.11 dB	0.30 dB
Noise Figure Uncertainty[3]	0.34 dB	0.53 dB
Gain Shape Uncertainty[3]	0.10 dB	0.10 dB

1 Assumes 0.05 dB uncertainty for each splice.

2 Assumes 0.25 dB uncertainty for each connector.

3 Calculated for 5.5 dB ratio for EELED ON and EELED OFF at output of EDFA.

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