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User's Guide

Fiber Optic Power Meter
FPM-8210/8210H



ILX Lightwave
Photonic Test & Measurement Instrumentation

ILX Lightwave Corporation · P. O. Box 6310 · Bozeman, MT, U.S.A. 59771 · U.S. & Canada: **1-800-459-9459** · International Inquiries: 406-586-1244 · Fax 406-586-9405
E-mail: support@ilxlightwave.com
www.ilxlightwave.com

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SAFETY AND WARRANTY INFORMATION

The Safety and Warranty Information section provides details about cautionary symbols used in the manual, safety markings used on the instrument, and information about the Warranty including Customer Service contact information.

Safety Information and the Manual

Throughout this manual, you will see the words *Caution* and *Warning* indicating potentially dangerous or hazardous situations which, if not avoided, could result in death, serious or minor injury, or damage to the product. Specifically:



Caution indicates a potentially hazardous situation which can result in minor or moderate injury or damage to the product or equipment.



Warning indicates a potentially dangerous situation which can result in serious injury or death.



Visible and/or invisible laser radiation. Avoid direct exposure to the beam.

General Safety Considerations

If any of the following conditions exist, or are even suspected, do not use the instrument until safe operation can be verified by trained service personnel:

- Visible damage
- Severe transport stress
- Prolonged storage under adverse conditions
- Failure to perform intended measurements or functions

If necessary, return the instrument to ILX Lightwave, or authorized local ILX Lightwave distributor, for service or repair to ensure that safety features are maintained (see the contact information on page xii).

All instruments returned to ILX Lightwave are required to have a Return Authorization Number assigned by an official representative of ILX Lightwave Corporation. See Returning an Instrument on page xi for more information.

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SAFETY SYMBOLS

This section describes the safety symbols and classifications.

Technical specifications including electrical ratings and weight are included within the manual. See the Table of Contents to locate the specifications and other product information. The following classifications are standard across all ILX Lightwave products:

- Indoor use only
- Ordinary Protection: This product is NOT protected against the harmful ingress of moisture.
- Class I Equipment (grounded type)
- Mains supply voltage fluctuations are not to exceed ±10% of the nominal supply voltage.
- Pollution Degree II
- Installation (overvoltage) Category II for transient overvoltages
- Maximum Relative Humidity: <80% RH, non-condensing
- Operating temperature range of 0 °C to 40 °C
- Storage and transportation temperature of –40 °C to 70 °C
- Maximum altitude: 3000 m (9843 ft)
- This equipment is suitable for continuous operation.

Safety Marking Symbols

This section provides a description of the safety marking symbols that appear on the instrument. These symbols provide information about potentially dangerous situations which can result in death, injury, or damage to the instrument and other components.

 Caution, refer to manual	 Earth ground Terminal	 Alternating current	 Visible and/or invisible laser radiation
 Caution, risk of electric shock	 Protective Conductor Terminal	 Caution, hot surface	 Frame or chassis Terminal
 or (I) On: In position of a bistable push control. The slash (I) only denotes that mains are on.		 or (O) Off: Out position of a bistable push control. The circle (O) only denotes that mains are off.	

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WARRANTY

ILX LIGHTWAVE CORPORATION warrants this instrument to be free from defects in material and workmanship for a period of one year from date of shipment. During the warranty period, ILX will repair or replace the unit, at our option, without charge.

Limitations

This warranty does not apply to fuses, lamps, defects caused by abuse, modifications, or to use of the product for which it was not intended**.**

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty of merchantability or fitness for any particular purpose. ILX Lightwave Corporation shall not be liable for any incidental, special, or consequential damages**.**

If a problem occurs, please contact ILX Lightwave Corporation with the instrument's serial number, and thoroughly describe the nature of the problem.

Returning an Instrument

If an instrument is to be shipped to ILX Lightwave for repair or service, be sure to:

1. Obtain a Return Authorization number (RA) from ILX Customer Service.
2. Attach a tag to the instrument identifying the owner and indicating the required service or repair. Include the instrument serial number from the rear panel of the instrument.
3. Attach the anti-static protective caps that were shipped with the instrument and place the instrument in a protective anti-static bag.
4. Place the instrument in the original packing container with at least 3 inches (7.5 cm) of compressible packaging material. **Shipping damage is not covered by this warranty.**
5. Secure the packing box with fiber reinforced strapping tape or metal bands.
6. Send the instrument, transportation pre-paid, to ILX Lightwave. Clearly write the return authorization number on the outside of the box and on the shipping paperwork. ILX Lightwave recommends you insure the shipment.

If the original shipping container is not available, place your instrument in a container with at least 3 inches (7.5 cm) of compressible packaging material on all sides.

Repairs are made and the instrument returned transportation pre-paid. Repairs are warranted for the remainder of the original warranty or for 90 days, whichever is greater.

Claims for Shipping Damage

When you receive the instrument, inspect it immediately for any damage or shortages on the packing list. If the instrument is damaged, file a claim with the carrier. The factory will supply you with a quotation for estimated costs of repair. You must negotiate and settle with the carrier for the amount of damage.

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Comments, Suggestions, and Problems

To ensure that you get the most out of your ILX Lightwave product, we ask that you direct any product operation or service related questions or comments to ILX Lightwave Customer Support. You may contact us in whatever way is most convenient:

Phone . . . . . (800) 459-9459 or (406) 586-1244

Fax . . . . . (406) 586-9405

On the web at: . . . http://ilx.custhelp.com/cgi-bin/ilx.cfg/php/enduser/ask.php

Or mail to:

ILX Lightwave Corporation
P. O. Box 6310
Bozeman, Montana, U.S.A 59771
www.ilxlightwave.com

When you contact us, please have the following information:

Model Number: _____

Serial Number: _____

End-user Name: _____

Company: _____

Phone: _____

Fax: _____

Description or sketch of what is connected to the ILX Lightwave instrument:

_____

Description of the problem:

_____

If ILX Lightwave determines that a return to the factory is necessary, you are issued a Return Authorization (RA) number. Please mark this number on the outside of the shipping box.

You or your shipping service are responsible for any shipping damage when returning the instrument to ILX Lightwave; ILX recommends you insure the shipment. If the original shipping container is not available, place your instrument in a container with at least 3 inches (7.5 cm) of compressible packaging material on all sides.

We look forward to serving you even better in the future!

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CHAPTER 1

INTRODUCTION AND SPECIFICATIONS

This chapter introduces the FPM-8210 and FPM-8210H Fiber Optic Power Meters with an overview description. Also included are a list of available accessories to extend the usefulness of your meter, installation instructions, a description of the start-up sequence, and specifications.

Product Overview

The FPM-8210 and FPM-8210H are precision, systems-capable fiber optic power meters optimized for production testing of fiber optic components.

The only difference between the FPM-8210 and the FPM-8210H is the allowable input power level. In this manual, any reference to "FPM-8210" applies to either model unless specifically stated. See Table 1.2, "FPM-8210/8210H Fiber Power Meters Specifications", on page 4 for details.

Some of the key benefits this design innovation delivers include:

Benefit	Reason
Make polarization dependent measurements without concern for meter PDL errors.	The FPM-8210 detector cavity virtually eliminates meter polarization response.
Get the same bare fiber results with different users.	The FPM-8210 has a wide allowance for fiber position in the holder.
No need to rotate the bare fiber holder for maximum or minimum reading.	The FPM-8210 detector cavity is virtually insensitive to light pattern movement.
Impossible to damage detector with fiber.	The FPM-8210 detector is located away from proximity of the fiber.
Compare bare and connectorized fiber measurements with confidence.	The FPM-8210 uses the same detector cavity entrance for all measurements.
Bare fiber measurements without tedium to slow your testing or introduce errors.	New-design ILX Lightwave BF-820 bare fiber holder easily guides the fiber to the correct place every time.
No need to change established procedures or training.	Detector accepts ILX Lightwave BF-820 or Agilent 82000BA bare fiber holders.
Moving the head cable will not disturb the meter reading.	The detector's signal is amplified inside the external head: higher cable signal levels.

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The FPM-8210 and FPM-8210H are precise and reliable tools for fiber optic power measurement. Accommodating wavelengths from 850 to 1650 nm, the FPM-8210 measures accurately over 90 dB dynamic range from +20 dBm to -70 dBm. The FPM-8210H measures accurately over 80 dB dynamic range from +30 dBm to -50 dBm. NIST-traceable calibration assures consistent results. Other features include:

- Average up to 100 measurements per reading for accuracy with unstable inputs
- SAVE and RECALL up to ten of your test setups
- Bargraph displays relative power for visual peaking of optical setups
- 0 ~ 10 V analog output for fine resolution relative power monitoring
- A sophisticated GPIB/IEEE 488 interface
- 2-meter head cable for convenience in positioning the head near your test
- Heavy robust head design for production test workstations

Accessories

Precision quick-align threadless adaptors are available for common connector types. The accessory case provides a convenient way to protect these precision optical components when not in use.

Table 1.1 Accessories

MODEL NUMBER	DESCRIPTION
CA-100	FC Adapter
CA-150	SC Adapter
CA-200	LC Adapter
CA-120	Bare Fiber Adapter Ring
BF-820	Bare Fiber Holder (requires CA-120)
CA-500	Accessory case (for adaptors and fiber holder)
RM-124	Rack mount kit, single instrument
RM-122	Rack mount kit, dual instrument

The CA-120 bare fiber adapter ring accepts ILX Lightwave BF-820 or Agilent 81000BA bare fiber holders. This compatibility also means you can use the BF-820 bare fiber holder with Agilent or HP power meters.

Model CA-500 accessory case holds your connector adaptors, bare fiber holder, and bare fiber adapter ring. Protect these precision optical components by storing them in their appropriate slot in this case.

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Specifications

This section discusses AC power considerations, tilt-foot adjustment, rack mounting, and describes the power up sequence.

AC Power

WARNING

To avoid electrical shock hazard, connect the FPM-8210 only to a properly earth-grounded, 3-prong receptacle. Failure to observe this precaution can result in severe injury or death.

The FPM-8210 is factory configured for operation at nominal line voltages of 100, 120, 220, or 240 VAC. Make sure the voltage printed on the back panel of the instrument matches the power-line voltage in your area. Contact ILX Lightwave Customer Service if you need to reconfigure the input voltage range.

Tilt-Foot Adjustment

The FPM-8210 has front legs that extend to make it easier to view the displays. To use them, rotate the legs downward until they lock into position.

Rack Mounting

The FPM-8210 conforms to international standards for a 2U-height $^1/_2$-width rack mounting. Available rack mount accessory kits contain detailed mounting instructions.

Power-Up Sequence

With the FPM-8210 connected to an AC power source, pressing **POWER** supplies AC line power to the instrument and starts the following power up sequence:

1. All front panel indicators ON, all 7-segment displays indicate "8".
2. All front panel indicators OFF.
3. Display shows the internal firmware version number.

   Each display lasts 2-3 seconds. During the front panel indicator test, the FPM-8210 performs a self-test to ensure that internal hardware and software are communicating. After the self test, FPM-8210 configuration is set to the same state as when power was last turned off. If you wish, you can then use the recall function to quickly get to a different setup. See Save and Recall on page 8. for more information. If the 8210 cannot successfully complete the test, an error message is displayed. See Appendix A, Error Messages for a complete list of error messages.

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Table 1.2 FPM-8210/8210H Fiber Power Meters Specifications

Wavelength range	850 to 1650 nm
Power range FPM-8210 FPM-8210H	 +20 dBm to -70 dBm[1] +30 dBm to -50 dBm[1]
Damage Threshold	>+40 dBm
Accuracy [2] Reference conditions[3] Operating conditions[4]	 ±2.5% ±5.0%
Polarization dependent response[5]	±0.002 dB, *typical ±0.001 dB*[6]
Measurement repeatability[7]	±0.003 dB, *typical ±0.002 dB*[6]
Compatible connector types	FC/PC, FC/APC, LC, SC, bare fiber holder[8]
Sensor type	InGaAs
Noise[9] FPM-8210 FPM-8210H	 ≤100 pW p-p (1200-1630 nm) Typical <40 pW p-p at 1310nm and 1550nm[6] ≤500 pW p-p (1200-1630 nm) Typical <250 pW p-p at 1310nm and 1550nm[6]
Sample rate	50 msec[10]
Temperature coefficient	Typical ±0.2%/°C [6]
Linearity[11] FPM-8210 (-60 dBm to +20 dBm) FPM-8210H (-40 dBm to +30 dBm)	 ±0.02 dB, ±100 pW ±0.04 dB, ±500 pW
Power display Type Resolution	 5-digit, 7-segment LED, log or linear mode 0.001 unit (log or linear)
Wavelength display (input) Type Range Resolution	 4-digit, 7-segment LED 850-1650 nm 1 nm
Power level bargraph	Relative to full scale, fast update
Display Filter Update Rate[12] Slow—100 measurements Medium—10 measurements Fast 1—measurements	 5.0 s 0.50 s 0.05 s
Analog output (rear panel) Bandwidth Voltage Impedance	 0-10 Hz 0-10 V Typical 1000 Ω[6]
Environment Operating temperature Storage temperature Humidity Line voltage Line frequency	 +10 °C to +40 °C -40 °C to +70 °C <85% RH, non-condensing 100 V ±10%, 120 V ±10%, 220 V ±10%, 230-240 V ±10% 50-60 Hz
Size Meter: Detector Head: Cable:	 88 x 212 x 270 mm (3.5 x 8.4 x 10.6 inches) 86 x 86 x 100 mm (3.4 x 3.4 x 3.9 inches) 2 meters (6.4 feet)
Weight	4.6 kg (10.2 lb) Includes meter, head, and cable

1. FPM-8210: +23 dBm to -60 dBm for λ <1000 nm. FPM-8210H; +33 dBm to -40 dBm for λ <1000 nm
2. 950-1630 nm. Includes traceability to NIST. Calibrated at 23°C ±3°C, at 10 nm intervals. Uncertainty evaluated according to NIST Technical Note #1297: "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results".
3. Temperature 23 ±2 ºC, λ 1000-1600 nm, spot diameter 1.1mm, power -20 dBm (10µW).
4. Within operating power and temperature ranges specified above. Add 1% for NA > 0.2. Maximum NA ≤ 0.30.
5. Variation in meter response associated with changes in input polarization state. Specification is for flat endface (cleaved) fiber. Add PDL for connectors or angled-cleave measurements. For example, 8° cleave in SMF-28 fiber typically adds 0.015 dB PDL.
6. Typical values provide supplemental information beyond guaranteed specification limits.
7. Variation in response from removing and replacing the fiber or connector into the detector head. Includes effects of variation in fiber orientation and bare fiber extension 1 mm to 5 mm from the holder. Add ±0.003 dB for NA > 0.20.
8. Compatible with ILX Lightwave BF-820 or Agilent 81000BA bare fiber holders. ILX Lightwave BF-820 fiber holders are designed for fiber diameter 125 µm (250 µm or 900 µm buffer).
9. Measured over 1 minute, in medium filter mode. Typical noise at 980nm <150 pW for FPM-8210 and <700 pW for FPM-8210H.
10. GPIB data transfer rate is faster than measurement sample rate.
11. 920nm to1630nm.Total variation from straight-line response. Valid across range limits if measured in auto-range mode. Measured at 23 ±5 °C, constant temperature. Add ±0.005 dB/dB for input power >0 dBm.
12. Applies to measurements taken within the same gain range. Display update rates will increase if changing gain ranges is required during measurements.

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CHAPTER 2

FRONT PANEL OPERATION

This chapter describes how to set up and operate your FPM-8210 or FPM-8210H Fiber Optic Power Meter using front panel controls. Discussions include installation, front and rear panel familiarization, and general operating procedures.

The only difference between the FPM-8210 and the FPM-8210H is the allowable input power level. In this manual, any reference to "FPM-8210" applies to either model unless specifically stated. See Table 1.2, "FPM-8210/8210H Fiber Power Meters Specifications", on page 4 for details.

The FPM-8210 Front Panel

Each of the labeled areas on the front panel (GPIB, MODE, PARAMETER SETUP, or INPUT), and the display and adjustment sections of the front panel, are described below.

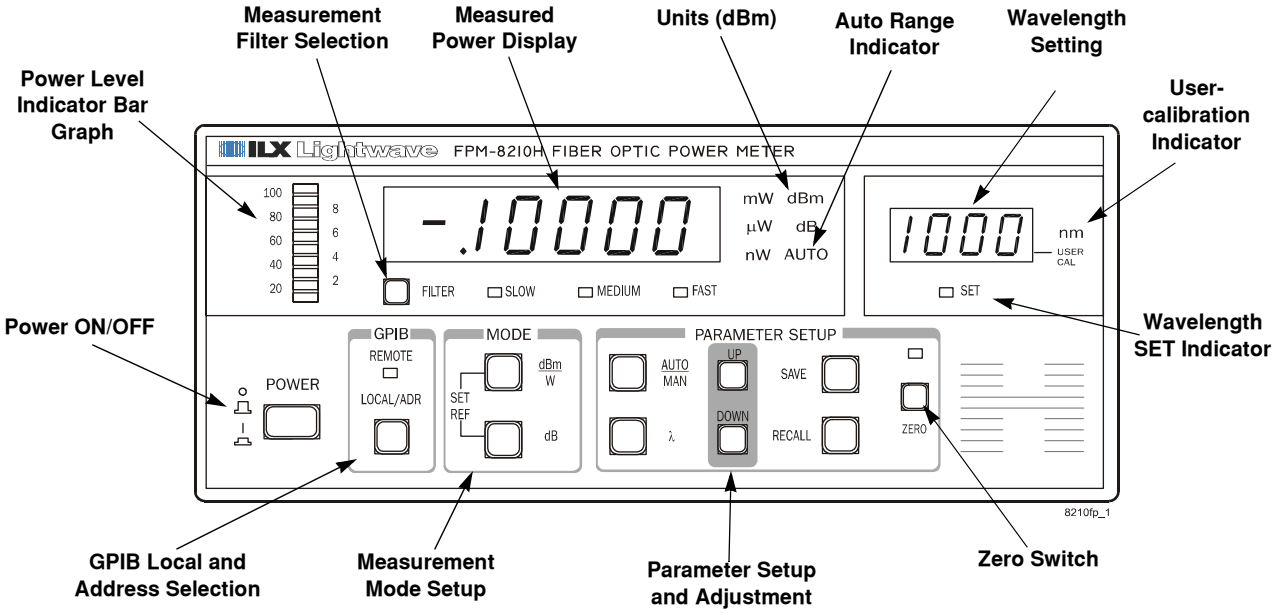


Figure 2.1 FPM-8210 Front Panel

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Front Panel Familiarization

This section describes the front panel controls.

Power On/Off



The POWER switch applies power to the FPM-8210 and starts the power up sequence described in Chapter 1 (see Power-Up Sequence on page 3).

GPIB Control

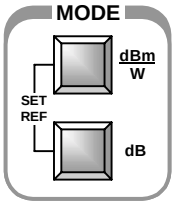


The GPIB section is located next to the Power switch on the left side of the front panel. The REMOTE light emmitting diode (LED) illuminates, indicating the FPM-8210 is under remote GPIB control. A flashing REMOTE LED indicates the GPIB controller has put the FPM-8210 in "Local Lockout mode"; in this mode the front panel is completely disabled, including the LOCAL/ADR switch below it.

The LOCAL/ADR button has two functions:

- In REMOTE mode (LED indicator steadily illuminated), press **LOCAL**/**ADR** to return control to the front panel ("local control").
- In LOCAL mode (indicator OFF), press **LOCAL**/**ADR** to display the GPIB address for three seconds. While the GPIB address is displayed, you can change it to any of 31 addresses from 00 to 30 by pressing the UP and DOWN switches in the PARAMETER SETUP section of the front panel. See Parameter Setup Control on page 7.

Mode Control



The MODE section sets the power display mode.

- Press **dBm**/**W** to select logarithmic (dBm) or linear (mW, µW, nW) units.
- Press **dB** to display power changes in dB relative to a reference value.
- Press **dBm**/**W** and **dB** together to set a reference value to the most recent power measurement.

Press **dB** and **RECALL** (see Parameter Setup Control on page 7) together to display the stored reference value for thee seconds.

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Parameter Setup Control

The PARAMETER SETUP section sets gain range and wavelength response, and includes the zero function. You can also save and recall setup parameters, including gain range, wavelength, display mode, filter mode, and user calibration offset value.

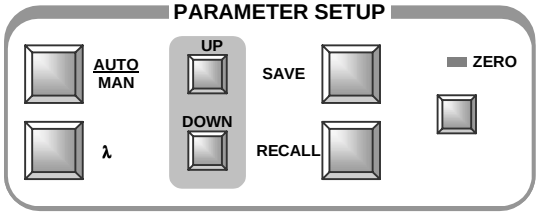


Figure 2.2 Parameter Setup Front Panel Controls

Gain Ranges

Press **AUTO/MAN** to alternately select auto-ranging or manual gain range setting. The AUTO indicator is illuminated in auto-ranging mode.

Gain range selection is the default function for the UP and DOWN keys when not enabled by another function, as described elsewhere in theParameter Setup Controlsection. If the AUTO indicator is on, pressing UP or DOWN turns the indicator off and steps one gain range.

For low level measurements, ILX Lightwave recommends stepping down the range as far as possible for improved resolution.

In Manual Gain Range Mode, eight different ranges may be selected by pressing the UP and DOWN keys. The front panel displays µW, nW or mW as appropriate. For more information about gain ranges, see Analog Output (BNC) on page 19.

Gain Range Display

By pressing and holding down the LOCAL/ADR button, the primary GPIB address is displayed as usual. For example if the primary GPIB address is 1, the front panel will display "-01-".

While simultaneously holding down the LOCAL/ADR and AUTO/MAN button, the front panel displays the current gain range setting. For example, if the current gain range setting is 7, then the front panel will display "--7--". The gain range can then be changed by continuing to hold down the LOCAL/ADR and the AUTO/MAN buttons and pressing the UP or DOWN button as appropriate. The instrument retains the gain range mode (auto or manual) only if the range is not modified. If the gain range is modified with the UP or DOWN buttons, then the instrument must be in manual gain range mode.

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Wavelength

Because the detector responds differently depending on wavelength, it is necessary to set the correct wavelength.

To set the wavelength:

1. Press λ to enable the wavelength setting and illuminate the SET indicator below the wavelength display.
2. While the SET indicator is on, press **UP** or **DOWN** to change the wavelength setting. The indicator remains illuminated for about three seconds.

For more information concerning wavelength, see Photodetector Responsivity on page 22.

Save and Recall

Use SAVE and RECALL to store and reuse FPM-8210 setup parameters for future use. These parameters include the gain range, wavelength, display mode, filter mode, and user calibration offset value. Stored setups save time and reduce the chance of setup error for tests that are repeated periodically.

Setup parameters are stored in non-volatile memory, so they are always available when you turn-on the instrument. You can save your own setup parameters in any of ten memory locations numbered from 1-10. When you RECALL that number, the FPM-8210 reconfigures to the stored setup parameters.

In addition, the FPM-8210 automatically stores two other configurations. When you turn off the FPM-8210, the instrument settings are stored and automatically recalled the next time you turn-on the FPM 8210. This happens whether or not you save the setup. Additionally, there is a consistent default configuration, stored as "0" (zero). Setup 0 sets the following configuration:

Function	Setting	GPIB Equivalent
Display mode	Linear (nW, µW, mW)	MODE: W
Wavelength	1550 nm	WAVE 1550
Filter mode	Medium *(average 10 measurements)*	FILTER MED
Range mode	AUTO	RANGE:AUTO
User cal value	1.000 *(indicator off)*	CAL:USER 1

Note: Note that the reference value is stored in volatile memory. Therefore, the reference is returned to 0.000 dBm upon any recall operation or a power down/up sequence.

If you recall setup zero by the front panel, GPIB mode is set to LOCAL. If you use GPIB to recall setup 0 (`*RCL 0`), GPIB mode is set to REMOTE.

To save a setup mode:

1. Press **SAVE** to display a memory number for three seconds.
2. Before the number display turns-off, press **UP** or **DOWN** to change the number as needed.

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3 When the desired memory number is displayed, press **SAVE** again.

To recall a setup mode:

1 Press **RECALL** to display a memory number for three seconds.

2 Before the number display turns-off, press **UP** or **DOWN** to change the number as needed.

3 When the desired memory number is displayed, press **RECALL** again.

If you do not press SAVE or RECALL within the three seconds of number display, the operation is aborted and the FPM-8210 returns to its previous state.

Zero

ZERO applies an offset to internal amplifiers that eliminates detectable fixed errors. These errors can be from internal effects such as detector dark current, as well as from external effects such as ambient light. Before any measurement, it is good practice to first zero the meter. The concept is similar to shorting the leads of a voltmeter and making sure the meter reads zero.

To zero the FPM-8210:

1 Make sure your fiber or connector is in place at the detector input and the light source is off.

2 Press **ZERO**. The process takes about ten seconds. During the zero process, the **ZERO** indicator blinks and the number 0 moves across the display. When the process is complete the display shows "-LO-".

If you press **ZERO** before the process completes, it stops the process with no change to the zero offset.

Note: The best results are obtained by minimizing external influences, because they are rarely stable. For this reason, the FPM-8210 limits the amount of acceptable zero offset. Error E-531 indicates there is too much ambient light for a reliable zeroing.

Filter Control

The FILTER control selects measurement averaging and display update rate. Measurement samples are taken every 50 ms. The SLOW and MEDIUM indicators momentarily turn-off when the display updates.

Indicator	Averaging	Display Update Rate
SLOW	100 measurements	5 seconds
MEDIUM	10 measurements	500 ms
FAST	(none)	50 ms

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Bar Graph Display

The Bar Graph display shows relative input level as a percentage of full scale for each gain range. The bright indicator signifies the ones' digit, and the dimmer indicators signify the tens' value. The tens' indicators are accumulative, while the ones' are not. Therefore, there is only one indicator lit for the ones' digit.

The bar graph update rate is always FAST. This allows you to monitor shorter-term fluctuations in measurements while displaying an averaged measurement.

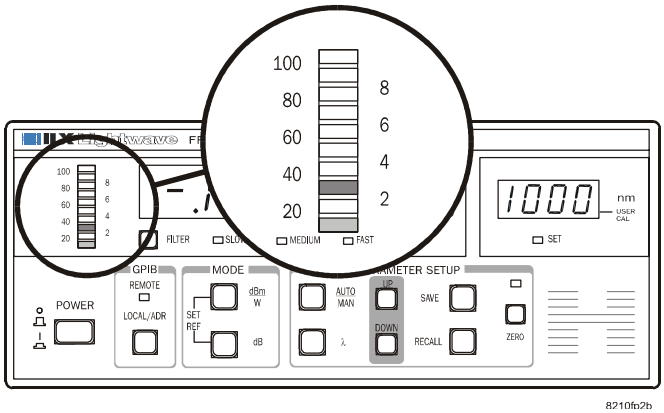


Figure 2.3 Bar Graph

User Calibration

User calibration (USER CAL) sets a multiplication factor that is applied to all FPM-8210 measurements. The USER CAL indicator (just right of the wavelength display) illuminates whenever the user calibration factor is any other value than the factory standard setting of 1.000. The range of USER CAL is 0.500 to 2.500. This means, for example, with USER CAL set to 0.500, all results are reported at half of their detected value.

To display or change USER CAL:

1. Press **LOCAL**/**ADR** and **dB** at the same time. The USER CAL factor displays for about three seconds.
2. While the USER CAL is displaying, press **UP** or **DOWN** to change it. The FPM-8210 saves USER CAL in non-volatile memory, so it retains this value the next time you turn-on the meter.

The most common application of USER CAL is calibrating the FPM-8210 to read correctly with an external attenuator. For example, if you attach a calibrated 3 dB attenuator, only 50% of the input signal gets to the meter. In this situation, set USER CAL to 2.000 and the meter displays correctly. Remember to consider the accuracy of the attenuator as well as the meter in attenuated measurements.

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Linear Power Mode Display

Depending on the input power level, the FPM-8210 in linear mode displays power in units nW, µW, or mW. Within these ranges, the decimal point is moved as appropriate for the value:

Power (watts)	$<100 \times 10^{-9}$	100×10^{-9} to $<1 \times 10^{-6}$	1×10^{-6} to $<100 \times 10^{-6}$	100×10^{-6} to $<1 \times 10^{-3}$	1×10^{-3} to $<100 \times 10^{-3}$	100×10^{-3} to <1W	≥1W
Units	nW	nW	µW	µW	mW	mW	mW
Decimal places	3	2	3	2	3	2	1
Example	85.436 nW	327.24 nW	38.361 µW	542.76 µW	38.974 mW	756.58 mW	1062.3 mW

To keep the display from rapidly changing when measuring at one of these boundaries, the display in linear mode includes 1% hysteresis. To illustrate, here is an example of changing from 99 nW to 100 nW (1% = 1 nW):

Increasing	Decreasing
98.999	100.01
99.000	100.00
99.001	99.99
99.002	99.98
.	99.97
.	.
99.998	.
99.999	99.01
100.00	99.00
100.01	98.999
100.02	98.998

Error Codes

FPM-8210 indicates front panel operation errors on the measurement display with an error code number. See Error Code Tables on page 73 for a list of error codes.

The FPM-8210 Detector Head

More than a simple integrating sphere, the innovative integrating cavity design in the FPM-8210 external detector head is the primary reason the FPM-8210 Fiber Optic Power Meter is able to deliver such remarkable repeatability in a production workstation environment. Key goals achieved in this design and their benefits to you include:

Table 2.1 Design Feature Benefits

FPM-8210 Design Feature	Benefit
Minimal response to changes in state of polarization	Measure component polarization dependent loss without concern for meter errors.

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Table 2.1 Design Feature Benefits

Minimized response to changes in fiber extension in the holder	Obtain the same results with different users.
Minimized response change from rotating the fiber holder with a non-angled cleave	No need to rotate the fiber holder for maximum reading with a non-angled cleave.
Bare fiber endface cannot contact detector surface	Impossible to damage detector with fiber.
Bare and connectorized fiber measurements from same fiber endface position	Compare bare and connectorized fiber measurements with confidence.
Production-tested bare fiber holder to easily guide the fiber to the correct place every time	No tedium to slow your testing or introduce errors.
Detector head designed to accept ILX Lightwave BF-820 or Agilent 81000BA bare fiber holders	Use ILX Lightwave BF-820 holder with Agilent power heads, or use Agilent 81000BA holders in the ILX Lightwave FPM-8210. This interchangeability means that there is no need to change established procedures, re-train, or buy different holders.
Precision quick-align threadless adaptors for bare fiber holder and for most connector types	Just push on, pull off. It easily self-aligns and snaps into place. No threads!

Protecting the Cavity

The detector cavity entrance is small (~2.5 mm) so it will not tend to pick up debris. However over time dust and pollution in normal air can degrade measurement accuracy. After using the detector, protect the detector cavity by covering the entrance with the plastic shipping protector over the bare fiber adaptor ring, or leave a connector or bare fiber holder in place.

Cavity contamination can also happen if you are doing environmental testing where humidity causes condensation. If you suspect the cavity has been contaminated, contact ILX Lightwave Customer Service. In most cases we can clean it and recalibrate it for you. The detector is not separable from the meter because its unique calibration is stored in the meter.

Contact ILX Lightwave Customer Service for a replacement protective cap if needed. See Comments, Suggestions, and Problems on page xii for contact information.

Accessory Case

Model CA-500 accessory case holds your connector adaptors, bare fiber holder, and bare fiber adaptor ring. Protect these precision optical components by storing them in their appropriate slot in this case.

Measurements Through a Connector

With adaptors available from ILX Lightwave, the FPM-8210 can make measurements through most common fiber optic connectors.

To remove an adaptor, grasp its outer ring and pull it out. Small spring-loaded balls (ball plungers) in the side of the adaptor mate with a channel in the FPM-8210 head to hold the adaptor in position.

To install an adaptor:

1. Align the mating hole on the connector with the alignment pin on the head.
2. Press it into place, then rotate it slightly until the alignment pin has seated. Make sure the

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adaptor is fully seeted around its circumference..

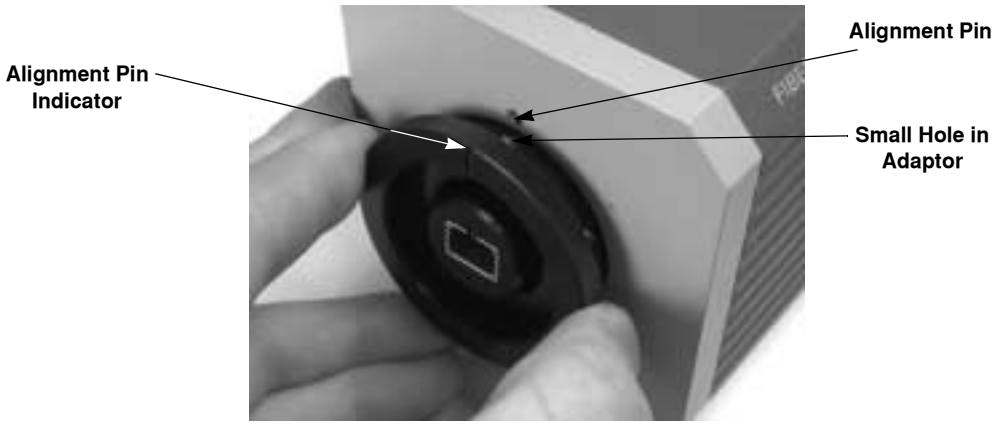


Figure 2.4 Seating the Alignment Pin

Once the adaptor is in place, you can connect patchcords repeatedly to the meter. There is no need to remove the adaptor unless you need to use a different connector type.

Note: Always clean the tip of the connector ferrule before a measurement, using proper tools and good technique. The core of a single-mode telecom-grade fiber is only about 9µm in diameter; the smallest contaminant can cause significant errors.

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Measurements Through Bare Fiber

Development of the FPM-8210 Fiber Optic Power Meter had its roots in solving measurement issues that affect repeatability when the fiber endface is not polished in a connector ferrule. The result was a fiber optic power meter optimized for bare fiber measurement: highly repeatable, easy to use, and virtually unaffected by polarization state or by rotating the fiber holder.

Power meters with a front panel detector such as the ILX Lightwave FPM-8200 normally have their detector mounted at an angle to prevent reflections back into the input fiber. However, this arrangement is less than ideal for measurements through bare fiber. Among the detractors from measurement repeatability are:

- Variation in distance from the fiber endface to the detector—how far it extends from the fiber holder. If you are not careful, you can scratch the detector face.
- Slight variations in the angle of the glass cleave at the core exit point. In a standard telecom fiber the core containing the light is only about 0.5% of the endface surface area. This is the only part that matters for exit angle.

  Here is an illustration of the problem with an angled fiber cleave and angled detector *(angles exaggerated)*:

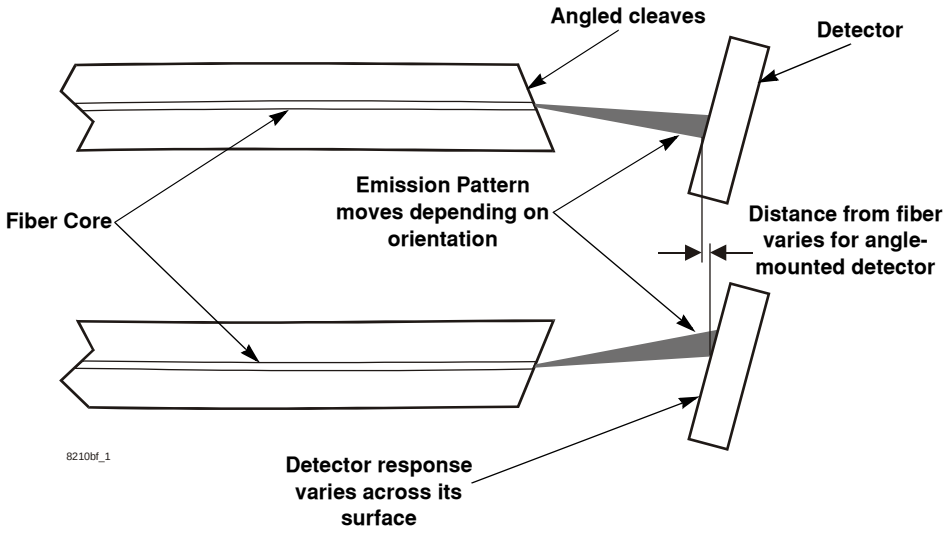


Figure 2.5 Bare Fiber Measurement Diagram

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The CA-120 Bare Fiber Adaptor Ring

The CA-120 Bare Fiber Adaptor Ring is a round ferrous ring that mounts in the front of the FPM-8210 head, and mates with magnets in either the ILX Lightwave BF-820 Bare Fiber Holder or the Agilent 81000BA Bare Fiber Holder. The adaptor ring has no alignment hole, so you can just press it into place in the detector head. Check that the adaptor ring is flush to the front of the detector all around. Rotating the ring helps to ensure that it is seated properly.



Figure 2.6 CA-120 Bare Fiber Adaptor Ring

Measuring with the BF-820 Bare Fiber Holder

The ILX Lightwave BF-820 Bare Fiber Holder was designed, tested, and optimized for production workstations. Its opening action and internal alignment guides make it easy and fast to place the fiber correctly every time.

1 Carefully strip, clean, and cleave the fiber. Strip the jacket, then strip at least 1.3 cm of buffer ($^1/_2$-inch) from the fiber. If the fiber endface touches anything after cleaving, clean it and cleave it again.

Note: The BF-820 is designed for 125 µm clad fiber.

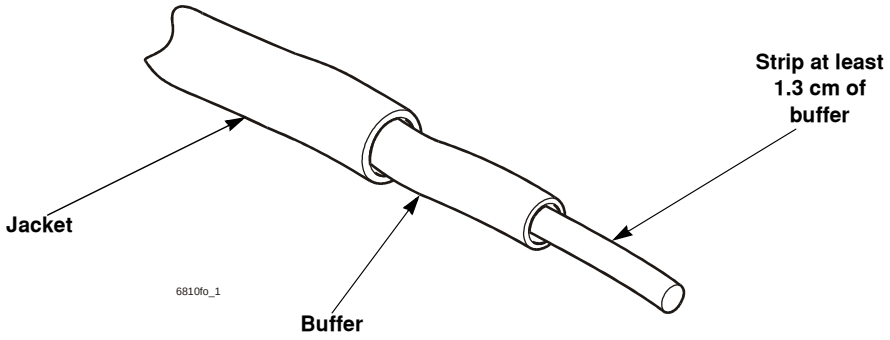


Figure 2.7 Strip and Cleave the Fiber

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2 Squeeze the BF-820 bare fiber holder by its feet to open the body and expose the alignment guides.

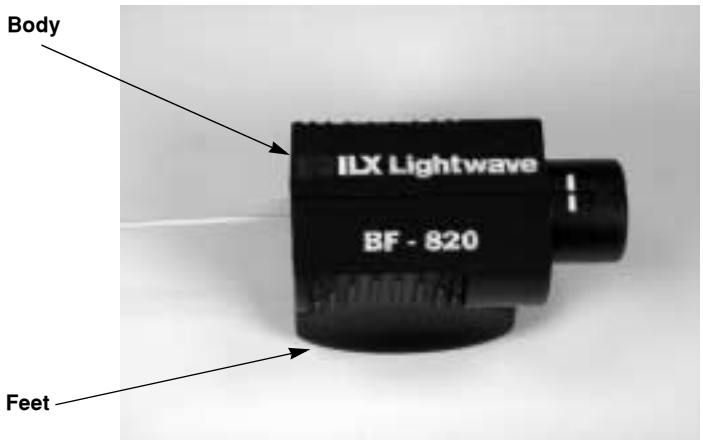


Figure 2.8 BF-820 Bare Fiber Holder

3 Lay the fiber in the holder with the stripped and cleaved fiber protruding from the nose (detector-side) of the holder.

4 Gently pull the fiber until the buffer is aligned with the marks on the holder. Make sure the buffer does not extend beyond the marks, toward the nose-end of the holder.

The fiber must extend between1.0 mm and 5.0 mm from the holder to ensure accurate measurements from the FPM-8210.

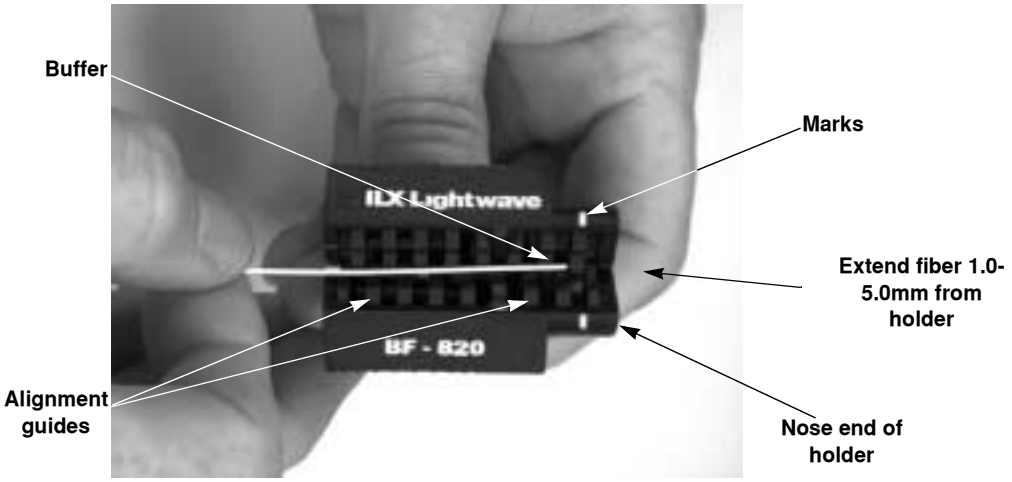


Figure 2.9 Place Fiber in BF-820 Fiber Holder

5 Release the feet and close the holder. The holder is held shut by its magnets and spring.

6 Grasping the holder by the body, insert the fiber holder into the bare-fiber adaptor ring making sure the fiber the endface does not touch anthing. If the fiber endface makes

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contact with anything, it must be cleaned and recleaved.

Note: Make sure to grasp the holder by the body when inserting or removing it from the detector. Grasping the holder by the feet can cause the bare fiber adaptor ring to come loose.

7 Connect (or turn on) your light source.



Figure 2.10 Inserting the BF-820

Measuring with the Agilent 81000BA Bare Fiber Holder

Refer to Agilent documentation for detailed instructions on use and care of the 81000BA. If you are familiar with the Agilent 81000BA bare fiber holder and have established procedures, the FPM-8210 does not require you to change those procedures.

The measurement procedure is basically the same as the BF-820 described above. Be sure to strip enough fiber to allow 3.0 mm protruding from the front of the Agilent holder after you have the fiber in place.

Check also that the fiber extension is straight from the front of the holder. If it is not straight, this indicates the holder is bending the fiber. Bending will definitely affect measurement accuracy, and may cause the fiber end to break off.

Measuring with Cleaved Angles

For some applications, you may want to use a special cleaver capable of cleaving fiber at an angle. This can reduce source instability caused by reflections from the cleaved endface. The FPM 8210 can reliably make this measurement.

If your fiber has an intentional cleave angle, rotate the fiber holder after inserting it into the head and check whether this affects the result. For small cleave angles (< ~2°) you will probably not see any effect. For larger cleave angles, rotate the holder for a maximum reading.

Be sure there is enough relaxed fiber behind the holder that this does not induce bending stresses.

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The FPM-8210 Back Panel

This section describes the back panel on the FPM-8210/H.

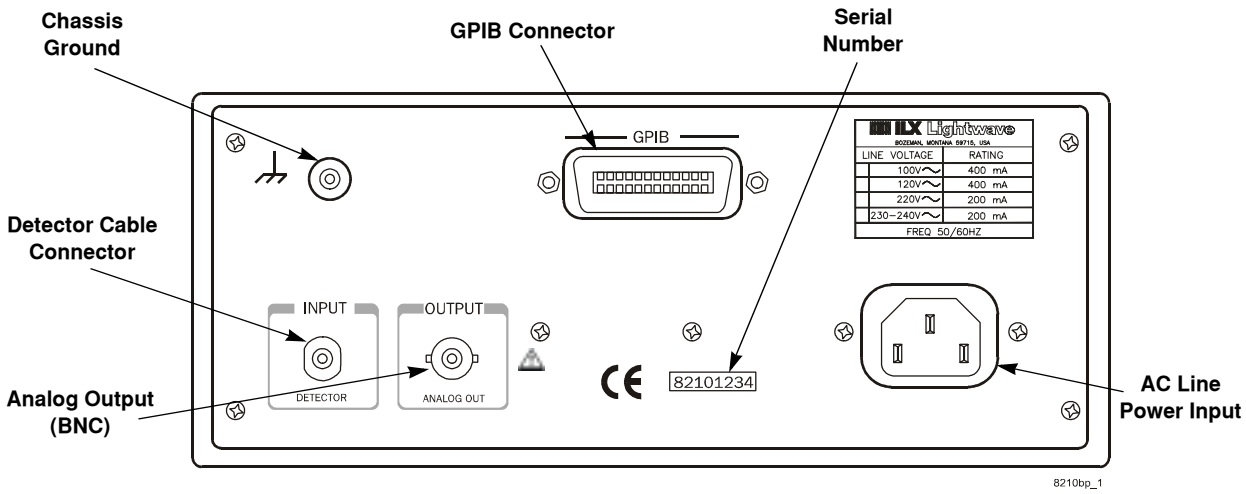


Figure 2.11 FPM-8210 Back Panel

GPIB Connector

The GPIB connector is located at the top center of the back panel. See Chapters Three and Four for more information about GPIB control.

AC Line Power Input

The FPM-8210 meter must be connected to a properly rated AC source in order to operate. Line voltage and frequency limits are defined in Specifications on page 3. You are responsible for ensuring the connection meets your local electrical code requirements. In most cases, ILX Lightwave Customer Service can supply special power cords.

WARNING

To avoid electrical shock hazard, connect the FPM-8210 only to a properly earth-grounded, 3-prong receptacle. Failure to observe this precaution can result in severe injury or death.

If your FPM-8210 meter does not turn on (no response) with AC power applied, make sure that AC power is available at the instrument end of the power cord: simply plug the power cord into another working instrument. If this cord is okay, contact ILX Lightwave Customer Service.

Chassis Ground

For your convenience, a chassis-ground post connector is located on the FPM-8210's back panel. This connection point is electrically identical to the earth ground through the AC power line third pin.

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Analog Output (BNC)

A BNC output connector is provided to give you direct access to the amplified photodetector signal. Keep the FPM-8210 in manual range mode when you use the analog output. This is a very low-noise, stable output normalized to 10V, representing percentage of full range. (For example: 7.1V = 71% of range). This information is shown by the bar graph on the front panel but with greater resolution. Since resolution is mostly determined by the instrument that you connect it to, this output is useful for monitoring small changes. With 1000Ω typical output impedance, you can directly connect it to most dataloggers or digital voltmeters. Analog output is most commonly used for relative power measurements, or as a controlling input for automatic fiber alignment systems. For such tests, the absolute value represented by the analog output voltage is usually not of concern, only the change relative to a starting point.

For monitoring relative power measurements, put the meter in auto range mode to find the appropriate gain range; then set the meter to manual range mode to avoid changing gain ranges during the test.

Gain Range Boundaries

Understanding how gain ranges and detector response relate to analog output can be useful in interpreting analog voltage. Gain ranges are related to the current from the photodetector, not to direct light power, because semiconductor photodetector response varies with wavelength.

The FPM-8210 meter has eight gain ranges. Each range increases gain by 10x over the previous range. The analog output varies 0 V to 10 V representing minimum to maximum current output for that range. The maximum current for each range is:

Table 2.2 Gain Range Boundaries

Range	Maximum Current
0	10 mA
1	1 mA
2	100 µA
3	10 µA

Range	Maximum Current
4	1 µA
5	100 nA
6	10 nA
7	1 nA

Determining Range

Depressing and holding LOCAL/ADR and AUTO/MAN together displays the gain range setting. For example, if the current gain range is 7, the front panel displays "--7--".

> **Note:** Depressing and holding only the LOCAL/ADR button, displays the primary GPIB address. For example, if the primary GPIB address is 1, the front panel displays "-01-".

While LOCAL/ADR and AUTO/MAN are depressed together you can change the gain range by pressing UP or DOWN. If the FPM-8210 was in autorange, changing the range this way will change it to manual range mode.

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Relating Optical Power to Analog Voltage

The most direct way to relate optical power to analog voltage is to read the power from the front panel or by GPIB while noting the voltage. If you set up a GPIB automated system with a datalogger or voltmeter, you can directly correlate power and analog output voltage in your data.

You can also get this information from calibrated detector response data. You can get the detector response data in two ways:

- The GPIB query **RESP?** tells you the calibrated detector response in mA/mW for the currently set wavelength. You can get the response for any wavelength by first using the **WAVE** command:

  For example: `WAVE 1480; RESP?`

  This sequence returns the calibrated detector response for 1480 nm.

- The factory calibration certificate includes a table of detector response at every 10 nm.

To convert analog voltage to optical power, follow these steps:

1. Make sure optical power input is ON.
2. Connect a voltmeter to the analog output.
3. Press and hold **LOCAL**/**ADR** and **AUTO**/**MAN** to display the gain range setting.
4. Using Table 2.2 on page 19, convert the voltage to detector current. For example, if the display shows "--3--", the instrument is set to range 3. pressed **UP** three times, the FPM 8210 is on range 3. A voltage reading 5.0V = 50% of scale = 5 µA.
5. Divide current by detector response to get optical power. For example, using 5 µA current, and 0.01193 mA/mW detector response:

$$\frac{0.005\text{mA}}{0.01193\text{mA/mW}} = 0.419\text{mW} = -3.77\text{dBm}$$

volt_powerEQ

This example is for 5.0V, range 3, detector responsivity 0.01193 mA/mW. Refer to Appendix A, Conversion Tables for converting mW to dBm.

Accuracy of the analog output is not a factory specification. However you will find it to be stable and reliable.

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Operating Guidelines

The discussion below presents guidelines for operation, as well as some common operating procedures. Remote operations are discussed in the next chapter.

Warm-up and Environmental Considerations

To achieve rated accuracy, let the FPM 8210 warm up for at least 1 hour before use. Operate the meter within the environmental limits specified in Chapter 1. Best accuracy will be available for operation near the calibration temperatures.

Summary of Operating Procedures

The following list is a summary of procedures discussed in more depth earlier in this chapter.

1 Install the appropriate fiber adaptor on the front panel **INPUT** connector. Connect your input fiber patchcord.

2 Recall your setup parameters by pressing **RECALL**, or by setting the parameters individually as described in the following steps.

3 If you need to set measurement parameters:

3a Press λ and adjust the wavelength by pressing **UP** or **DOWN**.

3b Press **AUTO**/**MAN** to select either auto-ranging or manual gain range. In manual gain mode, pressing **UP** or **DOWN** steps the gain by a factor of 10. To set a particular gain range, refer to the discussion earlier in this chapter.

4 Always check the USER CAL gain factor by pressing **dB** and **LOCAL**/**ADR** together. Normally this factor should be 1.000. You can change the gain factor while it is displayed by pressing **UP** or **DOWN**.

5 Input power:

5a In Manual Range mode, display "**- OL -**" indicates the input power is greater than 99.1% of range. In Auto Range mode, this indicates input power is greater than 200 mW for model 8210, or 2 W for model 8210H.

5b In Manual Range mode, display "**- LO -**" indicates the input power is less than 5.0% of range. In Auto Range mode, this indicates input power is greater than –80 dBm for model 8210, or –70 dBm for model 8210H.

6 To save a new setup, press **SAVE** followed by **UP** or **DOWN** for a memory number (1 through 10), then press **SAVE** again. Whether or not you save the setup, at next power-up the FPM 8210 will return to the same setup as you left it.

Measuring Higher Power

The FPM-8210 will not be damaged by input power up to 10W. However, linearity generally moves outside specification limits above the upper specified input power limit (see Table 1.2 on page 4).

The best way to measure high power is to use a calibrated attenuator. You can then use USER CAL to set a compensating factor into the FPM-8210 so it reads correctly.

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Understanding the Calibration Certificate

Your FPM-8210 is supplied with a certificate for NIST traceable calibration from ILX Lightwave's NVLAP® certified laboratory. The following section explains the information on your calibration certificate.

Photodetector Responsivity

The FPM-8210 Fiber Optic Meter is a stable low noise current meter with a photodetector inside a special optical cavity. The cavity randomizes light input, so changes in input polarization and pattern orientation have little net effect on the detector. Factory calibration is a process of recording detector current while varying wavelength. The result is a table of detector responses every 10 nanometers, in mA per mW. When you connect input light, the FPM-8210 measures detector current, then uses your wavelength setting to look up the conversion factor on the calibration table. Interpolation algorithms are used for wavelengths between these calibration points. Figure 2.12 is a sample of detector response plotted as a function of wavelength, based on data from FPM-8210 meter calibrations performed at ILX Lightwave's NIST-traceable calibration laboratory:

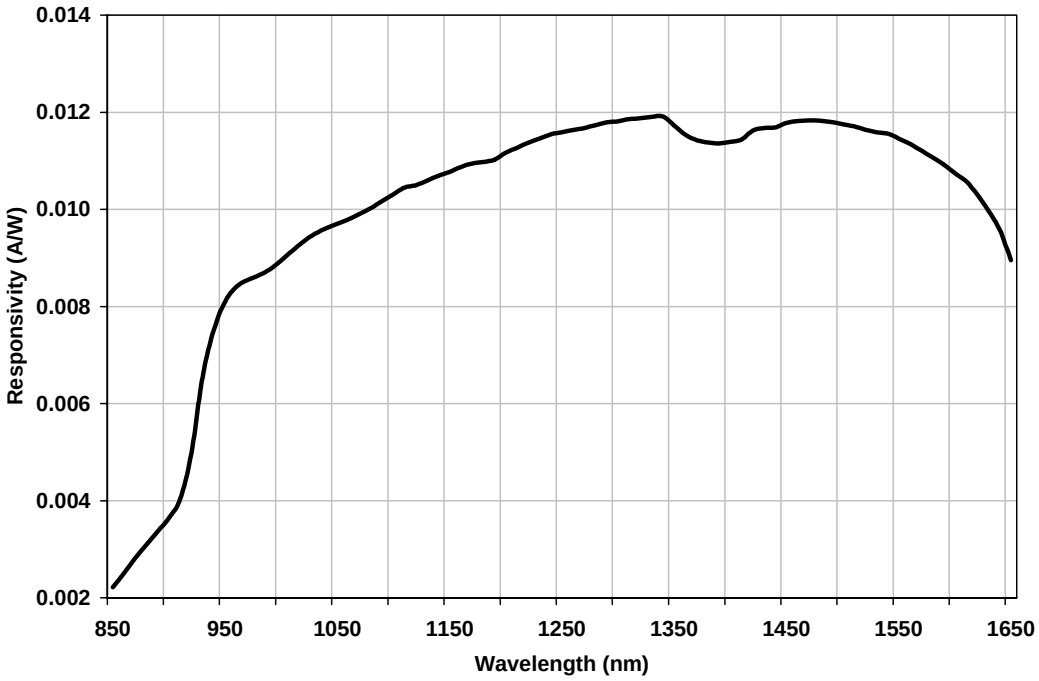


Figure 2.12 Sample Detector Response

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The detector response is shown as photodetector current (amperes) per unit of optical power (watts). If you are familiar with normal InGaAs detector responsivity values, you may also note that these values are reduced by the loss in the FPM-8210 integrating cavity. Note also:

- The highest detector current (greatest sensitivity) is at the longer wavelengths normally used for telecom work.
- Changes in detector response are significant enough that the meter must know the wavelength in order to properly display optical power.
- The flatness (or steepness) of the curve at any point is a measure of how much effect an error in wavelength input will have on the measurement result.
- Detector response is less at shorter wavelengths.

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CHAPTER 3

REMOTE OPERATION

GPIB (General Purpose Interface Bus) is the common name for ANSI/IEEE Standard 488, an industry standard for interconnecting test instruments in a system. Every operation that you can perform from your FPM-8210 or FPM-8210H front panel can also be done remotely through the rear panel GPIB interface. In addition, some features are available only through GPIB. For example, the DELAY command automatically sets a delay time before the execution of further commands.

The only difference between the FPM-8210 and the FPM-8210H is allowable input power level. In this manual, any reference to "FPM-8210" applies to either model unless specifically stated. See the specification table in Chapter 1 for details.

Remote control can be useful for building an automated test system that includes other instruments. It is also useful for structuring and collecting data for longer tests, such as environmental and component burn-in tests.

Features:

- A concise and straightforward command set
- Full talk/listen capability
- Full serial poll capability, with SRQ
- Full local/remote capability including LOCAL LOCKOUT

The FPM-8210 can be completely and effectively controlled by any controller that meets ANSI/IEEE-488 standards. This chapter explains GPIB concepts, system setup, and command syntax. Chapter 4 is a reference guide of FPM-8210 responses to GPIB commands.

This chapter assumes:

- Your computer has an appropriate GPIB interface.
- You have a basic knowledge of GPIB programming for instrument control, or other information sources for reference.
- You are familiar with the operating controls on the FPM-8210. (Chapter 2)

GPIB interface adaptors and support software for standard desktop PCs are available from several manufacturers. Contact ILX Lightwave Customer Service for more information.

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Basic GPIB Concepts

The information in this basic concepts discussion is normally not necessary to successfully operate the FPM 8210 through its GPIB interface, because your computer's GPIB controller will usually handle them for you. However this is a useful perspective in understanding GPIB.

Data and Interface Messages

GPIB devices communicate with each other by sending data and interface messages. Data contains device-specific information such as programming instructions, measurement results, and instrument status. Each device has an address number, and ignores all data traffic not addressed to it. Depending on its content, data is often called a "device dependent message" or a "device dependent command". Interface messages manage the bus, with functions such as initializing the bus and addressing or unaddressing devices. In addition, some individual bus lines are designated for this purpose (see below). The end of this chapter includes information on interface messages supported by the FPM-8210.

Talkers, Listeners, and Controllers

Every GPIB system consists of one or more "talkers" and "listeners", and often at least one "controller". Talkers supply data. Listeners accept data. A system can consist of simply a talker and listener, for example a meter connected to a datalogger or chart recorder. Controllers designate talkers and listeners. A controller is necessary when the active talkers or listeners must be changed. When the controller is a computer, it often also designates itself as a listener so it can collect data from designated talkers.

If there is more than one controller, only one can be the Controller In Charge (CIC). Control can be passed from one controller to another. In a multiple controller system, there can be one "System Controller" capable of asserting control (becoming CIC).

GPIB Cable Connections

Standard GPIB connectors can be connected together (stacked), allowing you to configure the system linearly, or in a star configuration.

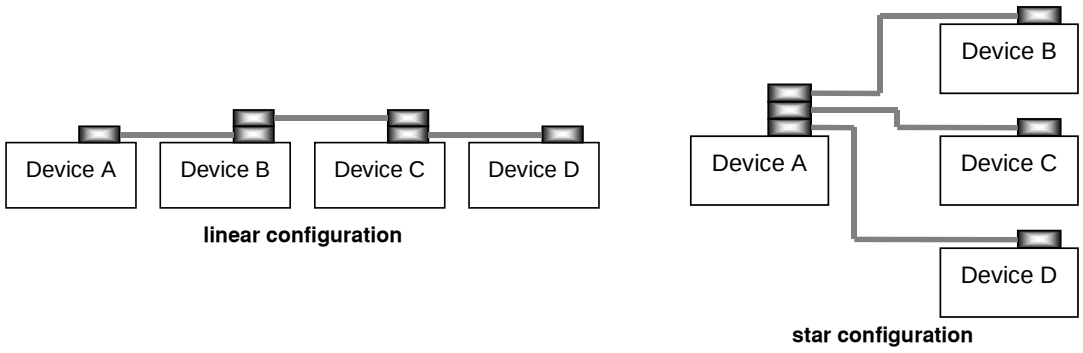


Figure 3.1 GPIB Cable Connections

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The GPIB Connector

The standard GPIB connector consists of 16 signal lines in a 24-pin stackable connector. The extra pins are used for some twisted-pair wires. There are eight data input/output (IO) lines, three handshake lines, and five interface management lines.

Eight data input/output (DIO) lines carry both data (including device dependent commands) and interface messages. The ATN interface management line determines whether these lines contain data or interface messages.

Three handshake lines ensure that all data and messages are reliably transferred:

- NRFD (not ready for data) indicates whether a device can receive the next byte of data or message.
- NDAC (not data accepted) indicates whether a receiving device has accepted a byte of data or message.
- DAV (data valid) indicates that the signal levels on the data lines are stable and available for the receiving device(s) to accept.

Five interface management lines control the flow of information:

- ATN (attention) is set by the controller in charge to define the I/O lines for data or interface messages.
- IFC (interface clear) is set by the system controller to initialize the bus and assert itself as controller in charge.
- REN (remote enable) is set by the controller to place addressed devices into remote or local (front panel) control mode.
- SRQ (service request) can be set by any device in the system to request service from the controller.
- EOI (end or identify) is used by talkers to identify the end of a message.

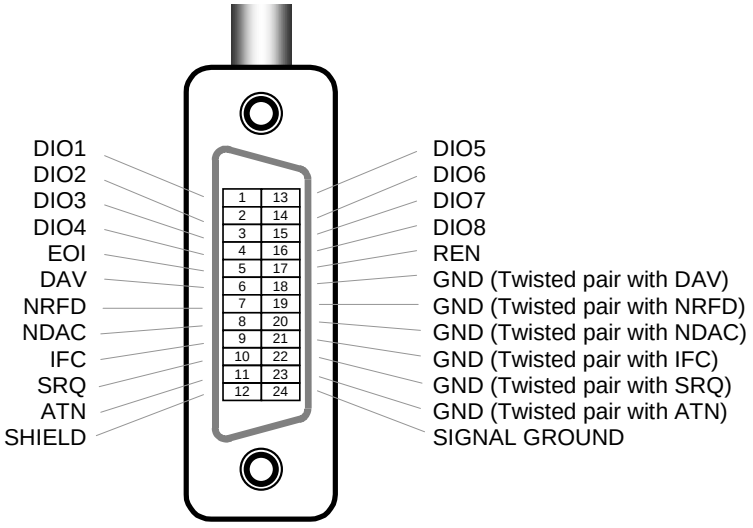


Figure 3.2 GPIB Connector Diagram

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Configuring the GPIB Controller

Refer to your computer's GPIB interface documentation for details on how to set it up. These settings are important:

Primary GPIB address:	0 through 30
Secondary GPIB address:	NONE
Timeout:	1 sec
Serial poll timeout:	1 sec
Terminate read on EOS:	No
Set EOI with EOS on writes:	Yes
Type of compare on EOS:	7-bit
EOS byte:	00h

Please note that overlooking these settings is a common cause of problems.

Changing Operation from Local to Remote

Sending a command over the GPIB bus addressed to the FPM-8210 automatically puts the instrument in REMOTE mode. In this mode the REMOTE indicator is ON. When the instrument is in REMOTE mode, press **LOCAL**/**ADR** to return to LOCAL (front panel) control.

If the REMOTE indicator is flashing ON/OFF, the controller has completely disabled the front panel with a local lockout (LLO) command.

Setting the GPIB Address

In LOCAL mode (REMOTE indicator OFF), press **LOCAL**/**ADR** to display the GPIB address for about 3 seconds. While the GPIB address is displayed, you can change it to any of 31 addresses from "- 00 --" to "- 30 -" by pressing **UP** or **DOWN**. Extended GPIB addressing (beyond 30) is not implemented in the FPM-8210.

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Command Syntax

The discussions below describe command syntax and structure. You need this information to effectively write GPIB control programs for the FPM-8210. The syntax of FPM-8210 GPIB commands follow the rules defined in the ANSI/IEEE-488 standard.

ANSI/IEEE-488 uses standard terminology. To clarify understanding, we use simpler terms for this manual. See Table 3.1.

Table 3.1 ANSI/IEEE-488 Terminology

Standard Term	In This Manual
Program Message	Command String
Program Message Unit	Command
Program Header	Command Mnemonic
Program Data	Parameters, or Data

Letters

Any GPIB command or query must contain all of the letters which are shown in upper case in the command definition. Some of the device dependent commands include additional optional letters shown in lower case in the command reference (Chapter 4). Upper/lower case does not matter to the FPM-8210, it is just used in this manual to identify optional letters. The optional letters must be in the correct sequence. Some examples of what works, and what does not:

Okay	Not Okay
DIS	DS
Disp	dsp
Displ	dply
Displa	DSPLY
Display	disply

The extra letters are allowed so you can make your control programs more readable.

White Space

"White space" is normally the space character (space bar). A single white space must separate a command from its parameters or data. For example:

Okay	Not Okay
DELAY 500	DELAY500

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To enhance readability you can also use one or more white spaces before a comma, semicolon, or terminator. Since your computer normally puts the terminator at the end of each command string (line), this simply means that an extra space character at the end of your command line works OK.

A query has no space between the mnemonic and the question mark. For example:

Okay	Not Okay
TIMER?	**TIMER ?**

Note that too many consecutive white spaces can overflow the FPM-8210's 256-byte data I/O buffer.

Terminators

A program message terminator identifies the end of a command string. These are the valid terminator sequences acceptable to the FPM-8210:

- <NL>
- <^END>
- <NL><^END>

The line length is limited by the 8210's 256-byte I/O buffer. The totol allowable is not necessarily 256 characters, because output commands in the command line use the same buffer.

Many computers terminate with <CR><NL><^END> (Carriage Return - New Line - EOI). This is not a problem, because the FPM-8210 ignores <CR> (Carriage Return) as white space.

The FPM-8210 terminates its responses with <CR><NL><^END>, unless you use the **TERM** command to change it.

If you encounter problems with GPIB communications with the FPM-8210, the terminator string can sometimes be the cause. Refer also to your GPIB interface (controller) manual.

Command Separators

You can put more than one command on the same line (same command string) if you separate them with a semicolon. The semicolon can be preceded by one or more spaces. Examples:

```
Mode:dB; Ref 1.0; Filter FAST
Mode:dB ; Ref -10.3 ; Filter SLOW
```

Parameters

Some commands require a parameter. For example, you can set FPM-8210 wavelength response to 1540 nm with the command **WAVE 1540**, where "1540" is the parameter. The parameter must be separated from the command by at least one space.

The syntax symbol <`nrf value`> refers to the flexible numeric representation defined by the GPIB standard. It means that you can represent numbers in integer or floating point form, or in engineering/scientific notation. The IEEE-488 standard uses the names NR1, NR2, and NR3

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respectively to denote "integer", "floating point", and "scientific notation". For example the number "twenty" may be represented by any of the following ASCII strings:

Integer	20	+20	NR1
Floating point	20.0	+20.0	NR2
Scientific notation	2.0E+1 2.0e+1	+2.0E+1 +2.0e+1	NR3

For more information on these definitions, refer to the IEEE-488 standard.

There are no default values for omitted parameters. If a command is expecting a parameter and none is entered, an error is generated.

Command Tree Structure

Some FPM-8210 device-dependent GPIB commands are compound commands, in which the first mnemonic opens a path to a set of commands relating to that path. The second mnemonic then defines the actual command. For example in the command `Mode:dB`, `Mode` opens the command path to FPM-8210 modes, and **dB** defines the relative dB mode. This is similar to defining a path for a computer file by starting with the root directory and listing intermediate subdirectories.

The diagram below illustrates this structure. All other (non-compound) commands are at the root of this tree.

> **Note:** The `Mode:dB` command accomplishes the same result as pressing the **dB** button on the front panel.

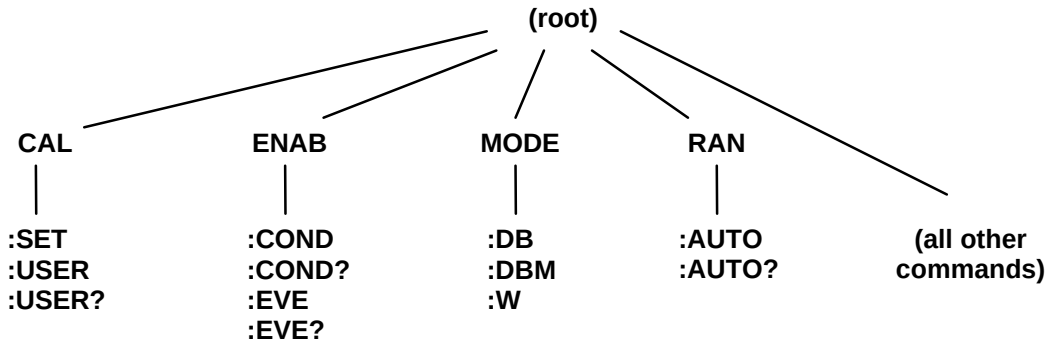


Figure 3.3 Command Tree Structure

The colon character (**:**) is important to using this structure. It plays two syntax roles:

- A colon (with no spaces) must separate the command path from the command. In the example above, there must be a colon and no spaces between **MODE** and **dB**.:

Okay	Not Okay
Mode:dB	Mode : dB Mode dB

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- A leading colon on a command causes the FPM-8210 to begin searching for the next command at the root node. Otherwise (after a semicolon) the FPM-8210 will first search the most recently used node for the command. These examples illustrate this distinction:

```
ENAB:COND?; EVE?

ENAB:COND?; :EVE?
```

These commands are different because **EVE?** is a command on the **ENAB:** path, and also exists at the root level. Each command string queries enabled condition, then another register. The first command string queries the events enabled register. The second string queries the event status register. The contents of these two registers can be different, with confusing results.

Syntax Summary

GPIB commands must contain all of the letters shown in upper case in the command definition. Optional letters shown in lower case for some device dependent commands in Chapter 4, GPIB Command Reference are useful for clarity, but must be in the correct sequence. Upper/lower case does not matter to the FPM-8210.

A single white space must separate a command from its parameters or data. White space is normally the space character (space bar). Other control characters are also interpreted as white space. Do not use white space before the question mark in a query command.

If you encounter problems with GPIB communications, the terminator string can be the cause. Refer also to your GPIB interface (controller) manual. The FPM-8210 accepts <NL>, or <^END>, or <NL><^END> as a command line terminator. Many computers terminate with <CR> <NL> <^END> (Carriage Return - New Line - EOI). The FPM-8210 ignores <CR> (Carriage Return) as white space. The FPM-8210 terminates its responses with <CR><NL><^END>, unless you use the **TERM** command to change it.

You can put more than one command on the same line (same command string) if you separate them with a semicolon.

GPIB uses a flexible representation for numeric parameters: integer, floating point, or engineering/scientific notation. There are no default values for omitted parameters.

Some FPM-8210 device-dependent GPIB commands are compound commands, in which the first mnemonic opens a path to a set of commands relating to that path. The second mnemonic then defines the actual command.

Following are examples of invalid syntax command strings that will produce errors:

Table 3.2 Invalid Syntax Command Strings

COMMAND	COMMENT
Mode dB	Compound command, missing colon between **MODE** and **DB**.
Mode:dBm Range:Auto	Missing semicolon between commands.
DIS ?	Space not allowed before question mark in queries.
Ran3;dis?	Missing space between **Ran** and parameter **3**.
Disply ON	Optional letters must follow the correct order.
Wave	Wavelength parameter missing.

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Internal Registers

Internal registers are used to inform the control program of events and conditions.

Concepts

The FPM-8210 includes three internal status registers to inform your control program of events and conditions:

- Standard event status—8-bit register required by GPIB standards
- Event status—16-bit register with additional event status
- Condition status—16-bit register with condition information

For example, operation complete (event) and over-range (condition) are reported in the appropriate bits of registers as a 1 (true) or 0 (false).

Each register is summarized into a single bit, which has an assigned place in a "status byte" register. The status byte register has a similar summary bit that initiates a service request.

For each register there is a corresponding enable register. Use the enable register as a mask so only the conditions you want to check are reported in the status byte register. This diagram illustrates the concept of enable registers:

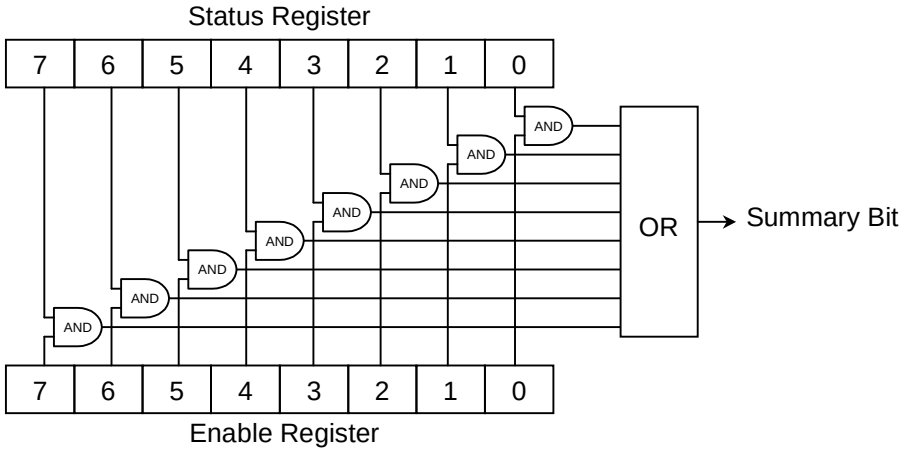


Figure 3.4 Enable Registers

A status register bit can only get to the input of the OR gate if a corresponding 1-bit is available from the enable register. The summary bit then goes true (1) if any of its inputs are true. This is why you need to use the enable register to mask off the ones you are not interested in.

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Register Structure and Contents

This section provides information about the structure and contents of the different internal registers.

Standard Event Status Register Pair

Standard Event Status is an 8-bit register/enable-register pair with this structure:

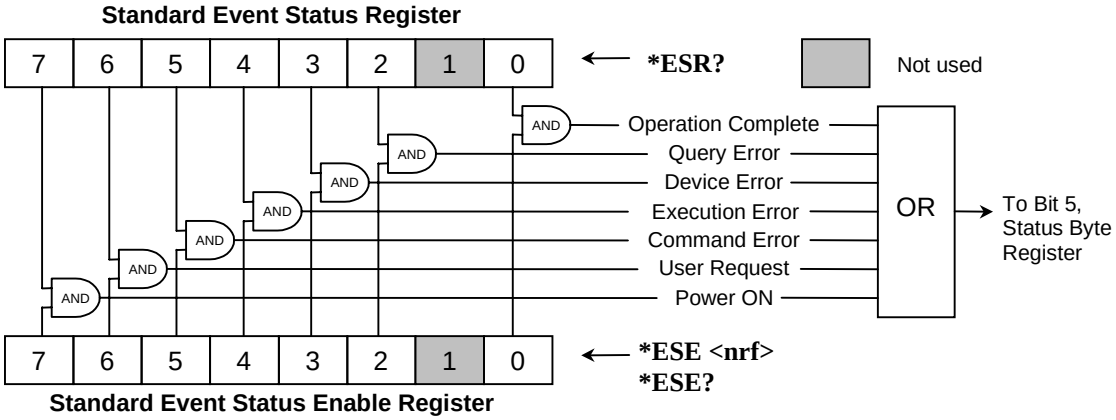


Figure 3.5 Standard Event Status

The Standard Event Status Enable Register allows you to control which events in the Standard Event Status Register can set bit 5 in the status byte register. The format of this register pair is defined by GPIB standards.

Standard event status indicates the FIRST occurrence, and does not change except when reset. The FPM-8210 starts at power ON with the standard event status register set to all zeros. Querying the Standard Event Status Register resets its contents to zeros.

Bit 0 is key to an interrupt-driven control program, because it allows you to generate a service request (SRQ) when current operations are completed before making a measurement. To generate an operation complete SRQ, follow this sequence:

- ***ESE 1**—Enable bit 0 of the Standard Event Status Enable Register.
- ***SRE 32**—Enable bit 5 of the Service Request Enable Register.
- ***OPC**—Set bit 0 in the Event Status Register when all pending overlapped commands have been completed. (See ***OPC** in Chapter Four).

Operation complete means:

- The FPM-8210 internal controller is idle.
- A measurement result is available.
- Calibration is not in progress.

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Related commands: (See GPIB Command Reference on page 41. for details)

- ***ESR?**—Query the contents of the Standard Event Status Register.
- ***ESE <nrf>**—Set an enable mask in the Standard Event Status Enable Register.
- ***ESE?**—Query the Standard Event Status Enable Register mask settings.

Event Status Register Pair Contents

Event Status is a 16-bit register/enable-register pair with this structure:

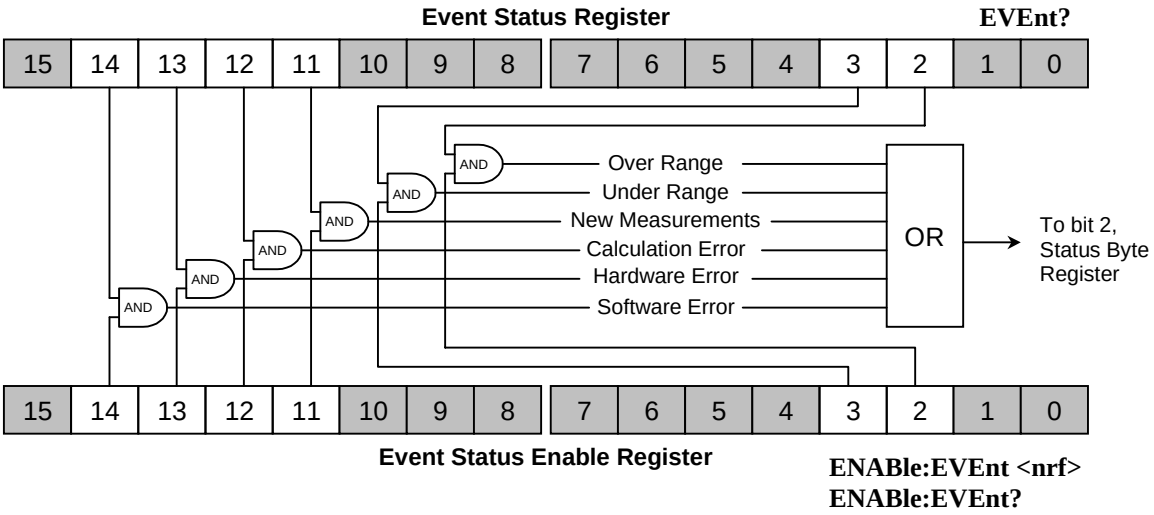


Figure 3.6 Event Status Register Pair

The Event Status Enable Register allows you to control which events in the Event Status Register can set bit 2 in the status byte register. Note that this register pair is identical to the Condition Status register pair , except for bit 11.

Event status indicates the FIRST occurrence, and does not change except when reset. The FPM-8210 starts at power ON with the event status register set to all zeros. Querying the Event Status Register resets its contents to zeros.

Related commands: (See GPIB Command Reference on page 41. for details).

- ***EVEnt?**—Query the contents of the Event Status Register.
- ***ENABle:EVEnt <nrf>**—Set an enable mask in the Event Status Enable Register.
- ***ENABle:EVEnt?**—Query the Event Status Enable Register mask settings.

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Condition Status Register Pair

Condition Status is a 16-bit register/enable-register pair with this structure:

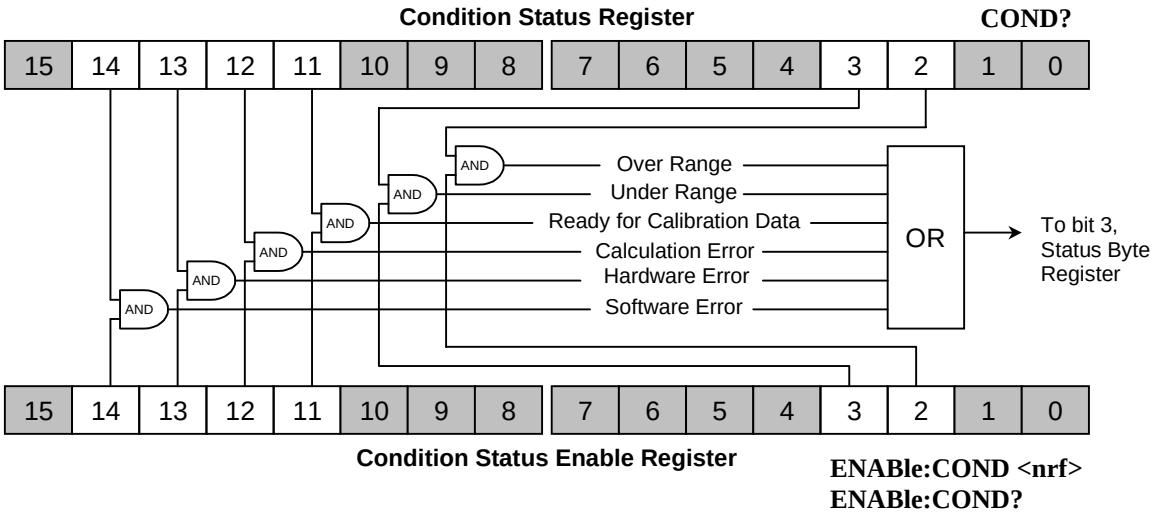


Figure 3.7 Condition Status Register Pair

The Condition Status Enable Register allows you to control which events in the Condition Status Register can set bit 3 in the status byte register. Note that this register pair is identical to the Event Status register pair (above), except for bit 11.

Conditions reflect the current state of the FPM-8210, and so may change often. Querying the Condition Status Register does NOT change its contents.

Related commands: (See Chapter Four for details).

- ***COND?**—Query the contents of the Condition Status Register.
- ***ENABle:COND <nrf>**—Set an enable mask in the Condition Status Enable Register.
- ***ENABle:COND?**—Query the Condition Status Enable Register mask settings.

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Status Byte and Service Request Enable Register Pair

Status Byte and Service Request Enable Register Pair are 8-bit registers with this structure::

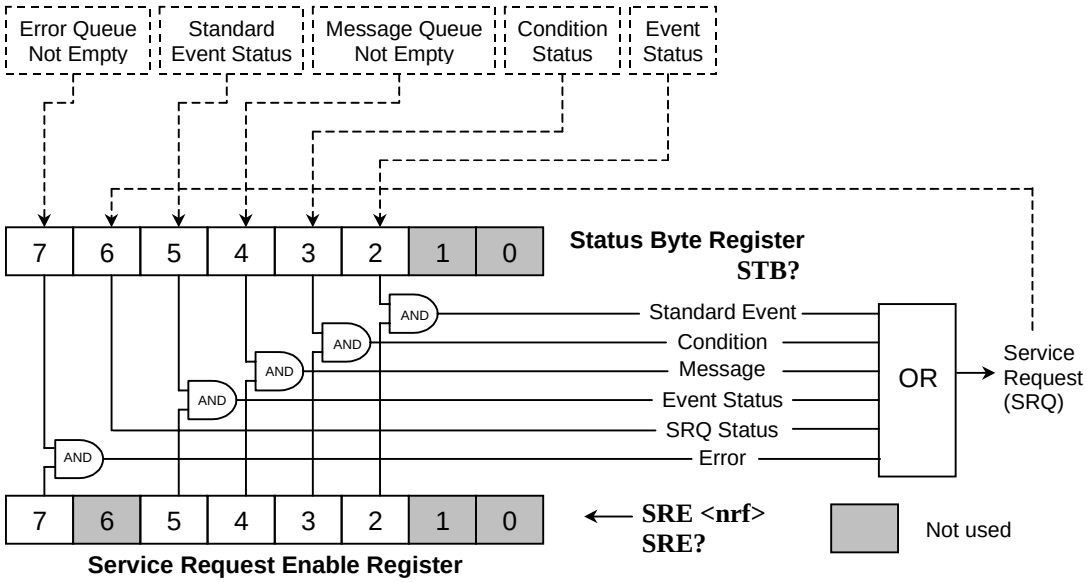


Figure 3.8 Service Request Enable Register

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Command Timing

This section describes, for each device-dependent command, whether that command is performed in an overlapped or sequential manner. In other words, it states whether the next command may begin while this command is being executed, or if the next command must wait until this command is completed before its execution begins.

Sequential/Overlapped Commands

All FPM-8210 device-dependent commands are executed in an overlapped manner: subsequent commands may begin before the current command is completed. Some common commands are sequential: the next command must wait until this command is completed.

The *WAI (common command) is an example of a sequential command which forces the next command to wait until the no-operation-pending flag is true. This is essentially the same as waiting for the OPC flag to become true, because the no-operations-pending flag is used to set the OPC flag (bit 0 of the Standard Event Status Register)

Query Response Timing

Query responses are evaluated at the time the query request is parsed, and not at the time the response message is sent. In most cases this does not create a problem since the time between parsing a query and sending its response is small.

Input/Output Buffer

GPIB program statements (input) and FPM-8210 responses (output) can be any length. These data I/O transfers are done by Direct Memory Access (DMA) in blocks of up to 256 bytes. Transfers longer than 256 bytes are done with multiple data blocks. This information should generally not be of concern, except for troubleshooting compatibility issues with a particular GPIB controller. If you are encountering these issues, ILX Lightwave Customer Service can probably help.

The FPM-8210 normally responds to multiple queries in a single response output. For example:

```
Mes?; Rad?; Mode?; Err?
```

This is a typical response:

```
TEST1,DEC,W,0
```


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Interface Messages

Interface messages manage the bus, and are mostly transparent to your GPIB programs. You usually will not need this information except for questions of FPM-8210 compatibility with a specific GPIB controller.

Interface Function Subsets

The following Interface Function Subsets are supported by the FPM-8210. For more information, refer to the ANSI/IEEE-488 standard documentation.

SH1	Source Handshake
AH1	Acceptor Handshake
T6	Talker Functions
L4	Listener Functions
SR1	Service Request
RL1	Remote Local Function

The following Interface Function Subsets are not supported by the FPM-8210:

PP0	Parallel Poll
DC0	Device Clear
DT0	Device Trigger
C0	Controller Function
E1, E2	Tri-state bus drivers with automatic switch to open collector during Parallel Poll

Recovering From a "Bus-Hung" Condition

GPIB instruments can occasionally get confused as a result of an unrecognizable or incomplete command. This can happen for various reasons, such as untimely interrupts in the controller's operating system software. When this happens, an instrument can get into a state where it no longer responds to controller commands. In some of these situations, the FPM-8210 does not fully reset in response to an Interface Clear (IFC) line or a DC1 (device clear) command. To recover from such a condition, it is normally necessary to turn the FPM-8210 power OFF for 10 seconds, then back ON.

Remote Messages

The following GPIB remote messages are compatible with the FPM-8210:

ACG	DAV	IFC	MTA	RFD	SPD	TAG
ATN	END	LAG	OTA	RQS	SPE	UCG
DAB	GTL	LLO	PCG	SCG	SRQ	UNL
DAC	IDY	MLA	REN	SDC	STB	UNT

The following GPIB remote messages are known to be incompatible with the FPM-8210. Other interface messages, which do not appear in this discussion, may also be incompatible with the FPM-8210.

DCL	GET	PPD	PPR4	PPR8
EOS	OSA	PPR1	PPR5	PPU
MSA	PPC	PPR2	PPR6	TCT
NUL	PPE	PPR3	PPR7	

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CHAPTER 4

GPIB COMMAND REFERENCE

This is a reference guide for GPIB commands that your FPM-8210 or FPM-8210H responds to, including both common and device dependent commands. A summary list of these commands follows the review of syntax below, for your convenience. The remainder of this chapter is an alphabetical list of command descriptions. Refer to Chapter 3, Remote Operation for additional information about register structure and GPIB programming.

The only difference between the FPM-8210 and the FPM-8210H is allowable input power level. In this manual, any reference to "FPM-8210" applies to either model unless specifically stated. See the specification table in Chapter 1 for details.

Command Types

Common commands and requests are defined by GPIB standards, and have consistent meanings for various instruments. "Common" commands start with "*". For example, ***IDN?** is a "GPIB common" query asking the instrument to identify itself. For more information on GPIB common commands, refer to an ANSI/IEEE 488 standard reference.

Device Dependent commands and requests are unique to the FPM-8210. For example, `MODE:DBM` selects measurements to be reported in logarithmic (dBm) units, same as pressing the dBm/W front panel switch.

Front Panel commands duplicate actions that you can also perform by front panel operation.

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Notes on Syntax

Refer to Command Syntax on page 29 for a more complete discussion of syntax. Here is a summary:

Required and Optional Letters

Commands must contain all of the letters shown in upper case in the definition. Optional letters shown in lower case are useful for clarity, but must be in the correct sequence. Upper/lower case does not matter to the FPM-8210.

White Space

A single white space must separate a command from its parameters or data.

Terminator String

If you encounter problems with GPIB communications, the terminator string can be the cause. Refer also to your GPIB interface (controller) manual. The FPM-8210 accepts <NL>, or <^END>, or <NL><^END> as a command line terminator. Many computers terminate with <CR> <NL> <^END> (Carriage Return - New Line - EOI). The FPM-8210 ignores <CR> (Carriage Return) as white space. The FPM-8210 terminates its responses with <CR><NL><^END>, unless you use the **TERM** command to change it.

Multiple Commands

You can put more than one command on a single line (same command string) if you separate the commands with a semicolon.

Numeric Parameters

GPIB uses a flexible representation for numeric parameters called **<nrf value>**. It means that you can represent numbers in integer or floating point form, or in engineering/scientific notation. For example the number "twenty" may be represented by any of the following ASCII strings:

Integer	20	+20
Floating point	20.0	+20.0
Scientific notation	2.0E+1 2.0e+1	+2.0E+1 +2.0e+1

There are no default values for omitted numeric parameters. If you omit a value, you will get an error. See the table of error codes in Appendix A, Error Messages.

To enter data in non-decimal form, use one of the following prefixes:

- **#H**—Hexadecimal
- **#O**—Octal
- **#B**—Binary

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Following are examples of *invalid* syntax command strings that will produce errors:

Table 4.1 Syntax Error Examples

COMMAND	COMMENT
Mode dB	Compound command, missing colon between MODE and DB.
Mode:dBm Range:Auto	Missing semicolon between commands.
DIS ?	Space not allowed before question mark in queries.
Ran3;dis?	Missing space between Ran and parameter 3.
Disply ON	Optional letters must follow the correct order.
Wave	Wavelength parameter missing.

See Appendix A, Error Messages for a list of error codes.

GPIB Command Reference Summary

Below is a summary reference list of all GPIB commands that the FPM-8210 responds to:

Table 4.2 GPIB Summary Reference Command List

Syntax	Meaning	Function
`*CAL?`	Calibrate	Calibrate internal analog to digital (A/D) converter
`CAL:USER <nrf value>`	User calibration	Set a gain factor
`CAL:USER?`	User calibration?	Request user-cal gain factor
`*CLS`	Clear status	Clear status event registers
`COND?`	Condition?	Request the status condition register
`DISplay <nrf value>`	Display on/off	Turn front panel display on or off
`DISplay?`	Display value?	Request the value on the measurement display
`ENABle:COND <nrf value>`	Set condition status enable register	Set the condition status enable register
`ENABle:COND?`	Condition status enable register?	Request the condition status enable register
`ENABle:EVEnt <nrf value>`	Event status enable register	Set the event status enable register
`ENABle:EVEnt?`	Event status enable register?	Request the event status enable register
`ERRors?`	Errors?	Request errors since last ERR? request
`*ESE <nrf value>`	Set standard event status enable register	Set the standard event status enable register
`*ESE?`	Standard event status enable register?	Request standard event status enable register
`*ESR?`	Standard event status register?	Request the standard event status register
`EVEnt?`	Event status register?	Requests the event status register

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Table 4.2 GPIB Summary Reference Command List

Syntax	Meaning	Function
FILTer FAST	Fast filter	Select fast averaging and display update
FILTer MED	Medium filter	Select medium averaging and display update
FILTer SLOW	Slow filter	Select slow averaging and display update
FILTer?	Filter?	Request the measurement filter setting
*IDN?	Identify?	Request the FPM-8210 to identify itself
MESsage <ASCII string>	Message	Store character string into message memory
MESsage?	Message?	Request character string from message memory
MODE?	Mode?	Request the measurement mode
MODE:DB	dB mode	Select decibels (dB) relative measurement mode
MODE:DBM	dBm mode	Select logarithmic (dBm) measurement mode
MODE:W	Watts mode	Select linear (watts) measurement mode
*OPC	Operation complete	Set operation complete flag
*OPC?	Operation complete?	Request operation complete status
POWer?	Power?	Request the value of measured optical power
*PSC <nrf value>	Power-on status clear	Set automatic power-on register clearing
*PSC?	Power-on status clear?	Requests status of power-on status clear flag
*PUD?	Protected user data?	Request the factory-stored identification string
RADix BIN	Binary radix	Set binary numeric responses
RADix DEC	Decimal radix	Set decimal numeric responses (default)
RADix HEX	Hex radix	Set hexadecimal numeric responses
RADix OCT	Octal radix	Set octal numeric responses
RADix?	Radix?	Request the radix of numeric responses
RANge <nrf value>	Range	Set the photodetector current gain range
RANge?	Range?	Request the photodetector current gain range
RANge:AUTO <nrf value>	Autorange on/off	Set AUTO or MANUAL ranging mode
RANge:AUTO?	Autorange?	Request status: AUTO or MANUAL range
*RCL <nrf value>	Recall setup	Recall a stored setup configuration
REF <nrf value>	Set reference	Set a reference level in dBm
REF?	Reference value?	Request the reference level value
RESP?	Responsivity?	Request the calibrated detector responsivity data
*RST	Reset	Recall setup #0, set OCIS and OQIS
*SAV <nrf value>	Save setup	Save the current setup configuration
*SRE <nrf value>	Service request enable	Set the service request enable register
*SRE?	Service request enabled?	Request the service request enable register
*STB?	Status byte?	Request the value in the status byte register
TERM <nrf value>	Set terminator	Define the message terminator

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Table 4.2 GPIB Summary Reference Command List

Syntax	Meaning	Function
TERM?	Terminator?	Request the message terminator
TIME?	Time?	Request time since powered ON
TIMER?	Timer?	Requests time since the last TIMER? query
*TST?	Test?	Performs internal self-test
*WAI	Wait	Waits for OPC (operation complete) status
WAVE <nrf value>	Set wavelength	Set wavelength for calibrating detector response
WAVE?	Wavelength?	Request wavelength for detector response
ZERO	Zero	Apply an internal offset
ZERO?	Zero?	Request status of zero operation

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GPIB Command Reference

Each GPIB command the FPM-8210 responds to is listed on the following pages in alphabetical order. Each command name is given in correct syntax, is identified as a common or device dependent command, and whether it duplicates a front panel action.

*CAL?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Adjusts the internal analog to digital (A/D) converter to reference points, then reports results.
Results	Zero = OK Non-zero = calibration error
Note	A/D referencing is performed each 10 minutes of inactive time.
Example	*CAL?

CAL:USER <nrf value>

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Sets a gain factor to be applied to all FPM-8210 measurements.
Value range	0.500 to 2.500
Indicators	Front panel **USER CAL** indicator is ON when the gain factor is any other value than 1.000.
Examples	CAL:USER .5—Results are half their normal value CAL:USER 1.01—Results are increased by 1%

CAL:USER?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Requests the FPM-8210 user-cal gain value.
Response	A value between 0.500 and 2.500.
Examples	**CAL:USER?**—Response 1.000 means there is no user calibration gain factor. **CAL:user?**—Response 1.010 means a user-calibration gain factor is increasing all results by 1%.

*CLS

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Clears status event registers: Event Status, Event Status Enable, and Error Queue.
Note	Useful to clear registers before enabling service requests (SRQ).
Example	***CLS**

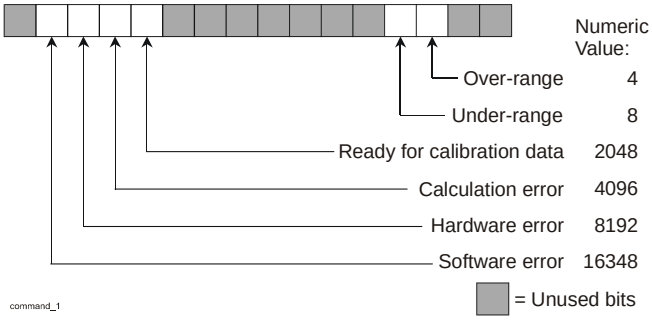
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COND?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the contents of the condition status register.

Response



Notes The conditions reported to the status byte are set through the **ENABle:COND** command.

The condition status may be constantly changing, while the event status is only cleared when it is cleared or read. See ***CLS** and **EVEnt?** commands.

See Chapter Three for more information about register structure.

Example **COND?**—Response = 8 under-range condition

DELAY <nrf value>

COMMON
DEVICE DEPENDENT
FRONT PANEL

Value range 1 to 65536

Action Delays processing of further commands for the defined time (in milliseconds).

Notes Decimal values are rounded.

Small delay values may have no effect, because of time required for command processing. The actual minimum delay depends on the situation, for example whether a measurement is being done in background.

The operation-complete flag is false until the delay time elapses.

This delay command can be useful for creating delays based on the FPM-8210 clock rather than using the controller's clock.

Examples **DELAY 2000**—Delay further processing 2 seconds.

DELAY 48.2—Delay further processing 48 milliseconds.

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DISplay <nrf value>

COMMON
DEVICE DEPENDENT
FRONT PANEL

Values 0 = OFF
1 = ON

Action Turns the front panel display on or off, including all indicators.

Notes Other non-zero values are interpreted as "1".
This command can be useful for working in a dark environment.

Examples **DISPLAY 0**—Turn off the front panel display.
dis 1—Enable the front panel display.

DISplay?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the value shown on the measurement display.

Response Returns the value shown on the measurement display as an ASCII string.

Notes When turned off by a **Display 0** command, the response is a string of space characters.

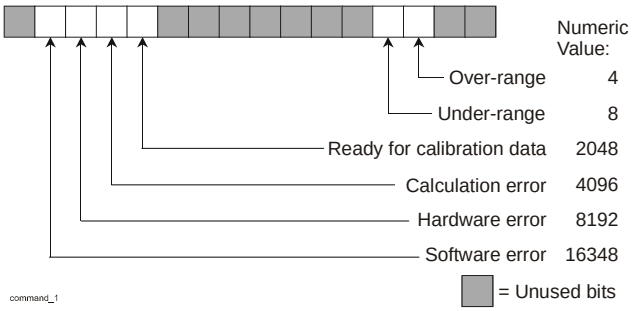
Examples **DISPLAY?**—Response "**- 0.6**" means the display is showing a value of 0.6.
Dis?—Response "**E-531**" means there is a zero error, usually caused by too much room light.

ENABle:COND <nrf value>

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Enables bits in the condition status enable register.

Values



Notes Enabled/disabled conditions can be read by **ENABle:COND?**.
Changing condition status may be monitored by **COND?**.

Bit 3 of the status byte register is set if any enabled conditions are true.
See Chapter Three for more information about register structure.

Enable registers normally retain their values through power OFF/ON, unless the power-on status clear flag is set true. See ***PSC**.

Examples **ENAB:COND 24576**—Enables the condition status register so that hardware or software error conditions are summarized in the status byte bit 3 (8192 + 16384 = 24576).

Enable:cond #H6000—Same as **ENAB:COND 24576**, except using hexadecimal numbering. See **RADix**.

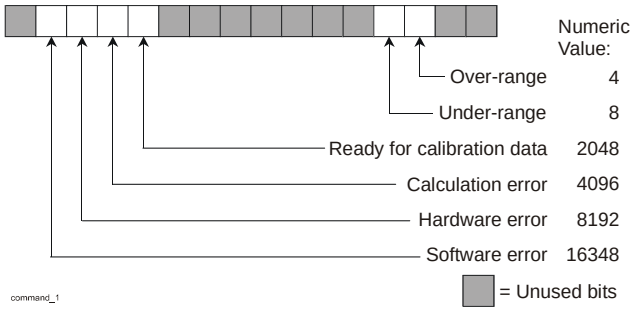
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ENABle:COND?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the value in the condition status enable register.

Response



Notes Enabled/disabled conditions can be set by **ENABle:COND**.

Changing condition status may be monitored by **COND?**.

See Chapter Three for more information about register structure.

Examples **ENAB:COND?**—Response 24576 means that hardware or software error conditions will be summarized and reported in the status byte bit 3 (8192 + 16384 = 24576).

Enable:cond—Response **#H6000** is the same as **24576**, except using hexadecimal numbering. See **RADix**.

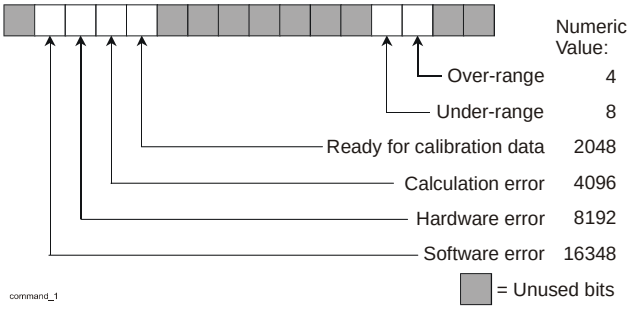
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ENABle:EVEnt <nrf value>

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Enables bits in the event status enable register.

Values



Notes Enabled/disabled events can be read by **ENABle:EVEnt?**.

Event status may be monitored by **EVEnt?**.

Bit 2 of the status byte register is set if any enabled conditions are true, for generation of service requests.

See Chapter Three for more information about register structure.

Enable registers normally retain their values through power OFF/ON, unless the power-on status clear flag is set true. See ***PSC**.

Examples **ENAB:EVE 12** Enables over-range and under-range events to be summarized in the status byte bit 2 (8 + 4 = 12).

Enable:event #HC Same as **ENAB:EVE 12**, except using hexadecimal numbering. See **RADix**.

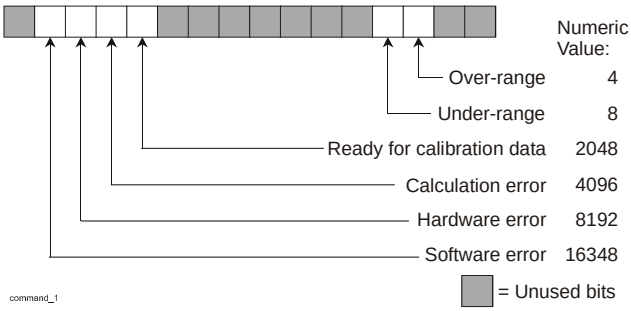
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ENABle:EVEnt?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the value in the event status enable register.

Response



Notes Enabled/disabled events can be set by **ENABle:EVEnt**.
Changing event status may be monitored by **EVEnt?**.
See Chapter Three for more information about register structure.

Examples
ENAB:EVE? Response **2048** means that measurement ready will be reported in the status byte bit 2.
Enable:event? Response **#H800** is the same as **2048**, except using hexadecimal numbering. See **RADix**.

ERRors?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests a list of errors which have occurred since the last **ERR?** request.
Response ASCII character string: list of error numbers, separated by commas.
Note 0 = no errors reported.
See Appendix A for a list of error numbers.

Examples
ERR? Response **0** means no errors to report.
Errors? Response **201** means a command parameter value was out of range.

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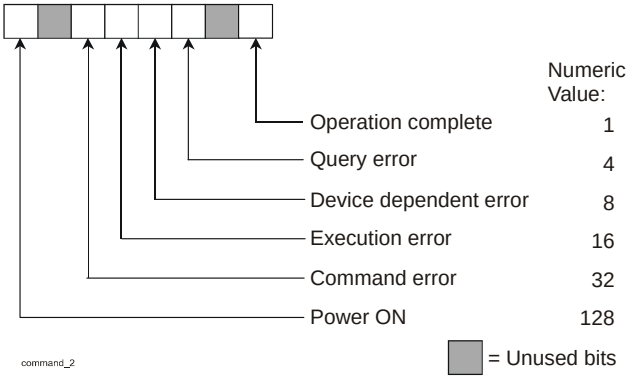
*ESE <nrf value>

Event Status Enable

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Enables bits in the standard event status enable register.

Values



Notes Bit 5 of the status byte register is set if any enabled conditions are true.

Setting bit 0 allows you to generate service requests from overlapped commands as previous operations complete. This may be useful for ensuring that an operation is complete before starting a measurement.

See Chapter 3 for more information about register structure.

Examples *ESE 128—Enables power-ON status to be reported in the status byte bit 5.

*Ese 60—Enables errors to be reported in the status byte bit 5
(4 + 8 + 16 + 32 = 60)

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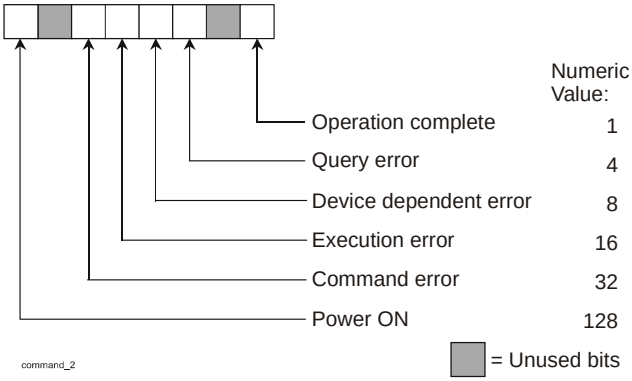
*ESE?

Event Status Enable?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the value in the standard event status enable register.

Response



Notes Bit 5 of the status byte register is set if any enabled conditions are true.
Response is the sum of the enabled bits.
See Chapter Three for more information about register structure.

Examples *ESE?—Response 128 means power-ON status will be reported in the status byte bit 5.
*Ese?—Response 60 means errors will be reported in the status byte bit 5. (4 + 8 + 16 + 32 = 60)

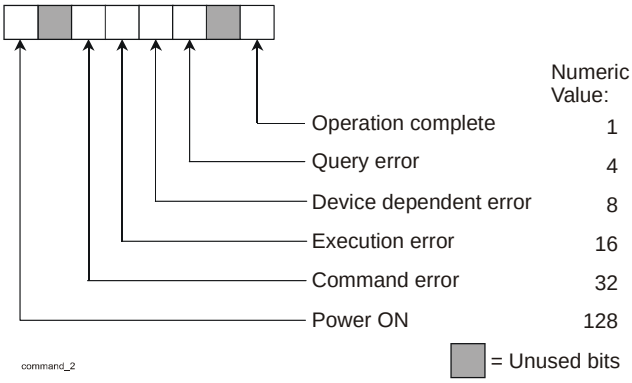
*ESR?

Standard Event Status Register?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the value in the standard event status register.

Response



Notes Response is the sum of the enabled bits.
This command allows you to determine which type of error has occurred.
See Chapter Three for more information about register structure.

Examples ***ESR?**—Response **32** means a command error happened.
***Esr?**—Response **48** means both execution and command errors happened. (16 + 32 = 48)

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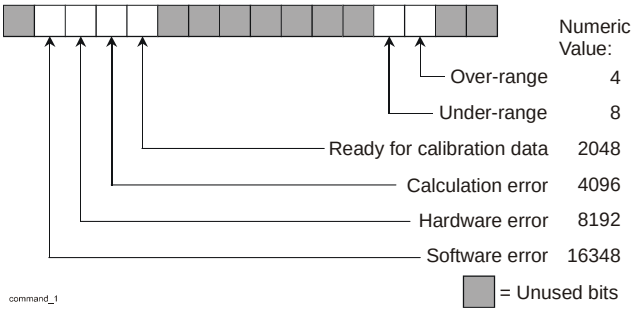
EVEnt?

Event status?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the value in the event status register.

Response



Notes Enabled/disabled events can be set by **ENABle:EVEnt**.

Status bits are set by events, and cleared when read or cleared by command. See ***CLS** and **EVEnt?** commands.

The measurement ready bit is set whenever the display value is updated. For example, in slow mode a new measurement is ready every 5 seconds. See **FILTer** below.

See Chapter Three for more information about register structure.

Examples **EVE?**—Response **2052** means that over-range and measurement ready events occurred since the last **EVE?** inquiry.

Event?—Response **#H804** is the same as **2052**, except using hexadecimal numbering. See **RADix**.

FILTer SLOW | MED | FAST

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Selects measurement averaging and display update rate.

Notes Measurement samples are taken every 50 mSec.

This command does not affect the bar graph update rate.

Examples

FILTER SLOW	Updates the display every 5 seconds with the average of 100 measurements.
Filter med	Updates the display every 0.5 seconds with the average of 10 measurements.
FILT Fast	Turns off measurement averaging. Updates the display every 0.05 seconds.

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FILTer?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the current setting for measurement averaging and display update.

Response One of the following ASCII character strings:
FAST **MED** **SLOW**

Note The filter rate is set by the front panel, or by the **FILTer** command.

Examples **FILTER?**—Response **SLOW** means the display is updating every 5 seconds with the average of the previous 100 measurements.

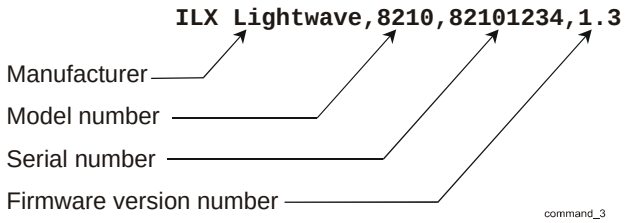
Filt?—Response **Fast** means measurement averaging is off and the display is updating every 0.05 seconds.

*IDN?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the FPM-8210 to identify itself.

Response Returns a comma delimited standard format ASCII identification string, from information stored in the FPM-8210 during manufacture. Here is an example of the response:



MESsage <ASCII string>

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Stores an ASCII string into FPM-8210 non-volatile memory.

Notes String is 1 to 16 non-zero ASCII characters. Strings longer than 16 characters are terminated to the first 16. Strings shorter than 16 characters are filled with spaces to 16.

Message string is retained through power OFF/ON, unless the power-on status clear flag is set true. See ***PSC**.

Useful as a "scratchpad" for storing intermediate test status or configuration information.

Examples **Message "Test 3"** Stores the string **Test 3** in non-volatile memory.

Message Test 3 Same as above. Quotes are optional.

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MESsage?

COMMON
DEVICE DEPENDENT
FRONT PANEL

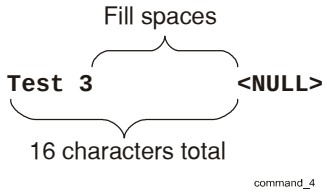
Action Requests an ASCII string from FPM-8210 message memory.

Response 16-character string, followed by NULL terminator.

Note As necessary, the string is filled with spaces to 16-character length. If no message string was stored, the response is a string of 16 spaces.

Example **Message?**

Response: This response means the previously stored message was **Test 3**.



MODE: DB | DBM | W

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Selects the units to be used in reporting measurements:

DB	Decibels (dB) relative to the reference value. See **REF**.
DBM	Logarithmic (dBm) units.
W	Linear (watts) units.

Notes dBm is the log of the ratio of output power relative to one milliwatt. The calculation is:

$$dBm = 10 \log \frac{\text{utput power in milliwatts}}{1 \text{ milliwatt}}$$

dBm_EQ

MODE defines the units of value that will be used for responses to a POW? request.

This command has the same effect as selecting the display mode on the front panel.

Example Mode:dB—Measurements will be reported in dB (decibels) relative to the reference value.

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MODE?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests FPM-8210's measurement mode.

Response One of the following ASCII character strings:
dB **dBm** **W**

Notes This information is available on front panel indicators. See Chapter Two.
The response to **MODE?** is the units of value that will be used for responses to a **POW?** request.

Example **Mode?**—Response **W** means that linear measurement mode (watts) is in effect.

*OPC

Operation Complete

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Sets the operation complete bit in the Event Status Register when all pending overlapped commands have been completed.

Note See Chapter Three for more information about register structure.

Example ***OPC**

*OPC?

Operation Complete?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests operation complete status.

Response ASCII "1" in the FPM-8210 output queue when all pending operations have been completed.

Note See Chapter Three for more information about register structure.

Example *OPC?

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POWer?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the most recent value of measured optical power.

Response Numeric value.

Notes Units defined by **MODE** command.

In **dB** or **dBm** mode, reports the same number as on the display.

In **W** mode, reports in scientific notation.

Responses in **W** mode may have more resolution than is supported by the FPM-8210's accuracy. This can be useful for stability, depending on noise level.

Monitor the Event Status Register (see page 53) for over-range or under-range conditions when using this query.

Examples **Mode?;Power?** Response of **DBM,-13.584** means the last measured power was 13.584 dBm.

MODE:W;POW? Response **2.79565E-006** means the last measured power was 2.79565 µW. Note the resolution to ±10 pW.

*PSC <nrf value>

Power-on Status Clear

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Sets automatic power-on clearing of the enable registers.

Values 0 = disable power-on clearing
1 = enable power-on clearing

Notes Any non-zero value is interpreted as 1.

Registers affected:

Condition Status Enable	Service Request Enable
Event Status Enable	Standard Event Status Enable

See Chapter Three for more information on register structure.

Factory default condition: disabled.

In the disabled state, the values of the enable registers are saved through power OFF/ON. The power-on status clear flag (see PSC?) is set false, disallowing service request interrupts after power-on.

In the enabled state, the enable registers are cleared during power ON. The power-on status clear flag (see PSC?) is set true, allowing service request interrupts after power-on.

Examples ***PSC 0** Disable automatic power-on clearing of the enable registers.

***PSC 1** Enable automatic power-on clearing of the enable registers.

*PSC?

Power-on Status Clear?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the state of the power-on status clear flag.

Response **0** The enable registers are saved through power OFF/ON.
1 The enable registers are cleared during power ON.

Registers affected:

Condition Status Enable:	Service Request Enable
Event Status Enable:	Standard Event Status Enable

See Chapter Three for more information on register structure.

Example ***PSC?** Request state of power-on status clear flag.

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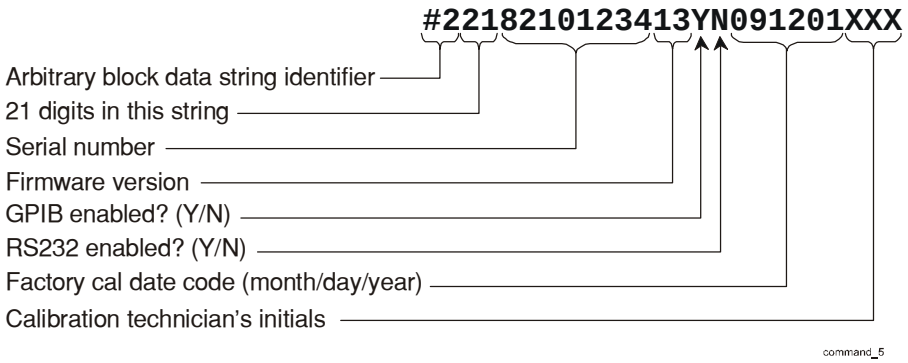
*PUD?

Protected User Data?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the factory-stored identification string.

Response (sample)



Note Most of this information is available through ***IDN?**.
RS232 is not available for the FPM-8210.
Response **#221SERIAL #..YYMMDDYYRTH** indicates no PUD data string.

Example ***PUD?**—Request the factory-stored identification string.

RADix

DEC
HEX
BIN
OCT

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Sets the form (radix) of numeric responses.

Rad DEC	Decimal numbers. (Default type when not specified).
Rad HEX	Hexadecimal numbers
Rad BIN	Binary numbers
Rad OCT	Octal numbers

Notes All status, condition, and event requests respond in the selected radix.
Decimal responses are in <nrf> form (see Chapter 3).
RADix defines responses, not data entry. To enter data in non-decimal form, use one of the following prefixes:

#H	Hexadecimal
#O	Octal
#B	Binary

Examples

RAD DEC	Reset to the factory default decimal radix.
Radix HEX; *ESR?	Set hexadecimal radix. Response **#H80** means power-on was detected.
rad oct	Set octal radix.

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RADix?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the current form (radix) of numeric responses.

Responses

Dec	Decimal numbers. (Default type).
Hex	Hexadecimal numbers
Bin	Binary numbers
Oct	Octal numbers

Note Use the **RADix** command to change the radix setting.

Example **Radix?**—Response **Hex** means numeric responses will be in hexadecimal numbers.

RANge <nrf value>

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Sets the FPM-8210 photodetector current gain range.

Value range 0 through 7

Notes The InGaAs photodetector in the FPM-8210 converts optical power into electrical current. The FPM 8210 is a stable low noise current meter that uses calibration to report photodetector current as optical power. This current is proportional to optical power, but it also varies with wavelength. For more information about gain ranges, see Gain Ranges on page 7.

There are eight ranges in the FPM-8210 meter. Each range increases gain by 10x over the previous range. The maximum photodetector current for each range is as follows

Range	Maximum Current
0	10 mA
1	1 mA
2	100 µA
3	10 µA

Range	Maximum Current
4	1 µA
5	100 nA
6	10 nA
7	1 nA

Setting the gain range puts the FPM-8210 into MANUAL range mode.

Examples **Range 5**—Set the photodetector current gain to range 5: 100 nA full scale

RAN 7—Set the photodetector current gain to range 7: 1 nA full scale

RANge?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the FPM-8210 photodetector current gain range.

Response Integer number: 0 through 7

Note See the discussion of **RANge** above for information about gain ranges.

Response is valid whether the FPM-8210 is in MANUAL or AUTO range mode.

Range information is not displayed on the FPM-8210 front panel.

Example **Range**—Response 5 means photodetector current gain is to range 5: 100 nA full scale

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RANge:AUTO <nrf value>

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Sets the FPM-8210 into AUTO or MANUAL ranging mode.

Values 0 = MANUAL ranging
1 = AUTO ranging

Note Same function as pressing **AUTO/MAN** on the front panel.

Examples
Range:AUTO 1 Set the FPM-8210 into AUTO ranging mode.
RAN:AUTO 0 Set the FPM-8210 into MANUAL ranging mode.

RANge:AUTO?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the status of AUTO or MANUAL range mode.

Response 0 = MANUAL ranging, 1 = AUTO ranging

Note This information is available on a front panel indicator.

Example
Range:AUTO? Response **1** means the FPM-8210 is in AUTO ranging mode.

*RCL <nrf value>

Recall

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Recalls a stored setup configuration from FPM 8210 memory.

Value range 0 through 10

Notes Setup **0** has a factory-set default configuration:

Function	Setting
Display mode	MODE:W
Wavelength	WAVE 1310
Filter mode	FILTER MED
Range mode	RANGE:AUTO
User cal value	CAL:USER 1

If you use GPIB to recall setup **0** (***RCL 0**), GPIB mode is set to REMOTE. If you recall setup "0" by the front panel, GPIB mode is set to LOCAL.

Same function as **RECALL** on the front panel. See Chapter Two.

Use ***SAV** to store various setup configurations for convenient recall.

The current setup is automatically stored and recalled at next power-ON, unless you use ***PSC** to tell the FPM-8210 not to do so.

For more information see the discussion of Save and Recall in Chapter Two.

Examples
***RCL 0** Recall the factory default setup.
***RCL 7** Recall setup #7, stored by front panel commands, or by ***SAV**.

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REF <nrf value>

Reference

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Sets a reference level in dBm.

Value range +1.5 to -75.0 (Specification limits)

Notes Measurements in dB are reported relative to this reference level. See **MODE:DB**.

"+" is accepted but not necessary for positive values.

Front panel operation allows you to set the reference to the most recent measurement. (Press **dBm/W** and **dB** together). However the GPIB command allows you to set any arbitrary reference level.

dBm is the log of the ratio of output power relative to one milliwatt. The calculation is:

$$\text{dBm} = 10 \log \frac{\text{output power in milliwatts}}{\text{1 milliwatt}}$$

dBm_EQ

Examples

REF 0 Set reference level to 0 dBm (1 mW).

Ref -18.24 Set reference level to -18.24 dBm (15 µW).

This sequence accomplishes the same as pressing **dBm/W** and **dB**:

Mode:dBm;Power?Get most recent power measurement in dBm.

REF <power> Using the result <power>, set the reference to the most recent power measurement.

REF?

Reference

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the reference level value.

Response GPIB-standard nrf value, in the units currently defined. See **MODE**.

Note Same function as pressing **dB** and **RECALL** together on the front panel.

Examples **REF?**—Response **0** means the reference level is 0 dBm.

Ref?—Response **-20** means the reference level is -20 dBm (10 µW).

Ref?—Response **2.79565E-006** means the reference level is 2.79565 µW. Note the change in units. See **MODE?**.

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RESP?

Responsivity?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the calibrated detector responsivity for the currently selected wavelength.

Response GPIB standard <nrf value>, in units: mA / mW

Note The information should correspond with that on your latest ILX Lightwave calibration certificate for this meter. If not, contact ILX Lightwave Customer Service to resolve the discrepancy.

This information can be useful for understanding the characteristics of your FPM-8210 meter. Notice for example that detector current is much less at shorter wavelengths.

For more information, see the discussion of the calibration certificate at the end of Chapter Two.

Examples **RESP?**—Response **1.193E-2** means the detector produces 0.01193 mA/mW at the currently set wavelength.

*RST

Reset

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Performs the following:

***RCL 0** (see above)

Sets OCIS state

Sets OQIS state

Notes **OCIS** = **O**peration-complete **C**ommand **I**dle **S**tate. This is the same FPM 8210 state as after ***OPC**: no further operations to complete.

OQIS = **O**peration-complete **Q**uery **I**dle **S**tate. This is the same FPM 8210 state as after ***OPC?**: no further operations to complete.

These idle states allow the FPM-8210 to complete its reset process (no operations pending) before continuing with other operations.

Example ***RST**

*SAV <nrf value>

Save

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Saves the current setup configuration in FPM 8210 memory.

Value range 1 through 10

Notes Configuration **0** is reserved for a factory-set default configuration. See ***RCL**.

Same function as **SAVE** on the front panel. See Chapter Two. See ***RCL**, or the discussion of Save and Recall in Chapter Two, for a list of the configuration functions saved.

It is normally not necessary to save the current setup for next power-ON. The current setup is automatically stored for recall at next power-ON unless you use ***PSC** to tell the FPM-8210 not to do so.

Example ***SAV 2**—Save the current setup configuration as #2.

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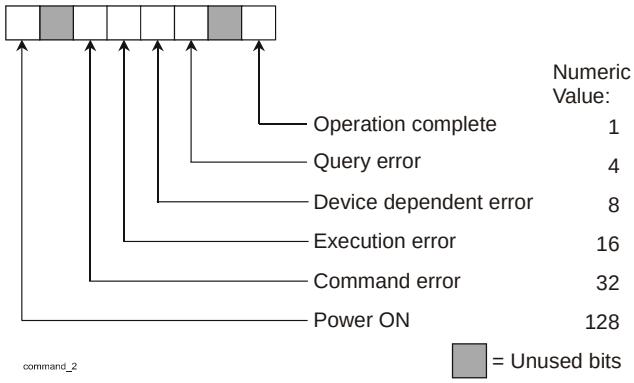
*SRE <nrf value>

Service Request Enable

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Enables bits in the service request enable register.

Values



Notes Response is the sum of the enabled bits.

See Chapter Three for more information about register structure.

Example ***SRE 136** Enable the service request enable register condition summary and error message bits (8 + 128 = 136).

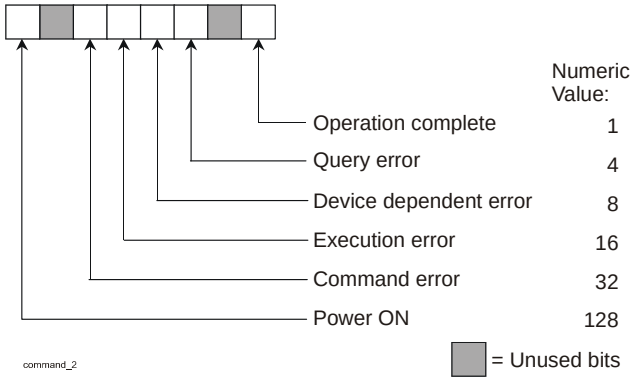
*SRE?

Service Request Enabled?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the value in the service request enable register.

Response



Notes Response is the sum of the enabled bits.

See Chapter Three for more information about register structure.

Example ***SRE?** Response **136** means the service request enable register condition summary and error message bits are enabled (8 + 128 = 136).

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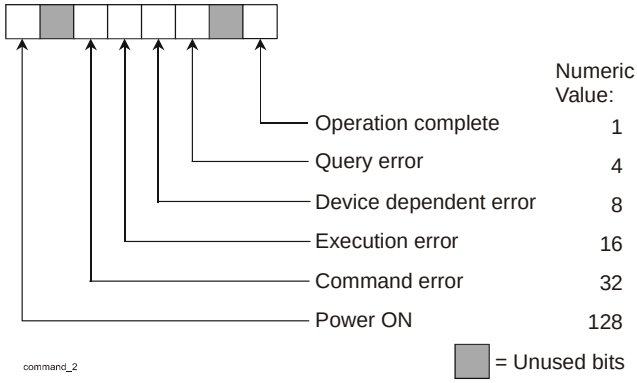
*STB?

Status Byte?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the value in the status byte register.

Response



Notes Response is the sum of the enabled bits.

See Chapter Three for more information about register structure.

Example ***STB?**—Response **200** means the status byte condition and master status summary bits, and error message bits, are enabled. (8 + 64 + 128 = 200)

TERM <nrf value>

Terminator

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Defines the message terminator.

Values
0 =<**CR**><**NL**><^**END**> FPM-8210 default
1 = <**CR**><**NL**>
2 = <**CR**><^**END**>
3 = <**CR**>
4 = <**NL**><^**END**> IEEE-488 Standard
5 = <**NL**>
6 = <^**END**>

Notes All other settings than **TERM 4** are technically out of compliance with IEEE 488 specifications. However they are provided for flexible compatibility with various GPIB drivers.

The FPM-8210 default is compatible with IEEE-488 compliant instruments because <**CR**> is ignored as white space.

TERM 3 will often cause "bus hang" problems, because IEEE-488 compliant instruments ignore the <**CR**> as white space, causing them to wait indefinitely for message termination.

Meanings of the acronyms are historical:
CR = Carriage Return (e.g.: a mechanical typewriter)
NL = New Line (e.g.: line-feed on a "line printer")
^END = EOI code (End Or Identify)

Example **Term 4**—Define the message terminator as the IEEE-488 standard: <**NL**><^**END**>

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TERM?

Terminator?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the currently defined message terminator.

Response 0 through 6, interpreted as follows:

0 = <CR><NL><^END> FPM-8210 default
1 = <CR><NL>
2 = <CR><^END>
3 = <CR>
4 = <NL><^END> IEEE-488 Standard
5 = <NL>
6 = <^END>

Notes All other settings than **TERM 4** are out of compliance with IEEE 488 specifications. They are provided for flexible compatibility with various GPIB drivers.

See **TERM** (above) for more information.

Example **Term?**—Response **0** means the message terminator is the FPM-8210 default: <CR><NL><^END>

TIME?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the time since the last time the FPM 8210 was powered ON.

Response ASCII character data in the form
hours:minutes:seconds

Notes Maximum time (clock "turns over") is1193 hours (~50 days).

The **TIME** clock is independent of the **TIMER** clock. See **TIMER?** below.

Example **Time?** Response **0:32:01.76** means 32 minutes and 1.76 seconds have elapsed since power-ON.

TIMER?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Actions Requests the time since the last **TIMER?** query.
Resets the **TIMER** clock to zero.

Response ASCII character data in the form
hours:minutes:seconds

Notes Maximum time (clock "turns over") is 1193 hours (~50 days).

The **TIMER** clock is independent of the **TIME** clock. See **TIME?** above.

The **TIMER** clock is set to zero at power-ON, so the first response will be the same as a **TIME?** query.

Example **Timer?**—Response **0:00:12.07** means 12.07 seconds have elapsed since the last **TIMER?** query.

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*TST?

Test?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Performs internal self-test, then reports results.

Response 0 = test completed with no errors.
Non-zero = test not completed, or was completed with errors.

Example **TST?**

*WAI

Wait

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Prevents the FPM-8210 from executing any further commands until OPC (operation complete) status is true.

Note Operation complete is defined for the FPM-8210 as:
The controller is idle.
Internal non-volatile memory write cycles are completed.
A power measurement result is available.
No calibration processes are running.

This command can be used to make the FPM 8210 wait until an operation is complete before continuing.

Example ***WAI** Wait until OPC status is true.

WAVE <nrf value>

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Sets the wavelength (in nanometers) to be used in calibrating detector response.

Value range 850 to 1650, in increments of 1

Notes The FPM-8210's InGaAs detector produces current in proportion to light input. The amount of current varies also with wavelength. For this reason, it is important to give the FPM-8210 correct wavelength information.

Calibration points are every 10 nm. When you give the FPM-8210 a wavelength between two calibration points, the resulting calibration factor is a linear interpolation between the two points.

Example **WAVE 1552**—Set wavelength response to 1552 nm. The calibration factor will be interpolated to include 20% of the change in calibration points from 1550 nm to 1560 nm.

WAVE?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests the wavelength to be used in calibrating detector response.

Response A GPIB-standard nrf value of the current wavelength setting.
See **WAVE** above.

Note This information is available on the FPM-8210 front panel.

Example **WAVE?** Response **1552** means FPM-8210 wavelength response is set to 1552 nm. The calibration factor will be interpolated to include 20% of the change in calibration points from 1550 nm to 1560 nm.

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ZERO

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Applies an offset to internal FPM 8210 amplifiers to eliminate fixed errors from such effects as detector dark current and ambient light.

Notes This function is the same as the front panel **ZERO** button.

Before starting measurements it is good practice to first zero the meter. The concept is similar to shorting the leads of a voltmeter and making sure the meter reads zero.

To eliminate all offsets, no light must be on the detector. A connector adaptor can be used for this purpose, provided a patch cord is connected and the other end of the fiber is not exposed to ambient light.

You can usually use **ZERO** with your test setup connected to eliminate small external effects such as ambient room light from your measurement. However, the FPM-8210 limits the amount of offset because large external influences are too unstable to include in measurements. Error **E-531** results when there is too much ambient light for the zero operation.

The FPM-8210 keeps the last zero setting, even when you turn power OFF. So if you zero the meter to your test setup, be sure to zero the meter again when you are finished. It may be more convenient to do this with the front panel **ZERO** button.

These commands will cause error **E-532** if they start before **ZERO** completes:

Range Range:AUTOWave Cal:User

After **ZERO**, you should confirm completion with **ZERO?**, or with **OPC?**. Then check the error queue (see **ERRors?**) before proceeding.

During the zero process, the **ZERO** indicator blinks on the front panel, and the number "0" moves across the display. When the process is complete the display shows "-LO-".

You can interrupt the zero process from the front panel even if it was initiated by GPIB by pressing the front panel **ZERO** button before it completes.

If the zero process is interrupted or was not successful, gain offsets remain unchanged.

Example **ZERO**—Start the zero process.

ZERO?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action Requests status of the FPM-8210 zero operation.

Response 0 = zero operation is not in progress.
1 = zero operation is in progress.

Note Since the OPC flag is held false during the zero process, zero status can also be determined by checking OPC status. See ***OPC?**.

Example **ZERO?**—Response **1** means the zero operation is in progress.

Zero?—Response **0** means the zero process is not in progress. If you just issued a **ZERO** command, this confirms the process is complete.

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CHAPTER 5

TROUBLESHOOTING

This chapter is to help you resolve problems quickly. If you need help, contact ILX Lightwave Customer Service. See page xii for contact information.

ILX Lightwave Corporation provides in-house and on-site calibration services for ILX instruments. Most ILX instruments, including the FPM-8210 and FPM-8210H, require yearly calibration to ensure performance to published specifications. ILX factory calibrations employ NIST traceable measurement instrumentation, and our calibration engineers and technicians use automated test equipment to accurately and efficiently capture and record calibration data. An original certificate of calibration authenticity is provided with all instrument calibrations, and a detailed report showing any pre-calibration out-of-tolerance conditions is available upon request. Calibration turn-times are normally five business days or less. On-site calibrations can be performed around your production schedule, night or day, seven days a week. Please contact ILX Customer Support (see Comments, Suggestions, and Problems on page xii for contact information) for additional calibration information.

For further assistance with technical solutions and troubleshooting, visit the www.ilxlightwave.com Support page (www.ilxlightwave.com/support/index.html), and the Library page (www.ilxlightwave.com/library/index.html) for Application Notes and Technical Notes.

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Troubleshooting Guide

This section lists some common problems and corrective actions. For a comprehensive list of frequently asked questions, see the ILX Lightwave website or contact ILX Lightwave Customer Service (see Comments, Suggestions, and Problems on page xii for contact infomation).

Front Panel Problems

Symptoms	Corrective Actions
Does not power up.	• Check the power cord to make sure that it is properly connected. One safe way to check a power connection is to connect it to another known working instrument.
ZERO function does not work.	• Error message E-531 normally indicates there is too much room light for a proper ZERO. The optic input connector head must have an adaptor with dark fiber attached. • Connector adaptor: Make sure you have a patchcord connected. Leave the other end of the patchcord connected to your source with its output set OFF. • Bare fiber adaptor ring: Make sure the ILX BF-820 Bare Fiber Holder is installed, with a fiber. Leave the other end of the fiber connected to your source with its output set OFF. • Agilent 81000BA bare fiber holder: Make sure Agilent holder is installed, including a fiber. Leave the other end of the fiber connected to your source with its output set OFF. Turn the fiber holder so the large V-groove along the top is facing down, or away from room light. • If the error persists, contact ILX Lightwave.
Display shows "**- OL -**".	• (**O**ver**L**oad)—Too much optical input power for this range. Press **UP** on the front panel to change the gain range. Or select **AUTO**/**MAN** so the **AUTO** indicator is ON to automatically select an appropriate gain range. You can then select **AUTO**/**MAN** again (**AUTO** indicator OFF) if you want to lock it manually into one range. • If you see an **- OL -** indication in auto-range mode, or in the highest range (lowest gain), the optical input power is beyond the FPM-8210's upper limit. • If you see an **- OL -** indication in manual-range mode, then the optical input power is greater than 99.1% of full scale for the current gain range.
Display shows "**- LO -**".	• (**LO**w)—Not enough optical input power for this range. Press **DOWN** on the front panel to change the gain range. Or select **AUTO**/**MAN** so the **AUTO** indicator is ON to automatically select an appropriate gain range. You can then select **AUTO**/**MAN** again (**AUTO** indicator OFF) if you want to lock it manually into one range. • If you see an - LO - indication in auto-range mode, or in the lowest range (highest gain), the optical input power is below the FPM-8210's lower limit. • If you see an - LO - indication in manual-range mode, then the optical input power is less than 5.0% of full scale for the current gain range.

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GPIB Problems

Symptoms	Corrective Actions
No response from a GPIB command (remote light OFF).	• Check that a GPIB cable is connected between the FPM 8210 and the system controller (your computer). This cable should be less than 3 meters (10 feet) long. • Press **LOCAL**/**ADR** to display the GPIB address for three seconds. If it is not correct, change it by pressing **UP** or **DOWN** until you see the correct address. • Check that your controlling software is sending commands to the correct GPIB address. • Check that no two devices are set to the same GPIB address. • Make sure that there are less than 15 devices on the bus. • Check that total GPIB cable length is less than 20 meters. • Check the configuration of your GPIB controller card. See Configuring the GPIB Controller on page 28. • Remove all other instruments from the GPIB bus to isolate the FPM-8210. If this corrects the problem, re-connect one instrument at a time until the problem returns. Then check the other instrument for address conflicts, and proper GPIB function.
Slow or unexpected response to GPIB commands	• Check that no two devices are set to the same GPIB address. • Make sure that there are less than 15 devices on the bus. • Check the configuration of your GPIB controller card. See Configuring the GPIB Controller on page 28. • Check that total GPIB cable length is less than 20 meters. • Remove all other instruments from the GPIB bus to isolate the FPM-8210. If this corrects the problem, re-connect one instrument at a time until the problem returns. Then check the other instrument for address conflicts, and proper GPIB function.
No response from a GPIB command (remote light ON).	• Read the error queue remotely (**ERR?**). The command syntax or command structure may be in error. • Read the status byte (***STB?**) and condition register (**COND?**) for possible device problems. • Check the configuration of your GPIB controller card. See Configuring the GPIB Controller on page 28.
Bus hangs at a particular GPIB command	• Place a software timeout around the command in question • Check the syntax of the command • Make sure the controlling software is not requesting information from the 8200 without first sending a query command. • Turn off other programs in your control computer. With some operating systems, interrupts from other programs can affect bus command timing. • Check the configuration of your GPIB controller card. See Configuring the GPIB Controller on page 28. • Check that no two devices are set to the same GPIB address. • Make sure that there are less than 15 devices on the bus. • Check the configuration of your GPIB controller card. See Configuring the GPIB Controller on page 28.

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Symptoms	Corrective Actions
Is the FPM-8210/H ANSI/IEEE 488.2 compatible?	• The FPM-8210/H is not fully compatible with the ANSI/IEEE 488.2 standard. However, it is used sucessfully by hundreds of customers. • The FPM-8210/H is IEEE/488.1 compliant.
Problems using the Device Clear	• The DCAS interrupt is not connected to the necessary microprocessor for clearing bus-hung conditions via Device Clear. • The firmware does not terminate or comlete all commands upon a Device Clear because of firmware/hardware timing issues and GPIB architecture.
Problems using white space	• IEEE 488.2 specifies that white space characters are ignored, but the meter does not always ignore them.
Exponential Form problems	• IEEE 488.2 specifies that either an upper of lower case "e" is acceptable in exponential data forms. The FPM-8210/H does not always recognize the lower case"e". Use an upper case "E".
*TST command does not execute	• *TST does not execute on this instrument.
Message Available or User-Request bits not found	• Not implemented on this instrument.
Addressing the instrument problems	• Repeat addressing is required by the instrument.

Optical Measurement Problems

Symptoms	Corrective Actions
Inconsistent Readings	• Make sure the connector adaptor is flush with the head. • Verify the quality of cleave and the placement in the bare fiber holder. • Rotate the connector adaptor until alignment pin snaps into place. • Verify the fiber ferrule is clean.
Poor PDR measurement	• Make sure you are using good, low PDL paddles.
Dirty Head	• Contact ILX Lightwave Customer Service (page 69). Head need to be sent to ILX for cleaning.
ZERO function does not work.	• Error message E-531 normally indicates there is too much room light for a proper ZERO. The connector head must have an adaptor with dark fiber attached. • Connector adaptor: Make sure you have a patchcord connected. Leave the other end of the patchcord connected to your source with its output set OFF. • Bare fiber adaptor ring: Make sure the ILX BF-820 Bare Fiber Holder is installed, with a fiber. Leave the other end of the fiber connected to your source with its output set OFF. • Agilent 81000BA bare fiber holder: Make sure Agilent holder is installed, including a fiber. Leave the other end of the fiber connected to your source with its output set OFF. Turn the fiber holder so the large V-groove along the top is facing down, or away from room light. • If the error persists, contact ILX Lightwave.

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Error Messages

Error messages may appear on the FPM-8210 display when error conditions occur that reflect hardware (or zeroing) errors in the instrument. In remote operation, use **ERR?** to read the current error list. When this is done, a string is returned containing up to 10 of the error messages that are currently in the error message queue.

Error Code Tables

The error codes are classified and placed in tables corresponding to their classification. The classifications are Internal Errors, Parsers Errors, Execution Control Errors, GPIB Errors, Operation Errors, and Hardware Errors.

Table 5.1 Internal Errors

Error Code	Explanation
E-001	Memory error

Table 5.2 Parser Errors

Error Code	Data Type	Explanation
E-101	Program mnemonic	Too long
E-102	Program message unit	Too long
E-103	Definite-length arbitrary block program data	Length too long
E-104	Nondecimal numeric program data	Type not defined
E-105	Decimal program data	Exponent not valid
E-106	Decimal program data	Digit expected
E-107	Decimal program data	Digit not expected
E-108	Decimal program data	More than one decimal point
E-109	Decimal program data	More than one exponent indicator ("E")
E-110	Suffix program data	Must have digit following sign
E-111	Suffix program data	Must have alpha character following operator
E-113	Arbitrary block program data	Length less than digit count
E-114	Definite-length block program data	Premature end of data
E-115	Placeholder program data	Identifier not valid
E-116		Syntax error, unexpected character
E-117	Program message terminator	No message to send
E-118	Program message termnator	Default error for parser
E-120	Program mnemonic	Lookup: word as part of a header path has no commands
E-121	Program mnemonic	Lookup: word as part of a header path is not found
E-122	Program mnemonic	Lookup: cannot find null entry

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Table 5.2 Parser Errors

Error Code	Data Type	Explanation
E-123	Program mnemonic	Lookup: word within context of current path is not found
E-124	Program mnemonic	Lookup: query/command type match failed
E-125	Program mnemonic	Lookup: word within context of common command path not found
E-126		Too many or too few program data elements

Table 5.3 Execution Control Errors

Error Code	Data Type	Explanation
E-201	Program data	Value out of range
E-202	Program data	Invalid type
E-203		Security violation
E-204	Program data	Suffix type not valid
E-205	Program data	Not a Boolean value or word
E-206	Program data	Will not convert to a signed 16-bit value
E-207	Program data	Will not convert to an unsigned 16-bit value
E-208	Program data	Will not convert to a signed 32-bit value
E-209	Program data	Will not convert to an unsigned 32-bit value
E-210	Program data	Will not convert to a floating point value
E-211	Program data	Will not convert to a character value
E-212	Program data	Will not convert to a byte array pointer
E-213	Program data	Incorrect data block length
E-214	Program data	Length exceeds maximum

Table 5.4 GPIB Errors

Error Code	Data Type	Explanation
E-301	Response message	Controller failed to read (query error)
E-302	Response message	Device was addressed to talk but controller failed to read all of the response

Table 5.5 Operation Errors

Error Code	Explanation
E-531	Unable to complete zero operation: input signal too great
E-532	Command operation denied: conflicts with zero operation

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Table 5.6 Hardware Errors

Error Code	Explanation
E-706	Auto calibration cycle aborted

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APPENDIX A

CONVERSION TABLES

Four tables are provided: dB to percentage, dBm to Watts, wavelength to frequency, and linewidth conversions ($\Delta\lambda$ to Δf). These last two do not apply to power measurements, but you may find them useful for telecommunication applications.

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Decibel to Percentage Conversion

Defined as 10x the logarithm (base 10) of the ratio of two power levels. Useful for expressing relative measurements:

$$dB = 10 \log \frac{Power_1}{Power_2}$$

logar_EQ

The FPM-8200 makes these relative measurements convenient. Just press **dBm/W** and **dB** buttons together to set a reference at the start of your test. Thereafter the front panel shows changes in dB relative to that reference value (Power $_2$).

Decibel (dB) is a convenient way to express large ratios. For example, +20 dB =100:1, and -20 dB =1%. For smaller ratios, here is a table relating dB and %. Remember that 0 dB =100%

Table A.1 Decibel to Percentage

10.0	dB =	1000%
9.5	dB =	891%
9.0	dB =	794%
8.5	dB =	708%
8.0	dB =	631%
7.5	dB =	562%
7.0	dB =	501%
6.5	dB =	447%
6.0	dB =	398%
5.5	dB =	355%
5.0	dB =	316%
4.5	dB =	282%
4.0	dB =	251%
3.5	dB =	224%
3.0	dB =	200%
2.5	dB =	178%
2.0	dB =	158%
1.5	dB =	141%
1.0	dB =	126%
0.5	dB =	112%

-0.5	dB =	89%
-1.0	dB =	79%
-1.5	dB =	71%
-2.0	dB =	63%
-2.5	dB =	56%
-3.0	dB =	50%
-3.5	dB =	45%
-4.0	dB =	40%
-4.5	dB =	35%
-5.0	dB =	32%
-5.5	dB =	28%
-6.0	dB =	25%
-6.5	dB =	22%
-7.0	dB =	20%
-7.5	dB =	18%
-8.0	dB =	16%
-8.5	dB =	14%
-9.0	dB =	13%
-9.5	dB =	11%
-10.0	dB =	10%

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dBm to Watts Conversion

Calculated as follows:

$$dBm = 10 \log \frac{\text{output power in milliwatts}}{1 \text{ milliwatt}}$$

dBm_EQ

For example, 2mW is equivalent to 3 dBm;10 log 2 = +3; and 0.5mW is equivalent to -3 dBm; 10 log 0.5 = -3. Notice that 0 dBm = 1 mW (log 1 = 0).

Table A.2 dBm to Watts

+	50	dBm =	100	W	+	3	dBm =	2.00	mW	-	44	dBm =	39.8	nW
+	49	dBm =	79.4	W	+	2	dBm =	1.58	mW	-	45	dBm =	31.6	nW
+	48	dBm =	63.1	W	+	1	dBm =	1.26	mW	-	46	dBm =	25.1	nW
+	47	dBm =	50.1	W		0	dBm =	1.00	mW	-	47	dBm =	20.0	nW
+	46	dBm =	39.8	W	-	1	dBm =	794	µW	-	48	dBm =	15.8	nW
+	45	dBm =	31.6	W	-	2	dBm =	631	µW	-	49	dBm =	12.6	nW
+	44	dBm =	25.1	W	-	3	dBm =	501	µW	-	50	dBm =	10.0	nW
+	43	dBm =	20.0	W	-	4	dBm =	398	µW	-	51	dBm =	7.94	nW
+	42	dBm =	15.8	W	-	5	dBm =	316	µW	-	52	dBm =	6.31	nW
+	41	dBm =	12.6	W	-	6	dBm =	251	µW	-	53	dBm =	5.01	nW
+	40	dBm =	10.0	W	-	7	dBm =	200	µW	-	54	dBm =	3.98	nW
+	39	dBm =	7.94	W	-	8	dBm =	158	µW	-	55	dBm =	3.16	nW
+	38	dBm =	6.31	W	-	9	dBm =	126	µW	-	56	dBm =	2.51	nW
+	37	dBm =	5.01	W	-	10	dBm =	100	µW	-	57	dBm =	2.00	nW
+	36	dBm =	3.98	W	-	11	dBm =	79.4	µW	-	58	dBm =	1.58	nW
+	35	dBm =	3.16	W	-	12	dBm =	63.1	µW	-	59	dBm =	1.26	nW
+	34	dBm =	2.51	W	-	13	dBm =	50.1	µW	-	60	dBm =	1.00	nW
+	33	dBm =	2.00	W	-	14	dBm =	39.8	µW	-	61	dBm =	794	pW
+	32	dBm =	1.58	W	-	15	dBm =	31.6	µW	-	62	dBm =	631	pW
+	31	dBm =	1.26	W	-	16	dBm =	25.1	µW	-	63	dBm =	501	pW
+	30	dBm =	1.00	W	-	17	dBm =	20.0	µW	-	64	dBm =	398	pW
+	29	dBm =	794	mW	-	18	dBm =	15.8	µW	-	65	dBm =	316	pW
+	28	dBm =	631	mW	-	19	dBm =	12.6	µW	-	66	dBm =	251	pW
+	27	dBm =	501	mW	-	20	dBm =	10.0	µW	-	67	dBm =	200	pW
+	26	dBm =	398	mW	-	21	dBm =	7.94	µW	-	68	dBm =	158	pW
+	25	dBm =	316	mW	-	22	dBm =	6.31	µW	-	69	dBm =	126	pW
+	24	dBm =	251	mW	-	23	dBm =	5.01	µW	-	70	dBm =	100	pW
+	23	dBm =	200	mW	-	24	dBm =	3.98	µW	-	71	dBm =	79.4	pW
+	22	dBm =	158	mW	-	25	dBm =	3.16	µW	-	72	dBm =	63.1	pW
+	21	dBm =	126	mW	-	26	dBm =	2.51	µW	-	73	dBm =	50.1	pW
+	20	dBm =	100	mW	-	27	dBm =	2.00	µW	-	74	dBm =	39.8	pW
+	19	dBm =	79.4	mW	-	28	dBm =	1.58	µW	-	75	dBm =	31.6	pW
+	18	dBm =	63.1	mW	-	29	dBm =	1.26	µW	-	76	dBm =	25.1	pW
+	17	dBm =	50.1	mW	-	30	dBm =	1.00	µW	-	77	dBm =	20.0	pW
+	16	dBm =	39.8	mW	-	31	dBm =	794	nW	-	78	dBm =	15.8	pW
+	15	dBm =	31.6	mW	-	32	dBm =	631	nW	-	79	dBm =	12.6	pW
+	14	dBm =	25.1	mW	-	33	dBm =	501	nW	-	80	dBm =	10.0	pW
+	13	dBm =	20.0	mW	-	34	dBm =	398	nW	-	81	dBm =	7.94	pW
+	12	dBm =	15.8	mW	-	35	dBm =	316	nW	-	82	dBm =	6.31	pW
+	11	dBm =	12.6	mW	-	36	dBm =	251	nW	-	83	dBm =	5.01	pW
+	10	dBm =	10.0	mW	-	37	dBm =	200	nW	-	84	dBm =	3.98	pW
+	9	dBm =	7.94	mW	-	38	dBm =	158	nW	-	85	dBm =	3.16	pW
+	8	dBm =	6.31	mW	-	39	dBm =	126	nW	-	86	dBm =	2.51	pW
+	7	dBm =	5.01	mW	-	40	dBm =	100	nW	-	87	dBm =	2.00	pW
+	6	dBm =	3.98	mW	-	41	dBm =	79.4	nW	-	88	dBm =	1.58	pW
+	5	dBm =	3.16	mW	-	42	dBm =	63.1	nW	-	89	dBm =	1.26	pW
+	4	dBm =	2.51	mW	-	43	dBm =	50.1	nW	-	90	dBm =	1.00	pW

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Wavelength to Frequency Conversion

By convention, wavelength is defined as if the light were traveling in a vacuum. Light travels about 66% of this speed in a telecom fiber, so the wavelength in the fiber is approximately 1/3 shorter than the values shown. ($f=c/\lambda$)

Table A.3 Wavelength to Frequency

THz	nm
185.00	1620.500
185.10	1619.624
185.20	1618.750
185.30	1617.876
185.40	1617.004
185.50	1616.132
185.60	1615.261
185.70	1614.391
185.80	1613.522
185.90	1612.654
186.00	1611.787
186.10	1610.921
186.20	1610.056
186.30	1609.192
186.40	1608.329
186.50	1607.466
186.60	1606.605
186.70	1605.744
186.80	1604.885
186.90	1604.026
187.00	1603.168
187.10	1602.311
187.20	1601.455
187.30	1600.600
187.40	1599.746
187.50	1598.893
187.60	1598.041
187.70	1597.189
187.80	1596.339
187.90	1595.489
188.00	1594.641
188.10	1593.793
188.20	1592.946
188.30	1592.100
188.40	1591.255
188.50	1590.411
188.60	1589.568
188.70	1588.725
188.80	1587.884
188.90	1587.043
189.00	1586.203
189.10	1585.365
189.20	1584.527
189.30	1583.690
189.40	1582.854
189.50	1582.018
189.60	1581.184
189.70	1580.350
189.80	1579.518
189.90	1578.686

THz	nm
190.00	1577.855
190.10	1577.025
190.20	1576.196
190.30	1575.368
190.40	1574.540
190.50	1573.714
190.60	1572.888
190.70	1572.063
190.80	1571.239
190.90	1570.416
191.00	1569.594
191.10	1568.773
191.20	1567.952
191.30	1567.133
191.40	1566.314
191.50	1565.496
191.60	1564.679
191.70	1563.863
191.80	1563.047
191.90	1562.233
192.00	1561.419
192.10	1560.606
192.20	1559.794
192.30	1558.983
192.40	1558.173
192.50	1557.363
192.60	1556.555
192.70	1555.747
192.80	1554.940
192.90	1554.134
193.00	1553.329
193.10	1552.524
193.20	1551.721
193.30	1550.918
193.40	1550.116
193.50	1549.315
193.60	1548.515
193.70	1547.715
193.80	1546.917
193.90	1546.119
194.00	1545.322
194.10	1544.526
194.20	1543.730
194.30	1542.936
194.40	1542.142
194.50	1541.349
194.60	1540.557
194.70	1539.766
194.80	1538.976
194.90	1538.186

THz	nm
195.00	1537.397
195.10	1536.609
195.20	1535.822
195.30	1535.036
195.40	1534.250
195.50	1533.465
195.60	1532.681
195.70	1531.898
195.80	1531.116
195.90	1530.334
196.00	1529.553
196.10	1528.773
196.20	1527.994
196.30	1527.216
196.40	1526.438
196.50	1525.661
196.60	1524.885
196.70	1524.110
196.80	1523.336
196.90	1522.562
197.00	1521.789
197.10	1521.017
197.20	1520.246
197.30	1519.475
197.40	1518.705
197.50	1517.936
197.60	1517.168
197.70	1516.401
197.80	1515.634
197.90	1514.868
198.00	1514.103
198.10	1513.339
198.20	1512.575
198.30	1511.813
198.40	1511.051
198.50	1510.289
198.60	1509.529
198.70	1508.769
198.80	1508.010
198.90	1507.252
199.00	1506.495
199.10	1505.738
199.20	1504.982
199.30	1504.227
199.40	1503.473
199.50	1502.719
199.60	1501.966
199.70	1501.214
199.80	1500.463
199.90	1499.712

THz=terahertz=10^{12} nm=nanometer=10^{-9} c=299,792,458 meters/sec

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Linewidth Conversions

Table A.4 Linewidth Conversions

$$\Delta f = \frac{c}{\lambda^2}\Delta\lambda$$

nm_EQ

1310 nm				1550 nm			
Dl			Δf	Dl			Δf
2.0	nm	=	349.4 GHz	2.0	nm	=	249.6 GHz
1.9	nm	=	331.9 GHz	1.9	nm	=	237.1 GHz
1.8	nm	=	314.4 GHz	1.8	nm	=	224.6 GHz
1.7	nm	=	297.0 GHz	1.7	nm	=	212.1 GHz
1.6	nm	=	279.5 GHz	1.6	nm	=	199.7 GHz
1.5	nm	=	262.0 GHz	1.5	nm	=	187.2 GHz
1.4	nm	=	244.6 GHz	1.4	nm	=	174.7 GHz
1.3	nm	=	227.1 GHz	1.3	nm	=	162.2 GHz
1.2	nm	=	209.6 GHz	1.2	nm	=	149.7 GHz
1.1	nm	=	192.2 GHz	1.1	nm	=	137.3 GHz
1.0	nm	=	174.7 GHz	1.0	nm	=	124.8 GHz
0.9	nm	=	157.2 GHz	0.9	nm	=	112.3 GHz
0.8	nm	=	139.8 GHz	0.8	nm	=	99.8 GHz
0.7	nm	=	122.3 GHz	0.7	nm	=	87.3 GHz
0.6	nm	=	104.8 GHz	0.6	nm	=	74.9 GHz
0.5	nm	=	87.3 GHz	0.5	nm	=	62.4 GHz
0.4	nm	=	69.9 GHz	0.4	nm	=	49.9 GHz
0.3	nm	=	52.4 GHz	0.3	nm	=	37.4 GHz
0.2	nm	=	34.9 GHz	0.2	nm	=	25.0 GHz
0.1	nm	=	17.5 GHz	0.1	nm	=	12.5 GHz
90	pm	=	15.7 GHz	90	pm	=	11.2 GHz
80	pm	=	14.0 GHz	80	pm	=	10.0 GHz
70	pm	=	12.2 GHz	70	pm	=	8.73 GHz
60	pm	=	10.5 GHz	60	pm	=	7.49 GHz
50	pm	=	8.73 GHz	50	pm	=	6.24 GHz
40	pm	=	6.99 GHz	40	pm	=	4.99 GHz
30	pm	=	5.24 GHz	30	pm	=	3.74 GHz
20	pm	=	3.49 GHz	20	pm	=	2.50 GHz
10	pm	=	1.75 GHz	10	pm	=	1.25 GHz
9	pm	=	1.57 GHz	9	pm	=	1.12 GHz
8	pm	=	1.40 GHz	8	pm	=	1.00 GHz
7	pm	=	1.22 GHz	7	pm	=	873 MHz
6	pm	=	1.05 GHz	6	pm	=	749 MHz
5	pm	=	873 MHz	5	pm	=	624 MHz
4	pm	=	699 MHz	4	pm	=	499 MHz
3	pm	=	524 MHz	3	pm	=	374 MHz
2	pm	=	349 MHz	2	pm	=	250 MHz
1	pm	=	175 MHz	1	pm	=	125 MHz
0.9	pm	=	157 MHz	0.9	pm	=	112 MHz
0.8	pm	=	140 MHz	0.8	pm	=	100 MHz
0.7	pm	=	122 MHz	0.7	pm	=	87 MHz
0.6	pm	=	105 MHz	0.6	pm	=	75 MHz
0.5	pm	=	87 MHz	0.5	pm	=	62 MHz
0.4	pm	=	70 MHz	0.4	pm	=	50 MHz
0.3	pm	=	52 MHz	0.3	pm	=	37 MHz
0.2	pm	=	35 MHz	0.2	pm	=	25 MHz
0.1	pm	=	17 MHz	0.1	pm	=	12 MHz

nm=nanometer=10^{-9} meter pm=picometer=10^{-12} meter c=299,792,458 meters/sec

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