MOPO FDO-970

Frequency Doubler Option

User's Manual

Preface

This manual contains information for safely installing, aligning, operating, maintaining, and servicing the FDO-970 optical parametric oscillator frequency doubler (FDO). The FDO is designed for use with the Quanta-Ray MOPO-710 or 730 optical parametric oscillator and will increase its tunable radiation range to include the region from 440 to approximately 220 nm.

Although the FDO is an optional MOPO accessory, it is housed inside the same enclosure as the MOPO and both devices use the same electronics controller and control menu structure. To minimize duplication, this manual is written as a companion to the MOPO manual and primarily covers the operation of the FDO. Please refer to your MOPO manual for information specific to that device.

Your MOPO manual contains a short section on unpacking your unit and inspecting it for damage. These brief instructions will allow you to verify your unit arrived in good condition. They also explain what to do in the rare event something has been damaged in shipping.

The introductory chapter describes the FDO system and gives some background theory on how it works, and it ends with specification tables and outline drawings.

Following that section is an important chapter on the safe use of laser products. The FDO emits radiation that can permanently damage eyes and skin, ignite fires, and vaporize substances. Moreover, focussed back-reflections of even a small percentage of its output energy can destroy expensive internal optics. To minimize the risk of expensive repairs, injury or even death, carefully follow the instructions contained in this chapter.

In the event the FDO was purchased after the MOPO, Chapter 3 lists the conditions and equipment that will be required in order to properly install it when the Spectra-Physics Lasers service engineer arrives for the initial set up. Although this manual contains a short alignment procedure in chapter 6, wait for the Spectra-Physics Lasers service engineer who has been assigned this task (under your service agreement) to install the unit and set up the system the first time. Thereafter, allow only personnel trained and authorized by Spectra-Physics Lasers to service and set up your laser system.

The maintenance section contains procedures you must perform from time to time in order to keep your system clean and operational on a day-to-day basis. The service and repair section, on the other hand, is intended to help guide you or your service representative to the source of any minor prob-

lems. It contains a replacement parts list and troubleshooting guide, as well as a list of Spectra-Physics Lasers service centers. Do not attempt repairs yourself while the unit is still under warranty; instead, report all problems to Spectra-Physics Lasers for warranty repair.

The FDO-970 includes a firmware upgrade for the MOPO electronic control unit that expands its operational functions to include the FDO. This firmware is installed by the Spectra-Physics Lasers service engineer when he sets the system up the first time. Once the firmware is installed, the user can set the operating parameters for both the MOPO and the FDO from this single system. The system can also be run remotely using either the optional RS-232 or IEEE-488 interfaces.

Lastly, we welcome your comments on the content and style of this manual. The last page is a form to aid in bringing any problems you may find to our attention. Thank you for purchasing a Spectra-Physics Lasers instrument.

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Warnings and Patents

Warning Conventions

The following warnings are used throughout this manual to draw your attention to situations or procedures that require extra attention. They warn of hazards to your health, damage to equipment, sensitive procedures, and exceptional circumstances.

Warning Conventions	
DANGER	Statement to warn of possible **injury or hazard to personal safety.**
WARNING	Statement to warn of **possible damage to equipment.**
CAUTION	Statement to warn against or to **prevent poor performance or error.**
NOTE	Statement to cover **exceptional circumstances or reference.**

Patents

The MOPO/FDO products are manufactured under one or more of the following patents:

5,033,057   5,047,668   5,053,641

SI Units

The following System International (SI) units, abbreviations, and prefixes are used in this Spectra–Physics Lasers manual:

Quantity	Unit	Abbreviation
mass	kilogram	kg
length	meter	m
time	second	s
frequency	hertz	Hz
force	newton	N
energy	joule	J
power	watt	W
electric current	ampere	A
electric charge	coulomb	C
electric potential	volt	V
resistance	ohm	Ω
inductance	henry	H
magnetic flux	weber	Wb
magnetic flux density	tesla	T
luminous intensity	candela	cd
temperature	kelvin	K
pressure	pascal	Pa
capacitance	farad	F
angle	radian	rad

Prefixes

tera	(10^{12})	T	deci	(10^{-1})	d	nano	(10^{-9})	n
giga	(10^{9})	G	centi	(10^{-2})	c	pico	(10^{-12})	p
mega	(10^{6})	M	mill	(10^{-3})	m	femto	(10^{-15})	f
kilo	(10^{3})	k	micro	(10^{-6})	μ	atto	(10^{-18})	a

Chapter 1   Introduction

The MOPO Frequency-Doubler Option (FDO)

Adding the FDO to the MOPO system

The FDO-970 is a MOPO option that extends its uv output to include the
wavelength range from 440 to 220 nm. The FDO platform installs in the
output end of the MOPO enclosure (Figure 1-1) and can be installed either
at the time the MOPO is purchased, or added to it at a later date. The soft-
ware that drives the MOPO controller is modified with firmware so that it
includes the controls required for selecting FDO wavelengths and other ser-
vice functions. If the FDO was purchased some time after the MOPO was
installed, the service engineer who originally installed the FDO also
installed this firmware upgrade.
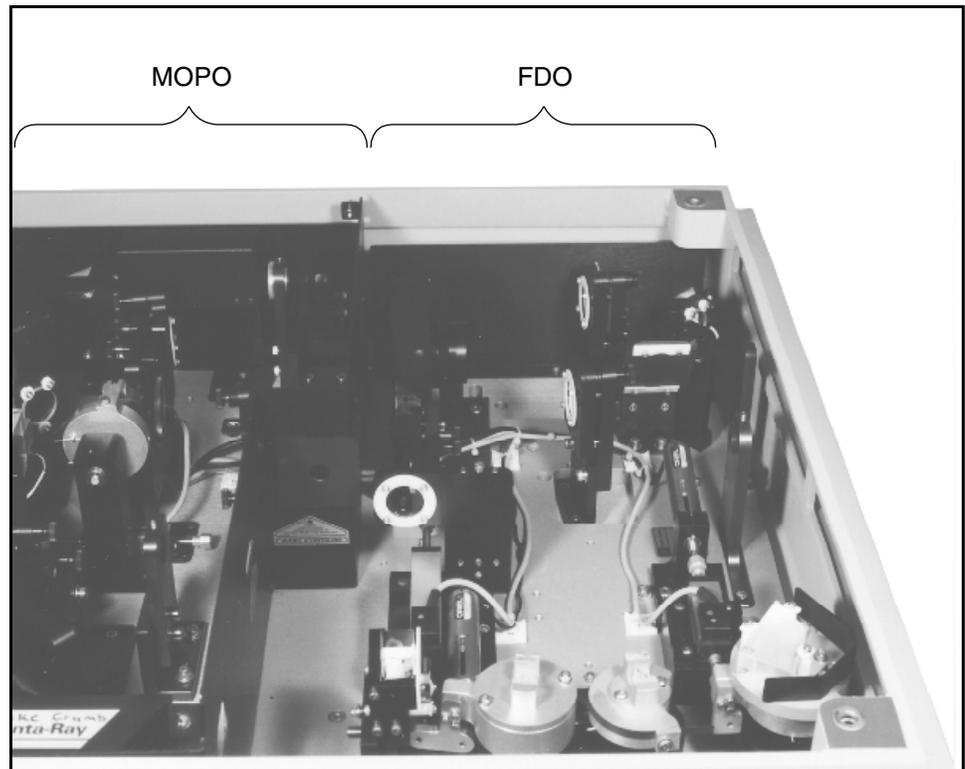
Figure 1-1: The MOPO showing the FDO unit installed.

To set the MOPO system for a frequency range covered by the FDO, simply use the normal MOPO commands to enter the desired output (uv) wavelength. The system will automatically set the MOPO BBO crystal angle for the proper fundamental Signal or Idler frequency, and then the angle of the FDO crystals and prisms for the selected doubled output wavelength.

How it Works

The FDO employs a Type I BBO doubling crystal that produces a second harmonic output frequency when it is tuned to the proper phase-matching angle for the MOPO output frequency (the FDO input frequency). Figure 1-2 shows the BBO crystal phase-matching angle as a function of output wavelength.

The equation below shows how much second harmonic output power ($P_{2\omega}$) can be expected for a given input power:

$$P_{2\omega} = \frac{d_{eff}^2 \, P_\omega^2 \, l^2 [\phi]}{A}$$

where d_{eff} is the effective nonlinear coefficient, P_ω is the fundamental input power, l is the crystal length, ϕ is a phase-matching factor, and A is the cross-sectional area of the beam in the doubling crystal. Both l and A have been selected for optimum second harmonic conversion efficiency in the FDO.
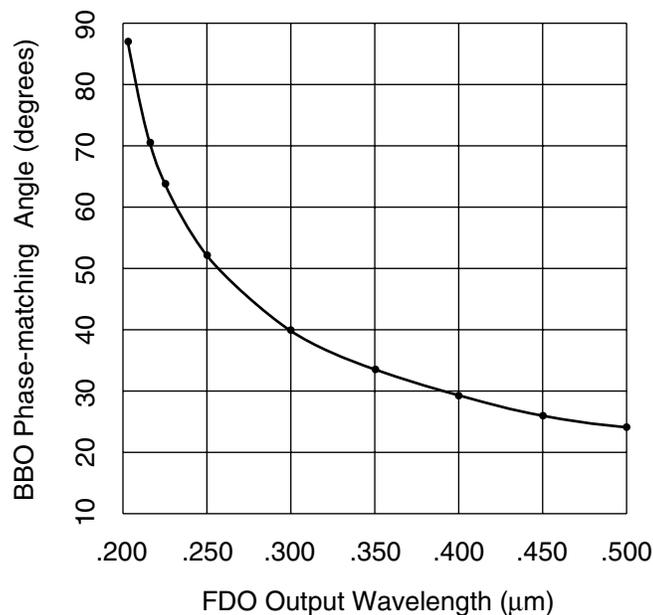
Figure 1-2: Type I BBO Crystal Phase-matching Angle vs. FDO UV Output Wavelength.

Figure 1-3 and Figure 1-4 show the components of the FDO and their relative positions, as well as the beam path.
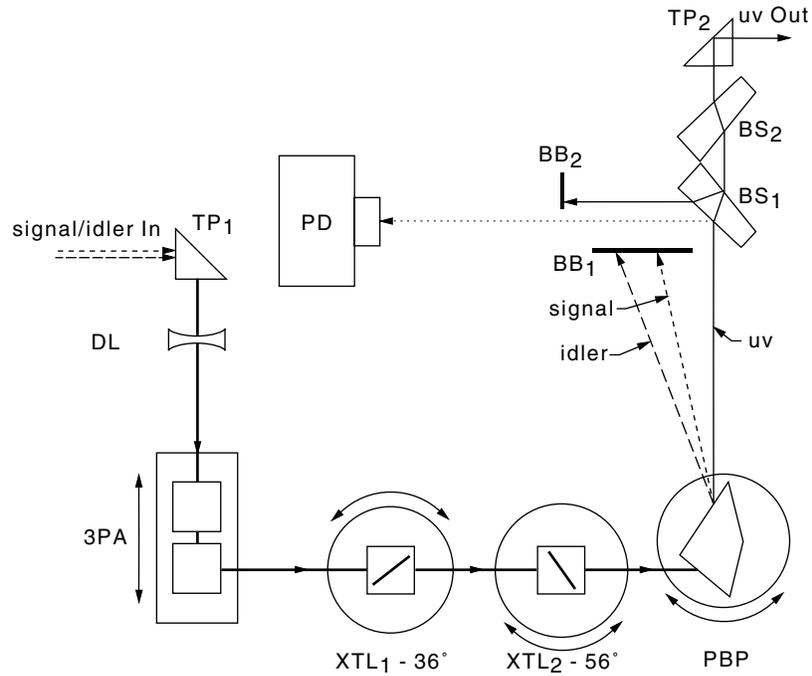
Figure 1-3: FDO Optical Schematic
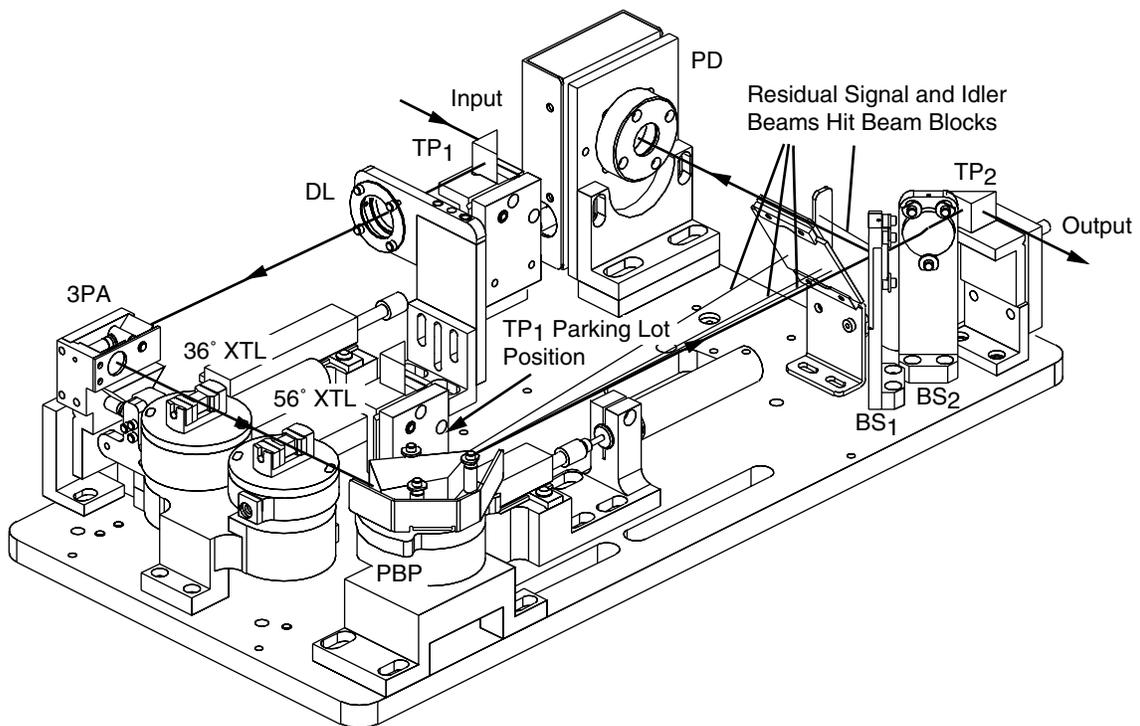
Figure 1-4: 3-D Layout, FDO

A turning prism intercepts the MOPO Signal/Idler beam prior to the two signals being separated and routes it into the frequency doubler. If the frequency-doubled range is not to be used, turning prism TP_1 is simply removed and placed in the parking area (Figure 1-4), and the Signal/Idler beams continue on their original path for separation.

When in place for FDO use, TP_1 turns the MOPO Signal/Idler output beam 90° and routes it through a long focal length lens, DL. DL diverges the beam slightly to increase the optical signal to the crystal tracking system. The lens is optional and is not required on the MOPO-710/FDO system to obtain a tracking signal. (Refer to the FDO electronics section later in this chapter for more information on tracking.)

Next, the beam passes through three-prism assembly 3PA where the horizontally polarized light from the MOPO is rotated 90° to orient it properly for the two frequency-doubling BBO crystals, XTL_1 and XTL_2, and the Pellin-Broca wavelength selection prism, PB. The 3PA also turns the beam 90° to route it toward these three optics.

The system uses a controller-driven motormicrometer to automatically rotate one of the crystals to the proper phase-matching angle for generating the requested output frequency. The second crystal becomes the "inactive" crystal. This is explained in greater detail under "The FDO Crystals" below.

The PB prism performs two tasks. First, it splits off the residual Signal and Idler beams and directs them to beam block BB where they are absorbed. Secondly, it routes the selected frequency-doubled uv beam through beam splitters BS_1 and BS_2 to turning prism TP_2. BS_1 directs a small portion of the beam to the bi-cell split detector as feedback for the crystal angle tracking system. BS_2 is mounted it so that its wedge faces the opposite that for BS_1 and provides dispersion compensation. Finally, turning prism TP_2 directs the uv beam through the output port.

Table 1-1 is an operation summary showing the relationship between the FDO output wavelengths, the crystals that produce them, and the crystal and prism motormicrometer relative set points. The latter numbers are displayed on the FDO Monitor menu (refer to chapter 4) to indicate the angle of rotation for each device and can be used as a reference to verify general alignment.

Table 1-1: Crystal Operation Summary

Wavelength Range (nm)	Active Crystal (Device)	Crystal Set Point Range (Typ.)	Prism Set Point Range (typ)
220 – 271.9	56°	1000 to 22000	10480 to 16000
272.0 – 345	36°	1000 to 12000	15880 to 19360
345.1 – 365.9	None	—	—
366.0 – 450	36°	12000 to 22000	19460 to 21060

The FDO Crystals
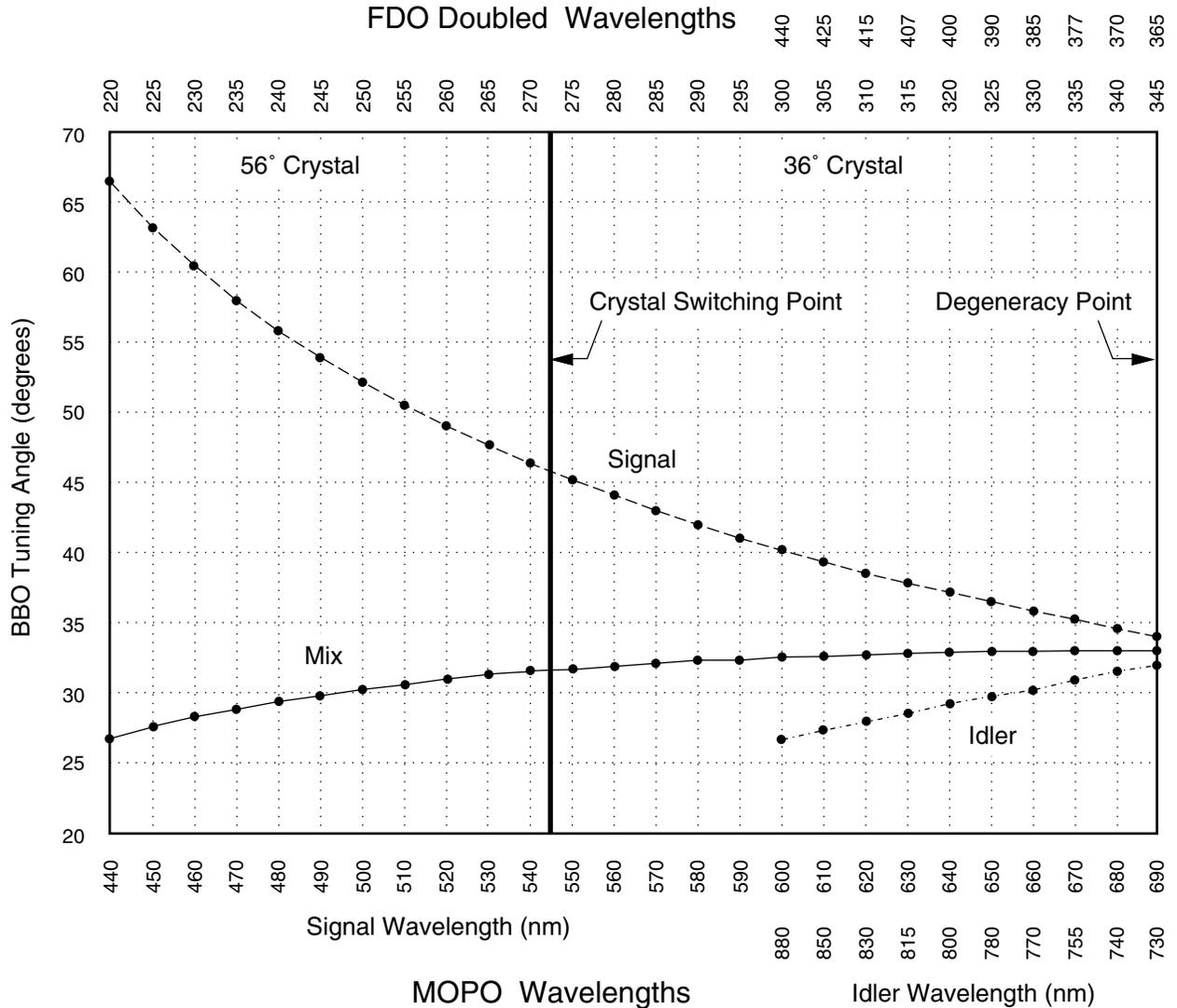
Figure 1-5: The BBO doubling tuning angle for the MOPO/FDO Signal, Idler, and mixed-frequency wavelengths.

The FDO incorporates a patented design that allows the operator to select any output wavelength from 220 to 440 nm *without changing crystals*. To do this, two crystals are used, one cut at 36°, the other at 56°, each covering a part of the total wavelength range as indicated by Table 1-1 and Figure 1-5. One of the crystals is rotated ±15° with respect to the input beam to set it to the proper phase-matching angle for frequency doubling the selected wavelength. This becomes the "active" crystal. The second crystal is not set to the phase-matching angle and is essentially "inactive." The incoming light simply passes though it. However, it is counter-rotated to the active one to the same degree of rotation in order to provide compensation for

beam translation and walk-off effects created by the active crystal. Only one crystal is ever active at a time.

As shown in Figure 1-5, the 56° crystal doubles the MOPO Signal wavelengths from 440 to 543 nm for an FDO output of 220 to 271.9 nm. The 36° crystal doubles the MOPO Signal wavelengths from 544 to 690 nm for an FDO output of 272.0 to 345 nm. The 36° crystal also doubles the MOPO Idler wavelengths from 732 to 880 nm for an FDO output of 366 to 450 nm.

The "Mix" wavelengths shown in Figure 1-5 represent back conversion of Signal and Idler in the BBO crystal. Because the GCR is capable of producing output at this wavelength (355 nm) and in much greater power than the FDO, the MOPO/FDO controller is designed to avoid this condition.

As shown in Table 1-1, neither crystal is active from 345.1 to 365.9 nm. This is the MOPO BBO crystal degeneracy range where no output is generated between these frequencies. Therefore, a scan is not permitted that includes these wavelengths.

There is an overlap from 266 to 280 nm where both crystals can perform the frequency-doubling function. To simplify operation, an arbitrary point at 272 nm is selected as the cross-over point. Whenever this point is reached during a GOTO or SCAN, a pause ensues as the crystals rotate to exchange active/inactive roles. The GOTO or SCAN function then continues to proceed to its end wavelength.

If you find the arbitrary 272 nm point inconvenient for your purposes, another point within the 266 to 280 nm range may be selected. Please call your Spectra-Physics Lasers representative for modified software. Please note, however, that you will be required to make the software update change yourself. It is a fairly simple procedure, however, and appendix A contains the information necessary for you to do this.

Crystal/PB Prism Backlash

It is important to note that there is a small amount of backlash in the drive system. To maintain the extreme accuracy of the MOPO/FDO, this backlash is accounted for by using a simple procedure. The MOPO/FDO always approaches the end wavelength of a GOTO or SCAN command from a defined direction. This direction depends on whether it is the Signal or Idler wavelength that is being doubled. When scanning to an end point from the opposite direction, there will be a noticeable 0.5 nm overshoot of the final wavelength, followed by an immediate direction reversal that approaches the final wavelength from the "correct" direction. This backlash correction feature produces highly accurate positioning of the FDO crystals and prism.

Beam Splitters

Beam splitter BS_1 picks off a small amount of the beam for use as feedback for the crystal/prism tracking system. The front surface beam reflection is routed to the bi-cell detector. The reflection off the wedge's second surface is unwanted and is captured by a small beam block. The second beam splitter, BS_2, is oriented with its wedge direction opposite to that of BS_1 in order to cancel wavelength dispersion effects on the output beam.

The FDO Electronics

The block diagram in Figure 1-6 and the description below explain how the FDO is connected electronically.

From the output frequency requested via the control panel, the MOPO/FDO electronics determines: (i) what Signal or Idler input frequency is required to produce the requested doubled output wavelength, (ii) what MOPO crystal angle is required to generate this input frequency, (iii) which FDO crystal should be used to double this input frequency, (iv) what the appropriate FDO crystal angle is, and (v) what PB prism angle is required for directing the resultant frequency out of the MOPO/FDO unit. Once these values are determined, the controller drives the various components to these value settings.
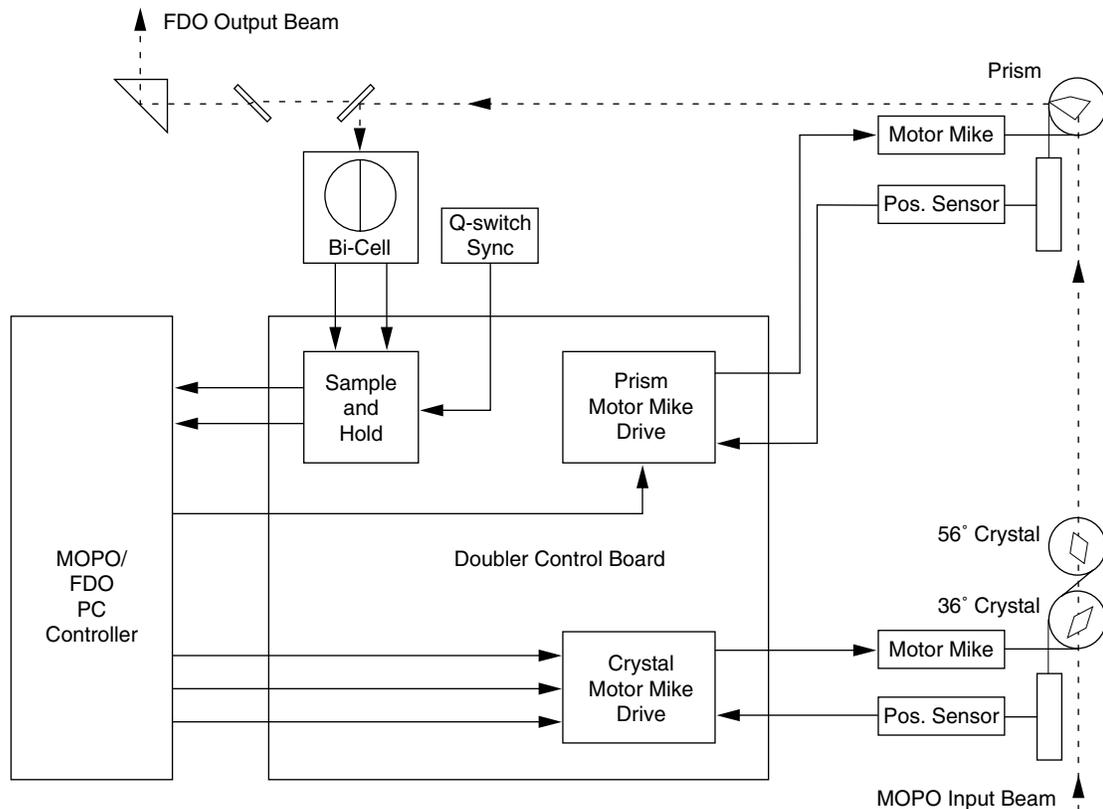
Figure 1-6: Electronics Interconnect Diagram

The crystal and prism drive circuits are dc servos. DC motor-driven micrometers are used to rotate the optics, and linear potentiometers sense the angular positions and feed back an appropriate signal to close the loop. Command analog voltages that represent the angular positions of these devices are summed with the sensor control voltages and, thus, close the loop to provide drive and position control.

The angles that are required to set the crystals for doubling and to set the PB prism to steer the resulting beam are stored as look-up tables. Instructions for creating and modifying these tables are found at the end of chapter 4. They are also in the MOPO Instruction Manual, chapter 6, section Vc.

The PB prism angle is always commanded from a look-up table, whereas the crystal angle can be commanded either from a table, which finds an angle close enough for phase-matching to create the desired doubled output wavelength, or by using the closed-loop tracking circuit which utilizes the bi-cell detector for more precise control.

The bi-cell detects a 1% sample of the doubled output beam. As the crystal is tuned through the optimum phase-matching angle, the beam energy shifts from one side of the detector to the other. During closed-loop tracking, the crystal angle command voltage is modified in order to keep the energies on the two sides of the detector balanced.

The bi-cell is a pyroelectric detector with a fairly uniform sensitivity over the wide wavelength range available from the FDO. It operates into a charge amplifier that has a resistive reset. The measured pulse energy is proportional to the peak of the pulse, which is sampled and held by the doubler control board. Sample time is synchronized to the laser pulse via a Q-switch sync signal.

A shift in the energy position as the crystal is tuned comes from different processes, depending upon whether the unit is a broad band Model 710 OPO or a narrow band Model 730 MOPO. The output beam in a Model 710 has frequency content (color), which is a function of angle because the frequency was determined by the phase-matching angle for the BBO OPO crystal (i.e., it has a spatial frequency chirp). Doubled output energy shifts because the doubling crystal picks out different colors to phase match at different angles.

The spatial color chirp in a Model 730 (narrow band MOPO) is significantly reduced because the operating bandwidth is limited by the grating in the master oscillator. To get an energy shift, a small amount of fundamental beam divergence must be present so that the doubling crystal phase-matching condition can pick out a portion of the fan of rays to double. Thus, the energy will shift as the crystal is tuned through its optimum angle.

Table 1-2: FDO Specifications

Tuning Range:	220 – 440 nm
Details of Tuning:	220 – 272 nm (56° crystal) 272 – 345 nm (36° crystal) 366 – 440 nm (36° crystal)
Efficiency:	With MOPO-730 >10% @ 250 nm guaranteed >10% @ 250 – 440 nm typical
Amplitude Stability[1]:	±15%
Linewidth	<0.3 cm^{-1}
Beam Diameter (Nominal):	6 mm (depends on MOPO used)
Beam Divergence:	<1 mrad
Pointing Stability[1]:	±250 µrad
Maximum Scan Rate:	≤0.125 nm/sec
System Repetition Rate:	10, 20 or 30 Hz (set at factory)

[1]*1 hour, 1 second average, static wavelength*

FDO/MOPO Tuning Curves
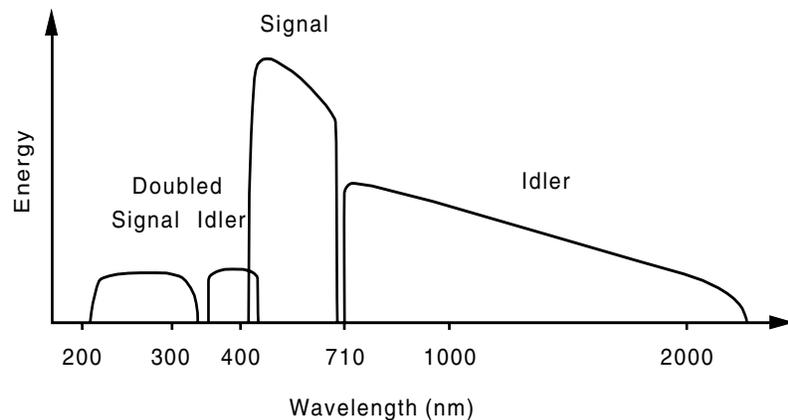
Outline Drawings

Because the FDO is an internal part of the MOPO system, the outline dimensions are the same as that for the MOPO. Refer to your MOPO manual.

Chapter 2   Laser Safety

The Quanta-Ray FDO-970 frequency doubler is an accessory for the MOPO optical parametric oscillator and is designed to extend the MOPO output wavelength range to include the wavelengths from 440 to 220 nm. Output from the FDO can be visible or invisible.

DANGER: HIGH POWER LASER RADIATION

The Quanta-Ray FDO frequency doubler is a high power laser accessory whose beam is a safety and fire hazard. Take precautions to avoid accidental exposure to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye or skin damage.

Precautions For The Safe Operation Of Class IV High Power Lasers

- Wear protective eyewear at all times; selection depends on the wavelength and intensity of the radiation, the conditions of use, and the visual function required. Protective eyewear vendors are listed in the *Laser Focus World*, *Lasers and Optronics*, and *Photonics Spectra* buyer's guides. Consult the ANSI or ACGIH standards listed at the end of this chapter for guidance.
- Keep the protective covers on the laser head and the MOPO/FDO at all times.
- Avoid looking at the output beam; even diffuse reflections are hazardous.
- Avoid wearing jewelry, belt buckles, or other objects that may reflect or scatter the beam while using the laser.
- Do not block the output beam or its reflections with any part of the body.
- Establish a controlled access area for laser operation. Limit access to those trained in the principles of laser safety.
- Maintain a high ambient light level in the laser operation area so the eye's pupil remains constricted, reducing the possibility of damage.
- Post prominent warning signs near the laser operating area (Figure 2-1).
- Set up experiments so the laser beam is either above or below eye level.

- Provide enclosures for beam paths whenever possible.
- Set up shields to prevent any unnecessary specular reflections.
- Set up a beam dump to capture the laser beam and prevent accidental exposure (Figure 2-2).
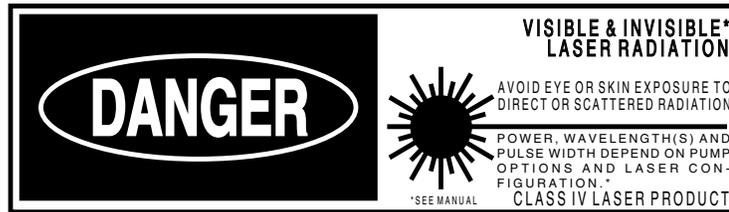
Figure 2-1: Standard Safety Warning sign
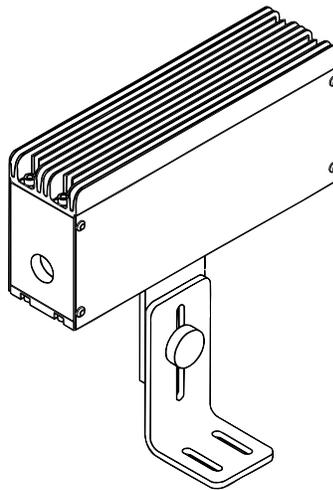
Figure 2-2: BD-5 High Energy Beam Dump

Electrical Safety

DANGER: HIGH VOLTAGE
Voltages present in this unit can cause serious or fatal injury. Only qualified personnel should install or perform service procedures on this equipment.
Voltage is present on unprotected pins when the unit is operational.
No short circuit protector for motor outputs is provided in the unit. The ac input is internally fused.
When power is applied, all parts of the circuit should be considered hazardous.
Allow at least ten minutes for capacitors to discharge. Capacitors remain at high voltages for several minutes after the power is removed.

The above warning label applies to any Spectra-Physics Lasers manufactured FDO pump laser.

WARNING
Do not connect or disconnect the motor or signal cables while ac power is applied.
Do not apply ac power until all the connections have been made correctly.
Do not exceed specified input voltages.

Follow the instructions in this manual for proper installation and safe operation of your laser accessory. At all times during installation, maintenance or service of your laser accessory, avoid unnecessary exposure to laser or collateral* radiation that exceeds the accessible emission limits listed in "Performance standards for Laser Products," *United States Code of Federal Regulations*, 21 CFR 1040 10(d).

We recommend the use of protective eyewear whenever possible; selection depends on the energy and wavelength of the laser beam used as well as operating conditions. Consult relevant OSHA, ACGIH or ANSI standards for further guidance.

* *Any electronic product radiation, except laser radiation, emitted by a laser product as a result of or necessary for the operation of a laser incorporated in to that product.*

Focussed Back Reflection Safety

Laser optics can be severely damaged even if a small percentage of the output beam is reflected and focussed back into the laser. For instance, a common simple lens, uncoated and positive, reflects about 4% of the beam at each surface. The first surface reflection back into the laser will diverge, but the second surface reflection will focus. Intensity at the focus will be very high, usually enough to cause optical damage. Even surfaces with antireflection coatings may reflect back enough focussed energy to cause damage.

To avoid this hazard, minimize focussed back reflections. When they are unavoidable, direct them off-axis to a harmless position or into a beam dump.

Damage due to focussed back reflections is not covered by the Spectra-Physics Lasers warranty.

Maintenance Required To Keep This Laser Product In Compliance With Center For Devices And Radiological Health (CDRH) Regulations

This laser product complies with Title 21 of the *United States Code of Federal Regulations*, Chapter 1, Subchapter J, parts 1040.10 and 1040.11, as applicable. The FDO is a passive laser accessory. As such, it has no inherent interlock devices. For verification of CDRH safety compliance including interlocks, verify pump laser safety features. To maintain compliance, verify the operation of all features listed in your Nd:YAG pump laser manual, either annually or whenever the product has been subjected to adverse environmental conditions (eg. fire, flood, mechanical shock, spilled solvents). Warning labels for the FDO are identified on the radiation control drawings below.

MOPO/FDO Right Side

MOPO/FDO Left Side

MOPO/FDO Output End

Controller Rear Panel

VISIBLE
AND INVISIBLE*
LASER RADIATION IS
EMITTED FROM THIS APERTURE
*SEE MANUAL

AVOID EXPOSURE

Aperture Label (7)

DANGER

VISIBLE AND INVISIBLE*
LASER RADIATION WHEN
OPEN-AVOID SKIN OR EYE
EXPOSURE TO DIRECT OR
SCATTERED RADIATION
*SEE MANUAL

Non-interlocked Protective
Housing Label (6)

Spectra-Physics Lasers
1330 TERRA BELLA AVENUE
MOUNTAIN VIEW,CALIF. 94039

THIS PRODUCT IS MANUFACTURED
UNDER ONE OR MORE OF THE
FOLLOWING U.S.A. PATENTS:

5,033,057   5,053,641
5,047,668

0448-8700

Patent Label (2)

DANGER!
LASER RADIATION WHEN
ADJUSTMENT ACCESS
PLUGS ARE REMOVED.
**AVOID EYE OR
SKIN EXPOSURE
TO DIRECT OR
SCATTERED
RADIATION.**

Non-interlocked Protective
Housing Label for
Adjustment Access Plugs (4)

SPECTRA-PHYSICS INC.
1250 WEST MIDDLEFIELD ROAD
MT. VIEW,CALIFORNIA 94042

MANUFACTURED

MONTH_____ YR _____

MODEL   S/N

THIS LASER PRODUCT COMPLIES
WITH 21 CFR 1040 AS APPLICABLE

MADE IN U.S.A.

Certification and
Identification Label (1)

VISIBLE & INVISIBLE*
LASER RADIATION

DANGER

AVOID EYE OR SKIN EXPOSURE TO
DIRECT OR SCATTERED RADIATION

POWER, WAVELENGTH(S) AND
PULSE WIDTH DEPEND ON PUMP
OPTIONS AND LASER CON-
FIGURATION.*
*SEE MANUAL   CLASS IV LASER PRODUCT

Warning Logotype Label (3)

Figure 2-3: FDO Radiation Control Drawing: Labels and Case Exteriors

Output End

Input End
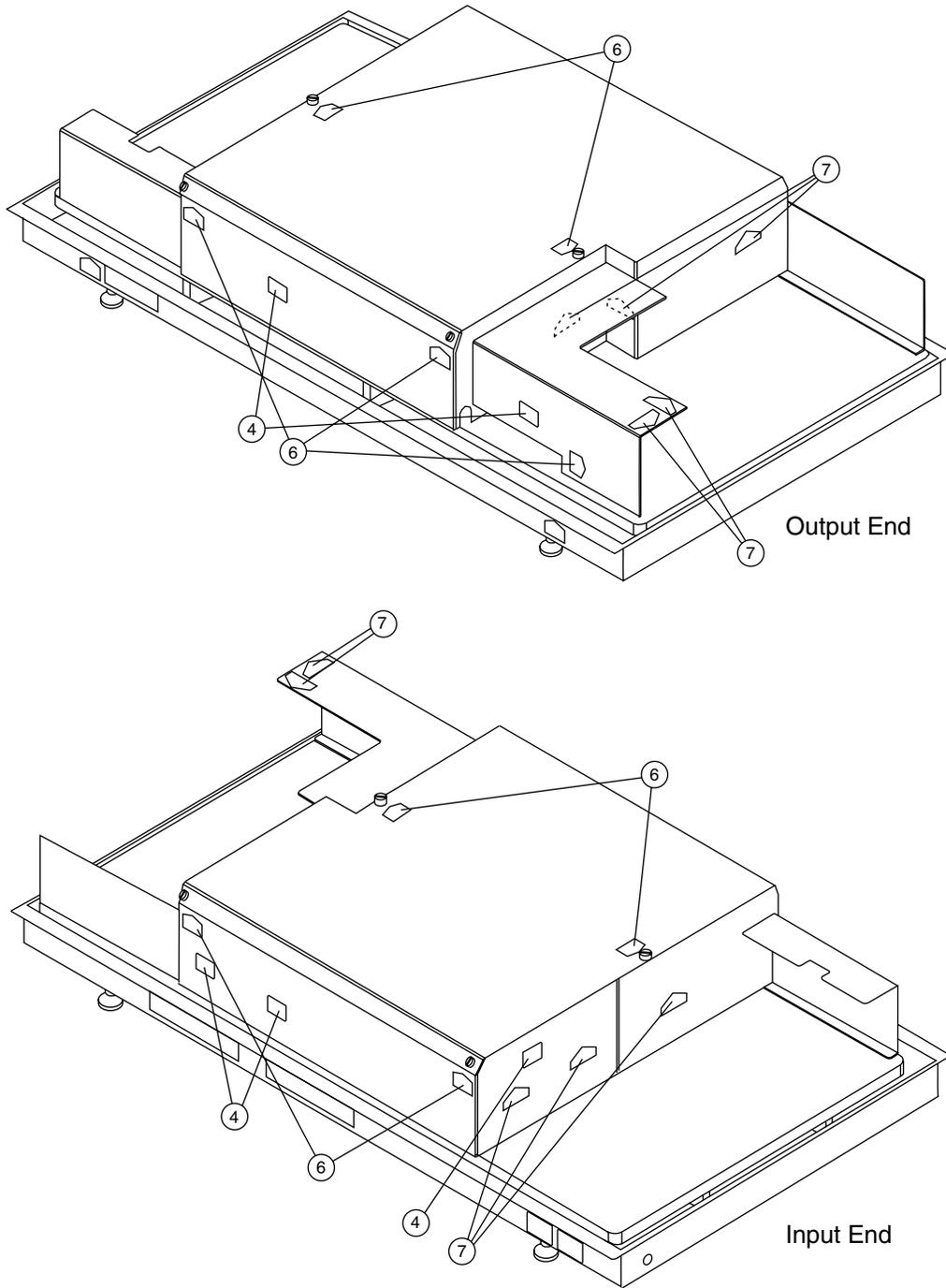
Figure 2-4: FDO Radiation Control Drawing: Case Interior

Sources for Additional Information

The following are some sources for additional information on laser safety standards, safety equipment, and training.

Laser Safety Standards

Safe Use of Lasers (Z136.1)
American National Standards Institute (ANSI)
11 West 42nd Street
New York, NY 10036
Tel: (212) 642-4900

A Guide for Control of Laser Hazards
American Conference of Governmental and
Industrial Hygienists (ACGIH)
1330 Kemper Meadow Drive
Cincinnati, OH 45240
Tel: (513) 742-2020

Laser Safety Guide
Laser Institute of America
12424 Research Parkway, Suite 125
Orlando, FL 32826
Tel: (407) 380-1553

Equipment and Training

Laser Focus World Buyer's Guide
Laser Focus World
Pennwell Publishing
10 Tara Boulevard, 5th Floor
Nashua, NH 03062
Tel: (603) 891-0123

Lasers and Optronics Buyer's Guide
Lasers and Optronics
Gordon Publications
301 Gibraltar Drive
P.O. Box 650
Morris Plains, NJ 07950-0650
Tel: (201) 292-5100

Photonic Spectra
Photonic Spectra
Laurin Publications
Berkshire Common
P.O. Box 4949
Pittsfield, MA 01202-4949
Tel: (413) 499-0514

Chapter 3

Unpacking Your FDO-970

IMPORTANT: The FDO is designed to be installed by a trained Spectra-Physics Lasers Service Engineer. If you have not already done so, please contact the SPL Service Organization to arrange installation.

Your FDO was carefully packed for shipment; if its crate arrives damaged, have the shipper's agent present when the unit is unpacked. Inspect it as you unpack: look for dents, scratches, or other damage. If you discover any damage, immediately file a claim against the carrier and notify your Spectra-Physics Lasers representative.

Keep the shipping containers. If you file a claim, you will need them to show that shipping caused the damage. If you must return the unit for service, these special crates provide maximum protection. Spectra-Physics Lasers will only ship Spectra-Physics Lasers equipment in original containers; you will be charged for replacement containers.

Required Utilities

Because the FDO resides inside the MOPO and uses the same controller, there are no new utilities required. All power and signals are provided by the MOPO controller.

Environmental Considerations

In order to maintain stable operation of the GCR/MOPO/FDO system, certain environmental conditions must be satisfied. The following is a list of these conditions:

- The GCR/MOPO/FDO system must be installed on an optical table to ensure stable, long-term operation

    Critically phase-matched OPOs are sensitive to changes in angle of 1/100th of a degree. This requires suitable vibration isolation, such as that provided by an optical table. We recommend using a 4 ft. by 10 ft. optical table for the GCR/MOPO/FDO system. An 8 in. thick optical bench or equivalent is required. Do not place the table near sources of vibration (i.e., water pumps, air conditioning ducts, excimer lasers, etc.).

All MOPO/FDO specifications are valid only when the GCR and MOPO/FDO units are mounted on the same optical table.

- The MOPO/FDO system should not be near any significant air drafts.

  The system should not be placed near air conditioning vents. This may result in changing temperature gradients near the system that can affect its performance, as well as stir up dust particles that might settle on sensitive optical surfaces.

- Ideal room temperature is 20°C.

  To ensure stable operation on a day-to-day basis, the recommended minimum and maximum room temperature is 15° and 25°C. In addition, the maximum allowable laboratory temperature variation is ± 2°C over 8 hours.

- Keep the humidity level below 60% (inside the MOPO/FDO unit).

  The MOPO/FDO unit may be purged with suitably filtered dry air or nitrogen to maintain the desired humidity levels.

- Keep dust to a minimum.

  The diffraction of the pump beam off dust on an optic can induce hot spots in the beam as the beam propagates. The hot spots in the beam can cause damage in the optics and the BBO crystal.

- Be careful to not place localized heat sources near the MOPO/FDO or under the optical table.

  Large power supplies under the table can have a negative affect on the performance of the GCR/MOPO/FDO system.

Chapter 4 Operation

FDO-970 Dos and Don'ts

The following do's and don'ts should be made part of your standard laboratory procedures for operating the MOPO/FDO. First, there is a list of things *not* to do, followed by items that should be done. By adhering to this list of procedures, you will minimize the possibility of damage to your system and be assured of many hours of error-free operation.

Don'ts

- ***Do not*** *turn the GCR pump laser from EXTERNAL or LONG PULSE to Q-SWITCH mode of operation when the flash lamps are running.*

   Diffraction in the beam and/or thermal shock to the optics can result in damage.

- ***Do not*** *remove a beam block from between the MOPO/FDO and the pump laser while the laser is running.*

   As in the case above, diffraction in the beam and/or thermal shock to the optics can result in damage.

- ***Do not*** *vary the GCR and/or MOPO/FDO energy with the Q-SWITCH DELAY control when the flash lamps are running.*

   This can cause a significant energy redistribution in the mode. Hot spots can form resulting in damage to system optics.

- ***Do not*** *adjust the Harmonic Generator (HG) during the GCR warm-up period.*

   During this warm-up period, the temperature in the crystals of the HG is changing. Adjusting the HG during this period can result in performance that changes within minutes and requires further adjustments during the warm-up period. Stable, reliable operation of the HG can only be realized once the system has come to thermal equilibrium (nominally 30 minutes).

- ***Do not*** *run the system with damaged optics.*

   Diffraction from damage spots reduce MOPO and FDO conversion efficiencies due to phase distortions, as well as increase the probability of further damage to optics down the beam line.

- ***Do not*** *use the VARIABLE REP-RATE option with the MOPO/FDO.*

At different rep-rates the beam will not be collimated, which will result in a degradation of FDO performance as well as the possibility of damaging the optics.

- ***Do not*** *run the GCR if the Seeder is off or is performing poorly.*

  Linewidth performance will degrade and parasitic oscillations may result. In addition, damage to the broadband dichroics may occur.

- ***Do not*** *use the GCR SINGLE SHOT option when running the MOPO/ FDO.*

  Increased thermal lensing in the rod may result in damage due to thermal shock to the optics. In addition, seeded performance of the *GCR is not possible and results in poor linewidth performance.*

- ***Do not*** *lean on the GCR or MOPO/FDO units during operation, nor place items on them. Also, do not lean on the optical table.*

  The entire MOPO system is very sensitive to small amounts of movement in the beam. Leaning on the optical table, the GCR, or the MOPO/ FDO will compromise system performance by inducing beam movement.

- ***Do not*** *remove the MOPO/FDO cover during operation.*

  The cover prevents room drafts from compromising temperature stability and also maintains a dust-free environment for stable, long-term operation. For reasons of safety, it keeps stray beams and reflections confined.

Dos

- Check the optics on a regular basis for dust and damage.

  If dust is present, blow it off with air or dry nitrogen. This will help prevent damage to them. If damage is present, replace the damaged optics as soon as possible to prevent further damage to them.

WARNING

If damage is present, turn the system off immediately to prevent damage to the BBO crystal and other optics. Notify your Spectra-Physics Lasers service representative of the problem.

- Monitor the uv pump power on a daily basis (pump power is displayed on the MOPO/FDO Monitor screen). Refer to the instructions in the "Daily Start-Up" procedure for operating the GCR pump laser.

  IMPORTANT. As specified in the "Daily Start-Up" procedure of the MOPO manual, a combined warm-up period of approximately 45 minutes is required before the uv power can be reliably read.

• Monitor the environmental conditions such as (temperature, humidity, dust and drafts) on a regular basis. If these conditions fall outside the recommended operating range, take corrective action.

Identifying potential issues related to environmental conditions helps ensure optimal system performance.

Daily Start Up Procedure

This short procedure is provided to minimize your daily start up efforts. The controls and display menus referred to are discussed later in this chapter or are covered in your *MOPO User's Manual*. This procedure assumes the system was used recently and has not been moved since that time. The MOPO/FDO controller should be off; do not turn it on until told to do so.

1. Verify TP_1 is in its proper position for frequency doubling.

   (If frequency doubling is not desired, i.e., either the MOPO Signal or the Idler is to be output, move TP_1 to its parking lot position so that it does not block the Signal and Idler beams from exiting their respective ports. Otherwise it should be in its normal position for FDO output.)

2. Turn on the following GCR pump laser controls. (Refer to the GCR manual for details.)

   a. The external cooling water supply.

   b. The seeder (turn from STANDBY to ON).

3. Set the GCR mode to LONG PULSE operation.

4. Press the GCR remote control ON button and wait for the simmer lights to turn on.

   This indicates the flash lamps are ready to use.

5. Turn the LAMP ENERGY control(s) to its full on position and run the GCR for about 20 minutes. (For oscillator/amplifier pump lasers, turn up the oscillator first, then the amplifier.)

6. Turn down LAMP ENERGY control(s) to the START position.

7. Switch to Q-SWITCH mode.

8. Turn on the MOPO/FDO controller.

9. Restore LAMP ENERGY to full on position for about 10 to 15 minutes (30 to 35 minutes total warm-up time).

10. Use the MOPO Monitor menu on the controller to verify the GCR output is within 10% of the value it had at installation. If necessary, perform minor adjustments of the crystal angles in the harmonic generator to ensure output is optimized.

11. Use the MOPO Monitor menu to verify the master oscillator reads within 10% of the value it had at installation.

12. Use the FDO Monitor menu to verify the FDO output is within 10% of the value it had at installation.

13. If you need to move the DL out of the beam path, simply flip it around. Loosen the screw on top, then remove the entire optic mount and turn it around. Place the mount so that the locating pins are reinserted, and tighten the screw.

If the system has just been installed or reinstalled, note the values from steps 10 to 12 for future use. If you have any problems following a reinstallation, refer to chapter 5, "FDO Alignment" and your *MOPO User's Manual*, or call your Spectra-Physics Lasers representative.

Daily Shut Down Procedure

Follow these steps to shut your system off between periods of frequent use.

1. Turn down LAMP ENERGY control(s) on the GCR to START.

2. Press the STOP button.

3. Turn the SEEDER switch to STANDBY.

4. Turn the key switch on the GCR power supply to the OFF position and remove the key.

   Leave the circuit breaker switch ON so that the HG and injector seeder heaters stay warm. This will reduce the warm up period next time.

5. Turn off the coolant supply.

6. Turn off the MOPO/FDO controller.

This completes the shut down procedure for day-to-day use. In the event the unit is to be moved or left off for a long period of time, turn off the circuit breaker on the GCR power supply.

Operating the Control Electronics

Use the MOPO controller to access FDO table, wavelength, and service functions. If you purchased the FDO unit after the MOPO, the Spectra–Physics Lasers service engineer that installed the FDO also installed a firmware upgrade that expanded the control capability of the MOPO electronics unit to include those for the FDO. The FDO functions are accessed in the same manner as the MOPO functions.

Ten buttons are used for operating the MOPO/FDO controller (Figure 4-1). Three buttons to the left of the display allow selection of the OPERATE, SCAN SETUP or MONITOR menus. Pressing the OPERATE button brings up the MOPO Service menu and then the FDO Service menu. The SCAN SETUP button brings up a menu that allows the user to set the scan parameters, and the MONITOR button toggles between the MOPO and FDO Monitor menus.

The five buttons on the bottom are "soft-keys," and they select and control various functions, depending on which menu is active and which function was previously selected. These keys are referred to throughout this manual as function keys 1 through 5 (F_{1-5}).

Use the two up/down arrow keys to the right of the display either to change the numerical value inside the highlighted box on the display or to scroll through the various selections that are offered.
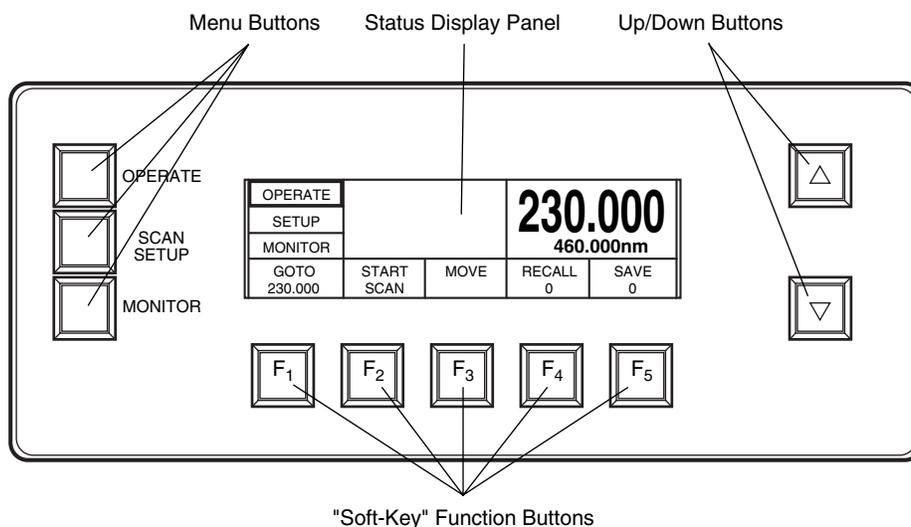
Figure 4-1: Initial configuration of the electronics panel

The "SSS" (Select, Scroll, Set) Procedure

When operating the MOPO/FDO, use the "select, scroll, set," or SSS, process to select an operation, scroll though various options upon which to operate (or to change the value of the selected operation), and then "set" that value or option to lock it in. To do this, press the appropriate function key to select the type of operation to be performed, then use the up/down keys to scroll through the options or values, then "set" that selection to lock it in by pressing and holding in the original "select" button until it beeps.

For example, if you wanted to Y-shift the calibration table for the 56° crystal, you would first select the 56° crystal as the device upon which to be operated (from the FDO Service menu which is covered later in this chapter), then select Y_DISP as the function operator. To do this, press the DEVICE function key, F_1, to highlight it. Next, use the up/down keys to scroll to 56_CRYS. Finally, press the DEVICE button again and hold it in until it beeps to set the 56° crystal as the selected device. In the same manner, use the SSS process to select the Y_DISP function: press the METHOD key, F_2, to select it, then use the up/down keys to scroll to the Y_DISP displacement function, then set it by holding the METHOD key in until it beeps.

The 56_CRYS and the Y_DISP function will remain the active selections until manually changed by the operator. Note that, although many procedures for the MOPO/FDO use the SSS process, not all require it. For example, setting the scan parameters (beginning, end, and number of scans) requires the operator to simply select them, they do not have to be "set." These requirements are explained later under the menu descriptions.

Powering Up the System

Turn on the power switch on the rear of the unit. The system will first perform an internal diagnostics routine, which takes about 10 seconds, then the front panel lights up and the OPERATE menu is displayed. At this point, any of the menus listed below and shown in can be chosen.

The Menu Structure

A brief overview of the controller's layout and functions is included here for your convenience. The menus and commands that are necessary for operating the FDO are listed here and are very similar to those used to control the MOPO. For MOPO menus and information on MOPO operation, refer to chapter 4 of the MOPO manual.

The illustration below shows the three mode keys (the buttons to the left of the display) and the services that are available through them. The following section give a brief description of the various menus that are displayed when these modes are selected and lists them in the order in which they are discussed in this chapter.

```
                        MODE KEYS
            ┌───────────────┼───────────────┐
        OPERATE         SCAN SETUP        MONITOR


     ┌──▶ ┌─────────────────┐      ┌──▶ ┌─────────────────┐
     │    │     OPERATE      │      │    │  MOPO MONITOR   │
     │    └─────────────────┘      │    └─────────────────┘
     │             │               │             │
     │             ▼               │             ▼
     │    ┌─────────────────┐      │    ┌─────────────────┐
     │    │  MOPO SERVICE   │      │    │   FDO MONITOR   │
     │    └─────────────────┘      │    └─────────────────┘
     │             │               │             │
     │             ▼               │             ▼
     │    ┌─────────────────┐      │    ┌─────────────────┐
     │    │   FDO SERVICE   │      │    │     REMOTE      │
     │    └─────────────────┘      │    └─────────────────┘
     └─────────────┘               └─────────────┘
```
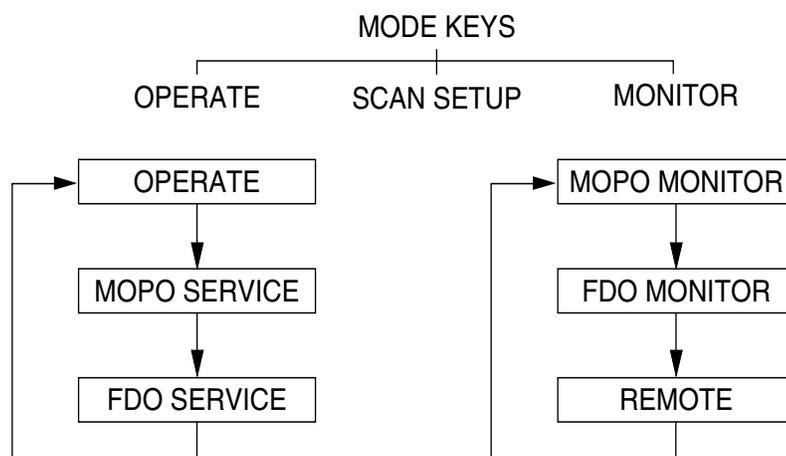
A Brief Description

The following is a short description of each menu. A complete description of each follows later in this chapter.

The Operate Menu (page 4-11): is displayed when the system is first turned on and any time the OPERATE key is pressed from any other menu.

OPERATE			**230.000**	
SETUP				
MONITOR		**DT**	**460.000nm**	
GOTO 230.000	START SCAN	MOVE	RECALL 0	SAVE 0

It displays:

• the actual doubled output wavelength (large numbers)
• the MOPO source wavelength (small numbers)

The function keys allow initiation of:

• a GOTO
• a SCAN
• a MOVE

- a SAVE of the present settings
- a RECALL of the previous settings

The MOPO Service Menu (page 4-13): is displayed when the OPERATE key is pressed once when the Operate menu is displayed, or twice from any other menu.

```
| SERVICE |  MOD=IDL 0    PWR=          0 |
|---------|  WVL=460000   CNT=-1202805    |
| SETUP   |  SET= 17667   POT=     17668  |
| MONITOR |  LPT= 19113   RPT=     12927  |
| MODE    | CALIB.  | INFO  | M-MIKE | RESET |
| 730D30  | MODIFY  |       | TRK    | WL    |
```

It displays:

- the MOPO mode setting
- output wavelength
- master oscillator power
- the command set point of the BBO crystal
- the actual (relative) position of the crystal.

The function keys allow selection of:

- device mode
- calibration mode
- feedback mode
- software revision information

The FDO Service menu (page 4-14): is displayed when the OPERATE key is pressed twice when the Operate menu is displayed, or three times from any other menu.

```
| SERVICE |  MOD=IDL 0                    |
|---------|  WVL=230000                   |
| SETUP   |  SET=  9000   CRY=    9010     |
| MONITOR |  SET= 12038   PRS=   12034     |
| DEVICE  | METHOD  | ADJUST | CONT | ABORT |
| 56_CRYS | Y_DISP  |        |      |       |
```

It displays:

- the FDO mode
- the output wavelength
- output power
- the command set point for the doubling crystals
- the actual position of the doubling crystals
- the command set point for the PB prism
- the actual position of for the PB prism

The function keys allow selection of:

- the device to be investigated
- the calibration mode
- the feedback mode

The Scan Setup Menu (page 4-19): is displayed when the SCAN SETUP key is pressed.

OPERATE			**230.000**	
SETUP				
MONITOR			**460.000nm**	
SCANS 101	BEGIN 230.000	END 260.000	CONT 0.0101	SHOTS 0

It displays:

• the current doubled output wavelength
• the source wavelength for the doubled output

The function keys provide a means to set up:

• the number of scans to be performed
• the starting and end wavelength for a SCAN
• whether the scan will be CONTinuous at a user-defined rate or
• will dwell at user-defined settings and a deliver a preset number of SHOTS at each dwell.

Once a scan begins, progress menus are displayed for monitoring the scan.

The MOPO Monitor Menu (page 4-23): is displayed whenever the MONITOR key is pressed once.

OPERATE				
SETUP				- -
MONITOR	0		0	
MOPO MONITOR	PUMP POWER		M-OSC POWER	M-OSC TRK

It displays:

• GCR pump power, numerically and graphically
• master oscillator power, numerically and graphically
• the error tracking signal of the master oscillator

The FDO Monitor Menu (page 4-25): is displayed whenever the MONITOR key is pressed twice.

OPERATE				
SETUP				- -
MONITOR			0	
MODE TRACK			FDO POWER	FDO DIFF

It displays:

• FDO output power, numerically and graphically
• FDO error tracking signal

The Remote Setup Menu (page 4-27): is displayed when the MONITOR key is pressed three times.

OPERATE				
SETUP				
REMOTE				
SELECT LOCAL	IEEE488 15	BAUD 2400		

The function keys allow the setting of the remote control source to:

- LOCAL
- RS-232
- IEEE-488

and allow the user to set the baud rate for the serial interface and the address for the IEEE-488 parallel interface.

The Operate Menu
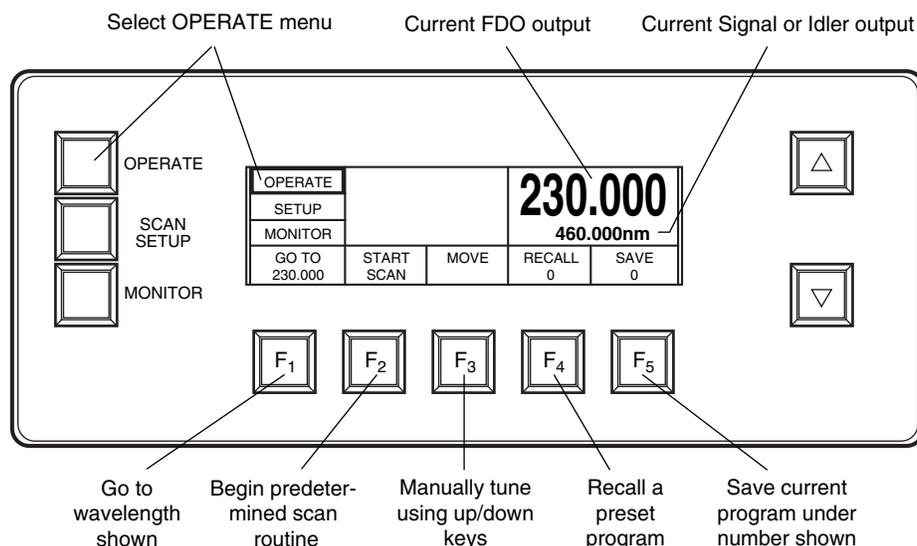
Figure 4-2: The Operate Menu

The Operate menu (Figure 4-2) appears when the system is first turned on. From other menus, pressing the OPERATE button at any time returns you to this menu. Pressing it a second time brings up the MOPO Service menu. A third push brings up the FDO Service menu. Pushed one more time will return you to the Operate menu. The Operate menu allows the operator to set the MOPO/FDO wavelengths directly, to initiating a scan, to manually tune the wavelength output, to recall one of 20 stored settings, and to save the present settings as one of the 20 stored settings.

The Display:

The large number in the upper right-hand box is the doubled output wavelength. The small number below it is the Signal or Idler wavelength that is being doubled.

The Function Keys:

F_1: **GOTO**—allows the operator to set the FDO output wavelength. Simply press the GOTO button, scroll to the wavelength value desired using the up/down keys, then hold the GOTO button in until it beeps to begin the operation (i.e., to move the system to that wavelength). Note that the value does not have to be "set" as required by the SSS procedure. The MOPO is automatically tuned for the proper Signal or Idler output and the FDO crystal is tuned to provide the output wavelength desired. Unlike the SCAN and MOVE commands, GOTO allows movement through the degeneracy range (between 345 and 366 nm) although there is no output.

F_2: **START SCAN**—initiates a scan between two wavelengths. Prior to performing a scan, several parameters must be programmed into the controller using the SCAN SETUP function (see "The Scan Menu" later in this chap-

ter). A scan is not allowed through the degeneracy range (between 345 and 366 nm).

F₃: MOVE—allows you to tune the output wavelength manually using the up/down buttons. Simply select MOVE, then press the up or down key to move the system to the wavelength wanted. The wavelength shown on the display is continuously updated as the system is tuned. Note: a MOVE is not allowed through the degeneracy range. Also, as you tune, if the system needs to change from Signal to Idler input for the output requested, or vice versa, or the FDO needs to change the active crystal, there will be a pause while the proper crystal rotates into place.

F₄: RECALL—recalls previously saved parameters, including the scan routine and the GOTO wavelength setting. Press the RECALL button, then use the up/down keys to select the set of stored parameters (numbered 0 - 19) you wish to use. Once chosen, hold the RECALL button in until it beeps to initiate the recall.

F₅: SAVE—saves the SCAN settings and the GOTO wavelength setting. Press the SAVE button, then use the up/down keys to select the set number (0 - 19) under which you wish to store the present parameters. Once chosen, hold the SAVE button in until it beeps to initiate the save.

The MOPO Service Menu
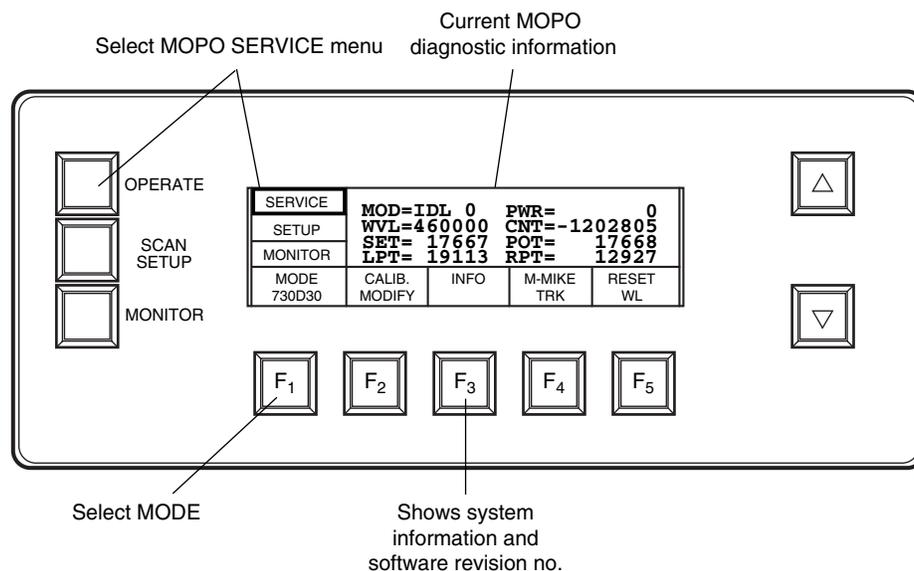
Figure 4-3: The MOPO Service Menu

Before using your system each time, toggle to the MOPO service menu (Figure 4-3) by pressing the OPERATE button twice, and verify MODE is set correctly to indicate the installed system. For example, the MODE display box should list your MOPO system type and its rep. rate. For example, if the installed system is a MOPO-730 with a rep. rate of 30 Hz and it includes an FDO, "730D30" should be displayed. A system without an FDO would display as "730-30." If the selection displayed is incorrect, use the SSS procedure to correct it.

If MOPO/FDO software updates are required, use the F$_3$ button to identify your software revision number. This number is also required if and when you talk to your Spectra-Physics Lasers service representative regarding service.

More information on the MOPO service menu is available in the *MOPO User's Manual*.

The FDO Service Menu
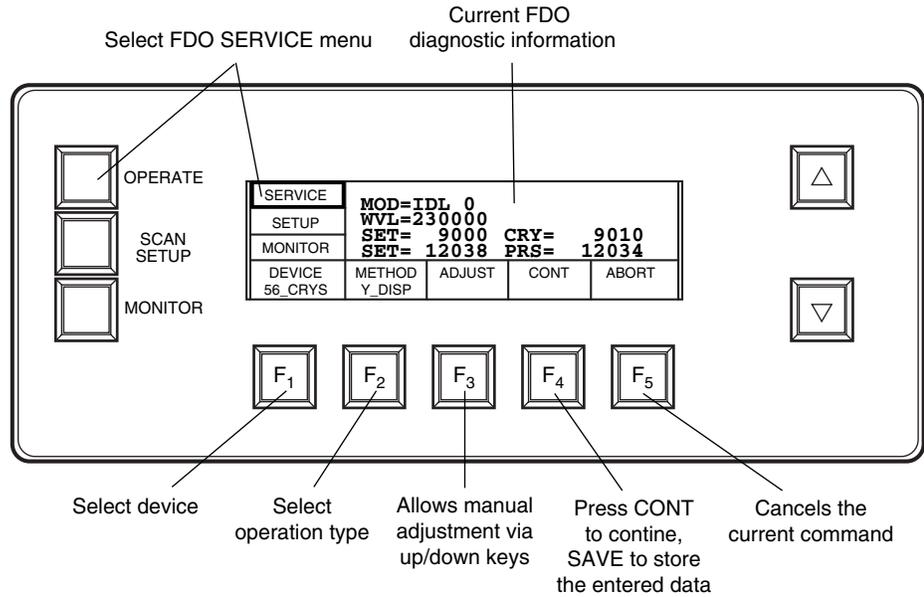
Figure 4-4: The FDO Service Menu

The FDO Service menu (Figure 4-4) is used to setup, test and monitor various system components, and to set the type of feedback to be used, TRACK or TABLE, to drive the system. It also provides routines for modifying the database tables associated with the doubling crystals, the PB prism, and the MOPO crystal. Following this section is a section on "FDO Table Writing," which explains how to create and modify a user-defined table for each device.

Press the OPERATE key to toggle the menu first to the MOPO service menu, then to the FDO service menu. (A third press will take you back to the OPERATE menu.)

The Display:

The FDO service menu displays these system parameters:

MOD: (Mode) Displays the system operating mode:
          IDL 0 - "Idle," the unit is not moving
          GOTO - a goto is in progress
          SCN - a scan is in progress

WVL: (Wavelength Value) Displays the current wavelength.

SET: (Set Point) Command position value for either the crystal (CRY) or prism (PRS). This is a relative table value from 1 to 32,760 that is associated with the wavelength requested (WVL).

CRY: (Crystals) Actual position value from the crystal feedback unit (it should match the corresponding SET value).

PRS: (PB Prism) Actual position value from the crystal feedback unit
           (it should match the corresponding SET value).

The Function Keys:

F₁: DEVICE—allows the operator to use the SSS procedure to select the
device to be investigated or operated. Available devices are: 56_CRYS,
36_CRYS, PB_PRSM, and OPO_CRYS. Each is described below.

36_CRYS: The 36° BBO crystal generates doubled Signal wavelengths
           below the MOPO degeneracy band from 272 to 345 nm and dou-
           bled Idler wavelengths above the degeneracy band from 366 to
           450 nm.

56_CRYS: The 56° BBO crystal is generates doubled Signal wavelengths
           from 219 to 271.9 nm.

PB_PRSM: The PB prism is responsible for separating the selected doubled
           frequency from the fundamental frequency and directing the
           former toward the exit prism.

OPO_CRY: is the MOPO BBO crystal responsible for generating the Signal
           and Idler wavelengths from the GCR pump source.

F₂: METHOD—allows the operator to choose one of eight methods for oper-
ating the DEVICE selected. Use the SSS procedure to choose: MANUAL,
DEV_SCN, LSQ_MRQ, LSQ_SVD, LAGRNG, LIN_INT, Y_DISP, or DEV_RST.
Each is described below. Once selected, the highlight box appears around
the ADJUST button (refer to the description of F₃).

LAGRNG, LSQ_SVD, and LSQ_MRQ, are curve-fitting routines that are used
when writing the user tables. The following guidelines are useful for deter-
mining which curve-fitting method to use with a particular device:

> MOPO Crystal: Use the LAGRANG method to optimize the
>   table over several 100 nm ranges.
>
> FDO 56° Crystal:Use the LAGRANG method over 25 – 50 nm
>   ranges, then fine tune using one of the LSQ
>   methods in 10 – 20 nm segments.
>
> FDO 36° Crystal:Same as for the 56° crystal.
>
> PB Prism: Use the LAGRANG method over 25 – 50 nm
>   ranges, then fine tune using the LSQ_MRQ
>   method in 10 – 20 nm segments.

The following describes each of the eight selections available under
METHOD.

MANUAL: This selection allows the manual manipulation of the chosen
           DEVICE via the up/down keys when the ADJUST button is
           pressed.

DEV_SCN: Do not use this option. This diagnostic technique is used by the
           factory to align and optimize the performance of the instrument.

LSQ_MRQ: This is a least squares (Levenberg/Marquardt) fitting routine, similar to the LSQ_SVD routine described below, and it is primarily intended for use with the PB prism to improve its pointing stability. It differs slightly from the LSQ_SVD routine in the way it generates the curve points. You might have to experiment with this method and the LSQ_SVD and LAGRANG methods in order to determine the optimum curve fit for your application.

LSQ_SVD: This is a least squares (singular value decomposition) fitting routine that is primarily intended for use with the PB prism to improve its pointing stability. It is similar to the LAGRNG routine (below) but it differs in three ways. It cycles through 10 points instead of 7, it has better noise immunity, and it takes much less time to compute. This method uses a quadratic fit to produce the curve, and, at the end of the procedure, the "quality of fit" parameters are displayed.

These parameters are the fitting coefficients a_0, a_1, a_2, and the merit function of the chi-squared distribution (the computed points on the curve). The merit function is the most important. Function values on the order of 5 or less indicate reasonable performance, 1 or less excellent performance. Numbers higher than 50 may indicate the need to repeat the process with a different (generally smaller) wavelength range. Use the following general rules to determine the best wavelength range for selection:

• For FDO devices where the table density is 10 values per nanometer, a 20 nm wavelength range works very well. Exceptions are when the 56° crystal is used below 250 nm. In this case, use 10 nm ranges.
• The MOPO crystal needs a smaller range at shorter wavelengths. Since the MOPO table has 1 value per nm, wavelength ranges of 20 to 30 nm generally work well.

You might have to experiment with this method and the LSQ_MRQ and LAGRANG methods in order to determine the optimum curve fit for your application.

LAGRNG: This Lagrange curve-fitting method requires that proper SETUP parameters be set (as in the previous method—see above). The algorithm cycles through 7 points within a range specified by the operator and computes a higher order polynomial fitted curve to those points. At the end, the operator is prompted to save the new values. This method is very effective for large wavelength ranges. It is intended to get the instrument close enough in calibration for the tracking system to take over.

LIN_INT: This linear interpolation method requires that appropriate wavelengths be set for a wavelength scan in the SETUP menu. This means (i) the beginning scan wavelength has to be less than the ending wavelength, and (ii) the wavelengths must be appropriate for the selected device.

This algorithm moves the FDO to the start wavelength, allows the operator to adjust the selected device, moves to the end wavelength, again allows adjustment, then recomputes the curve between the points and stores the new values if the SAVE function is invoked. This is an effective method for quickly optimizing small wavelength regions.

Y_DISP: This Y-displacement routine uses the ADJUST function key and the up/down keys to shift up or down the data table section associated with the selected device and wavelength. It sets the FDO to the nearest wavelength for which there is a table value.

   36_CRYS: When selected and a wavelength was chosen that is below the MOPO degeneracy band (the doubled Signal wavelength) and is within the operating range of this crystal, the section of the table corresponding to 272 – 345 nm is shifted appropriately. For a wavelength above the MOPO degeneracy band (the doubled Idler wavelengths), the section of the table corresponding to 366 – 450 nm is shifted.

   56_CRYS: When selected, the table values from 219.0 to 271.9 nm are shifted.

   PB_PRSM: Three table sections are associated with this device. The appropriate section will be automatically selected and moved up or down depending on what wavelength the device is at when the adjustments are made.

   Section A: 220.0 – 271.9 nm
   Section B: 272.0 – 345.0 nm
   Section C: 366.0 – 450.0 nm

DEV_RST: This routine, "device reset," automatically reverses the selected device 25 counts, then slowly brings it forward again to its present position. It is useful for minimizing backlash when manually positioning the crystals and the PB prism. This function is disabled for the MOPO crystal.

F₃: ADJUST—allows activation of the appropriate adjustment environment once DEVICE and METHOD are selected. Displayed is the current device set point (e.g., CS: 9000), the current device position (e.g., CV: 9026), and the doubled wavelength (e.g., WL: 230000). For devices 56_CRYS, 36_CRYS, and PB_PRSM, a normalized vertical bar graph of the power at the split detector is displayed on the screen (Figure 4-5). A bar graph of the split detector difference signal is displayed to the right of it. The two-digit number between the bars shows the percentage of full scale.

Select FDO SERVICE menu Current FDO diagnostic information Relative output power Error signal

Selected device Selected operation type Allows manual adjustment via up/down keys Press CONT to contine, SAVE to store the entered data Cancels the current command
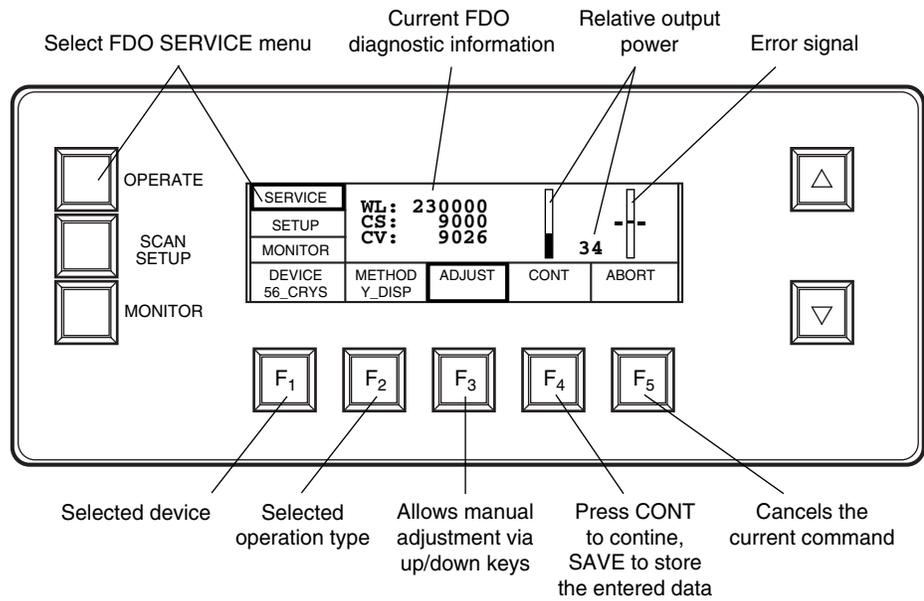
Figure 4-5: The Adjustment Environment

Use the up/down keys to change the device set point and position. Then watch the display and optimize the power and/or balance at the split detector. (If the up/down keys are held down for more than 100 counts, the count speed increases by up to 20x. Release the key from time-to-time to maintain a slow count speed.)

The OPO_CRYS is adjusted in a similar manner. The second vertical bar graph represents the tracking signal. Tracking is disabled during adjustment, however, and the bar graph merely verifies the tracking state and display consistency.

F_4: **CONT/SAVE?**—press CONT to continue the process that was selected using the METHOD function key. When the cycles dictated by METHOD are complete, SAVE? is displayed. Press SAVE? until it beeps to save the entered data.

F_5: **ABORT**—cancels the current command and returns the system to the initial screen. It *does not* return the FDO to the start position. If the data entered must be deleted, hold this button in until the DELETE button is displayed, then hold the DELETE button in until it beeps. ***Be sure this is what you want to do!*** The entire user-defined table associated with that device will be erased and will *not be retrievable*. If DELETE was selected in error, press the button *momentarily* to return to ABORT, then press ABORT to return to the initial screen.

The Scan Setup Menu
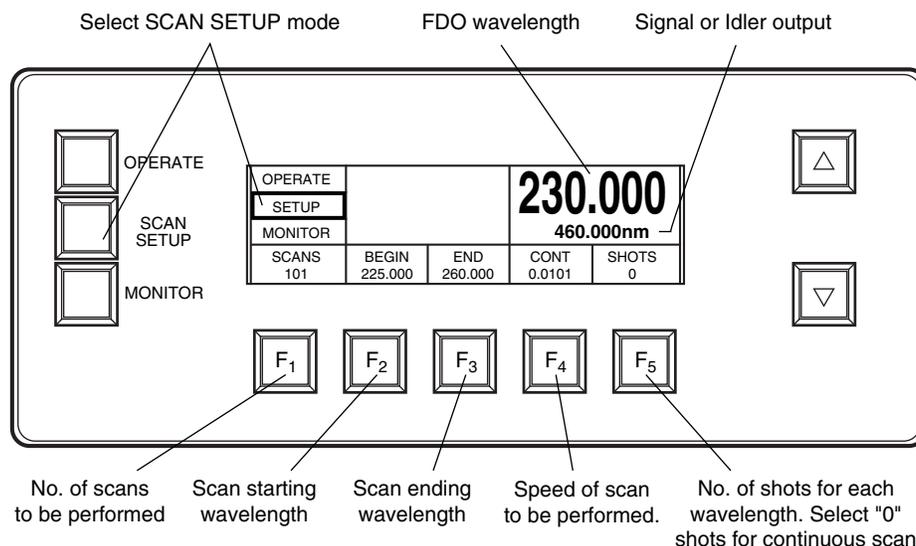
Figure 4-6: The Scan Setup Menu

Press the SCAN SETUP button at any time to display this menu (Figure 4-6).

This menu allows the operator to set the number of scans to be performed, as well as the starting and ending wavelengths. When SHOTS is set to "0," CONT is displayed over F_4 to indicate a continuous scan is selected (i.e., there will be no dwell during the scan). Just below CONT is the scan rate in nm/sec. When SHOTS is set to "1" or greater, INCR is displayed over F_4 to indicate the system is set for an incremental scan. An incremental scan starts at the beginning wavelength and moves the scan by the nm increments (.xxx nm) shown under INCR. The scan stops (dwells) at each increment and the system delivers the number of shots displayed under SHOTS. The scan then progresses and repeats this process until it reaches the scan END wavelength.

Like the MOPO scan rate, the FDO scan rate is nonlinear for a MOPO-710 and 730. This is because the scan rate is dependent on the rotation of the BBO crystal and the beam angle, and beam angle vs. wavelength is a non-linear function. The maximum scan rate is lower for scans in the blue end of the spectrum. Refer to your *MOPO User's Manual* for more information.

Scanning through the degeneracy range is not permitted and a warning to this effect will be displayed. The degeneracy range is 345 to 366 nm for the FDO and 690 to 732 nm for the MOPO.

The SSS procedure is not used with this menu. Simply select the function by pressing its button, then use the up/down keys to set the numerical value inside the associated window.

The Display:

The large number in the upper right-hand box is the FDO doubled output wavelength. The small number below it is the Signal or Idler wavelength that is being doubled.

The Function Keys:

F_1: **SCANS**—sets the number of consecutive scans to be performed.

F_2: **BEGIN**—sets the beginning scan wavelength. The FDO beginning wavelength can be any number from 220 to < 450 nm.

F_3: **END**—sets the end scan wavelength. The FDO end wavelength can be any number from > 220 to 450 nm.

F_4: **INCR**.—indicates the FDO is set for an incremental scan. The increment scan size between dwells is displayed in nanometers below INCR. This mode is selected by setting SHOTS to "1" or greater. A Setting of "0" sets the system to continuous scan, CONT (see below).

F_4: **CONT**—indicates the FDO is set for a continuous (non-incremental) scan. It is selected by setting the SHOTS parameter to "0." A setting of "1" or greater sets the system to incremental scan, INCR (see above). The scan rate is set in nm/sec and is limited to a maximum rate dictated by the wavelength chosen.

F_5: **SHOTS**—sets the number of shots that will be issued during an incremental scan dwell. If the number is set to "0," a continuous scan is selected.

Running an FDO Scan
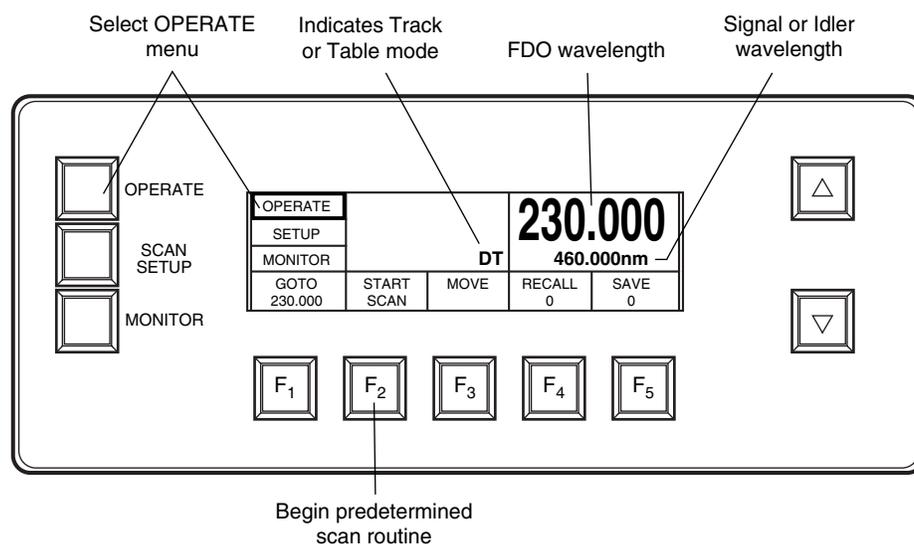
Figure 4-7: Initiating a Scan

Figure 4-7 shows a scan being initiated from the Operate menu, and the following procedure explains how to perform a scan in the FDO wavelength range. It is similar to that used for the MOPO.

Before a scan can be performed, there are parameters that must be set. These are entered via the Scan Setup Menu (see the previous section and refer to Figure 4-6.

1.   Press the SCAN SETUP button to access the Scan Menu.

2.   Press the SCANS button to select this function, then use the up/down keys to set the number of scans you wish to perform.

3.   In like manner, set the scan BEGIN and END wavelengths.

4.   If an incremental scan is desired, set the SHOTS value to the number of shots required per dwell. If a continuous scan is desired, set the SHOTS value to "0" and set the scan rate (the number under CONT) in nm/sec.

5.   If an incremental scan was selected in step 4, set INCR to the number of nanometers desired between dwells.

6.   Press OPERATE to return to the Operate Menu.

7.   Press START SCAN to begin the scan process.

     When the scan process begins, the Operate Menu changes to indicate the progress of the scan (refer to Figure 4-8) and to provide the operator control of the scan as it progresses. A horizontal bar graph displays the percentage of scan completed, and the wavelength displays show the progress of the doubled Signal or Idler output as well as the Signal or Idler output.

Of the five soft keys, two remain present and become ABORT SCAN and HOLD SCAN. Press the HOLD SCAN key to momentarily pause the scan.
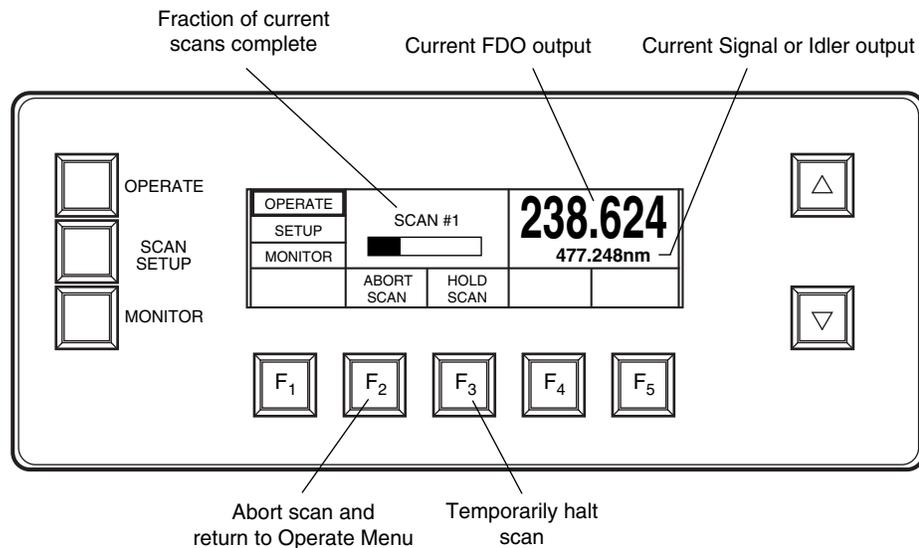
Figure 4-8: Scanning in Progress

8. Once paused, the HOLD SCAN key changes to RESUME SCAN. Press this key to resume the scan.

9. Press the ABORT SCAN button to return to the Operate menu.

When the scan completes, the system moves to the starting wavelength (unless the ABORT key is pressed) and returns to the Operate menu.

The MOPO Monitor Menu
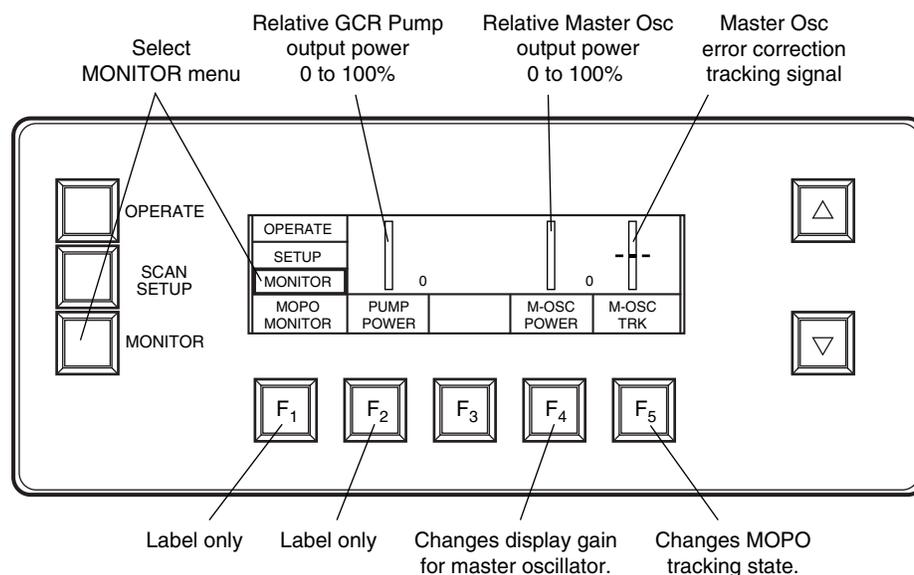
Figure 4-9: MOPO Monitor Menu

The MOPO Monitor menu (Figure 4-9) is accessed by pressing the MONI-TOR button. It is displayed the first time it is pressed. Pressing it a second time displays the FDO Monitor. A third press displays the Remote menu. A fourth press returns the display to the MOPO Monitor menu.

The MOPO Monitor Menu provides a visual display of relative GCR pump power, MOPO output power, and the MOPO tracking (difference) signal. Although the output power displayed is a running average of the last 0.8 seconds of shots, it is not an absolute indication of power, but a relative reference to be used when optimizing output. For increased resolution of low signals, the gain of the display can be increased up to 16 times.

The F_4 function key sets the display gain appropriate for the task. A higher gain can be helpful, for example, when calibrating the oscillator at a low-power wavelength. Lower resolutions are useful in most cases to monitor system output. Available gain settings are 1, 2, 4, 8, or 16x, and are set using the SSS procedure. This feature is saved along with all other data when using the SAVE function from the Operate menu.

The Display:

The left-most bar graph and digit expresses the GCR pump power in relative terms of 0 to 100% of full power. The center bar graph and digit does the same for the master oscillator output power. The right-most bar graph shows the master oscillator tracking error signal. This bar is ideally at the center of the graph, i.e., in its balanced position.

The Function Keys:

F_1**: MOPO MONITOR**—display box is a label to indicate the menu displayed; the button provides no function.

F_2**: PUMP POWER**—display box is a label to indicate the bar graph above it; the button provides no function.

F_3**: N/A**

F_4**: M-OSC POWER**—display box is a label to indicate the bar graph above it. The function key sets the screen gain to 1, 2, 4, 8, or16x using the SSS procedure.

F_5**: M-OSC TRK**—changes the MOPO tracking mode (see the *MOPO User's Manual*). It also identifies the bar graph displayed above it.

The FDO Monitor Menu
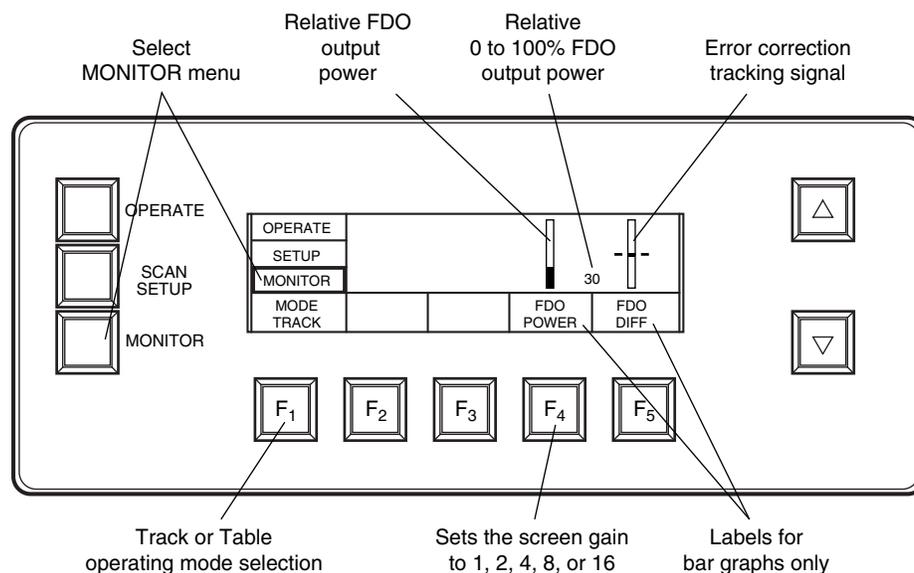
Figure 4-10: FDO Monitor Menu

The FDO Monitor menu (Figure 4-10) is accessed by pressing the MONI-TOR button. The MOPO Monitor menu is displayed the first time it is pressed. Pressing it a second time displays the FDO Monitor menu. A third press displays the Remote menu. A fourth press returns the display to the MOPO Monitor menu.

The FDO Monitor Menu provides a visual display of relative FDO output power and the tracking (difference) signal. Although the output power displayed is a running average of the last 0.8 seconds of shots, it is not an absolute indication of power, but a relative reference to be used when optimizing output. For increased resolution of low signals, the gain of the display can be increased up to 16 times.

The F_4 function key sets the display gain appropriate for the task. A higher gain can be helpful, for example, when calibrating the oscillator at a low-power wavelength. Lower resolutions are useful in most cases to monitor system output. Available gain settings are 1, 2, 4, 8, or 16x, and are set using the SSS procedure. This feature is saved along with all other data when using the SAVE function from the Operate menu.

F_1 offers two operating modes: TRACK or TABLE. Figure 4-10 shows TRACK mode selected which uses the split-cell detector to locate the position of the output beam. As the beam moves from one side of the cell to the other, an error signal is generated that the system uses to continuously adjust the crystal to maintain optimum power and a balanced signal on the split-cell detector. The relative magnitude and direction of the error signal is displayed by the right-hand bar graph.

If TABLE mode is selected, the crystal angle is adjusted based on one of two preset table values. The first table is a factory-set, read-only table that is

based on calculated data. It is valid for all FDO systems. The second table is a read/write table that can be filled with values entered by the user, based on actual measured values for his system, for increased accuracy. The system automatically selects the user-defined table when it exists, otherwise it uses the factory-set table. "FDO Table Writing" later in this chapter explains how to create, modify and erase a user-defined table.

The Display:

The number between the bar graphs indicates output power as a numerical percentage, whereas the bar graph to the left of it shows the same thing graphically. In some cases, the numbers are easier to observe. Both displays are relative indicators.

Note: setting the screen resolution gain effects both displays, i.e., both the height of the bar graph and the displayed percentage are altered by the gain setting.

The error-correction tracking signal (FDO DIFF) is shown in the bar graph on the right. Because the tracking process requires that the optimum power and mode distribution for a given wavelength be achieved by a balanced output, the split-cell detector difference signal is used to accurately position the PB prism during calibration.

The Function Keys:

F_1: **MODE**—sets TRACK or TABLE monitoring using the "SSS" process.

F_2: **N/A**

F_3: **N/A**

F_4: **FDO POWER**—display box is a label to indicate the bar graph above it. The function key sets the screen gain to 1, 2, 4, 8, or16x using the SSS procedure.

F_5: **FDO DIFF**—display box is a label to identify the bar graph above it; the button provides no function.

The Remote Menu
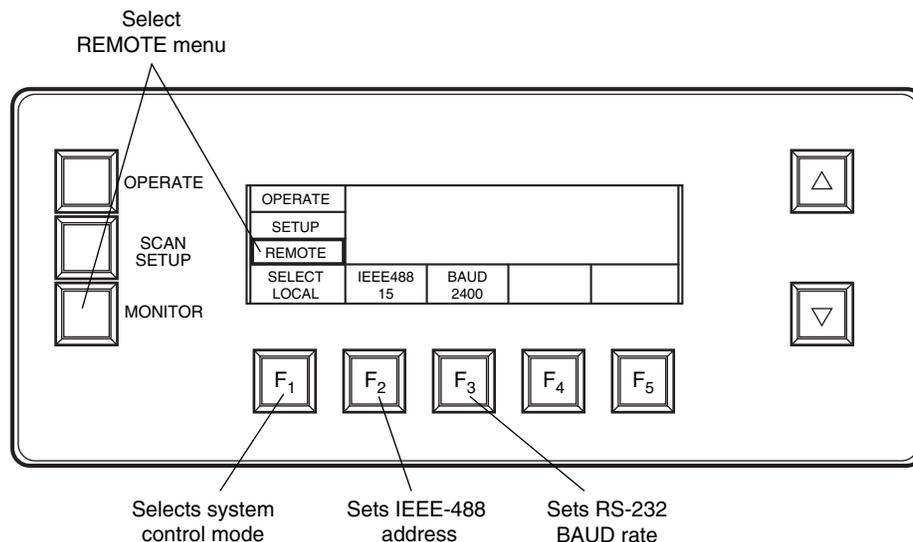
Figure 4-11: Remote Menu

The Remote menu (Figure 4-11) is used to select the system control source. The default is the front panel, or LOCAL, but it can be set so that the MOPO/FDO can be controlled by a serial device, such as a terminal or a personal computer configured as a terminal, or an IEEE-488 control source. Once set, this becomes the default control source until changed again by you.

The Remote menu is accessed by pressing the MONITOR button three times. The first time it is pressed from another menu, the MOPO Monitor menu is displayed. Pressing it a second time displays the FDO Monitor menu. A third press displays the Remote menu (and the MONITOR button label changes to REMOTE). A fourth press returns the display to the MOPO Monitor menu.

Appendix D, "Using the RS-232/IEEE-488 Interface," provides a complete description of these interfaces and their command structure and explains how to use them. Several software examples are also provided.

Caution: When activating the selection during the following procedures, if the function key is not held in until the beep, the unit will revert back to its previous setting when you leave this menu.

Control Source Selection

To select the control source:

1. Press F$_1$ to begin the selection process.

2. Use the up/down keys to toggle to the desired device: RS-232, IEEE-488 or LOCAL.

3. Press F$_1$ and hold it in until it beeps to activate the chosen control source.

When one of the optional interfaces is selected as the control source, LOCAL is displayed over F_5. Pressing F_5 returns the system to local operation (Figure 4-12).

Returns control
back to front panel
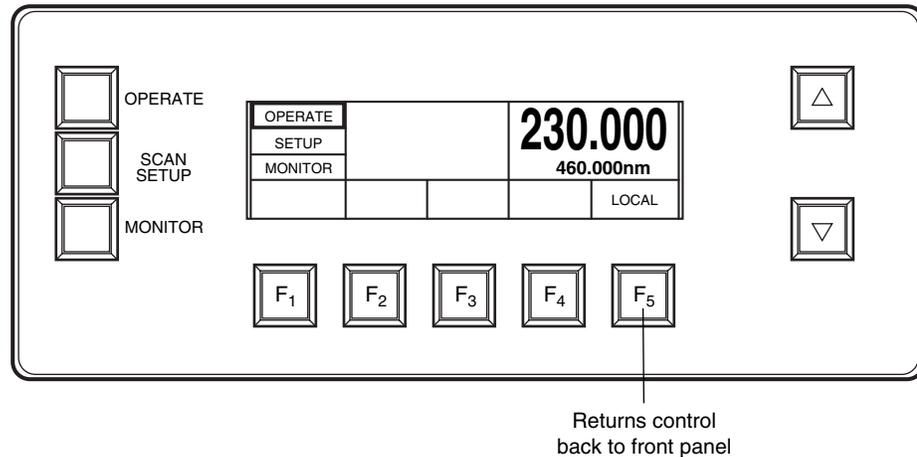
Figure 4-12: Returning Local Control to the System

IEEE-488 Address Selection

The default address for the IEEE-488 interface is 15, but it can be changed to any address from 0 to 31. To change it:

1. Press F_2 to place the cursor under the digit to be changed.
2. Use the up/down keys to scroll the number to the digit desired.
3. Repeat this procedure to select the second digit.
4. When the new address is selected, activate the IEEE-488 at this address by holding in F_2 until it beeps.

BAUD Rate Selection

The default serial BAUD rate is 2400, but it can be changed to 300 or 1200. To change it:

1. Press F_3 to indicate the serial address is to be changed.
2. Use the up/down keys to scroll to the BAUD rate desired.
3. Activate the serial interface at the selected BAUD rate by holding in F_3 until it beeps.

The Display:

Nothing is displayed in the large window.

The Function Keys:

F_1: **LOCAL**—sets system control to either the front panel (local) or to the IEEE-488 or the RS-232 interface. The selection is shown in the display box.

F_2: **IEEE-488**—sets the address for the IEEE-488 parallel interface shown in the display box. See "IEEE-488 Address Selection" above for information on changing this address.

F_3: **BAUD**—sets the BAUD rate for the RS-232 serial interface shown in the display box. See "BAUD Rate Selection" above for information on changing the BAUD rate.

F_4: **N/A**

F_5: **N/A**

Switching Between MOPO and FDO Operation

Switching from MOPO to FDO Operation

1. Press the OPERATE button to select the MOPO Service menu.

2. Press F_1 to select the mode key.

3. Use the up/down keys to select your MOPO model and repetition rate, and make sure it includes the "D" for the FDO option.

    Example: a Model 730 operating at 10 Hz with the FDO option is designated as "730D10."

4. Hold in the F_1 key until it beeps to activate this selection as the default.

5. Turn down the LAMP ENERGY control(s) on the GCR controller.

6. Install the FDO TP_1 turning prism in its normal (non-parked) position.

    The prism is fastened to the mounting plate by two 10-32 lock-down screws.

CAUTION
Be careful. Hold the prism by the edges of its back plate.

7. Bring up the LAMP ENERGY control(s) to full power.

8. Once the MOPO is operating, check FDO uv output power. If uv output is at full power, the FDO is ready to operate.

    If uv power is low, try increasing it by slightly adjusting TP_1. The vertical axis is most sensitive (the lower right control knob).

This completes the conversion from MOPO to FDO output operation.

Switching from FDO to MOPO Operation

1. Turn down the LAMP ENERGY control(s) on the GCR controller.

2. Move the FDO TP_1 turning prism from its normal position to its parked position near the crystal and PB prism turntables.

3. Press the OPERATE button to select the MOPO Service menu.

4. Press F_1 to select the mode key.

5. Use the up/down keys to select your MOPO model and repetition rate without the "D" for the FDO option.

    Example: a Model 730 operating at 10 Hz without the FDO option (or when it is not used) is designated as "730-10."

6. Hold in the F_1 key until it beeps to activate this selection as the default.

7. Bring up the LAMP ENERGY control(s) to full power.

This completes the conversion from FDO to MOPO output operation.

Preparing the System for Scanning

For wavelength scans above 366 nm, it is preferable to set the FDO to TABLE mode. When set to TABLE mode, a "DT" appears in the lower right portion of the Operate menu. For wavelength scans below 345 nm, it is generally preferable to have the FDO set to TRACK mode. When TRACK mode is selected, "DL" is displayed. When scanning outside the FDO wavelength region, it is preferable to have the FDO operating in TABLE mode. TRACK and TABLE are selected via the FDO Monitor menu.

CAUTION

It is essential that the FDO be in TABLE mode while performing any adjustments to the crystal or prism tables.

Scanning Wavelengths Above 366 nm

1. From the Operate menu, GOTO the desired starting wavelength.
2. From the FDO Monitor menu, press F_1 to select the mode key.
3. Use the up/down keys to select TABLE.
4. Hold in the F_1 key until it beeps to activate TABLE as the default setting.
5. From the Scan Setup menu, enter the desired scan parameters.
6. From the Operate menu, initiate the scan by pressing F_2, the START SCAN key.

Scanning Wavelengths Below 345 nm

1. From the Operate menu, GOTO the desired starting wavelength.

If TABLE mode is already selected ("DT" is displayed in the Operate menu), skip to step 5.

2. From the FDO Monitor menu, press F_1 to select the mode key.
3. Use the up/down keys to select TABLE.
4. Hold in the F_1 key until it beeps to activate TABLE as the default setting.
5. From the FDO Monitor menu, verify:
   a. uv power is maximized.

   Perform a Y-DISP on the FDO crystal from the FDO Service menu if required (refer to the FDO Service menu section in this chapter).
   b. the FDO difference signal is balanced.

   Perform a Y-DISP on the PB crystal from the FDO Service menu if required.

6. From the FDO Monitor menu, press F₁ to select the mode key.

7. Use the up/down keys to select TRACK.

8. Hold in the F₁ key until it beeps to activate TRACK as the default setting.

9. From the Scan Setup menu, enter the desired scan parameters.

10. From the Operate menu, initiate the scan by pressing the F₂, the START SCAN key.

Operating at Fixed Wavelengths

If TABLE mode is already selected ("DT" is displayed in the Operate menu), skip to step 4.

1. From the FDO Monitor menu, press F₁ to select the mode key.

2. Use the up/down keys to select TABLE.

3. Hold in the F₁ key until it beeps to activate TABLE as the default setting.

4. From the Operate menu, GOTO the desired wavelength.

5. If uv power does not appear optimized, use MANUAL or Y-DISP from the FDO Service menu for the active FDO crystal to optimize uv output power. Some improvement in power stability might be achieved by placing the MOPO in TRK TO or TBL TO mode from the MOPO Service menu (refer to the MOPO Service menu section in this chapter).

FDO Table Writing

The MOPO/FDO system supports two wavelength (crystal angle) sets of tables. The first is a backup, read-only computer-generated theoretical table that is based on the phase-matching properties of the BBO crystal. The second table set is created by the user to fine-tune the system and to set the wavelength parameters based on actual measurements. The controller uses the compter-generated table *only when the default user-table is not present* (i.e., it has been erased). The FDO is shipped with an optimized, factory-generated user table.

There are six tables in each set:

36° crystal:	272 – 345 nm range
	366 – 450 nm range
56° crystal:	220 – 271.9 nm range
PB prism:	220 – 271.9 nm range
	272 – 345 nm range
	366 – 450 nm range

Each segment of the user table can be modified in whole or in part, typically in part. Refer to the "FDO Service Menu" section earlier in this chapter for information on methods that can be used to modify the curve. Once a wide section of the crystal angle vs. wavelength range curve is close to the ideal, a smaller range can be calibrated to best fit the scan range of immediate interest.

If the factory table values are not precise enough for your application, they can be changed. The following procedure steps you through a typical table-writing sequence. There are two parts, one for setting the wavelength values associated with a particular crystal at a particular angle, and one where the procedure is repeated so the same wavelength values associated with prism position can be entered. This procedure assumes the table addressed covers the 375 to 440 nm range of the 36° crystal (see Table 4-1) and that a MOPO Model 730D10 laser will be used as the pump source.

Note that if either of the up/down buttons is held down for more than 100 counts during a table-writing procedure, the count mode becomes accelerated by up to 20x. To resume or to maintain the normal count speed, release the key momentarily from time to time.

An example of writing a table.

1. Press the SETUP mode key.

2. Press the BEGIN function key to enter the starting wavelength.

    Use the up/down keys and BEGIN to input the correct starting wavelength; in this case 375 nm.

3. Press the END function key to enter the ending wavelength, in this case, 440 nm.

Enter the ending wavelength in the same manner as the beginning wavelength.

4. Press the OPERATE mode key twice to access the MOPO Service menu.

5. Ensure that MODE is set to the proper laser configuration; in this case 730D10.

6. Press OPERATE again. This brings up the FDO Service Menu.

7. Press DEVICE and use the up/down keys to select 36_CRYS, then hold the DEVICE button in until it beeps.

    If the device selection is not permitted, the screen will tell you.

8. Press METHOD and use the up/down keys to toggle to LAGRNG, then hold the LAGRNG button down until it beeps.

    The ADJUST function key is automatically selected.

9. Press ADJUST once.

10. Use a power meter or the on-screen display and the up/down keys to adjust the crystal for maximum output power at the specified wavelength.

    Always approach optimum power from the lower wavelength to avoid errors introduced by backlash.

11. Press the CONTinue function key until it beeps.

12. Repeat steps 9 through 11 until all the wavelengths have been recorded for the crystal position portion of this procedure. After seven points have been entered, SAVE? will appear. *Press and hold this button in until it beeps to save the data or it will be lost!* It takes about 30 seconds for the computation to complete and the highlight box around SAVE? to disappear.

This completes the writing of a new user-defined table section for the 36° crystal over the wavelength range selected in steps 2 and 3 above.

Table 4-1: Crystal Operation Summary

Wavelength Range (nm)	Active Crystal (Device)	Crystal Set Point Range (Typ.)	Prism Set Point Range (typ)
220 – 271.9	56°	1000 to 22000	10480 to 16000
272.0 – 345	36°	1000 to 12000	15880 to 19360
345.1 – 365.9	None	—	—
366.0 – 450	36°	12000 to 22000	19460 to 21060

Chapter 5   FDO Alignment

Quick Start Procedure

Refer to your MOPO manual for instructions on how to quickly align the MOPO/FDO to the GCR pump laser. This procedure is meant for use by field service engineers or trained personnel to set up the system after it has been relocated, *not as a first time setup.* It assumes the GCR and MOPO/FDO currently used were originally set up together.

General Procedure

The following alignment procedure is provided in the event the FDO becomes misaligned. It provides enough information so that it can be realigned if something is merely a little off. It is not meant as a first-time or major alignment. No HeNe alignment is required but pinholes are supplied for possible future realignment. Such an alignment is beyond the scope of this manual and should be performed by a Spectra-Physics Lasers service representative. Allow only qualified personnel to align your FDO.

The following procedure is only for the FDO. Refer to your *MOPO User's Manual* for MOPO alignment instructions. The cover must be off the unit and the MOPO must be running in order to perform this procedure.

DANGER: HIGH POWER LASER RADIATION

The Quanta-Ray FDO frequency doubler is a high power laser accessory whose beam is a safety and fire hazard. Take precautions to avoid accidental exposure to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye or skin damage. Always wear proper eye protection and follow the safety precautions in chapter 2, "Laser Safety."

Refer to the beam path drawings in Figure 5-1 and Figure 5-2 for the procedure below.

1. Verify the controller is set to the appropriate doubler mode; e.g., 730D10.

2. Enter 220 for the START wavelength and 250 for END in the SCAN menu.

3. Verify the FDO is set to TABLE mode.

4. Go to 250 nm.

    The controller should position the FDO for operation at 250 nm.

5. Turn down the GCR LAMP ENERGY control and, if not already in place, install TP$_1$ onto its operating position in the FDO.

6. Reset the GCR LAMP ENERGY control for full operation and use the vertical and horizontal adjustments on TP$_1$ to align the MOPO Signal and Idler beams through the center of the FDO crystals and PB Prism.

    These adjustments should be performed while viewing the transmitted beam on the FDO beam block to locate the edges of the crystal aperture. Once the edges are located, adjust TP$_1$ to guide the beam through the best center position of the crystal.

    Note: If you are realigning the FDO following a change from MOPO to FDO operation, merely fine-tuning the vertical adjustment (the lower right-hand knob) on TP$_1$ may be all that is required to re-optimize the system.

7. Using a white business card or other uv-sensitive viewing card, look for a uv beam in the vicinity of the output beam splitter pair (just to the right of the beam block). If no beam is seen, try a Y-DISP operation on the 56° crystal to approximately maximize the uv fluorescence on the viewing card.

8. Using Y-DISP, rotate the PB prism to achieve best centering through the output beam splitters and output prism. Use the horizontal adjustment of TP$_1$ and the vertical adjustment of the 3PA to achieve the best vertical centering.

9. Place a power meter in the uv output beam path and perform a second Y-DISP to the 56° crystal to maximize output power.

    Note: Finish this and all adjustment operations with the "up" key in order to minimize any backlash effects.

10. Perform a Y-DISP on the PB prism to balance the FDO difference signal reading (the center bar indicator on the vertical graph).

Note: Following this realignment, it may be necessary to perform a **Y-DISP** *of the crystal and/or prism tables in the other wavelength ranges (272 - 345 nm and 366 - 440 nm) as well.*

This completes the FDO alignment.
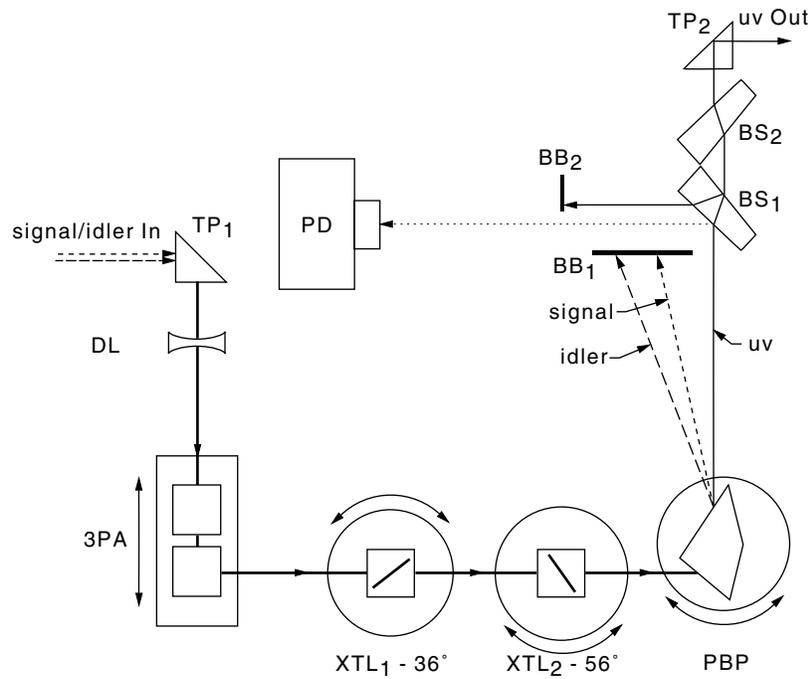
Figure 5-1: FDO Optical Schematic
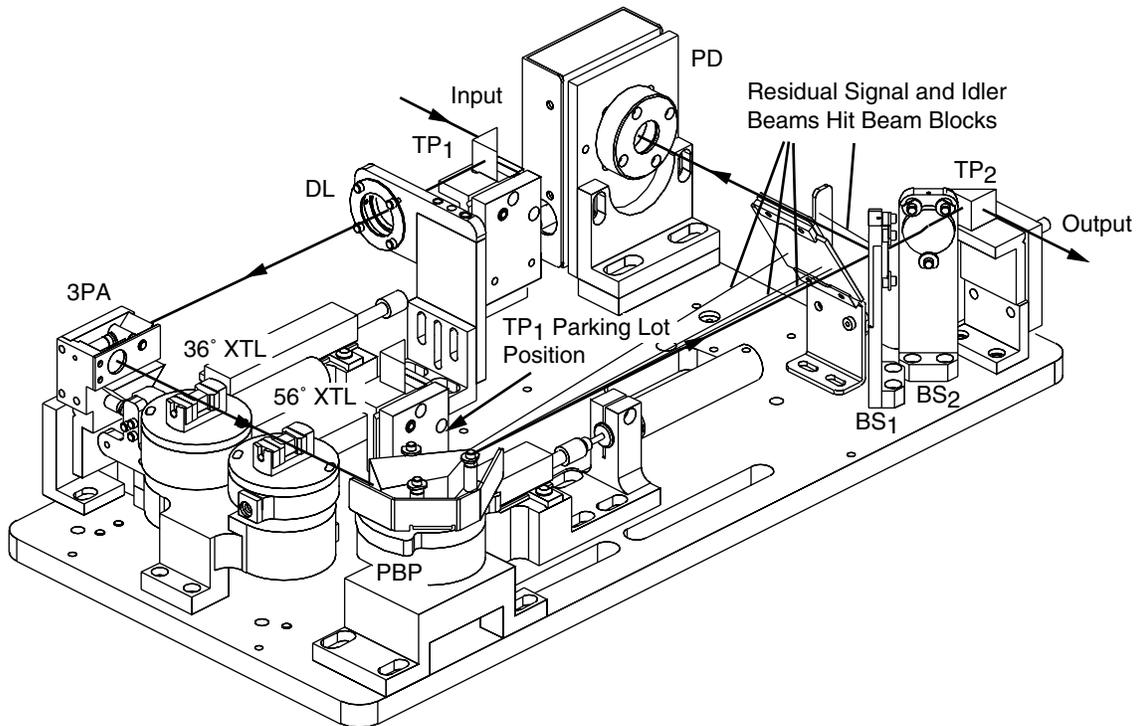
Figure 5-2: 3-D Layout of the FDO

Chapter 6   Maintenance

Preventive Maintenance

The MOPO/FDO has been designed for "hands-off" operation, requiring minimal maintenance.

The top cover protects the internal components from outside contamination and prevents unwanted stray optical radiation from escaping the system.

The MOPO/FDO should always be operated with the top cover in place.

Inspect all windows daily for contamination or damage. Windows should be cleaned with lens tissue and acetone any time contamination is suspected or observed. Damaged windows should be immediately replaced.

It is recommended to annually check the safety features of the pump laser as well as the MOPO/FDO to ensure safety is maintained (see Laser Safety section for details).

Cleaning Laser Optics

Losses due to unclean optics, which might be negligible in ordinary optical systems, can disable a laser and severely reduce the effectiveness of a frequency doubler. Dust on mirror surfaces can reduce output power or cause total failure due to damage. Cleanliness is essential, and the maintenance techniques used with laser optics must be applied with extreme care and attention to detail.

"Clean" is a relative description; nothing is ever perfectly clean, and no cleaning operation ever completely removes contaminants. Cleaning is a process of reducing objectionable materials to acceptable levels.

Since cleaning simply dilutes contamination to the limit set by solvent impurities, solvents must be as pure as possible. Use spectroscopic, electronic, or reagent grade solvents, and leave as little solvent on the surface as possible. As any solvent evaporates, it leaves impurities behind in proportion to its volume. Avoid rewiping a surface with the same swab; a used swab and solvents will redistribute contamination, they will not remove it.

Both methanol and acetone collect moisture during prolonged exposure to air. Avoid storage in bottles where a large volume of air is trapped above the solvent; instead, store solvents in squeeze bottles from which trapped air can be removed.

Laser optics are made by vacuum-deposited microthin layers of materials of varying indices of refraction on glass substrates. If the surface is scratched to a depth as shallow as 0.01mm, the operating efficiency of the optical coating will be reduced significantly.

Stick to the following principles whenever you clean any optical surface:

- Remove and clean one optical element at a time. If all of the optics are removed and replaced as a group, all reference points will be lost, making realignment extremely difficult.
- Work in a clean environment, over an area covered by a soft cloth or pad.
- Wash your hands thoroughly with liquid detergent, then put on finger cots before touching any optic. Body oils and contaminants can render otherwise fastidious cleaning practices useless.

CAUTION
Always wear clean finger cots or gloves when handling intracavity parts and optics.

- Use dry nitrogen, canned air, or a rubber squeeze bulb to blow dust or lint from the surface before cleaning with solvent. Permanent damage can occur if dust scratches the glass or mirror coating.
- Use spectroscopic, electronic, or reagent grade solvents. Don't try to remove contamination with a cleaning solvent that may leave other impurities behind.

WARNING
Do not use lens tissue designated for cleaning eye glasses. Such tissue contains silicones. These molecules bind themselves to the optic coatings and can cause permanent damage. Also, do not use cotton swabs, e.g., Q-Tips™. Solvents dissolve the glue used to fasten the cotton to the stick, resulting in contaminated coatings. Only use photographic lens tissue to clean optical components.

- Use photographic lens tissue to clean optics and windows. Use each piece only once: dirty tissue merely redistributes contamination, it doesn't remove it.

Cleaning Optical Components

Equipment Required

- Dry nitrogen, canned air, or rubber squeeze bulb
- Photographic lens tissue
- Spectroscopic-grade methanol and acetone
- Forceps
- Hemostats

Cleaning Prisms, Crystals, and Mirrors

Most optics can be cleaned in place. If you do not remove them, there is less chance of misalignment. However, be careful you do not allow excess solvent to wick or run down the surface. It is very possible the solvent can attack the adhesive holding the optic to the mount or base and either loosen it or, worse, contaminate the optical surface with adhesive material. A high energy pulse can then burn the material into the surface and permanently damage the optic.

1. Blow away dust particles or lint using nitrogen or air.

2. Fold a piece of lens tissue into a pad about 1 cm on a side and clamp it in a hemostat (Figure 6-1). Saturate the pad with methanol, shake off the excess, resaturate, and shake again. *No not use excessive solvent*!
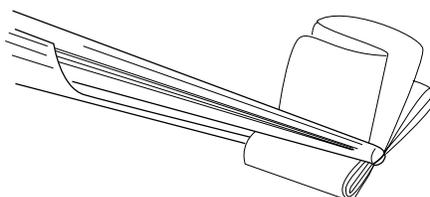
Figure 6-1: Lens Tissue Folded for Cleaning

3. Wipe one surface, bottom to top, in a single motion. Be careful that the tip of the hemostat does not scratch the surface. Repeat the operation with a clean tissue on the second surface (if any). Note: a clean surface scatters little or no laser light.

4. If the optic was removed, install the optic back into its holder or mount and adjust its controls (if any) vertically and horizontally for maximum optical output power.

This concludes the maintenance procedures.

Chapter 7   Service and Repair

This troubleshooting guide is for use by you, the user. It is provided to assist you in isolating some of the problems that might arise while using the system. A complete repair procedure is beyond the scope of this manual. For information concerning the repair of your unit by Spectra-Physics Lasers, please call your local service representative. A list of world-wide service sites is included at the end of this chapter.

Important: for proper operation, the FDO is critically dependent on the performance of the GCR/MOPO system. These systems provide important signals and laser input to the FDO. *Before performing any corrective adjustments to the FDO, always verify proper operation of the GCR/MOPO first.* A simple re-optimization of the MOPO input may be all that is needed to restore the FDO to normal operation.

The troubleshooting suggestions that follow (except for those that refer to the controller electronics and software) all assume that the GCR/MOPO system has been checked out and that it is optimized and operating properly.

As a general note, for controller and/or software problems (as is the case with many computers or computer-based systems) reboot the controller (shut it off and turn it back on) as a first step to solving the problem. This is often sufficient to provide full recovery.

Troubleshooting Guide

Symptom: Controller screen does not light up.	
Possible Causes	**Corrective Action**

Power is not available to the system.	If the fan is off,
	    a. verify that the power cord is plugged in.
	    b. verify the voltage selector is set to the correct line voltage.
	    c. verify the internal voltages are correct (call your SPL rep).

Memory card is missing.	If the fan is on, verify the PCMCIA card is correctly plugged into the motherboard (refer to Figure A-1).
Memory card fault.	Call the factory.

Symptom: System is on, but there is no doubled light.	
Possible Causes	**Corrective Action**
Pump light is not present.	Verify the GCR is operating. Verify the correct output and wavelength is available from the MOPO. Refer to the *MOPO User's Manual*
The master oscillator in the MOPO is not running.	Verify the master oscillator is running. Refer to the *MOPO User's Manual*.
The power oscillator in the MOPO is not running.	Verify the power oscillator is running. Refer to the *MOPO User's Manual*.
No fundamental light is delivered to the FDO.	Verify turning prism TP_1 is in place and that the beam is properly routed through the FDO.
The FDO crystal is not properly located.	Use the FDO Service menu to verify the crystal set point and actual reading are in approximate agreement. The set point values should be within ±1000 counts of the reference values listed in appendix D.

Symptom: Current crystal value (CRY) is not equal (±200) to its SET value, or the prism value (PRS) is not equal to its SET value in the FDO Service menu.

Possible Causes	Corrective Action
The MANUAL/NORM switch on the electronics pc board for either the crystal or the prism is not in the NORM position.	Set the switch(es) to the NORM position.
Motormike(s) not connected or wiring is open.	Verify wires are properly connected to the head board. If they are, then check for continuity. TP22 to ground and TP13 to ground should read about 115 Ω
Alignment apertures are interfering with mechanical movement.	Verify all the apertures have been removed.
There is a sticky mechanism.	If there is no CRV or PRSV reading movement, move the crystal and prism rotating tables by hand against the spring to see if the values change. The normal value range for each device is: 1000 < crystal SET < 23000 8000 < prism SET < 24000 Reboot the unit to see if it can clear itself. Use manual motor drive circuits on the FDO control pcb to drive past the set value, then return to normal computer control.
The 36° crystal is "mixing" the Signal plus the Idler input to produce 355 nm output.	Rewrite the Lagrangian table(s) for the 36° crystal to shift the crystal angles to higher values (lower set point numbers) if doubling Signal wavelengths, or to lower values (higher set point values) if doubling Idler wavelengths.
Q-switch sync signal is not present.	Verify the Q-switch signal is present. Change to internal sync (e.g., 730DINT) and see if the situation changes. Check the cables.

Symptom: No power reading on the FDO MONITOR menus, but uv is exiting the MOPO enclosure.

Possible Causes	Corrective Action
The output pick-off beam is not properly pointed into the photodetector.	Use a business card to verify the pick-off beam is properly aligned to photodetector PD.
There is no Q-switch Sync signal to the FDO.	Verify the Q-switch sync cable from the GCR is attached to the Q-SWITCH SYNC connector on the controller back panel. If it is, verify the signal is actually present (o-scope).
The 8-pin DIN cable connector at the photodetector is loose.	Verify it is properly connected.
The photodiode cable connection at J1 on the head pcb is loose.	Verify it is properly connected.

Symptom: The photodetector seems to be overloaded (the power bar is at maximum).

Possible Causes	Corrective Action
The display gain may be set too high.	Press F_4 to change the gain setting.
Fundamental light is present.	If working around the 450 nm range, the fundamental wavelength is also present (this is normal). At other wavelengths, verify the prism is correctly aligned.

Symptom: The FDO DIFF bar graph does not move up and down.

Possible Causes	Corrective Action
The prism is not properly aligned.	Align the prism to direct the pick-off beam at the photodetector. Use the PB prism table adjust.
Only half of the bi-cell is working.	Verify both sides of the cell work by directing a beam at both sides and noting the signal on the menu. If one side is truly dead, replace the detector assembly.
There is not enough beam divergence for proper detection.	Adjust the DL lens to increase the divergence. Beam width should be about 3 mm.
The pump beam is not collimated.	Refer to the *GCR* and *MOPO User's manuals* for instructions.

Symptom: Low UV output.	
Possible Causes	**Corrective Action**
The FDO crystal is not located properly.	Access the FDO Service menu and use the MANUAL modification method to determine if the crystal can be tuned to a better location. Then perform a Y_DISP and note the PB prism tracking signal. If it not symmetric, adjust it using the appropriate algorithms.
Output uv beam is clipped or obscured.	Verify the FDO DIFF signal on the FDO Service menu is balanced. Verify the uv beam is centered on the output optics and window.

Symptom: Tracking does not work.	
Possible Causes	**Corrective Action**
The PB prism is not properly positioned.	Verify uv output and optimize the crystal position if necessary. Then rebalance the FDO DIFF signal using the PB prism Y_DISP algorithm.
The doubling crystals are in the wrong order.	Verify the 56° crystal is closest to the PB prism and the optical axis of each is oriented correctly.
There is insufficient power to enable tracking.	Verify the crystal position is optimized for maximum uv output.
Pump beam divergence is set incorrectly (710 systems only)	Adjust the MOPO telescope positive lens to obtain a slightly focusing uv input mode. It may also be necessary to reposition the power oscillator HR mirror to collimate the MOPO output beam following this adjustment. Use appropriate alignment references to maintain correct alignment of the systems.

Symptom: UV power unstable at fixed wavelengths.	
Possible Causes	**Corrective Action**
FDO tracking is not optimized.	From the FDO Monitor menu, switch the FDO to TABLE mode and optimize the crystal angle using MANUAL or Y_DISP.
MOPO power is fluctuating.	Switch the MOPO to TRK TO or TBL TO mode.

Symptom: UV power unstable while scanning.	
Possible Causes	**Corrective Action**
FDO is operating below 345 nm and FDO tracking is not enabled.	From the FDO Monitor menu, switch the FDO to TRACK mode.
FDO is operating above 366 nm and FDO tracking is enabled.	From the FDO Monitor menu, switch the FDO to TABLE mode.
The prism position table is incorrect.	Go to the starting point of a scan and optimize the crystal position (if necessary) using Y_DISP; then shift the PB prism position to rebalance the FDO DIFF signal using Y_DISP. Restart the scan.

Symptom: UV power drops when returning to previous wavelength setting(s).	
Possible Causes	**Corrective Action**
The crystal positioning mechanism is sticky or backlash is present.	Perform a DEVICE RESET from the FDO Service menu for the active crystal. Also try a MANUAL shift followed by an ABORT. Then perform a Y_DISP to optimize uv output power, followed by a SAVE, to correct the table. If scanning, activate the TRACK mode from the FDO Monitor menu to restore uv output power.

Symptom: System does not get to certain wavelengths.	
Possible Causes	**Corrective Action**
Target wavelength is out of range.	The standard FDO software will not allow operation at wavelengths below 220 nm or above 450 nm. There is also a degeneracy gap between 345 and 366 nm; wavelengths in this range are also inaccessible.
There are no table values entered for the desired wavelength.	Rewrite the Lagrangian table for crystal(s) and/or prism as necessary to cover the "new" wavelengths.

Symptom: Controller crashes during software update.	
Possible Causes	**Corrective Action**
Wrong software revision.	Verify the software being installed is numbered 2.05D-f or later. If this is not the case, contact Spectra-Physics Lasers for updated software.

Symptom: Controller crashes during calibration procedure. (Software revisions 2.05D-e and earlier.)	
Possible Causes	**Corrective Action**
A function key(s) was pressed during the procedure while not in the Service menu.	For example, if while modifying the PB prism table using the LAGRNG method, an excursion was made to the Monitor menu and a button such as TRACK was pressed, the calibration procedure would no longer be true and should be aborted. If the procedure was continued through to the SAVE command, a crash occurs. Reboot and restart the procedure.

Symptom: The output beam is misshapen.	
Possible Causes	**Corrective Action**
The UV beam is clipped or obstructed.	Verify the uv beam path is clear and that the beam is properly centered on all optics and apertures.
There is excessive divergence in the MOPO input beam.	Readjust the uv pumping optics and/or the MOPO power oscillator. Contact your Spectra-Physics Lasers service representative.

Symptom: The output beam shifts while tuning.	
Possible Causes	**Corrective Action**
The FDO prism table is incorrect.	Optimize and rebalance the FDO crystal and PB prism at a convenient wavelength in the range of interest, then set up a reference alignment target 2 to 3 m away. Using this target, generate a new PB prism table using a Lagrangian fit over the can range of interest.

Symptom: Problems scanning 2 x the Idler.	
Possible Causes	**Corrective Action**
The FDO is in TRACK mode.	Switch to FDO TABLE mode (on FDO Monitor menu). Doubled Idler scans should be performed from tables.

Replacement Parts

The following is a list of parts that may be purchased to replace broken or misplaced components. Also listed are optional components that may be purchased to enhance your system.

Description	Part Number
Coated window	0002-0540
36° BBO crystal	0449-8460
56° BBO crystal	0449-8470
Pyrodetector bi-cell pcb assembly	0449-9240
Beam splitters, matched pair, 1° wedge	0449-9340
Roof prism, 35.92 mm	0449-9470
Turning prism	0449-9480
FDO controller pcb assembly	0450-0070
Absorber	0450-0100
-600 cm meniscus lens	0450-7550
-800 cm meniscus lens	0450-7560
Turning prism, UV	1002-0640
UV dispersion prism	1002-0640
Position sensor	4809-0364
Motormicrometer	5401-1579

Customer Service

At Spectra-Physics Lasers, we take great pride in the reliability of our products. Considerable emphasis has been placed on controlled manufacturing methods and quality control throughout the manufacturing process. Nevertheless, even the finest precision instruments will need occasional service. We feel our instruments have excellent service records compared to competitive products, and we hope to demonstrate, in the long run, that we provide excellent service to our customers in two ways: first by providing the best equipment for the money, and second, by offering service facilities that get your instrument repaired and back to you as soon as possible.

Spectra-Physics Lasers maintains major service centers in the United States, Europe, and Japan. Additionally, there are field service offices in major United States cities. When calling for service inside the United States, dial our toll free number: **1 (800) 456-2552**. To phone for service in other countries, refer to the "Service Centers" listing located at the end of this section

Order replacement parts directly from Spectra-Physics Lasers. For ordering or shipping instructions, or for assistance of any kind, contact your nearest sales office or service center. You will need your instrument model and serial numbers available when you call. Service data or shipping instructions will be promptly supplied.

To order optional items or other system components, or for general sales assistance, dial **1 (800) SPL-LASER** in the United States, or **1 (415) 961-2550** from anywhere else.

Warranty

This warranty supplements the warranty contained in the specific sales order. In the event of a conflict between documents, the terms and conditions of the sales order shall prevail.

Unless otherwise specified, all mechanical and electronic parts and assemblies manufactured by Spectra-Physics Lasers are unconditionally warranted to be free of defects in workmanship and materials for a period of two years following delivery of the equipment to the F.O.B. point. All optical elements including the BBO crystal are unconditionally warranted to be free of defects in workmanship and materials for a period of 90 days following delivery.

Liability under this warranty is limited to repairing, replacing, or giving credit for the purchase price of any equipment that proves defective during the warranty period, provided prior authorization for such return has been given by an authorized representative of Spectra-Physics Lasers. In-warranty repaired or replaced equipment is warranted only for the remaining unexpired portion of the original warranty period applicable to the repaired or replaced equipment.

This warranty does not apply to any instrument or component not manufactured by Spectra-Physics Lasers. When products manufactured by others

are included in Spectra-Physics Lasers equipment, the original manufacturer's warranty is extended to Spectra-Physics Lasers customers. When products manufactured by others are used in conjunction with Spectra-Physics Lasers equipment, this warranty is extended only to the equipment manufactured by Spectra-Physics Lasers.

This warranty does not apply to equipment or components that, upon inspection by Spectra-Physics Lasers, discloses to be defective or unworkable due to abuse, mishandling, misuse, alteration, negligence, improper installation, unauthorized modification, damage in transit, or other causes beyond the control of Spectra-Physics Lasers.

This warranty is in lieu of all other warranties, expressed or implied, and does not cover incidental or consequential loss.

The above warranty is valid for units purchased and used in the United States only. Products with foreign destinations are subject to a warranty surcharge.

Return of the Instrument for Repair

Contact your nearest Spectra-Physics Lasers field sales office, service center, or local distributor for shipping instructions or an on-site service appointment. You are responsible for one-way shipment of the defective part or instrument to Spectra-Physics Lasers.

We encourage you to use the original packing boxes to secure instruments during shipment. If shipping boxes have been lost or destroyed, we recommend that you order new ones.We can return instruments only in Spectra-Physics Lasers containers.

Service Centers

Australia

Spectra-Physics Pty. Ltd.
25 Research Drive
Croydon, Victoria 3136
Telephone: (03) 761-5200
Fax: (03) 761-5600

Benelux

Spectra-Physics BV
Prof. Dr. Dorgelolaan 20
5613 AM Eindhoven
The Netherlands
Telephone: (40) 2 65 99 59
Fax: (40) 2 43 99 22

France

Spectra-Physics S.A.R.L.
Z.A. de Courtaboeuf
Avenue de Scandinavie
91941 Les Ulis Cedex
Telephone: (01) 1 69 18 63 10
Fax: (01) 1 69 07 60 93

Germany and Export Countries*

Spectra-Physics GmbH
Siemensstrasse 20
D-6100 Darmstadt-Kranischstein
Telephone: 06151 7080
Fax: 06151 79102

Japan

Spectra-Physics KK
Daiwa-Nakameguro Building
4-6-1 Nakameguro
Meguro-ku, Tokyo 153
Telephone: (03) 3794-5511
Fax: (03) 3794-5510

* All European and Middle Eastern countries in this region not included elsewhere on this list.

Service Centers (cont.)

United Kingdom

Spectra-Physics Ltd.
Boundary Way
Hemel Hempstead
Herts, HP2 7SH
Telephone: (01442) 25 81 00
Telex: 826411
Fax: (01422) 68 538

United States and Export Countries*

Spectra-Physics Lasers
1330 Terra Bella Avenue
Post Office Box 7013
Mountain View, CA 94039-7013
Telephone: 1 (800) 456-2552 (Service) or
　　　　　1 (800) SPL-LASER (Sales) or
　　　　　1 (800) 775-5253 (Sales) or
　　　　　1 (415) 961-2550 (Operator)
Fax: 1 (415) 964-3584

**And all countries not included elsewhere on this list.

Appendix A   Installing a Software Upgrade

From time to time new releases of the MOPO/FDO software might be issued that will upgrade your system to add new capabilities or increase its performance. The following procedure takes you through the steps required to install the software. It is simple and straight-forward, but it must be followed precisely to prevent any loss of any data tables already stored in your unit.

1. Verify the MOPO/FDO electronics controller is off.

2. Remove the cover from the controller.

3. Remove the PCMCIA card that is plugged vertically into the mother board just behind the front panel (see Figure A-1).
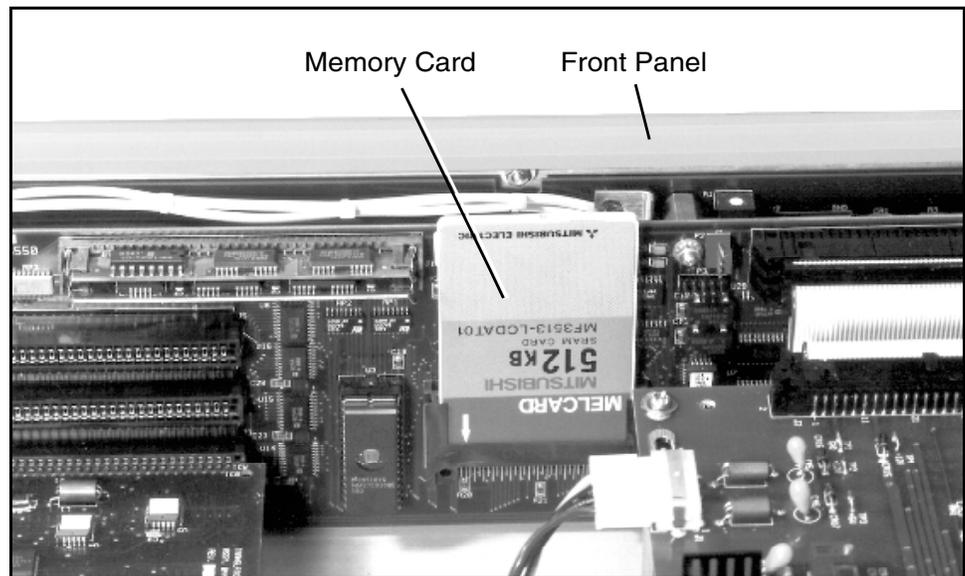
Figure A-1: Electronics unit showing location of removable PCMCIA memory card.

4. Carefully insert the new PCMCIA card, making sure the rectangular notch at the base of the card is to the right (as viewed from the front of the controller).

5. Turn on the controller.

6. Once the opening menu is displayed, access the MOPO service screen by pressing the OPERATE button. The MENU displayed should be 710-INT. This is normal.

7. Highlight the CALIB button.

8. Leaving the system on, replace the new PCMCIA card in with the original card, again being careful to note its orientation.

9. Use the up/down buttons to scroll the CALIB menu to the LOAD command.

10. Hold in the LOAD button until the system beeps, then observe the various messages that indicate the status of the loading operation.

11. When the loading is complete, replace the original PCMCIA card with the new one

12. Scroll the CALIB menu to the SAVE command.

13 Hold in the SAVE button until the system beeps.

14. When the save process is completed, leave the new PCMCIA card plugged in and replace the cover.

15. Turn the system off, then back on to reboot the unit with the old table values and new software.

16. Note the following:

    • To successfully perform a MOPO/FDO software transfer, use 2.05D-c or later revision software.

    • The operating mode should be identical to that when the system was last operated using the original PCMCIA card. The only exception to this is when a MOPO-only unit is upgraded to include the FDO. In this case, change to the correct operating mode immediately.

    • All the settings that were in place using the original card, including the IEEE address, the baud rate, the local or remote mode setting, and the tracking state (for both the MOPO and FDO), should still be evident using the new card.

    • The user-defined files that were originally saved using the SAVE function from the OPERATE menu when the original card was installed should now be transferred to the new card.

Appendix B   BBO Frequency Doubling

The table below shows the relationship between the MOPO fudamental wavelength, the FDO single harmonic output wavelength (SHG), the BBO crystal phase-matching angle, the non-linear coefficient at that angle, and the amount of beam walk-off that can be expected at that angle..

Table B-1: Frequency Doubling in Type I BBO

MOPO Fundamental Wavelength	FDO SHG Wavelength (output)	Crystal Phase-matching Angle (θ)	d_{eff} (pM/V) (non-linear coefficient)	Walkoff (mm/cm)
0.4000	0.2000	No solution		
0.4100	0.2050	86.715	0.018	0.108
0.4200	0.2100	75.833	0.285	0.444
0.4300	0.2150	70.491	0.431	0.582
0.4400	0.2200	66.520	0.537	0.668
0.4500	0.2250	63.287	0.621	0.727
0.4600	0.2300	60.537	0.691	0.768
0.4700	0.2350	58.135	0.751	0.798
0.4800	0.2400	56.001	0.803	0.819
0.4900	0.2450	54.079	0.850	0.833
0.5000	0.2500	52.332	0.891	0.843
0.5100	0.2550	50.732	0.928	0.848
0.5200	0.2600	49.256	0.961	0.851
0.5300	0.2650	47.889	0.991	0.852
0.5400	0.2700	46.616	1.019	0.851
0.5500	0.2750	45.427	1.045	0.848
0.5600	0.2800	44.313	1.068	0.844
0.5700	0.2850	43.265	1.090	0.839
0.5800	0.2900	42.277	1.110	0.834

Table B-1: Frequency Doubling in Type I BBO

MOPO Fundamental Wavelength	FDO SHG Wavelength (output)	Crystal Phase-matching Angle (θ)	d_{eff} (pM/V) (non-linear coefficient)	Walkoff (mm/cm)
0.5900	0.2950	41.344	1.129	0.828
0.6000	0.3000	40.461	1.146	0.821
0.6100	0.3050	39.624	1.162	0.814
0.6200	0.3100	38.828	1.177	0.807
0.6300	0.3150	38.071	1.192	0.800
0.6400	0.3200	37.350	1.205	0.793
0.6500	0.3250	36.662	1.218	0.785
0.6600	0.3300	36.005	1.230	0.777
0.6700	0.3350	35.377	1.241	0.770
0.6800	0.3400	34.776	1.251	0.762
0.6900	0.3450	34.200	1.262	0.755
0.7000	0.3500	33.648	1.271	0.747
0.7100	0.3550	33.118	1.280	0.740
0.7200	0.3600	32.609	1.289	0.733
0.7300	0.3650	32.120	1.297	0.726
0.7400	0.3700	31.650	1.304	0.718
0.7500	0.3750	31.198	1.312	0.712
0.7600	0.3800	30.763	1.319	0.705
0.7700	0.3850	30.344	1.325	0.698
0.7800	0.3900	29.940	1.332	0.691
0.7900	0.3950	29.550	1.338	0.685
0.8000	0.4000	29.175	1.343	0.679
0.8100	0.4050	28.813	1.349	0.672
0.8200	0.4100	28.463	1.354	0.666
0..8300	0.4150	28.126	1.359	0.660
0.8400	0.4200	27.800	1.364	0.654
0.8500	0.4250	27.485	1.369	0.649
0.8600	0.4300	27.181	1.373	0.643
0.8700	0.4350	26.888	1.377	0.638

Table B-1: Frequency Doubling in Type I BBO

MOPO Fundamental Wavelength	FDO SHG Wavelength (output)	Crystal Phase-matching Angle (θ)	d_{eff} (pM/V) (non-linear coefficient)	Walkoff (mm/cm)
0.8800	0.4400	26.604	1.381	0.633
0.8900	0.4450	26.329	1.385	0.627
0.9000	0.4500	26.064	1.389	0.622
0.9100	0.4550	25.808	1.393	0.617
0.9200	0.4600	25.560	1.396	0.613
0.9300	0.4650	25.320	1.399	0.608
0.9400	0.4700	25.089	1.402	0.603
0.9500	0.4750	24.865	1.405	0.599
0.9600	0.4800	24.648	1.408	0.595
0.9700	0.4850	24.439	1.411	0.590
0.9800	0.4900	24.236	1.414	0.586
0.9900	0.4950	24.040	1.416	0.582
1.0000	0.5000	23.851	1.419	0.579

Appendix C

Wavelengths vs. Nominal Device Set Point

Use the following table as a guide to verify that the set point values read from the Service menu for these four MOPO/FDO devices are in general alignment for the MOPO and FDO wavelengths given. Note that these values are approximate (±100) and can only be used as a rough reference. Values have been rounded to the nearest 50 for simplicity
.

Table C-1: Wavelength vs. Nominal Device Set Point

Wavelength MOPO (nm)	Wavelength FDO (nm)	MOPO Crystal	36° Crystal	56° Crystal	PB Prism
400	200	32800	na	na	na
410	205	29700	na	na	na
420	210	26500	na	na	na
430	215	23600	na	na	na
440	220	21000	na	2700	10500
450	225	18600	na	5750	11200
460	230	16400	na	8150	12000
470	235	14500	na	10150	12650
480	240	12700	na	11900	13150
490	245	11200	na	13500	13650
500	250	9800	na	14900	14250
510	255	8500	na	16250	14750
520	260	7400	na	17500	15100
530	265	6400	na	18650	15550
540	270	5500	2700	19750	15800
550	275	4700	4400	21500	16200
560	280	4000	5400	22650	16550

Table C-1: Wavelength vs. Nominal Device Set Point

Wavelength MOPO (nm)	Wavelength FDO (nm)	MOPO Crystal	36° Crystal	56° Crystal	PB Prism
570	285	3400	6300		16900
580	290	2800	7150		17200
590	295	2300	7950		17500
600	300	1900	8650		17750
610	305	1500	9350		18000
620	310	1200	10000		18200
630	315	900	10600		18350
640	320	700	11200		18550
650	325	500	11800		18800
660	330	350	12450		19050
670	335	250	13000		19350
680	340	150	13200		19300
690	345	50	13600		19350
700	350	0	14800		19600
710	355	0	15255		19750
720	360	0	14750		19400
730	365	0	15200		19550
740	370	0	15900		19800
750	375	0	16300		19900
760	380	0	16650		20050
770	385	0	17000		20200
780	390	0	17350		20300
790	395	0	17650		20400
800	400	0	18000		20450
810	405	0	18300		20550
820	410	0	18600		20650
830	415	0	18850		20750
840	420	0	19150		20800
850	425	0	19400		20900

Table C-1: Wavelength vs. Nominal Device Set Point

Wavelength MOPO (nm)	Wavelength FDO (nm)	MOPO Crystal	36° Crystal	56° Crystal	PB Prism
860	430	0	19650		20900
870	435	0	19900		20950
880	440	0	20200		21050
890	445	0	20650		21150
900	450	0	20900		21200

This appendix explains how to operate the MOPO/FDO system from a remote source using either the optional RS-232 serial interface or the IEEE-488 parallel interface, the latter commonly referred to as the General Purpose Interface Bus, or GPIB. The parallel interface is much faster than the serial interface, but at the control speeds required by the MOPO/FDO system, either is acceptable. Note: not all systems have these optional interfaces installed. If the computer interface option is included in your system, a 25-pin D-sub serial connector and a 34-pin Centronics parallel connector will be present in the upper right-hand corner of the rear panel of the MOPO/FDO controller.

Scope

This appendix describes how to install, set up, and use these interfaces. Chapter 4, "Operation: Remote Menu," contains information on how to select either of these interfaces for remote control, and how to return control to the controller front panel. It also explains how to set the address for the IEEE-488 interface and the BAUD rate for the RS-232 serial interface.

Overview

Two modes of control are available: LOCAL or REMOTE. In LOCAL mode, the keys and the display on the MOPO/FDO controller front panel are used to enter parameters, initiate operations and monitor system status. In REMOTE mode, a terminal or computer is used to perform the same operations. In addition to the terminal or computer, an interface cable is required to connect the command source to the MOPO/FDO controller.

Command messages are strings of ASCII characters the computer or terminal can send to the MOPO/FDO controller where they are interpreted and implemented. These messages are organized into two categories: commands and queries. Commands direct the MOPO/FDO to store a setup parameter or execute an operation, whereas queries interrogate the MOPO/FDO for a stored parameter value or for an operating status.

Using these predefined command messages, a terminal can provide manual, interactive control of the system via the serial connection. Messages are sent from the terminal keyboard and status responses are returned to the video monitor. A computer can also provide automatic control in addition to interactive control, and it can use either interface. For automatic control,

a program designed by the user and based on the command messages can be run on the computer to step the controller through a sequence of operations.

The following tables contain a complete list of commands and queries that provide full control of the MOPO/FDO system through either interface.

Setup Commands	Setup Queries
:SOURCE: **BEGIN**	:SOURCE: **BEGIN?**
:SOURCE: **END**	:SOURCE: **END?**
:SOURCE: **GOTO**	:SOURCE: **GOTO?**
:SOURCE: **INCR**	:SOURCE: **INCR?**
:SOURCE: **RATE**	:SOURCE: **RATE?**
:SOURCE: **SCANS**	:SOURCE: **SCANS?**
:SOURCE: **SHOTS**	:SOURCE: **SHOTS?**

Operate Commands	Operate Queries
:**ABORT**	:READ: **COUNT?**
:**EXEGOTO**	:READ: **POWER?**
:**RECALL**	:READ: **WLEN?**
:**SAVE**	
:**SCAN**	***IDN?**
	*STB?

Installation

RS-232-C Interface

The RS-232-C interface of the MOPO/FDO is configured as data communications equipment (DCE). Table D-1 and Table D-2 at the end of this appendix describe the interface connectors and cabling.

The serial communications port of a typical computer is configured as data terminal equipment (DTE). A standard 9-wire RS-232 cable is required to connect a computer (DTE device) to the MOPO/FDO (DCE device). Connection should be simple with no cross connections required.

MOPO/FDO Serial Interface Parameters

The parameter settings for the MOPO/FDO serial interface are: eight data bits, one stop bit, no parity. Configure the parameters of your computer's serial interface to match these.

BAUD Rate

The MOPO/FDO serial interface baud rate can be set anywhere from 300 to 2400 bits per second. Chapter 4, "Operation," describes how to set the BAUD rate. For your convenience, it is repeated below under "Selection."

IEEE-488 Interface

The IEEE-488 (GPIB) interface of the MOPO/FDO system is configured as a talker-listener device (i.e., it can both send and recieve data). Your computer must also have talker-listener and bus controller capabilities. Use a standard GPIB cable to connect your computer GPIB interface to the MOPO/FDO.

The GPIB interface of the MOPO/FDO system includes a National Instruments GPIB-PC II/IIA interface card that is installed inside the MOPO/FDO controller. Figure D-1 at the end of this appendix shows the dip-switch and jumper settings for this card. The card is shipped with the default settings shown.

If you have an IBM-PC compatible computer, you will have to install a GPIB controller card in it. There are many brands of GPIB controller cards and you may use any one of them that gives your computer GPIB controller capability. If you use the National Instruments GPIB-PC II/IIA interface card, you can use the dip-switch and jumper settings shown in Figure D-1.

The GPIB device address of the MOPO/FDO system is set at the factory to address 15. If this address conflicts with the address of another instrument on the GPIB bus, select another GPIB address for the MOPO/FDO. Refer to "Selection" below for instructions on how to select another GPIB address.

Selection (RS232, IEEE, LOCAL)

Use the Remote menu to select the system control source. The default setting from the factory is the front panel, or LOCAL, but the setting can be changed so that the MOPO/FDO can be controlled from a serial device, such as a terminal or a personal computer configured as a terminal, or an IEEE-488 parallel control source. When one of the remote interfaces is the control source, LOCAL is displayed in F_5 to allow the user to return control to the front panel.

Before the RS-232-C or the IEEE-488 interface can be used, it must first be selected and its parameters set from the Remote menu. See chapter 4, "Operation: The Remote Menu."

1. Press the MONITOR menu key until the Remote menu is displayed.

    The MONITOR label changes to REMOTE and the SELECT, IEEE-488, and BAUD functions are displayed in the display boxes:

    F_1**: SELECT**—allows the user to set the control interface to IEEE-488, RS-232 or LOCAL.

    F_2**: IEEE-488**—allows the bus address to be set.

    F_3**: BAUD**—allows the serial BAUD rate to be set.

2. Set the address for the IEEE-488 interface from 0 to 31 (default is 15).

    a. Press F_2 to place the cursor under the digit to be changed.

    b. Use the up/down keys to toggle to the digit desired.

    c. Move to the second digit (if necessary) and repeat steps a and b.

    d. When the address is selected, press F_2 until it beeps to activate the address.

3. Set the serial BAUD rate to 300, 1200 or 2400 (default is 2400).

    a. Press F_3 to select the BAUD rate.

    b. Use the up/down keys to toggle to the rate desired.

    c. Press F_3 until it beeps to activate the BAUD rate.

4. Select the active interface.

    a. Press F_1 momentarily.

    b. Use the up/down keys to toggle to the interface desired.

    c. Press F_1 until it beeps to activate the selected interface.

The MOPO/FDO controller should now be set to either the RS-232 or IEEE-488 remote control modes and command and query messages can now be sent to it from your computer. The selected interface will remain active until changed again by you.

5. Press F_5, LOCAL, to return control to the front panel.

Saving Setup Parameters

The RS-232 and IEEE-488 setup parameters will not be saved via remote command. Only GOTO and SCAN parameters can be saved via remote command.

Initialization

After turning on the MOPO/FDO controller and selecting either RS-232 or IEEE-488 control, initialize the computer interface as outlined below.

Procedure to Initialize the Interface

1. If the IEEE-488 interface is used, send the Select Device Clear bus command. Refer to the instruction manual for your computer's GPIB interface card for specific details on how to execute a Select Device Clear command.

2. Next, whether the GPIB or RS232 interface is used, send a null string to the MOPO/FDO. Written in the BASIC programming language, this statement would look like:

        PRINT #1, "   "

After the interface is initialized, the MOPO/FDO interface hardware and data input buffer are reset. Proceed with the communications link verification test.

Verification Test

The communications link between your computer and the MOPO/FDO controller is easily and quickly tested. Simply send the query message to request the MOPO/FDO to send back a device identification message.

1. Send this query message to the MOPO/FDO:

        *IDN?

2. Receive this device identification message back from the MOPO/FDO:

        QUANTA-RAY, MOPO/FDO:
        710/730,0,V2.05D-g

NOTE: Refer to the Command and Query Messages section later in this appendix for more information about the *IDN? message.

The communications link is fully functional when the device identification message is received from the MOPO/FDO. The system is now ready to receive commands for operation.

MOPO/FDO Firmware Revision

In the MOPO/FDO ID message shown above, the last piece of data specifies the revision level of the MOPO/FDO system firmware. The ID message should indicate that the MOPO/FDO system firmware is Version 2.05D-C or a later revision.

NOTES
If the firmware in your MOPO/FDO system is an earlier version than Version 2.05D-C, you need to update your firmware to the latest version in order to use the computer interface. If you need an update, call our Spectra-Physics Lasers service engineer for assistance.

Format and Syntax Rules

Format

All messages sent to the MOPO/FDO must be transmitted in ASCII format. The MOPO/FDO also sends back all response data in ASCII format.

Syntax

The syntax of the messages sent must conform exactly to the syntax of the examples shown in the next section on Command and Query Messages. Notice that all messages begin with a colon (:). A colon is also required between key words of the command string.

Message Termination

Use the ASCII Line Feed character to terminate all messages that are sent to the MOPO/FDO.

The MOPO/FDO terminates the response messages that it sends to your computer in two ways. It sends the ASCII Line Feed character at the end of all messages. Also, when using the GPIB interface, it additionally sends the GPIB END bus message.

Command and Query Messages

Setup Commands	
Message	**Parameter being set**
:SOURCE: BEGIN ####.####	Initial wavelength for a scan.
:SOURCE: END ####.####	Final wavelength for a scan.
:SOURCE: GOTO ####.####	Destination of the goto wavelength.
:SOURCE: INCR #.###	Step size (in nm) between scan wavelengths (increment scan only).
:SOURCE:RATE #.###	Scan speed (nm per sec.) for continuous scans.
:SOURCE:SCANS #####	Number of consecutive scans to be made in one scan operation.
:SOURCE:SHOTS 0	Continuous scan mode.
:SOURCE:SHOTS #####	Number of shots to be taken at each wavelength (incremental scan only).

Setup Queries	
Message	**Parameter being queried**
:SOURCE: BEGIN?	Initial scan wavelength.
:SOURCE: END?	Final scan wavelength.
:SOURCE: GOTO?	Goto wavelength number.
:SOURCE: INCR?	Step size (in nm) between scan wavelengths (increment scan only).
:SOURCE:RATE?	Scan speed (nm per sec.) for continuous scans.
:SOURCE:SCANS?	Number of consecutive scans to be made in one scan operation.
:SOURCE:SHOTS?	Continuous scan mode.

Operate Commands	
Message	**Operation**
:EXEGOTO	Execute a GOTO operation.
:SCAN	Execute a GOTO or SCAN operation.
:ABORT	Terminate a GOTO or SCAN operation.
:RECALL #	Load setup parameters from non-volatile memory.
:SAVE #	Store setup parameters to non-volatile memory.

Operate Queries	
Message	**Status being queried**
:READ: COUNT?	Current SCAN count.
:READ: POWER?	Power of the master oscillator.
:READ: WLEN?	Current wavelength position.
*IDN?	SCPI ID string.
*STB?	SCPI status byte.

Programming Examples

The following program statements illustrate the correct format and syntax of MOPO/FDO command and query messages. These examples are written in Microsoft QuickBasic. They do not compose a complete program. Refer to the sample program in the next section to see how these program statements can be used in a complete and executable program.

```
'-----------------------------------------------------------------------
'INITIALIZATION
'-----------------------------------------------------------------------
OPEN "COM1:2400,N,8,1" FOR RANDOM AS 1
PRINT #1, "   "                         'Clear MOPO/FDO input buffer
'-----------------------------------------------------------------------
'VERIFICATION TEST
'-----------------------------------------------------------------------
PRINT #1, "*idn?"                       'Read MOPO/FDO ID message
MopoID$ = INPUT$(35, #1)
PRINT MopoID$
'-----------------------------------------------------------------------
'GOTO OPERATION
'-----------------------------------------------------------------------
PRINT #1, ":source:goto 250.000"       'Set GOTO WL to 250nm
PRINT #1, ":exegoto"                    'Execute GOTO operation
'-----------------------------------------------------------------------
'CONTINUOUS SCAN SETUP
'-----------------------------------------------------------------------
ScanBegin = 255!                        'Start at 255.000 nm
ScanEnd = 260!                          'Stop at 260.000 nm
Rate = .1                               '100 picometers/second
Shots = 0                               'Continuous scan
Scans = 2                               'Make two passes
PRINT #1, ":source:begin", ScanBegin
PRINT #1, ":source:end", ScanEnd
PRINT #1, ":source:rate", Rate
PRINT #1, ":source:shots", Shots
PRINT #1, ":source:scans", Scans
'-----------------------------------------------------------------------
'INCREMENTAL SCAN SETUP
'-----------------------------------------------------------------------
ScanBegin = 300!                        'Start at 300.000 nm
ScanEnd = 310!                          'Stop at 310.000 nm
Increment = 2.5                         '2.5 nanometer steps
Shots = 100                             '100 shots at each WL
Scans = 3                               'Make three passes
PRINT #1, ":source:begin", ScanBegin
PRINT #1, ":source:end", ScanEnd
```

```
PRINT #1, ":source:incr", Increment
PRINT #1, ":source:shots", Shots
PRINT #1, ":source:scans", Scans
'-----------------------------------------------------------------------------
'SCAN OPERATION
'-----------------------------------------------------------------------------
PRINT #1, ":scan"
'-----------------------------------------------------------------------------
'READ SETUP PARAMETERS
'-----------------------------------------------------------------------------
PRINT #1, ":source:begin?"
GOSUB ReadData
PRINT #1, ":source:end?"
GOSUB ReadData
PRINT #1, ":source:rate?"
GOSUB ReadData
PRINT #1, ":source:shots?"
GOSUB ReadData
PRINT #1, ":source:scans?"
GOSUB ReadData
PRINT #1, ":source:incr?"
GOSUB ReadData
'-----------------------------------------------------------------------------
'MONITOR OPERATING STATUS
'-----------------------------------------------------------------------------
PRINT #1, ":read:wlen?"
GOSUB ReadData
PRINT #1, ":read:count?"
GOSUB ReadData
PRINT #1, ":read:power?"
GOSUB ReadData
'-----------------------------------------------------------------------------
'READ DATA SUBROUTINE
'-----------------------------------------------------------------------------
'Inputs: None
'Outputs: Response$
ReadData:
   Chars$ = ""
   NewChar$ = ""
WHILE NewChar$ <> CHR$(10)               'Loop until LF is receiving
   Response$ = Chars$                    'Save all but the LF char
WHILE EOF(1): WEND                       'Wait for next char
   NewChar$ = INPUT$(1, #1)              'Input next char
   Chars$ = Chars$ + NewChar$            'Combine all chars
WEND
RETURN
```

Sample Programs

The following programs are written in the Microsoft QuickBasic programming language. They will run on any IBM-PC compatible computer. The first program sends messages to the MOPO/FDO through the RS-232-C serial communications port, the second uses the optional GPIB IEEE 488 parallel interface.

```
'**********************************************************
'FDO 700-SERIES SAMPLE PROGRAM              LJB 07/28/95
'This program tests the RS232 doubler interface. Max. baud rate is 2400.
'**********************************************************
'
'----------------------------------------------------------
'INITIALIZATION
'----------------------------------------------------------

CLS
DoWaits = 0                               '1 = wait 5 seconds between many of
                                          'the queries
multiloopmax = 50


OPEN "COM2:2400,N,8,1" FOR RANDOM AS 1

TotalLoops = 0
TotalLoop:
   FOR multiloop = 1 TO multiloopmax
   TotalLoops = TotalLoops + 1
   CLS
   PRINT "MOPO SERIAL COMMUNICATIONS TEST AND DEMO PROGRAM"
   PRINT "multiLoop number "; multiloop; " of ", multiloopmax
   PRINT "Total loops"; TotalLoops
   PRINT
   PRINT #1, "  "                         'Clear MOPO input buffer

'----------------------------------------------------------
'VERIFICATION TEST
'----------------------------------------------------------

PRINT #1, "*idn?"
MopoID$ = INPUT$(35, #1)
PRINT MopoID$
```

```
'-----------------------------------------------------------
'GOTO OPERATION
'-----------------------------------------------------------


GotoWL = 448 - multiloop                    'go to idler extreme wavlength
PRINT #1, ":source:goto "; GotoWL
PRINT #1, ":exegoto"

PRINT "GOTO running..."
PRINT


Wavelength = 0
STB = 1                                     'anything other than zero
REM WHILE (Wavelength <> GotoWL!)           'old-style Wait for GOTO to finish
WHILE (STB <> 0)                            ' wait for GOTO to finish
   PRINT #1, ":read:wlen?"
   GOSUB readdata
   Wavelength = VAL(response$)
   PRINT #1, "*stb?"                         'read SCPI status byte
   GOSUB readdata
   STB = VAL(response$)
   PRINT TotalLoops, multiloop; "/"; multiloopmax; "  Wavelength = "; Wavelength,
   PRINT "STB="; STB
   IF DoWaits THEN GOSUB WaitFiveSeconds
WEND


ContinScanSetup:


REM GOTO IncrScanSetup:
'-----------------------------------------------------------
'CONTINUOUS SCAN SETUP
'-----------------------------------------------------------


PRINT
PRINT "Setting up continuous scan of signal range"
PRINT "TotalLoops="; TotalLoops, "MultiLoop="; multiloop
PRINT


'***************************************************************
' Test scanning through signal range (continuous)
' This scan involves the crystal switch and should provide
' adequate torture of the system.

ScanBegin = 220! + multiloop                'Start at 220.000+ nm
ScanEnd = 270! + multiloop                  'Stop at  270.000+ nm
Rate = .1                                   '100 picometers/second
```

```
Shots = 0                                       'Continuous scan
scans = 2                                       'Make two passes


PRINT #1, ":source:begin", ScanBegin
PRINT #1, ":source:end", ScanEnd
PRINT #1, ":source:rate", Rate
PRINT #1, ":source:shots", Shots
PRINT #1, ":source:scans", scans


'----------------------------------------------------------
'CONTINUOUS SCAN SETUP VERIFICATION
'----------------------------------------------------------


GOSUB ReadSetup


faultflag = 0
IF Response1 <> ScanBegin THEN faultflag = 1
IF Response2 <> ScanEnd THEN faultflag = 1
IF Response3 <> Rate THEN faultflag = 1
IF Response4 <> Shots THEN faultflag = 1
IF Response5 <> scans THEN faultflag = 1


PRINT
PRINT "     Continuous Scan Setup (multiloop"; multiloop; " of "; multiloopmax;
")"
PRINT "     TotalLoops: "; TotalLoops
PRINT "-------------------------------"
PRINT "Parameter     Sent       Received"
PRINT "-------------------------------"
PRINT "Begin", ScanBegin, Response1
PRINT "End", ScanEnd, Response2
PRINT "Rate", Rate, Response3
PRINT "Shots", Shots, Response4
PRINT "Scans", scans, Response5
PRINT


IF faultflag = 1 THEN
   PRINT "Continuous Scan ... Setup ERROR"
   PRINT "Program Terminated"
   END
END IF


'----------------------------------------------------------
'CONTINUOUS SCAN
'----------------------------------------------------------


PRINT #1, ":scan"
```

```
PRINT "Continuous scan running..."
PRINT


type$ = "Cont:"
GOSUB WaitForScan


IncrScanSetup:
'----------------------------------------------------------
'INCREMENTAL SCAN SETUP
'----------------------------------------------------------


PRINT "Setting up incremental scan of idler range..."
PRINT


ScanBegin = 365 + multiloop
ScanEnd = 375 + multiloop
Increment = 2                              '2 nanometer steps
Shots = 100                                '100 shots at each WL
scans = 3                                  'Make three passes


PRINT #1, ":source:begin", ScanBegin
PRINT #1, ":source:end", ScanEnd
PRINT #1, ":source:incr", Increment
PRINT #1, ":source:shots", Shots
PRINT #1, ":source:scans", scans


'----------------------------------------------------------
'INCREMENTAL SCAN SETUP VERIFICATION
'----------------------------------------------------------


GOSUB ReadSetup


faultflag = 0
IF Response1 <> ScanBegin THEN faultflag = 1
IF Response2 <> ScanEnd THEN faultflag = 1
IF Response6 <> Increment THEN faultflag = 1
IF Response4 <> Shots THEN faultflag = 1
IF Response5 <> scans THEN faultflag = 1


PRINT
PRINT "     Incremental Scan Setup ("; multiloop; " of "; multiloopmax; ")"
PRINT "     TotalLoops:"; TotalLoops
PRINT "--------------------------------"
PRINT "Parameter     Sent        Received"
PRINT "--------------------------------"
PRINT "Begin", ScanBegin, Response1
```

```
PRINT "End", ScanEnd, Response2
PRINT "Increment", Increment, Response6
PRINT "Shots", Shots, Response4
PRINT "Scans", scans, Response5
PRINT

IF faultflag = 1 THEN
    PRINT "Incremental Scan ... Setup ERROR"
    PRINT "Program Terminated"
    END
END IF


'-----------------------------------------------------------
'INCREMENTAL SCAN
'-----------------------------------------------------------

PRINT #1, ":scan"

PRINT "Incremental scan running..."
PRINT

type$ = "Incr:"
GOSUB WaitForScan

'-----------------------------------------------------------
'SAVE AND RECALL
'-----------------------------------------------------------

PRINT "Saving parameter setup..."; TotalLoops; " total loops"
PRINT

PRINT #1, ":save 3"'                     'Save current operating parameters
                                         'into non-volatile memory as setup
                                         'record #3.

PRINT "Recalling parameter setup..."; TotalLoops; " total loops"
PRINT

PRINT #1, ":recall 4"                    'Load setup parameters (record #4) from
                                         'non-volatile memory
GOSUB WaitFiveSeconds                    'are interrupts dead during read?
                                         'routinely hangs w/o this wait
NEXT multiloop

GOTO TotalLoop                           'makes an infinite loop program
```

```
`------------------------------------------------------------
'PROGRAM END
`------------------------------------------------------------
PRINT "End of Sample Program"
END                                         'End of Sample Program


`------------------------------------------------------------
'READ SETUP SUBROUTINE
`------------------------------------------------------------

ReadSetup:

PRINT "Verifying setup..."
PRINT

PRINT #1, ":source:begin?"
GOSUB readdata
Response1 = VAL(response$)

PRINT #1, ":source:end?"
GOSUB readdata
Response2 = VAL(response$)

PRINT #1, ":source:rate?"
GOSUB readdata
Response3 = VAL(response$)

PRINT #1, ":source:shots?"
GOSUB readdata
Response4 = VAL(response$)

PRINT #1, ":source:scans?"
GOSUB readdata
Response5 = VAL(response$)

PRINT #1, ":source:incr?"
GOSUB readdata
Response6 = VAL(response$)

RETURN

`------------------------------------------------------------
'READ DATA SUBROUTINE
`------------------------------------------------------------

'Inputs: None
```

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```
'Outputs: Response$

readdata:
   Chars$ = ""
   NewChar$ = ""
   WHILE NewChar$ <> CHR$(10)              'Loop until LF is received
      response$ = Chars$                   'Save all but the LF char
      WHILE EOF(1): WEND                    'Wait for next char
   NewChar$ = INPUT$(1, #1)                'Input next char
      Chars$ = Chars$ + NewChar$           'Combine all chars
      WEND
   RETURN


'-------------------------------------------------------------
'WAIT FOR SCAN SUBROUTINE
'-------------------------------------------------------------


WaitForScan:

count = 0
WHILE count <> scans                       'Wait for last scan to start
   IF DoWaits THEN GOSUB WaitFiveSeconds
   PRINT #1, ":read:count?"
   GOSUB readdata
   count = VAL(response$)
   PRINT #1, ":read:wlen?"
   GOSUB readdata
   wl = VAL(response$)
   PRINT type$; TotalLoops; multiloop; "/"; multiloopmax; "    "; count; " "; wl
WEND

WHILE count <> 0                 'Wait for last scan to finish
   IF DoWaits THEN GOSUB WaitFiveSeconds
   PRINT #1, ":read:count?"
   GOSUB readdata
   count = VAL(response$)
   PRINT #1, ":read:wlen?"
   GOSUB readdata
   wl = VAL(response$)
   PRINT type$; TotalLoops; multiloop; "/"; multiloopmax; "    "; count; " "; wl
WEND

RETURN
```

```
'------------------------------------------------------------
'FIVE-SECOND DELAY SUBROUTINE
'------------------------------------------------------------

WaitFiveSeconds:
Time1 = TIMER
Time2 = Time1
WHILE ABS(Time1 - Time2) < 5
   Time2 = TIMER
WEND
SOUND 1000, 3
SOUND 2000, 2
RETURN
```

The following is a sample program that tests the optional GPIB IEEE-488 interface.

```
'************************************************************
' DOUBGPIB.BAS  (DOUBLER GPIB INTERFACE TEST) 02/09/95
'************************************************************
'
'------------------------------------------------------------
'GPIB INITIALIZATION
'------------------------------------------------------------

COMMON SHARED /NISTATBLK/ IBSTA%, IBERR%, IBCNT%, IBCNTL&

CONST EERR = &H8000                      'Error detected
CONST TIMO = &H4000                      'Timeout

DECLARE SUB IBCLR (BYVAL BD%)
DECLARE SUB IBFIND (BDNAME$, BD%)
DECLARE SUB IBRD (BYVAL BD%, RD$)
DECLARE SUB IBWRT (BYVAL BD%, WRT$)

DECLARE SUB GpibError (Msg$)
DECLARE SUB MopoError (Msg$)
CLS
PRINT "GPIB initialization"
PRINT
```

```
`........................................
'Get GPIB device descriptor for MOPO device
`........................................

BDNAME$ = "Dev_Mopo"
CALL IBFIND(BDNAME$, Mopo%)
IF (Mopo% < 0) THEN CALL GpibError("IBFIND ERROR")


`........................
' Clear MOPO GPIB interface
`........................

CALL IBCLR(Mopo%)
IF (IBSTA% AND EERR) THEN CALL GpibError("IBCLR ERROR")


`-----------------------------------------------------------
'TEST LOOP INITIALIZATION
`-----------------------------------------------------------

CLS
DoWaits = 0                              '1 = wait 5 seconds between many of the
                                         'queries
multiloopmax = 50


TotalLoops = 0

`-----------------------------------------------------------
' START OF MULTILOOP
`-----------------------------------------------------------

TotalLoop:

FOR multiloop = 1 TO multiloopmax

   TotalLoops = TotalLoops + 1
   CLS
   PRINT "DOUBLER GPIB COMMUNICATIONS TEST AND DEMO PROGRAM"
   PRINT "multiLoop number "; multiloop; " of ", multiloopmax
   PRINT "Total loops"; TotalLoops
   PRINT
```

```
'------------------------------------------------------------
'VERIFICATION TEST
'------------------------------------------------------------

Expected$ = "QUANTA-RAY,MOPO-710/730,0,V2.05-g"

Cmd$ = "*IDN?"
GOSUB WriteMopo
GOSUB ReadMopo

IF Expected$ <> MID$(Response$, 1, 31) THEN
   PRINT "GPIB communications error..."
   PRINT "  Response expected: ", Expected$
ELSE
   PRINT "GPIB okay..."
END IF
PRINT "  Response received: ", Response$
PRINT

REM GOTO ContinScanSetup

'------------------------------------------------------------
'GOTO OPERATION
'------------------------------------------------------------

GotoWL = 450 - multiloop
Cmd$ = ":source:goto " + STR$(GotoWL)
GOSUB WriteMopo

Cmd$ = ":exegoto"
GOSUB WriteMopo

PRINT "GOTO running..."
PRINT
PRINT "Going to "; GotoWL
PRINT

Wavelength = 0
STB = 1                                    'anything other than zero

REM WHILE (Wavelength <> GotoWL!)          'old-style Wait for GOTO to finish

WHILE (STB <> 0)                           'wait for GOTO to finish

   Cmd$ = ":read:wlen?"
   GOSUB WriteMopo
```

```
   GOSUB ReadMopo

   Wavelength = VAL(Response$)

   Cmd$ = "*stb?"                           'read SCPI status byte
   GOSUB WriteMopo
   GOSUB ReadMopo

STB = VAL(Response$)

   PRINT TotalLoops, multiloop; "/"; multiloopmax; "  Wavelength = "; Wavelength,
   PRINT "STB="; STB
   IF DoWaits THEN GOSUB WaitFiveSeconds

WEND

ContinScanSetup:

REM GOTO IncrScanSetup:

'-----------------------------------------------------------
'CONTINUOUS SCAN SETUP
'-----------------------------------------------------------

PRINT
PRINT "Setting up continuous scan..."
PRINT "TotalLoops="; TotalLoops, "MultiLoop="; multiloop
PRINT

ScanBegin = 365! + multiloop               'Start at 365.000 nm
ScanEnd = 367! + multiloop                 'Stop at 367.000 nm
Rate = .1                                   '100 picometers/second
Shots = 0                                   'Continuous scan
scans = 2                                   'Make two passes

Cmd$ = ":source:begin" + STR$(ScanBegin)
GOSUB WriteMopo

Cmd$ = ":source:end" + STR$(ScanEnd)
GOSUB WriteMopo

Cmd$ = ":source:rate" + STR$(Rate)
GOSUB WriteMopo

Cmd$ = ":source:shots" + STR$(Shots)
GOSUB WriteMopo
```

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```
Cmd$ = ":source:scans" + STR$(scans)
GOSUB WriteMopo


'-------------------------------------------------------------
'CONTINUOUS SCAN SETUP VERIFICATION
'-------------------------------------------------------------


GOSUB ReadSetup


faultflag = 0
IF Response1 <> ScanBegin THEN faultflag = 1
IF Response2 <> ScanEnd THEN faultflag = 1
IF Response3 <> Rate THEN faultflag = 1
IF Response4 <> Shots THEN faultflag = 1
IF Response5 <> scans THEN faultflag = 1


PRINT
PRINT "      Continuous Scan Setup (multiloop"; multiloop; " of "; multiloopmax;
")"
PRINT "      TotalLoops: "; TotalLoops
PRINT "--------------------------------"
PRINT "Parameter      Sent       Received"
PRINT "--------------------------------"
PRINT "Begin", ScanBegin, Response1
PRINT "End", ScanEnd, Response2
PRINT "Rate", Rate, Response3
PRINT "Shots", Shots, Response4
PRINT "Scans", scans, Response5
PRINT


IF faultflag = 1 THEN
   PRINT "Continuous Scan ... Setup ERROR"
   PRINT "Program Terminated"
   END
END IF


'-------------------------------------------------------------
'CONTINUOUS SCAN
'-------------------------------------------------------------


Cmd$ = ":scan"
GOSUB WriteMopo


PRINT "Continuous scan running..."
PRINT


type$ = "Cont:"
```

```
GOSUB WaitForScan

IncrScanSetup:

'-----------------------------------------------------------
'INCREMENTAL SCAN SETUP
'-----------------------------------------------------------

PRINT "Setting up incremental scan..."
PRINT

ScanBegin = 220 + multiloop
ScanEnd = 240 + multiloop
Increment = 2                              '2 nanometer steps
Shots = 100                                '100 shots at each WL
scans = 3                                  'Make three passes

Cmd$ = ":source:begin" + STR$(ScanBegin)
GOSUB WriteMopo

Cmd$ = ":source:end" + STR$(ScanEnd)
GOSUB WriteMopo

Cmd$ = ":source:incr" + STR$(Increment)
GOSUB WriteMopo

Cmd$ = ":source:shots" + STR$(Shots)
GOSUB WriteMopo

Cmd$ = ":source:scans" + STR$(scans)
GOSUB WriteMopo

'-----------------------------------------------------------
'INCREMENTAL SCAN SETUP VERIFICATION
'-----------------------------------------------------------

GOSUB ReadSetup

faultflag = 0
IF Response1 <> ScanBegin THEN faultflag = 1
IF Response2 <> ScanEnd THEN faultflag = 1
IF Response6 <> Increment THEN faultflag = 1
IF Response4 <> Shots THEN faultflag = 1
IF Response5 <> scans THEN faultflag = 1

PRINT
```

```
PRINT "      Incremental Scan Setup ("; multiloop; " of "; multiloopmax; ")"
PRINT "      TotalLoops:"; TotalLoops
PRINT "-------------------------------"
PRINT "Parameter     Sent      Received"
PRINT "-------------------------------"
PRINT "Begin", ScanBegin, Response1
PRINT "End", ScanEnd, Response2
PRINT "Increment", Increment, Response6
PRINT "Shots", Shots, Response4
PRINT "Scans", scans, Response5
PRINT

IF faultflag = 1 THEN
    PRINT "Incremental Scan ... Setup ERROR"
    PRINT "Program Terminated"
    END
END IF


'-------------------------------------------------------------
'INCREMENTAL SCAN
'-------------------------------------------------------------


Cmd$ = ":scan"
GOSUB WriteMopo

PRINT "Incremental scan running..."
PRINT

type$ = "Incr:"
GOSUB WaitForScan


'-------------------------------------------------------------
'SAVE AND RECALL
'-------------------------------------------------------------


PRINT "Saving parameter setup..."; TotalLoops; " total loops"
PRINT

Cmd$ = ":save 3"                          'Save current operating parameters
                                          'into non-volatile memory as setup
                                          'record #3
GOSUB WriteMopo

PRINT "Recalling parameter setup..."; TotalLoops; " total loops"
PRINT
```

```
Cmd$ = ":recall 4"                              'Load setup parameters
                                                '(record #4) from non-
                                                'volatile memory

GOSUB WriteMopo


GOSUB WaitFiveSeconds                           'are interrupts dead during read?
                                                'routinely hangs w/o this wait


'-----------------------------------------------------------
' END OF MULTILOOP
'-----------------------------------------------------------


NEXT multiloop

GOTO TotalLoop                                  'makes an infinite loop program


'-----------------------------------------------------------
'PROGRAM END
'-----------------------------------------------------------


PRINT "End of Sample Program"
END                                             'End of Sample Program


'*******************************************************
'                        SUBROUTINES
'*******************************************************


'-----------------------------------------------------------
'READ SETUP SUBROUTINE
'-----------------------------------------------------------


ReadSetup:

PRINT "Verifying setup..."
PRINT

Cmd$ = ":source:begin?"
GOSUB WriteMopo
GOSUB ReadMopo
Response1 = VAL(Response$)

Cmd$ = ":source:end?"
GOSUB WriteMopo
GOSUB ReadMopo
Response2 = VAL(Response$)
```

```
Cmd$ = ":source:rate?"
GOSUB WriteMopo
GOSUB ReadMopo
Response3 = VAL(Response$)


Cmd$ = ":source:shots?"
GOSUB WriteMopo
GOSUB ReadMopo
Response4 = VAL(Response$)


Cmd$ = ":source:scans?"
GOSUB WriteMopo
GOSUB ReadMopo
Response5 = VAL(Response$)


Cmd$ = ":source:incr?"
GOSUB WriteMopo
GOSUB ReadMopo
Response6 = VAL(Response$)


RETURN


'-----------------------------------------------------------
'WRITE SUBROUTINE  (GPIB)
'-----------------------------------------------------------

'Inputs:  Cmd$
'Outputs: None

WriteMopo:
CALL IBWRT(Mopo%, Cmd$)
IF (IBSTA% AND EERR) THEN CALL GpibError("IBWRT ERROR")
RETURN


'-----------------------------------------------------------
'READ SUBROUTINE  (GPIB)
'-----------------------------------------------------------

'Inputs:  None
'Outputs: Response$

ReadMopo:
Response$ = SPACE$(40)
CALL IBRD(Mopo%, Response$)
IF (IBSTA% AND EERR) THEN CALL GpibError("IBRD ERROR")
RETURN
```

```
'-------------------------------------------------------------
'WAIT FOR SCAN SUBROUTINE
'-------------------------------------------------------------

WaitForScan:

Count = 0
WHILE Count <> scans                      'Wait for last scan to start

   IF DoWaits THEN GOSUB WaitFiveSeconds

   Cmd$ = ":read:count?"
   GOSUB WriteMopo
   GOSUB ReadMopo
   Count = VAL(Response$)

   Cmd$ = ":read:wlen?"
   GOSUB WriteMopo
   GOSUB ReadMopo
   Wl = VAL(Response$)
   PRINT type$; TotalLoops; multiloop; "/"; multiloopmax; "   "; Count; " "; Wl
WEND

WHILE Count <> 0                          'Wait for last scan to finish
   IF DoWaits THEN GOSUB WaitFiveSeconds
   Cmd$ = ":read:count?"
   GOSUB WriteMopo
   GOSUB ReadMopo
   Count = VAL(Response$)

   Cmd$ = ":read:wlen?"
   GOSUB WriteMopo
   GOSUB ReadMopo
   Wl = VAL(Response$)
   PRINT type$; TotalLoops; multiloop; "/"; multiloopmax; "   "; Count; " "; Wl
WEND

RETURN

'-------------------------------------------------------------
'FIVE-SECOND DELAY SUBROUTINE
'-------------------------------------------------------------

WaitFiveSeconds:
Time1 = TIMER
Time2 = Time1
```

```
WHILE ABS(Time1 - Time2) < 5
    Time2 = TIMER
WEND
SOUND 1000, 3
SOUND 2000, 2
RETURN


`********************************************************


SUB GpibError (Msg$) STATIC

PRINT "GPIB: ";
PRINT Msg$

END SUB

SUB MopoError (Msg$) STATIC

PRINT "MOPO: ";
PRINT Msg$

END SUB
```

Connections

Table D-1: RS-232-C Interface to PC Comm Port

DTE Device	RS-232-C communications Link*	DCE Device
PC Computer	<-------------------------------------->	**MOPO/FDO**
25-Pin connector	Standard 9-Wire Serial Interface Cable	25-Pin Connector
1	Protective Ground	1
7	Signal Ground	7
2	Transmitted Data	2
3	Received Data	3
4	Request To Send	4
5	Clear To Send	5
6	Data Set Ready	6
8	Data Carrier Detect	8
20	Data Terminal Ready	20

* Signals of the communications link are named with respect to the DTE device.

Table D-2: RS-232-C Interface to PC-AT Comm Port

DTE Device	RS-232-C communications Link*	DCE Device
PC Computer	<-->	**MOPO/FDO**
9-Pin connector	**PC-AT 9 to 25 Pin Serial Interface Cable**	**25-Pin Connector**
shell	Protective Ground	1
5	Signal Ground	7
3	Transmitted Data	2
2	Received Data	3
7	Request To Send	4
8	Clear To Send	5
6	Data Set Ready	6
1	Data Carrier Detect	8
4	Data Terminal Ready	20

* Signals of the communications link are named with respect to the DTE device.

PC Computer   MOPO

National Instruments   National Instruments
GPIB-PC II/IIA Card   GPIB-PC II/IIA Card
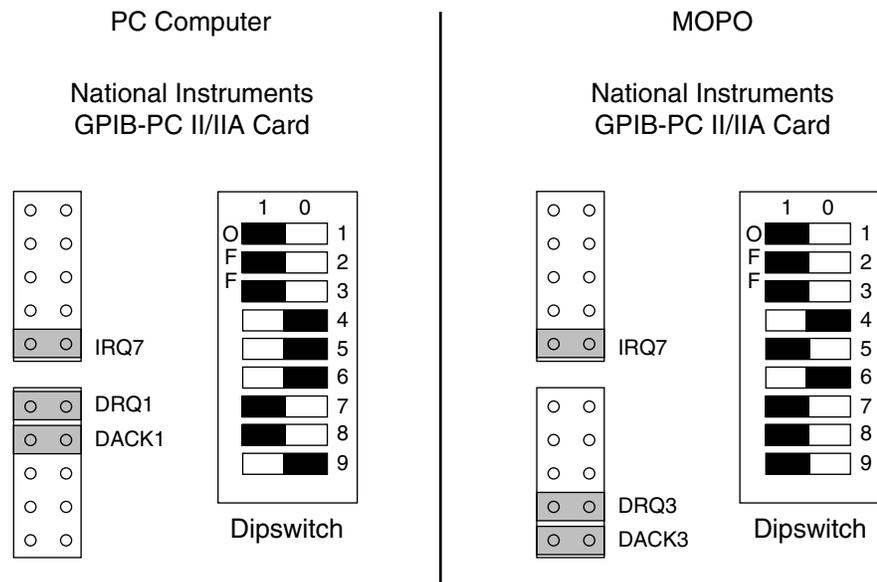
■ This side of the dip switch is depressed

Figure D-1: IEEE-488 Dip Switch and Jumper Settings

Notes

Spectra-Physics Lasers User's Manual–
Problems and Solutions

We have provided this form to encourage you to tell us about any difficulties you have experienced in using your Spectra-Physics Lasers instrument or its manual—problems that did not require a formal call or letter to our service department, but that you feel should be remedied. We are always interested in improving our products and manuals, and we appreciate all suggestions.

Thank you.

From:

Name _____

Company or Institution _____

Department _____

Address _____

_____

Instrument Model Number _____ Serial Number _____

Problem: _____

_____

_____

_____

_____

Suggested Solution(s): _____

_____

_____

_____

Mail To:

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Internet: www.spectra-physics.com

[*]*And all European and Middle Eastern countries not included on this list.*
[**]*And all non-European or Middle Eastern countries not included on this list.*

Report Form for Problems and Solutions

We have provided this form to encourage you to tell us about any difficulties you have experienced in using your Spectra-Physics instrument or its manual—problems that did not require a formal call or letter to our service department, but that you feel should be remedied. We are always interested in improving our products and manuals, and we appreciate all suggestions.

Thank you.

From:

Name _____

Company or Institution _____

Department _____

Address _____

_____

Instrument Model Number _____   Serial Number_____

Problem: _____

_____

_____

_____

_____

Suggested Solution(s): _____

_____

_____

Mail To: **FAX to:**

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