Quanta-Ray MOPO-HF

Optical Parametric Oscillator

User's Manual

Spectra-Physics
The Solid-State Laser Company

1335 Terra Bella Avenue
Mountain View, CA 94043

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Preface

Thank you for purchasing the Spectra-Physics Quanta-Ray *MOPO-HF* system. This manual contains information you need in order to safely install, align, operate, maintain, and service your *MOPO-HF* optical parametric oscillator. The system comprises two or three elements: the MOPO-HF head, a digital controller, and an optional *Model FDO-970* frequency doubler (that installs inside the laser head). The table-top controller can be placed near the head in a convenient location (typically under the *BeamLok*® *PRO-series* Nd:YAG pump laser controller).

The "Introduction" chapter contains a brief description of the *MOPO-HF* system and the digital controller.

Following that section is an important chapter on safety. The *MOPO-HF* is a Class IV laser product and, as such, emits laser radiation which can permanently damage eyes and skin. This section contains information about these hazards and offers suggestions on how to safeguard against them. To minimize the risk of injury or expensive repairs, be sure to read this chapter—then carefully follow the instructions listed there.

"Laser Description" contains a short section on MOPO theory (regarding the BBO crystal) and frequency doubling (using the *Model FDO-970*), and is followed by a more detailed description of the *MOPO-HF* system. The chapter concludes with system specifications and outline drawings.

The next few chapters describe the *MOPO-HF* controls, indicators and connections, then guide you through its installation, alignment and operation. The last part of the manual covers maintenance and service and includes a replacement parts list and a list of world-wide Spectra-Physics service centers you can call if you need help.

Whereas the "Maintenance" section contains information you need to keep your system clean and operational on a day-to-day basis, "Service and Repair" is intended to help you guide your Spectra-Physics field service engineer to the source of any problems. *Do not attempt repairs yourself while the unit is still under warranty*; instead, report all problems to Spectra-Physics for warranty repair.

Should you experience any problems with any equipment purchased from Spectra-Physics, or you are in need of technical information or support, please contact Spectra-Physics as described in "Customer Service." This chapter contains a list of world-wide Spectra-Physics Service Centers you can call if you need help.

This product has been tested and found to conform to "Directive 89/336/EEC for electromagnetic Compatibility." Class A compliance was demonstrated for “EN 50081-2:1993 Emissions” and “EN 50082-1:1992 Immunity” as listed in the official *Journal of the European Communities*. It also meets the intent of “Directive 73/23/EEC for Low Voltage.” Class A compliance was demonstrated for “EN 61010-1:1993 Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory use” and “EN 60825-1:1992 Radiation Safety for Laser Products.” Refer to the “CE Declaration of Conformity” statements in Chapter 2.

Finally, if you encounter any difficulty with the content or style of this manual, please let us know. The last page is a form to aid in bringing such problems to our attention.

Every effort has been made to ensure that the information in this manual is accurate. All information in this document is subject to change without notice. Spectra-Physics makes no representation or warranty, either express or implied, with respect to this document. In no event will Spectra-Physics be liable for any direct, indirect, special, incidental or consequential damages resulting from any defects in this documentation.

Finally, if you encounter any difficulty with the content or style of this manual, please let us know. The last page is a form to aid in bringing such problems to our attention.

CE Environmental Specifications

CE Electrical Equipment Requirements

For information regarding the equipment needed to provide the electrical service listed under "Service Requirements" at the end of Chapter 3, please refer to specification EN-309, "Plug, Outlet and Socket Couplers for Industrial Uses," listed in the official *Journal of the European Communities.*

Environmental Specifications

The environmental conditions under which the laser system will function are listed below:

Indoor use

Altitude:	up to 2000 m
Temperatures:	10° C to 40° C
Maximum relative humidity:	80% non-condensing for temperatures up to 31° C.
Mains supply voltage:	do not exceed ±10% of the nominal voltage
Insulation category:	II
Pollution degree:	2

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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. All messages are set apart by a thin line above and below the text as shown here.

Danger! Laser Radiation	Laser radiation is present.
Danger!	Condition or action may present a hazard to personal safety.
Danger!	Condition or action may present an electrical hazard to personal safety.
Warning!	Condition or action may cause damage to equipment.
Warning! ESD	Action may cause electrostatic discharge and cause damage to equipment.
Caution!	Condition or action may cause poor performance or error.
Note	Text describes exceptional circumstances or makes a special reference.
Don't Touch!	Do not touch.
Eyewear Required	Appropriate laser safety eyewear should be worn during this operation.
	Refer to the enclosed documents and manual before operating or using this device.

Standard Units

The following units, abbreviations, and prefixes are used in this Spectra-Physics 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	celcius	C
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

Unpacking and Inspection

Unpacking Your MOPO-HF

Your *MOPO-HF* system was packed with great care, and its container was inspected prior to shipment—it left Spectra-Physics in good condition. Upon receiving your system, immediately inspect the outside of the shipping containers. If there is any major damage (holes in the containers, crushing, etc.), insist that a representative of the carrier be present when you unpack the contents.

Carefully inspect your system as you unpack it. If any damage is evident, such as dents or scratches on the covers or broken knobs, etc., immediately notify the carrier and your Spectra-Physics sales representative.

Keep the shipping containers. If you file a damage claim, you may need them to demonstrate that the damage occurred as a result of shipping. If you need to return the system for service at a later date, the specially designed container assures adequate protection.

System Components

The following components comprise the *MOPO-HF* system:

- *MOPO-HF* laser head
- *MOPO-HF* digital controller

Verify the two components are present. They are shipped in separate containers.

Accessories

Included with the *MOPO-HF* system is this manual, a packing slip listing all the parts shipped, and an accessory kit containing the following items:

- US or European (German) power cord for the controller (2 m)
- BNC Q-SW SYNC cable for the controller
- table clamp kit: 4 clamps and hardware
- a Bondhus SAE Allen wrench set
- two alignment pinhole apertures
- black pinhole aperture
- infrared (IR) card

Chapter 1 Introduction

The Quanta-Ray MOPO-HF Optical Parametric Oscillator

Overview

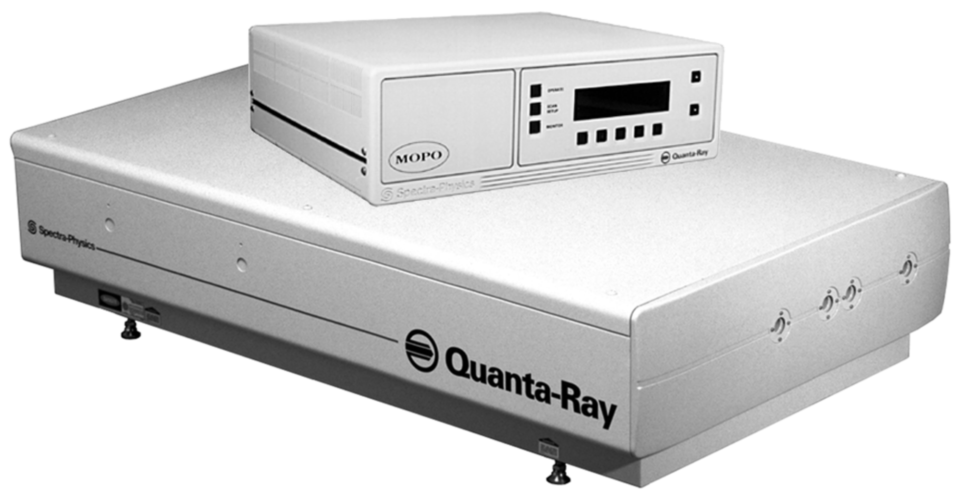


Figure 1-1: The Quanta-Ray *MOPO-HF* System

The principal of operation for an optical parametric oscillator (OPO) is quite different from that for a laser system. Whereas a laser derives its gain from the spontaneous and stimulated emission generated by atomic transitions, an OPO's gain is derived from a nonlinear frequency conversion process.

The atomic transitions in a laser have inherent linewidths which define the maximum tuning range of the laser. For example, a dye laser tunes over 20 nm per dye while Ti:sapphire lasers can tune over 200 nm. The most common tunable systems have historically been pulsed dye lasers which require 15 or more dye compounds to cover the visible wavelength range. In contrast, a 355 nm, BBO-based OPO can tune continuously from 440 nm to wavelengths greater than 2200 nm.

The *MOPO-HF* (high finesse) OPO combines many of the popular features of the standard *MOPO* family with an even narrower linewidth oscillator. Linewidths measured over a typical scanning range average less than $<0.075\ cm^{-1}$, making *MOPO-HF* linewidths comparable to those of pulsed dye-laser systems. This narrow linewidth capability extends the number of applications to which MOPO technology can be applied: for example, studies of combustion processes, atmospheric chemistry and other gas-phase spectroscopies.

The tuning and energy range of the *MOPO-HF* have not been compromised in the effort to narrow the linewidth. Tuning with a single optics set still exceeds 450–1700 nm and some systems have output energy levels in excess of 75 mJ. Optimum performance is achieved when the *MOPO-HF* is pumped with a Quanta-Ray *BeamLok®* *PRO-series* 230 or 250, 10 Hz pump laser, due to its enhanced alignment and power stability.

The patented Spectra-Physics *MOPO FDO-970* frequency doubler extends the output to include the uv from 225 to 445 nm. This doubling option fits inside the *MOPO series* for ultimate integrity and long-term alignment.

The *MOPO-HF* system includes the oscillator head, the digital controller, and optionally, the *MOPO FDO-970* frequency doubler. Chapter 3 contains a complete description of the *MOPO-HF* system.

The MOPO OPO

The OPO head contains all the mechanical and optical components necessary to generate laser light. It houses the master oscillator and power oscillator (ergo, MOPO) and it uses a Type I beta barium borate (BBO) crystal as its nonlinear parametric gain medium.

The MOPO Digital Controller

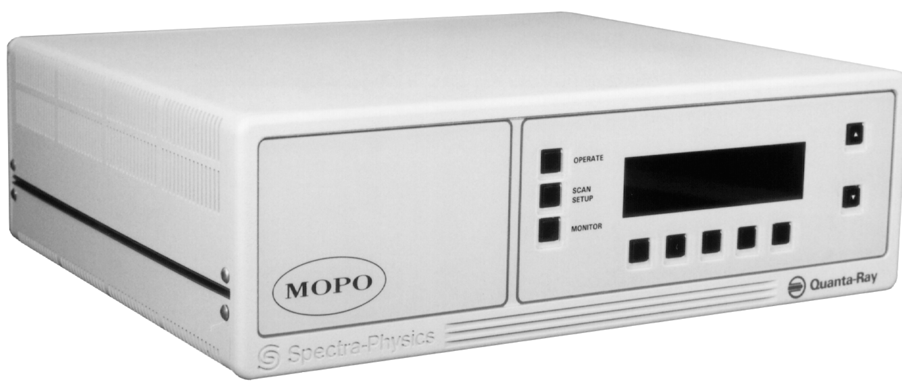


Figure 1-2: The Quanta-Ray *MOPO-HF* Digital Controller

The digital controller contains a simple, menu-driven control program that uses "soft" keys and clear, large characters on a back-lit display to provide an easy method of controlling and monitoring the system. The intuitive, layered menu structure provides operational options along with diagnostic information for fast, efficient control of the unit. For remote control, an optional RS-232 serial interface and IEEE-488 parallel interface is available. An 8-foot cable connects the controller to the laser head.

The Advantage of the MOPO-HF

- Narrow linewidth
- Highest damage threshold optics in the industry
- Microprocessor-based controller
- A user-friendly, menu-driven graphical interface
- Optional IEEE-488 parallel and RS232 serial interfaces for remote control

Patents

The Quanta-Ray *MOPO-HF* series is manufactured under one or more of the following patents:

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

Chapter 2 Laser Safety

The Spectra-Physics Quanta-Ray *MOPO-HF* Optical Parametric Oscillator and its pulsed Nd:YAG pump laser are a Class IV-High Power Laser Products whose beams are, by definition, safety and fire hazards. Take precautions to prevent accidental exposure to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye or skin damage.

Because the 1064 nm Nd:YAG output and its *MOPO-HF* extended range of 450 to 1700 nm and the optional FDO-extended range of 220 to 440 nm include harmonics that are invisible, they are especially dangerous. Infrared radiation passes easily through the cornea, which, when focussed on the retina, can cause instantaneous and permanent 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 is available from suppliers listed in the *Laser Focus World*, *Lasers and Optronics*, and *Photonics Spectra* buyer's guides. Consult the ANSI and ACGIH standards listed at the end of this section for guidance.
- To avoid unnecessary radiation exposure, keep the protective cover on the laser head at all times.
- Avoid looking at the output beam; even diffuse reflections are hazardous.
- Avoid blocking the output beam or its reflections with any part of the body.
- Avoid wearing reflective jewelry while using the laser.
- Use an infrared detector or energy detector to verify the laser beam is off before working in front of the laser.
- Operate the laser at the lowest beam intensity possible, given the requirements of the application.
- Operate in the "long pulse" mode whenever possible, especially during alignment of the experiment.
- Expand the beam whenever possible to reduce beam intensity.

- Establish a controlled access area for laser operation. Limit access to those trained in the principles of laser safety.
- Set up experiments so the laser beam is either above or below eye level.
- Provide enclosures for beam paths whenever possible.
- Maintain a high ambient light level in the laser operation area so the eye's pupil remains constricted, reducing the possibility of damage.
- Set up shields to prevent any unnecessary specular reflections.
- Post prominent warning signs near the laser operating area (Figure 2-1).
- Set up an energy absorbing beam trap to capture the laser beam and prevent accidental exposure to unnecessary reflections or scattering (Figure 2-2).

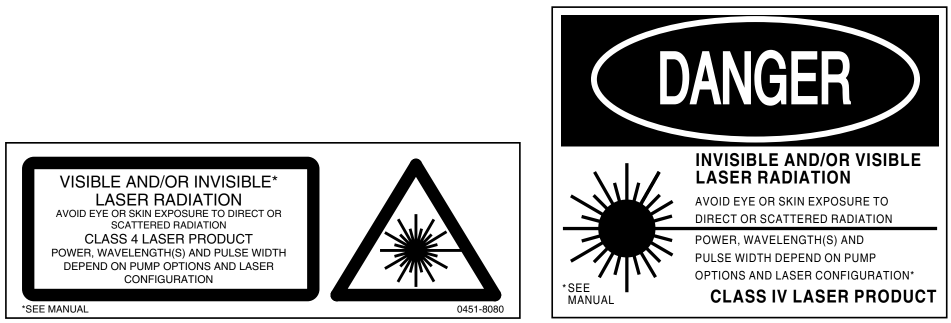


Figure 2-1: These standard safety warning labels would be appropriate for use as entry warning signs (EN60825-1, ANSI 4.3.10.1).

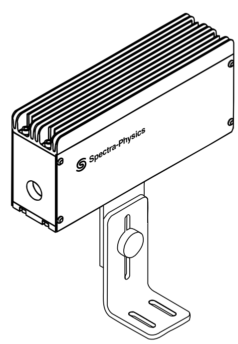


Figure 2-2: Optical Beam Dump, *BD-5*

Caution!

Use of controls or adjustments, or performance of procedures other than those specified herein may result in hazardous radiation exposure.

Operating this laser without due regard for these precautions or in a manner that does not comply with recommended procedures may be dangerous. At all times during installation, maintenance or service of your laser, 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*, 21CFR1040.10(d).

Follow the instructions contained in this manual to ensure proper installation and safe operation of your laser.

Focused Back-Reflection Safety

Focused back-reflections of even a small percentage of the output energy of any Pro-series laser can destroy its optical components. To illustrate, consider an uncoated convex lens, which reflects about 4% of the energy incident on each of its surfaces. While the reflection off the first surface diverges harmlessly, the reflection off the second surface focuses, and the power density at the point of focus is high enough to destroy the Q-switch, Nd:YAG rod, and output coupler of the laser. Even anti-reflection coated optics can reflect enough energy to damage optical components of the laser.

To avoid damage to your laser, minimize back-reflections of its output beam, and where they are unavoidable, direct them away from the optical axis.

Warning! This Quanta-Ray warranty does not cover damage caused by focused back-reflections.

Maintenance Necessary 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. To maintain compliance with these regulations, once a year, or whenever the product has been subjected to adverse environmental conditions (e.g., fire, flood, mechanical shock, spilled solvent, etc.), check to see that all features of the product identified below function properly. Also, make sure that all warning labels remain firmly attached (refer to the CE/CDRH drawing later in this chapter).

1. Verify removing the remote interlock plug on the pump laser prevents laser operation.
2. Verify the laser system will only operate when the pump laser's interlock key switch is in the ON position, and that the key can only be removed when the switch is in the OFF position.
3. Verify the emission indicator on the pump laser works properly; that is, it emits a visible signal whenever the laser is on.
4. Verify that the time delay between turn-on of the pump laser emission indicator and that starting of that laser gives you enough warning to allow action to avoid exposure to laser radiation.
5. Verify removing the cover of the pump laser shuts off the laser.

* *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 into that product.*

6. Verify, when the cover interlock on the pump laser is defeated, the defeat mechanism is clearly visible and prevents installation of the cover until disengaged.

Safety Interlocks

Because the *MOPO-HF* is not a laser and therefore cannot generate output energy without being pumped by a laser, it requires no safety interlocks. All safety interlocks are associated with the pump laser. When the pump laser is disabled, the *MOPO-HF* is disabled.

Danger! Laser Radiation

Collateral radiation present! While the head cover is removed and the pump laser is on, be extremely careful to avoid exposure to laser or collateral radiation.

Battery Disposal

Caution!

When the battery in the controller is depleted, please dispose of it in accordance with local laws and regulations.

CE/CDRH Radiation Control Drawing
(Labels shown on next page)

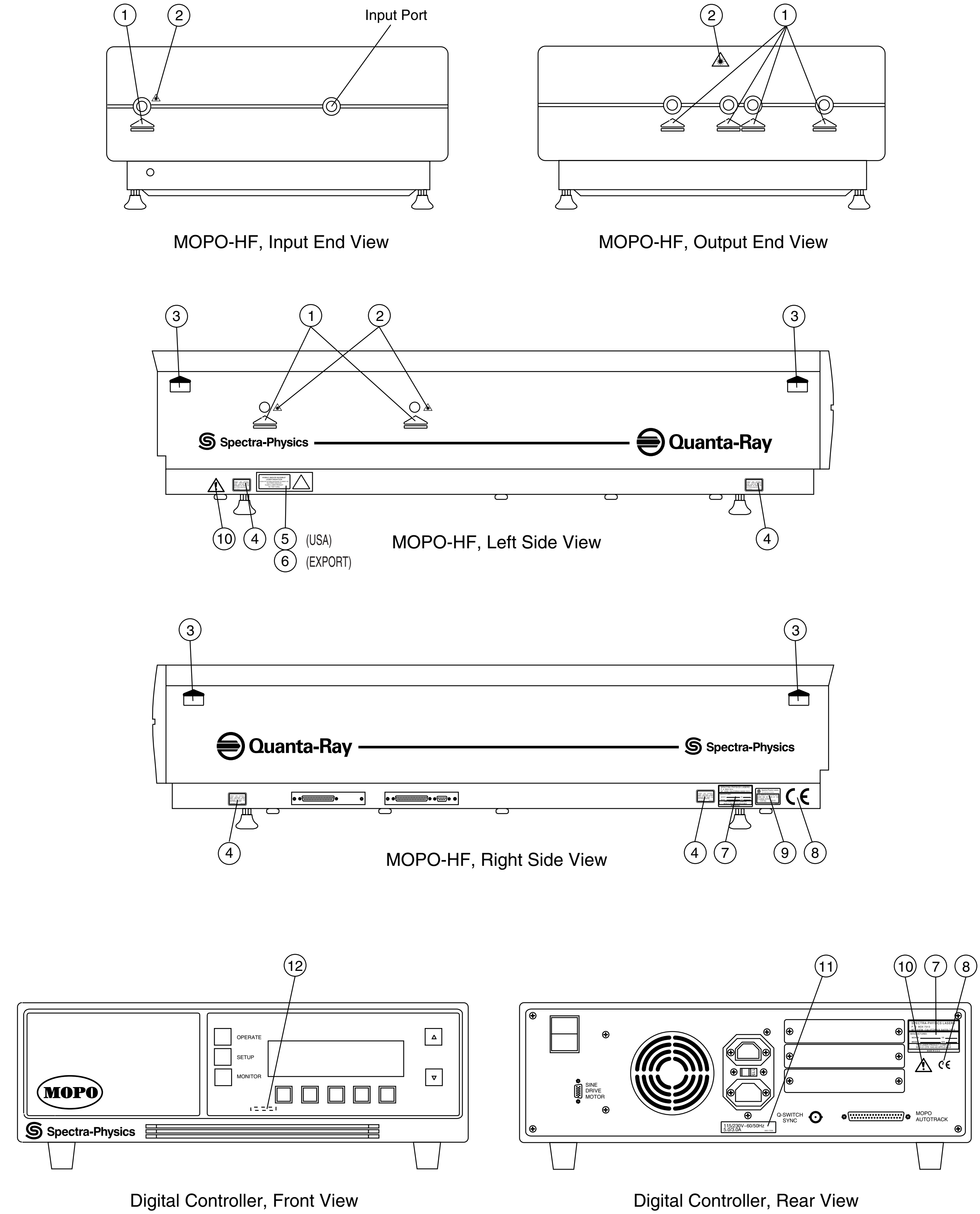


Figure 2-3: CE/CDRH Radiation Control Drawing

CE/CDRH Warning Labels

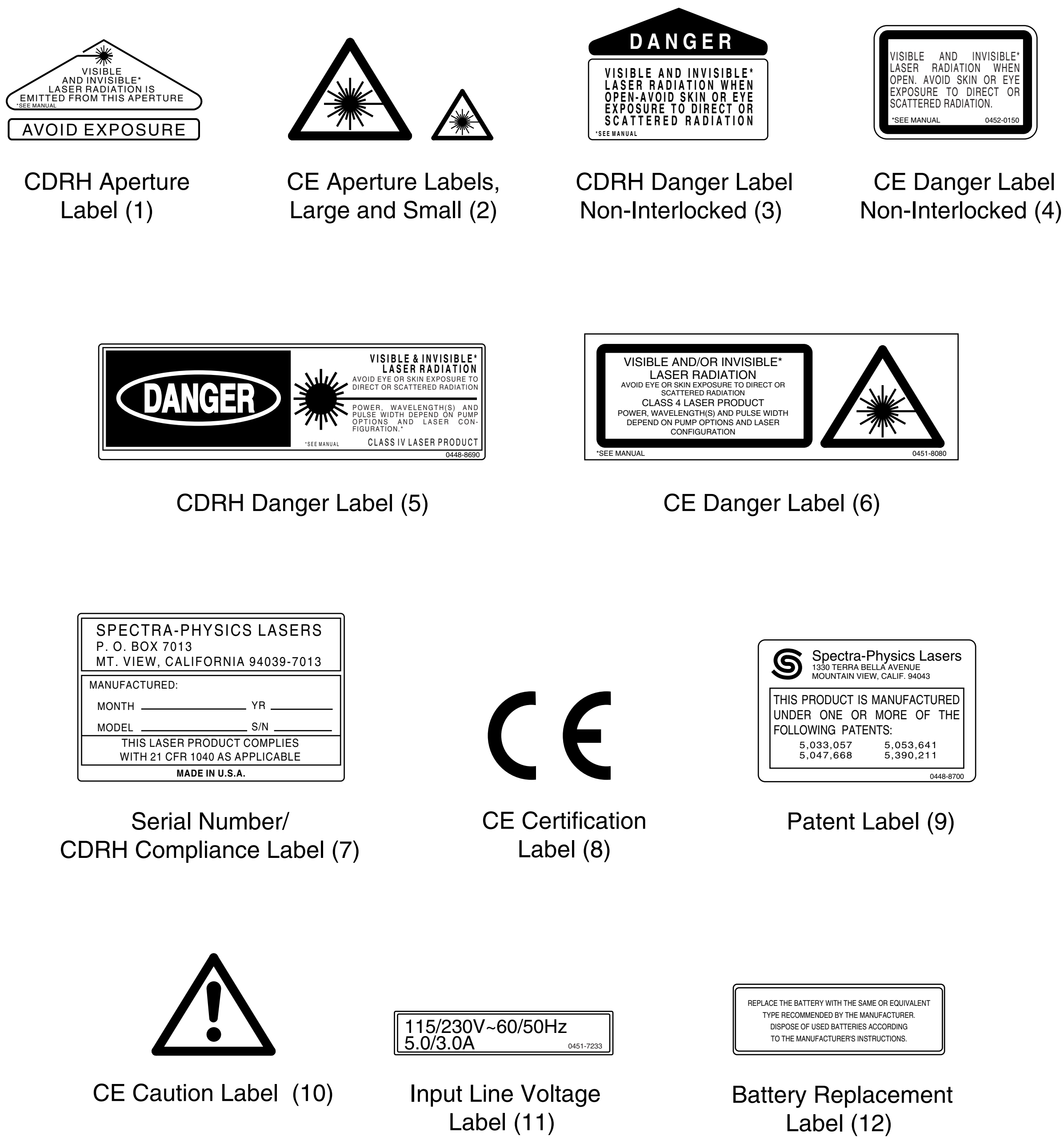


Figure 2-4: CE/CDRH Warning Labels

Label Translations

For safety, the following translations are provided for non-English speaking personnel. The number in parenthesis in the first column corresponds to the label number listed on the previous page.

Label #	French	German	Spanish	Dutch
Aperture Label (1)	Ouverture Laser - Exposition Dangereuse - Un Rayonnement laser visible et invisible est emis par cette ouverture.	Austritt von sichtbarer und unsictbarer Laserstrahlung; nicht dem Strahl aussetzen.	Por esta abertura se emite radiacion laser visible e invisible; evite la exposicion.	Vanuit dit apertuur wordt zichtbare en niet zichtbare laserstraling geemiteerd; vermijd blootstellilng.
Non Inter-locked (3)	Attention; Rayonnement Laser Visible et Invisible en Cas D"Ouverture; Exposition Engereuse de L'Oeil ou de la Peau au Rayonnement Direct ou Diffus.	Vorsicht; beim Offnen Austritt von sichtbare und unsichtbare Laserstrahlung; Bestrahlung von Auge oder Haut durch direkte oder Streustrahlung vermeiden.	Peligro, Cuando se abre existe Radiacion Laser Visible e Invisible; Evite que los ojos y la piel queden expuestos tanto a la radación directa como a la dispersa.	Gevaar; zichtbare en niet zichtbare laserstraling wanneer geoend; vermijd blootsteling aan huid of oog aan disecte straling of weerkaatsingen.
CE Non-Inter-locked Label (4)	Rayonnement Laser Visible et Invisible en Cas D'Ouverture; Exposition Engereuse de L'Oeil ou de la Peau au Rayonnement Direct ou Diffus.	Beim Offnen Austritt von sichtbare und unsichtbare Laserstrahlung; Bestrahlung von Auge oder Haut durch direkte oder Streustrahlung vermeiden.	Cuando se abre existe Radiacion Laser Visible e Invisible; Evite que los ojos y la piel queden expuestos tanto a la radación directa como a la dispersa.	Zichtbare en niet zichtbare laser-straling wanneer geoend; vermijd blootsteling aan huid of oog aan disecte straling of weerkaatsingen.
CDRH Logo-type Danger Label (5)	Attention– Rayonnement Laser Visible et Invisible en Cas D'Ouverture et lorsque la securite est neutralisee; exposition dangereuse de l'oeil ou de la peau au rayonnement direct ou diffus. Puissance et longueurs D'onde dependant de la configuration et de la puissance de pompe. Laser de Classe 4.	Vorsicht; Austritt von sichtbarer un unsichtbarer Laserstrahlung wenn Abdeckung geoffnet und Sicherhetisschalter uberbruckt; Bestrahlung von Auge oder Haute durch direkte oder Streustrahlung vermeiden. Leistung, Wellenlange und Pulsbreite sind abhangig von Pumpquelle und Laserkonfiguration. Laserklasse 4.	Peligro, al abrir y retirar el dispositivo de seguridad exist radiación laser visible e invisible; evite que los ojos o la piel queden expuestos tanto a la radiación directa como a la dispersa. Potencia, Longitud de onda y anchura de pulso dependen de las opciones de bombeo y de la configuracion del laser. Producto laser clase 4.	Gevarr, zichtbare en neit zichtbare laserstraling wanneer geopend en bij uitgeschakelde interlock; Vermijd blootstelling van oog of huid aan directe straling of weerkaatsingen daarvan. Vermogen golfleugten en pulsduur afhankelijk van pomp optics en laser configuratie. Klasse 4 Laser Produkt.

Label #	French	German	Spanish	Dutch
CE Danger Label (6)	Rayonnement Laser Visible et Invisible en Cas D'Ouverture et lorsque la securite est neutralisee; exposition dangereuse de l'oeil ou de la peau au rayonnement direct ou diffus. Puissance et longueurs D'onde dependant de la configuration et de la puissance de pompe. Laser de Classe 4.	Austritt von sichtbarer un unsichtbarer Laserstrahlung wenn Abdeckung geoffnet und Sicherhetisschalter uberbruckt; Bestrahlung von Auge oder Haute durch direkte oder Streustrahlung vermeiden. Leistung, Wellenlange und Pulsbreite sind abhangig von Pumpquelle und Laserkonfiguration. Laserklasse 4.	Al abrir y retirar el dispositivo de seguridad exist radiación laser visible e invisible; evite que los ojos o la piel queden expuestos tanto a la radiación directa como a la dispersa. Potencia, Longitud de onda y anchura de pulso dependen de las opciones de bombeo y de la configuracion del laser. Producto laser clase 4.	Zichtbare en neit zichtbare laserstraling wanneer geopend en bij uitgeschakelde interlock; Vermijd blootstelling van oog of huid aan directe straling of weerkaatsingen daarvan. Vermogen golfleugten en pulsduur afhankelijk van pomp optics en laser configuratie. Klasse 4 Laser Produkt.
Patent Label (9)	Ce produits est fabriqué sous l'un ou plusieurs des brevets suivants.	Dieses Produkt wurde unter Verwendung einer oder mehrerer der folgenden US-Patente hergestellt.	Este producto esta fabricado con una o más de las siguientes patentes de los Estados Unidos.	Dit product is gefabriceerd met een of meer van de volgende USA patenten.
Battery Label (12)	Remplacer la pile par le même modèle ou un modèle équivalent. Se débarasser des piles usagées conformément au recommandations du fabricant.	Batterie nur durch gleichen oder baugleichen Typ gemäß Herstellerangaben ersetzen. Verbrauchyte Batterien ordnungsgemäß entsorgen.	Reemplazar la batería con el mismo tipo, o equivalente, recomendado por el fabricante. Peligro. Deshacerse de las baterías usadas de acuerdo con las instrucciones del fabricante.	Vervang batteryen door de zelfde, of door de fabrikant geadviseerde equivalente typen. Voer de gebruikte battereien af volgens de instructies van de fabrikant.

CE Declaration of Conformity

We,

Spectra-Physics, Inc.
Scientific and Industrial Systems
1330 Terra Bella Avenue
P.O. Box 7013
Mountain View, CA. 94039-7013
United States of America

declare under sole responsibility that the:

Quanta-Ray MOPO-HF series Pulsed Optical Parametric Oscillators with digital controller,

manufactured after December 31, 1995 meets the intent of "Directive 89/336/EEC for Electromagnetic Compatibility."

Compliance was demonstrated (Class A) to the following specifications as listed in the official *Journal of the European Communities*:

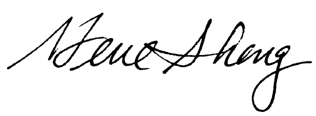
EN 50081-2:1993 Emissions:

EN 55011 Class A Radiated
EN 55011 Class A Conducted

EN 50082-1:1992 Immunity:

IEC 801-2 Electrostatic Discharge
IEC 801-3 RF Radiated
IEC 801-4 Fast Transients

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directives and Standards.



Steve Sheng
Vice President and General Manager
Spectra-Physics, Inc.
Scientific and Industrial Systems
December 31, 1995

CE Declaration of Conformity

We,

Spectra-Physics, Inc.
Scientific and Industrial Systems
1330 Terra Bella Avenue
P.O. Box 7013
Mountain View, CA. 94039-7013
United States of America

declare under sole responsibility that the

Quanta-Ray *MOPO-HF* series Pulsed Optical Parametric Oscillators with digital controller,

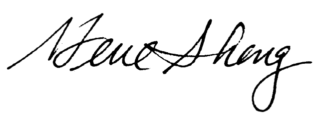
meets the intent of "Directive 73/23/EEC, the Low Voltage directive."

Compliance was demonstrated to the following specifications as listed in the official *Journal of the European Communities*:

EN 61010-1: 1993 Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory use:

EN 60825-1: 1993 Safety for Laser Products.

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directives and Standards.



Steve Sheng
Vice President and General Manager
Spectra-Physics, Inc.
Scientific and Industrial Systems
January 1, 1997

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: 1993)
American National Standards Institute (ANSI)
11 West 42nd Street
New York, NY 10036
Tel: (212) 642-4900

Occupational Safety and Health Administration (Publication 8.1-7)
U. S. Department of Labor
200 Constitution Avenue N. W., Room N3647
Washington, DC 20210
Tel: (202) 693-1999

A Guide for Control of Laser Hazards, 4th Edition, Publication #0165
American Conference of Governmental and
Industrial Hygienists (ACGIH)
1330 Kemper Meadow Drive
Cincinnati, OH 45240
Tel: (513) 742-2020
Internet: www.acgih.org/home.htm

Laser Institute of America
13501 Ingenuity Drive, Suite 128
Orlando, FL 32826
Tel: (800) 345-2737
Internet: www.laserinstitute.org

Compliance Engineering
70 Codman Hill Road
Boxborough, MA 01719
Tel: (978) 635-8580

International Electrotechnical Commission
Journal of the European Communities
EN60825-1 TR3 Ed.1.0—Laser Safety Measurement and Instrumentation
IEC-309—Plug, Outlet and Socket Coupler for Industrial Uses
Tel: +41 22-919-0211
Fax: +41 22-919-0300
Internet: http://ftp.iec.c.h/

Cenelec
European Committee for Electrotechnical Standardization
Central Secretariat
rue de Stassart 35
B-1050 Brussels

Document Center
1504 Industrial Way, Unit 9
Belmont, CA 94002-4044
Tel: (415) 591-7600

Equipment and Training

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

Laser Focus World Buyer's Guide
Laser Focus World
Penwell Publishing
10 Tara Blvd., 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: (973) 292-5100

Photonics Spectra Buyer's Guide
Photonics Spectra
Laurin Publications
Berkshire Common
PO Box 4949
Pittsfield, MA 01202-4949
Tel: (413) 499-0514

Chapter 3 Description

OPO Theory of Operation

The gain of an optical parametric oscillator (OPO) system is derived from the nonlinear interaction between an intense optical wave and a crystal having a large nonlinear polarizability coefficient. Beta Barium Borate (BBO) is a negative uniaxial crystal with intrinsic birefringence properties that are used to achieve critical phase matching required by this process.

OPO operation can be most easily understood as the inverse of the familiar nonlinear frequency mixing process used to generate harmonics in a Nd:YAG laser. For example, the third harmonic of a Nd:YAG laser is 355 nm, and it is generated by mixing the 1064 nm fundamental output with the 532 nm second harmonic in a nonlinear crystal material such as BBO or KD*P.

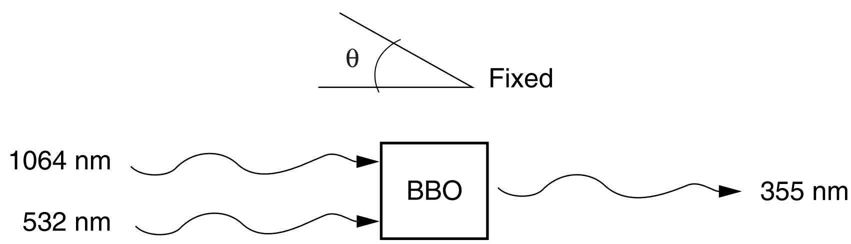


Figure 3-1: Frequency mixing to generate the third harmonic of Nd:YAG

An OPO works in the reverse fashion in which the energy contained in a pump photon at frequency ω_p is transferred to two other photons ω_s (the signal wave) and ω_i (the idler wave) in such a way as to satisfy the energy conversion law:

$$\omega_p = \omega_s + \omega_i \qquad [1]$$

Or, in terms of wavelength:

$$1/\lambda_p = 1/\lambda_s + 1/\lambda_i \qquad [2]$$

By placing the parametric gain medium (BBO) in an appropriate resonant cavity, oscillation at the signal and/or idler wavelength can be obtained. In OPOs, the gain can be large enough that no signal input wave is necessary. The signal will grow from quantum noise in the crystal. Both the signal wave and the idler wave can be resonated simultaneously (doubly resonant), or individually (singly resonant). The Quanta-Ray *MOPO-HF*® series is designed such that both cavities (the master and power oscillators) are singly resonant over the signal wavelength range.

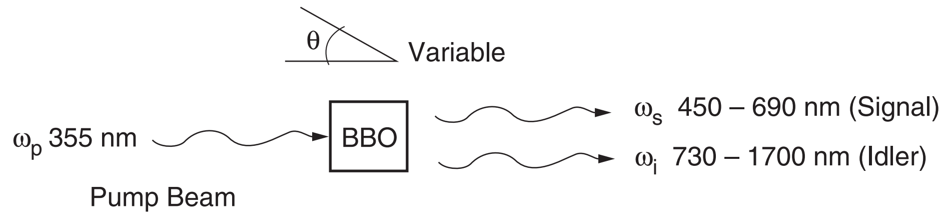


Figure 3-2: Parametric Amplification to Generate Tunable Output from 450 nm to Beyond 1700 nm.

The output of an OPO is very similar to that of a laser. The signal and idler beams exhibit strong coherence, are highly monochromatic, and have a spectrum consisting of one or more longitudinal modes. Although similar in structure and operation to that of a laser, the OPO obtains gain from a nonlinear conversion rather than an atomic transition. Because of this difference, the OPO has no gain storage, and thus only operates when the pump wave is present.

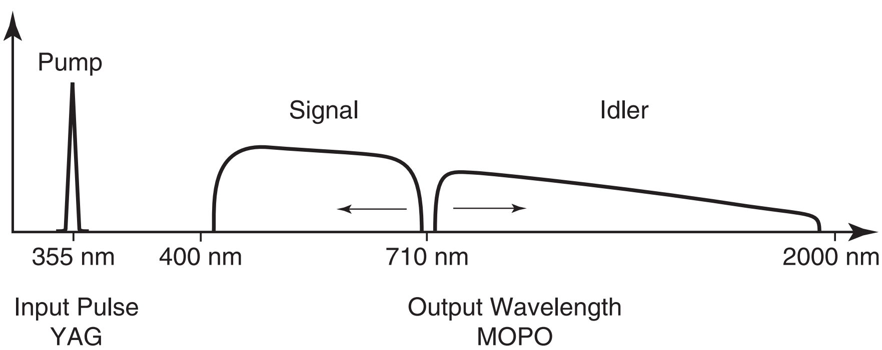


Figure 3-3: Theoretical signal and idler Output wavelengths for 355 nm Pump

In the *MOPO-HF* system, the pump wavelength λ_p is always 355 nm. In theory, however, an infinite number of signal and idler wavelengths exist to satisfy equation 1. The angular dependence of the birefringence in anisotropic crystals, such as BBO results in a variation of refractive index as the crystal is rotated. By fixing the pump wavelength and beam path, any variation in signal and idler index of refraction caused by a rotation in the crystal will vary the wavelength resonated within the cavity, thus allowing tuning to be accomplished.

For further information on OPO theory, refer to “Tunable Optical Parametric Oscillators” by Steven E Harris, *Proceedings of the IEEE*, Volume 57, No. 12, December 1969, p. 2096-2113.

BBO Enables OPO Commercialization

The commercialization of OPO technology has taken more than 25 years due to the lack of suitable, commercially available nonlinear materials. In order for a material to be suitable for OPO use, the crystal must possess five critical properties simultaneously:

- Phase matching conditions for pump, signal and idler wavelengths over the tuning range of interest.

- High damage threshold to sustain the intense pump fluence required for the nonlinear interaction.
- Low absorption over the entire tuning range.
- Ability to be fabricated in useful sizes.
- No significant degradation with time.

The only material fitting these criteria is BBO, and it has only been in recent years that high quality BBO crystals have been available in useful sizes necessary for the commercialization of OPO devices.

MOPO Operation

The *MOPO-HF* is a coupled dual oscillator system. In this scheme, a high energy power oscillator is injection seeded with the narrow linewidth output from a master oscillator. This enables the coupled oscillator system to produce narrow bandwidth, high energy, tunable coherent radiation. The acronym MOPO (master oscillator/power oscillator) is derived from this design concept.

The *MOPO-HF* is a pulsed optical parametric oscillator (OPO) which uses type I phase matched beta barium borate (BBO) as the nonlinear gain medium. BBO is a negative uniaxial crystal with intrinsic birefringence properties that are used to achieve critical phase matching. Tuning the MOPO output is, therefore, accomplished by rotating the OPO crystal with respect to the optical axis of the resonator (angle tuning).

Master Oscillator

The master oscillator design uses a grating in grazing incidence geometry to produce a narrow linewidth output. There are three optical elements which form the optical resonator: a broadband high reflector, a high modulation holographic grating designed to provide suitable diffraction efficiency over the desired tuning range, and a broadband reflective tuning mirror critically mounted on a high resolution sine bar drive to provide linear scanning capability. In addition, two high damage threshold 355 nm dichroics are inserted into the cavity to route the pump beam through the BBO gain medium, then out of the resonator and into a beam dump. This patented design avoids the necessity of directing the pump beam through the resonator optics which have limited damage threshold capability due to coating materials and optical design constraints.

The grazing incidence cavity, also referred to as the Littman oscillator, can provide the necessary dispersion to achieve narrow linewidth output. As with other wavelength selective optics, the grating adds a significant amount of loss to the cavity. In a Littman cavity, a larger incidence angle (nearer to 90 degrees) increases the wavelength selectivity, but also significantly increases the cavity losses. Increased cavity losses, in general, will shrink the effective tuning range. In the *MOPO-HF* the incidence angle and grating design parameters were chosen to minimize the losses at a level where the tunability of the oscillator is not compromised, yet still provide suitable wavelength selectivity to achieve the linewidth specification (<0.075 cm^{-1} mean linewidth).

When a pump pulse enters the BBO crystal in the master oscillator, quantum noise fluctuations result in the parametric generation of signal and idler photons. These photons have an intrinsic gain bandwidth that is determined by the dispersion of the BBO crystal. Factors such as pump beam bandwidth and divergence, as well as crystal length also effect the parametric gain bandwidth. After exiting the crystal, the photons interact with the grating at the grazing incidence angle. The idler photons deflect out of the cavity in the zeroth order (mirror) reflection, while the resonated signal photons diffract off the grating at an angle given by diffraction theory.

$$\alpha \sin\theta = \lambda \qquad [3]$$

The quantity α is the grating groove spacing and λ is the wavelength. As shown in Figure 3-4 the signal photons diffracted off of the grating form a "fan" of wavelengths. The tuning mirror is oriented to reflect the signal photons centered at the peak of the crystal gain bandwidth. These "spectrally narrowed" photons are retroreflected into the cavity where they make a second pass through the crystal in a direction that opposes the pump beam.

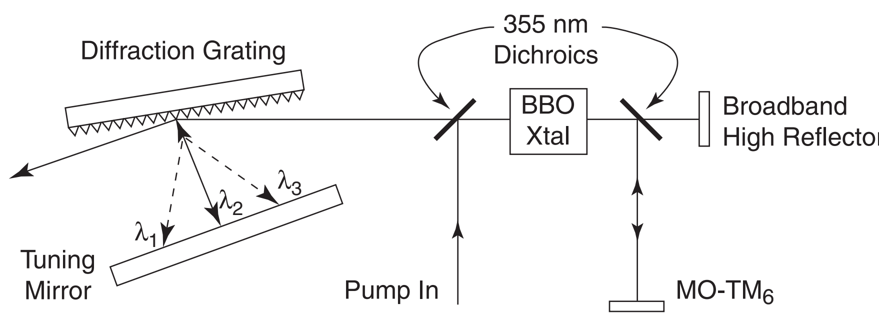


Figure 3-4: The *MOPO-HF* Master Oscillator uses a Grazing Incidence geometry to produce sub 0.075 cm^{-1} mean linewidths. The wave length centered at the peak of the BBO gain bandwidth, λ_2, is reflected back into the cavity, while those at the edge of the gain bandwidth walk out of the cavity and do not oscillate.

After passing through the crystal, the photons encounter the broadband high reflector and are retroreflected back into the cavity in the phase-matching direction. The number of signal photons in the second round trip through the cavity dominates the parametric light generated by quantum noise fluctuations. Thus, the gain realized for the spectrally narrowed signal photons dominates the gain experienced by other wavelengths. Further passes through the resonator continue to occur until the oscillation threshold is reached. Once this happens, multiple passes through the resonator result in gain depletion of the pump pulse and useful parametric output from the *MOPO-HF* (Figure 3-5). In addition, the increased number of interactions with the grating enhances the wavelength narrowing performance of the resonator. The pump pulse continues to be depleted until the round-trip gain level drops below threshold and oscillation ceases.

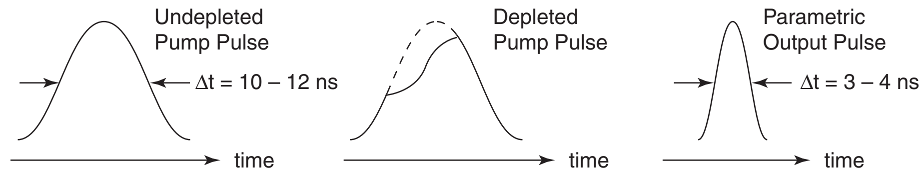


Figure 3-5: Pump pulse depletion and resulting parametric output pulse.

Power Oscillator

The key feature of the power oscillator is the use of a geometrically unstable resonator design, originally patented by Quanta-Ray for use in Nd:YAG lasers. Previous OPO designs employed conventional geometrically stable cavities, which provided no transverse mode control. These designs were capable of delivering high output energy but with poor spatial mode quality and highly divergent beams. Only the *MOPO-HF* series geometrically unstable resonator provides high energy, single transverse mode output pulses. The resonator provides an output beam with a smooth Gaussian like profile, minimal structure, no hot-spots, and submilliradian divergence at all wavelengths.

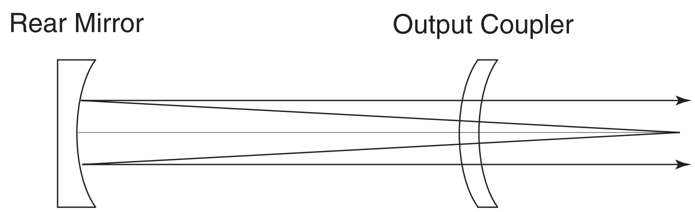


Figure 3-6: Schematic of an Unstable Resonator Design used in the *MOPO-HF* Series.

The power oscillator is a standard two mirror linear cavity which contains the BBO crystal, a broadband high reflector, and an output coupler. In addition, the cavity contains two 355 nm dichroics and a crystal compensator. As in the master oscillator, the dichroics route the pump beam into the cavity, through the BBO crystal, then out of the cavity. The crystal compensator corrects for beam displacement which results from rotation of the BBO crystal. As described in the following section, the power oscillator is configured in a manner that allows optimal seeding.

The signal and idler output beams from the power oscillator are overlapped as explained in “Angle is Everything in OPOs” below. After exiting the oscillator, the signal and idler are directed onto a broadband dichroic at normal incidence. The dichroic transmits the idler beam which then passes through the idler output port. The signal beam is reflected and directed near normal incidence onto another broadband dichroic, which removes residual idler and directs it through the signal output port (Figure 3-7).

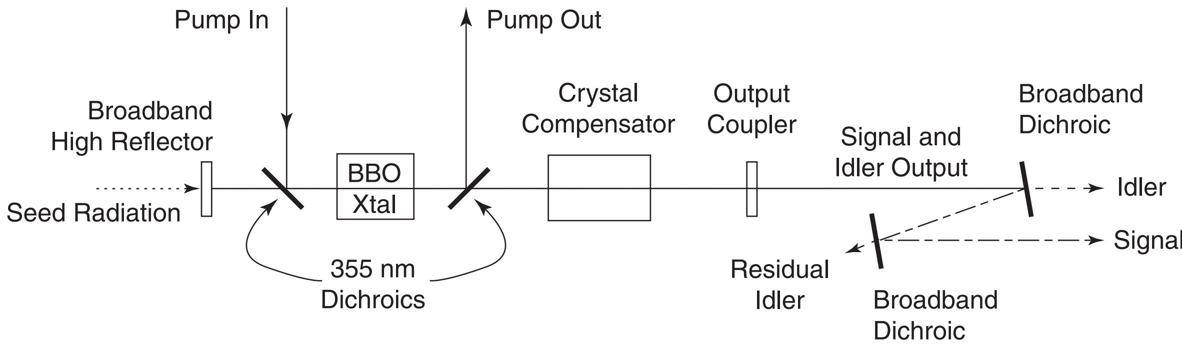


Figure 3-7: Power oscillator cavity geometry. Illustration shows separation of signal and idler output beams with broadband dichroic mirrors.

The Seeding Process

The master oscillator output is obtained from the zeroth order (mirror) reflection from the diffraction grating. The beam is directed onto a routing mirror (STP_1) which has an IR absorbing filter to remove the idler. This minimizes the chance of optical damage by reducing the total energy on the mirror. The remaining signal beam is directed through an uncoated beam splitter. The reflection from the beam splitter is used to monitor the operation of the master oscillator.

Another routing mirror, STP_2 is used to direct the beam through an upsizing telescope and onto the backside of the power oscillator broadband high reflector (PO-BBHR). The energy levels that leak through the high reflector are suitable to achieve seeded operation (tens of microjoules is sufficient to seed the oscillator).

Successful injection seeding of the power oscillator requires that the phase match angle of the power oscillator crystal be identical to that of the master oscillator crystal. Thus, the angle which the pump beam makes with the optic axis of the two crystals must be the same. This frequency overlap process is accomplished with an independent adjustment of the power oscillator crystal angle. When frequency overlap is achieved, injection seeding will result.

In seeded operation, the output power of the power oscillator will increase due to reduction in the oscillation threshold. Threshold reduction occurs when there are “seed” photons, with appropriate polarization and frequency, present at the beginning of the pump pulse. These “injected” photons overwhelm those that are produced from quantum noise fluctuations in the crystal. As a result, it takes fewer round trips through the cavity are required to reach oscillation threshold. Thus, more of the pump pulse is depleted and a proportional increase in output power is realized.

The injected “seed” photons determine the nature of the spectral bandwidth of the power oscillator. Therefore, if an unseeded power oscillator with a free-running bandwidth of 10 cm^{-1} is injection seeded with sub 0.1 cm^{-1} linewidth source, the output linewidth will collapse to sub 0.1 cm^{-1}.

Optimal seeding requires that the seed pulse arrive in the crystal before the pump pulse. This requirement is satisfied by a suitable optical delay line for the pump beam. The seeding process is also enhanced when the oscillator is running near-threshold. This is realized in the power oscillator with an appropriate choice of pump energy, and spot size the BBO crystal. These factors allow the seed radiation to overwhelm the quantum noise-induced parametric generation in the crystal resulting in a well seeded operation.

Dichroic Beam Separation

The output beam from the power oscillator contains the collinear signal and idler waves, which need to be separated for most applications. Consequently, all *MOPO-HF* systems contain a broadband dichroic pair to separate the two beams. The use of two dichroic optics ensures >97% spectrally pure beams (Figure 3-8). The final outputs are parallel and are spaced two inches apart.

By designing the oscillators to be singly resonant over the signal wavelength range, a single set of broadband optics allow continuous tuning from 450 to 1680 nm. This means that no mirror change or realignment is necessary when scanning across the visible or near IR spectrum.

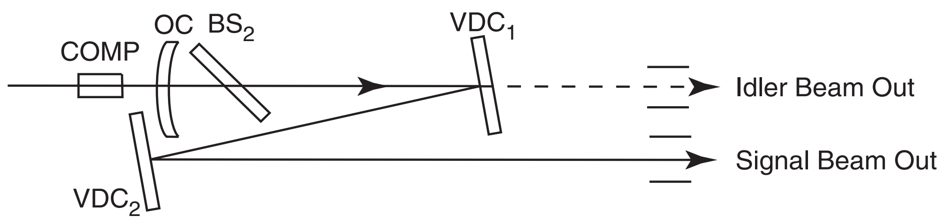


Figure 3-8: Dichroic Beam Separation

Angle is Everything in OPOs

The process by which gain is derived in an optical parametric oscillator is fundamentally different than that in a laser. In a laser, gain is derived from energy stored in the excited states of an atomic or molecular transition. The source of this excitation energy may be radiative, thermal, or electrical. Once energy is stored in an excited state, it may be extracted through the process of stimulated emission in an appropriately configured optical resonator. In this process, photons are initially produced by spontaneous emission from the laser transition. The photons that are directed along the optical axis of the resonator force (stimulate) the emission of photons from other excited atoms or molecules encountered in the gain medium. These photons have the same frequency, phase, and directional character of the primary photon. Multiple passes through the gain medium results in a geometrical increase in the number of photons in the cavity. Oscillation threshold is reached when the number of photons generated (gain) equals the number lost in one round trip.

The source of gain in an optical parametric oscillator is physically distinct. It is this difference that underscores the dissimilarity between lasers and

OPOs as commercial devices. As discussed previously, gain in an OPO is derived from a nonlinear optical phenomenon which results in the decomposition of a pump photon into a signal and idler photon. Unlike a laser, this process does not require a real atomic or molecular transition. Thus, there is no energy storage capability. Useful gain in an OPO is derived by appropriate phase matching in a birefringent crystal. This occurs at a unique angle formed by the direction the pump wave (defined by its corresponding wave or "k" vector) and the optic axis of the crystal. Thus, in a critically phase matched OPO such as the MOPO, preservation of this angle is crucial for maintaining appropriate performance.

Figure 3-9 shows two wave (or *k*) vector diagrams that are geometric descriptions of the law of conservation of momentum. Figure 3-9a represents the collinear phase-matching process. The pump wave (k_p) is converted to the signal wave (k_s) and the idler wave (k_i). If the resonated signal wave is collinear with the pump beam and the pump beam is overlapped with the resonator axis, the idler must also be collinear in order to satisfy the equation: $k_p = k_i + k_s$. The idler is always the longest wavelength (or shortest wave vector). Note: k_i and k_s are actually overlapped but are offset in the illustration for clarity.

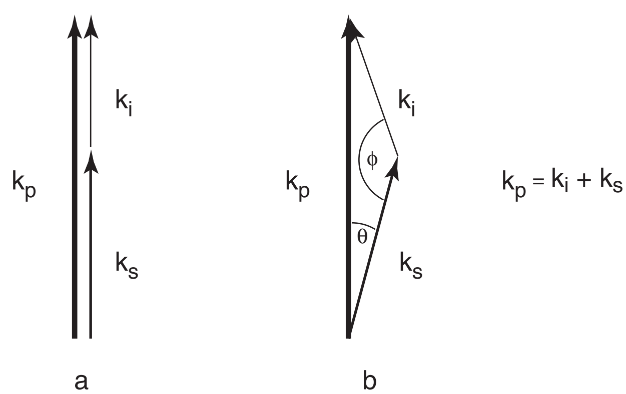


Figure 3-9: Collinear (a) and noncollinear (b) phase matching

Figure 3-9b is wave vector diagram that describes the phase matching of the three beam components when the signal beam is not collinear with the pump beam, but is aligned at an angle ϕ with respect to the pump beam. When this is the case, angle ϕ remains constant as the signal frequency varies, however the length of k_s varies, as does k_i and the angle θ, to abide by the law of energy conservation. As a consequence, whenever $\theta \neq 0$, the idler will walk off the optical axis of the cavity (as defined by the pump beam) as the frequency is tuned.

In the real world, the pump beam is rarely perfectly collimated and the simple *k* vector diagram is not sufficient; a more complex description representing the converging or diverging beam is required. However, simply stated, since the idler is a product of the pump and the signal, defining the pump and signal characteristics constrains the divergence of the idler. In other words, a "perfect" system includes a collimated pump source with a collimated signal and idler, whereas, in the real world, a typical system might include a converging pump source and a collimated signal with a divergent idler to compensate for the angular divergence of the pump source. If, on the other hand, we had a diverging pump source and collimated signal beam, we would see a converging idler beam.

To assist in linewidth reduction, the *MOPO-HF* master oscillator uses non-collinear phase matching. According to the previous statements, this might appear undesirable because of the idler walk-off. However, since the idler is not used for seeding, there are no deleterious consequences associated with the small amount of idler beam wander. And because the signal beam is constrained by the cavity, it does not exhibit any beam-pointing changes.

Automated Control Electronics

The *MOPO-HF* series makes use of the latest generation of microprocessor-based control electronics to provide the ultimate in ease of use and reliability. The front panel of the controller has a large, easy to read backlit LCD display, and push button controls provide simple access to menus that allow you to set all the necessary operating parameters. Options include: continuous or incremental scans, scan speed, scan increment, delay times, number of scans and home position. Optional RS-232 and IEEE-488 interfaces, and even a fax modem, allow easy connection to existing laboratory control and data acquisition equipment.

The controller contains a UL-compatible switching power supply, a microprocessor-based controller pc board, and a drive pc board for crystal rotation (the BBO crystal is tuned by rotating the crystal to a known angle for each wavelength).

Tuning Curves

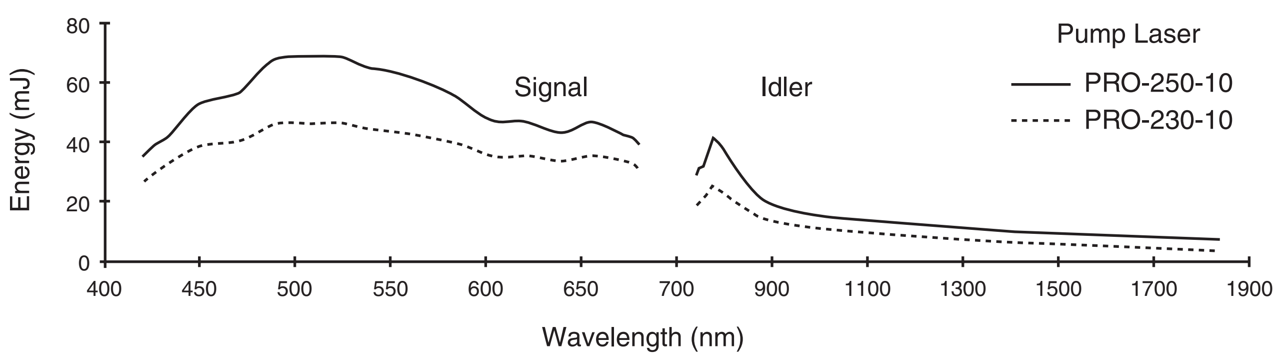


Figure 3-10: *MOPO-HF* Turning Curves

MOPO-HF Specifications

Table 3-1: *MOPO-HF* Output[1] Characteristics

Polarization	Horizontal >97%
Beam diameter (typical)[2]	5 mm
Beam shape (typical)[3]	Round ±20%
Beam divergence[4]	<1 mrad
Pointing stability[5]	<200 μrad
Pulse width (typical)	2 ns less than pump
Resettability	<1 x linewidth
Electronic readout accuracy (typical)	<10 x linewidth
Long-term stability	1 x linewidth/°C/hr
Pulse-to-pulse stability[6]	±10%
Timing jitter[7]	<2 ns
Linewidth[8]	<0.075 cm^{-1}

Table 3-2: Output Energy vs. Pump Source

Pump Laser	Output Energy[9]
PRO-290-10	**
PRO-290-30	**
PRO-270-10	**
PRO-270-30	**
PRO-250-10	60
PRO-250-30	**
PRO-230-10	40

Table 3-3: Tuning Characteristics[10]

Signal tuning range (typical)	440 to 690 nm
Idler tuning range (typical)	735 to 1800 nm

1 All specifications subject to change without notice. The parameters marked "typical" are not specifications. They are indications of typical performance and will vary with each unit we manufacture. Unless stated, all specifications are at 500 nm.
2 Beam diameter is measured in the Signal wavelength range at the $^1/e^2$ point and can vary depending on the pump source energy level.
3 Measured at 1 m from the output in the Signal wavelength range.
4 Full angle measured at the $^1/e^2$ point.
5 Over an 8-hour period with temperature variations of <±3° C.
6 Pulse-to-pulse stability for >99% of pulses, measured over 1 hour.
7 rms jitter from the Q-switched sync pulse in the PRO-series pump Nd:YAG laser using an injections seeder.
8 Measured at 500 nm only. Typically <0.2 cm^{-1} across the tuning range.
9 Specifications at 500 nm for the Signal wavelength only. See the tuning curves for typical output at other wavelengths.
10 Nitrogen purging is recommended to avoid water absorption while tuning and to improve system cleanliness.

Service Requirements

Electrical service:	115/230 V, 5/3 A, 50/60 Hz single phase

Mechanical Specifications

Size:	See Outline Drawings
Weight:	
MOPO-HF	84 kg (185 lb)
Digital controller	10 kg (22 lb)

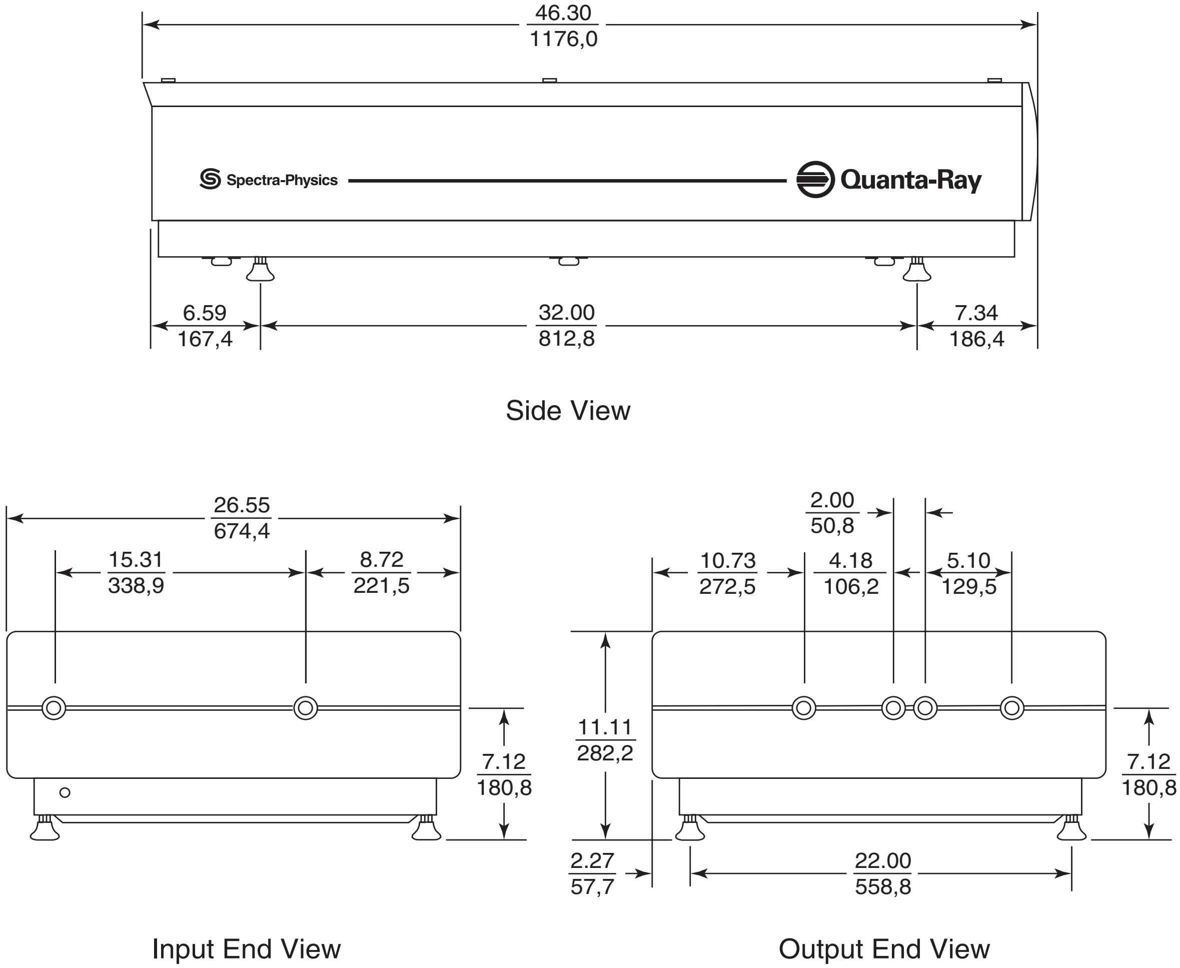
Environmental Specifications

The environmental conditions under which the *MOPO-HF* system will function are listed below:

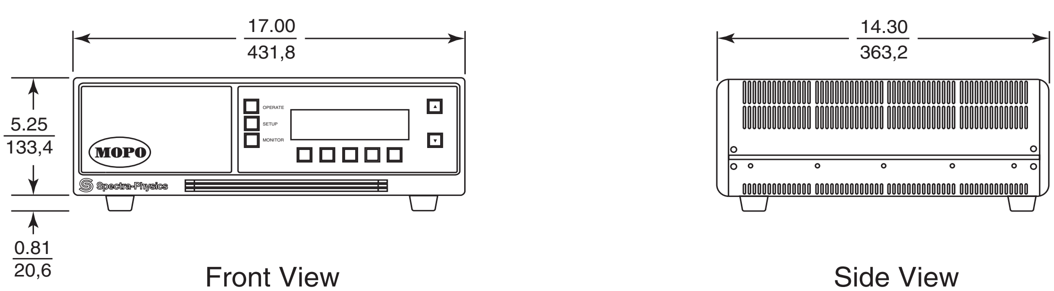
Indoor use

Altitude:	up to 2000 m
Temperatures:	10° C to 40° C
Maximum relative humidity:	80% non-condensing for temperatures up to 31° C.
Mains supply voltage:	do not exceed ±10% of the nominal voltage for the controller
Insulation category:	II
Pollution degree:	2

Outline Drawings



MOPO-HF Head



MOPO-HF Digital Controller

All dimensions in $\frac{\text{inches}}{\text{mm}}$

Figure 3-11: Outline Drawings

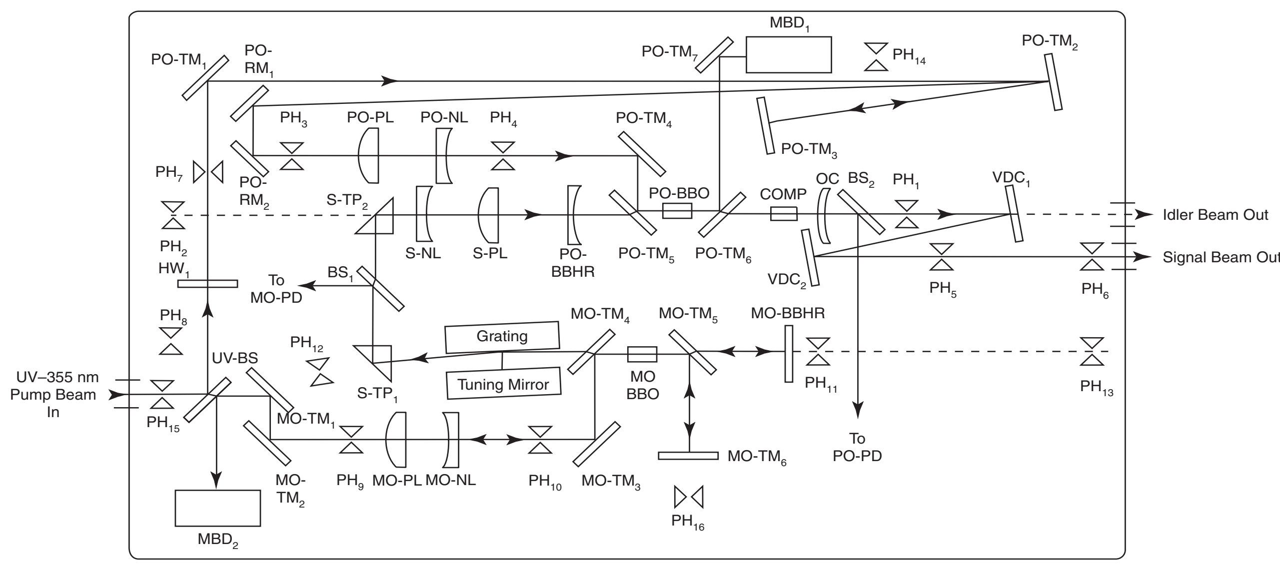
Chapter 4 Controls, Indicators and Connections

Introduction

This section defines the user controls, indicators and connections of the *MOPO-HF* system. It is divided into two sections: the *MOPO-HF* head and the *MOPO-HF* control module.

Figure 4-1 shows the relative position of the various components in the *MOPO-HF*.

MOPO-HF



BS$_{1,2}$	Beam Splitters	PO-BBHR	PO High Reflector
COMP	Compensating Crystal	PO-BBO	PO BBO Crystal
HW$_1$	Halfwave Plate	PO-PD	PO Photodectector
MBD$_{1,2}$	Mini Beam Dumps	PO-TM$_{1–7}$	PO Turning Mirrors
MO-BBHR	MO High Reflector	PO-RM$_{1,2}$	PO Routing Mirrors
MO-BBO	MO BBO Crystal	PO-PL	PO Positive Lens
MO-PD	MO Photodetector	PO-NL	PO Negative Lens
MO-PL	MO Positive Lens	S-NL	Seeder Negative Lens
MO-NL	MO Negative Lens	S-PL	Seeder Positive Lens
MO-TM$_{1–6}$	MO Turning Mirrors	S-TP$_{1,2}$	Seeder Turning Prisms
OC	Output Coupler	UV-BS	Ultraviolet Beam Splitter
PH$_{1–16}$	Pin Holes	VDC$_{1,2}$	Visual Dichroics

Figure 4-1: The *MOPO-HF* Beam Path

External Controls

Shutter—there is none. Because the *MOPO-HF* is not a laser, it does not have a shutter. When you need to block the beam temporarily, set the pump laser to Q-SWITCH OFF.

Cover clamping screws (4)—hold the cover securely in place. One screw is located on each corner of the cover.

Foot height adjustments (4)—provide a means to level the *MOPO-HF* and to adjust its height to match that of the pump laser or target device. The legs are large screws with swivel feet that can be screwed up and down from inside the laser head using an Allen driver. Once the height adjustment has been made, a jam nut on each leg is tightened up against the chassis to lock them in place.

Internal Controls

Master Oscillator

UV-BS—(uv beam splitter) divides the beam, sending approximately 60 to 75 mJ to the master oscillator (MO) and the rest to the power oscillator (PO). The mount is fastened to the base plate by two screws. Although the mirror can be cleaned in place, it can be removed by unscrewing the bezel. There are vertical (top) and horizontal (side) alignment knobs for directing the beam.

MBD_2—(mini beam dump) absorbs the return MO beam that is reflected from the UVBS. Two screws fasten the beam dump to the base plate. There are no adjustments.

$MO\text{-}TM_1$—(master oscillator turning mirror) provides adjustment to align the incoming beam from UVBS and direct it to $MO\text{-}TM_2$. The mount is fastened to the base plate by two screws, and the mount is slotted so it can be moved forward and backward. Although the mirror can be cleaned in place, it can be removed by removing 4 screws of the retaining ring with an Allen ball driver and removing the mirror with the retaining ring. The optic is flat so there is no set orientation, and it is spring-loaded against 3 balls for repeatability after removal. There are vertical (upper) and horizontal (lower) alignment knobs for directing the beam.

$MO\text{-}TM_2$—(master oscillator turning mirror) provides adjustment to direct the beam from $MO\text{-}TM_1$ to the telescope through pin hole PH_9 (when present). The mount is fastened to the base plate by two screws, and the mount is slotted so it can be moved forward and backward. Although the mirror can be cleaned in place, it can be removed by removing 4 screws of the retaining ring with an Allen ball driver and removing the mirror with the retaining ring. The optic is flat so there is no set orientation, and it is spring-loaded against 3 balls for repeatable seating. There are vertical (upper) and horizontal (lower) alignment knobs for directing the beam.

PH_9—(pin hole) is used for alignment purposes only. There are several of these and they can be removed and placed in several positions for the different stages of alignment. The number designates a position rather than a particular pin hole mount.

MO Telescope—is made up of the MO-PL and MO-NL (described below) and is used to set the diameter size of the beam.

MO-PL—(master oscillator positive lens) is the input end of the MO telescope (see above). It is mounted on a spring-loaded slide, and a micrometer provides fine adjustment for setting the separation between the two lenses. Although the lens can be cleaned in place, it can be removed by removing the 4 screws of the retaining ring with an Allen ball driver and removing the lens with the retaining ring. The lens is spring-loaded against 3 balls for repeatable seating. There are no vertical or horizontal adjustments for directing the beam. The mount is fastened to the base plate by 2 screws.

MO-NL—(master oscillator negative lens) is the output end of the MO telescope (see above). It is firmly mounted to the base plate by 2 screws, but the holes are slotted to allow for some minor horizontal adjustment. Two screws can be loosened for vertical adjustment. Although the lens can be cleaned in place, it can be removed by removing the 4 screws of the retaining ring with an Allen ball driver and removing the lens with the retaining ring. The lens is spring-loaded against 3 balls for repeatable seating. There are no vertical or horizontal adjustments for directing the beam.

MO-TM$_3$—(master oscillator turning mirror) routes the beam from the telescope to turning mirror MO-TM$_4$. A white "flag" on the top of this mirror captures and absorbs any stray reflections resulting from the rotation of the crystal. Although the mirror can be cleaned in place, it can be removed by removing 3 screws of the retaining ring with an Allen ball driver and removing the mirror along with the retaining ring. The optic is flat so there is no set orientation, and it is spring-loaded against 3 balls for repeatable seating. There are vertical (lower) and horizontal (upper) alignment knobs for directing the beam.

MO-TM$_4$—(master oscillator turning mirror) routes the beam from MO-TM$_4$ to the BBO crystal. Although the mirror can be cleaned in place, it can be removed by using an Allen ball driver to loosen the 3 D-cams that hold it in place, then turning the cams to release the mirror. The optic is wedged so there is a set orientation, but there are no markings on the mirror for orientation. Orientation is set during the alignment procedure. It is spring-loaded against 3 balls for repeatable seating. There are vertical (lower) and horizontal (upper) alignment knobs for directing the beam.

MO-BBO crystal—(master oscilltor crystal) is the nonlinear wavelength tuning element. A single screw holds it in its holder, and the holding arm rotates the crystal via a motor driven by the MOPO controller. Although the crystal rotates, the entry and exit beam angles remain constant. The entry beam comes from MO-TM$_4$ and is directed toward MO-TM$_5$. There are no other adjustments on the crystal mount.

MO-TM$_5$—(master oscillator turning mirror) routes the beam from the crystal to MO-TM$_6$ and MO-BBHR. Although the mirror can be cleaned in place, it can be removed by using an Allen ball driver to loosen the 3 D-cams that hold it in place, then turning the cams to release the mirror. The optic is wedged so there is a set orientation, but there are no markings on the mirror for orientation. Orientation is set during the alignment procedure. It is spring-loaded against 3 balls for repeatable seating. There are vertical (lower) and horizontal (upper) alignment knobs for directing the beam.

MO-BBHR—(master oscillator high reflector) reflects the beam back through $MO\text{-}TM_5$, the crystal, $MO\text{-}TM_4$ and to the grating. The mount is fastened to the base plate by two screws, and the mount is slotted so it can be moved forward and backward. Although the mirror can be cleaned in place, it can be removed by removing 4 screws of the retaining ring with an Allen ball driver and removing the mirror with the retaining ring. Two screws can be loosened for vertical adjustment. The optic is flat so there is no set orientation, and it is spring-loaded against 3 balls for repeatability after removal. There are vertical (upper) and horizontal (lower) alignment knobs for directing the beam.

Seeder

Grating—provides, along with the tuning mirror, a means to separate and then select a wavelength for amplification. The grating splits the beam into its various component wavelengths and fans them out toward the tuning mirror. The tuning mirror then reflects one of these wavelengths back to the grating. The other wavelengths are reflected away from the grating and are lost. The selected wavelength then becomes the seeder wavelength. There are adjustments and clamping screws for holding the grating optic in place, but there are no field adjustments on this device. Unless the grating breaks, there should be no need to replace it in the field. The grating should be cleaned in place, but only with puffs of dry air from a squeeze bulb. Four screws fasten the mount to the base plate.

Warning!

Do not use solvents or air from a pressurized can to clean the grating! Using anything other than puffs of dry air from a squeeze bulb can cause material to become lodged in the gratings and ruin the optic. Such damaged is not covered by your warranty!

Tuning Mirror—provides, along with the grating, a means to separate and then select a wavelength for amplification. It selects one of the several wavelengths "fanned out" by the grating and reflects it back to the grating. The other wavelengths are reflected away from the grating and are lost. The selected wavelength then becomes the seeder wavelength. There are adjustments and clamping screws for holding the mirror in place, but there are no field adjustments on this device. Unless the mirror breaks, there should be no need to replace it in the field. The mirror should be cleaned in place, but only with puffs of dry air from a squeeze bulb. Four screws fasten the mount to the base plate.

Warning!

Do not use solvents or air from a pressurized can to clean the tuning mirror! Using anything other than puffs of dry air from a squeeze bulb can ruin the optic. Such damaged is not covered by your warranty!

$S\text{-}TP_1$—(seeder turning prism) directs the beam through BS_1 and on to $S\text{-}TP_2$. It has a backing flag to prevent any stray light from getting past the prism. Two screws can be loosened for vertical adjustment, and 2 screws fasten the mount to the base plate.

BS_1—(beam splitter) directs part of the beam to the master oscillator photo detector, which monitors master oscillator output. Two screws fasten the mount to the base plate.

S-TP_2—(turning prism) directs the beam from S-TP_1 and on to the seed telescope (see below). It has a backing flag to prevent any stray light from getting past the prism. Two screws can be loosened for vertical adjustment, and 2 screws fasten the mount to the base plate.

Seeder Telescope—contains the seeder positive and negative lenses (S-PL and S-NL) for changing the diameter of the seed beam. A single clamping screw on top of the negative lens allows you to move it in order to adjust the separation between the lenses. Two screws fasten the mount to the base plate.

Power Oscillator

PO-BBHR—(power oscillator high reflector) allows the seed from the telescope to pass through, but reflects light from the power oscillator side back through the PO-BBO crystal. A white flag capture any stray light from the PO-BBO crystal as it rotates. There are vertical (upper) and horizontal (lower) alignment knobs for directing the beam. Two screws can be loosened to move the optic vertically, and 2 screws fasten the mount to the base plate and slotted holes allow the mount to be moved forward and backward in the beam.

PO-TM_5—(power oscillator turning mirror) allows the seed beam to pass through, but turns the amplified power oscillator beam from the PO-BBO crystal and directs it to turning mirror PO-TM_4. The optic is wedged so there is a set orientation, but there are no markings on the mirror for orientation. Orientation is set during the alignment procedure. Although the mirror can be cleaned in place, it can be removed or rotated using an Allen ball driver to loosen the 3 D-cams that hold it in place. Loosen to rotate the mirror, turn the cams to release the mirror. The mount is spring-loaded against 3 balls for repeatable seating. There are vertical (upper) and horizontal (lower) alignment knobs for directing the beam. Two screws can be loosened to move the optic vertically, and 2 screws fasten the mount to the base plate. Slotted holes allow the mount to be moved forward and backward in the beam.

PO-BBO crystal—(power oscillator crystal) is the nonlinear wavelength tuning element on the power oscillator side. A single screw holds it in its holder, and the holding arm rotates the crystal via a motor driven by the MOPO controller. Although the crystal rotates, the entry and exit beam angles remain constant. The entry beam comes from PO-TM_5 and is directed toward PO-TM_6. There are no other adjustments on the crystal mount.

PO-TM_6—(power oscillator turning mirror) allows the output beam to pass through, but turns a residual beam from the PO-BBO crystal and directs it to turning mirror PO-TM_7 and on to the beam dump MBD_1. The optic is wedged so there is a set orientation, but there are no markings on the mirror for orientation. This rotation setting is set during the alignment procedure. Although the mirror can be cleaned in place, it can be removed or rotated using an Allen ball driver to loosen the 3 D-cams that hold it in place.

Loosen to rotate the mirror, turn the cams to release the mirror (you may have to actually remove one of the cams in order to remove the optic). The mount is spring-loaded against 3 balls for repeatable seating. There are vertical (upper) and horizontal (lower) alignment knobs for directing the beam. Two screws can be loosened to move the optic vertically, and 2 screws fasten the mount to the base plate. Slotted holes allow the mount to be moved forward and backward in the beam.

Compensator—compensates for the beam offset caused by the rotation of the BBO crystal by rotating in the opposite direction. A single screw holds it in its holder, and the holding arm rotates the crystal via a motor driven by the MOPO controller. The entry beam comes from $PO\text{-}TM_6$ and is directed toward the output coupler, OC. There are no other adjustments on the compensator mount.

BS_2—(beam splitter) directs part of the output beam to the power oscillator photo detector, which monitors power oscillator output. The optic is wedged so there is a set orientation, but there are no markings on the mirror for orientation. This rotation setting is set during the alignment procedure. Although the beam splitter can be cleaned in place, it can be removed by unscrewing the bezel and grabbing the barrel with the optic. There are vertical (top) and horizontal (side) alignment knobs for directing the beam. Before removing the optic, however, it is prudent to mark the rotation position of the lens so that it is easy to put it back the way it was.

VDC_1—(visible dichroic) removes any residual visible wavelengths from the output beam from the output coupler, then directs the beam toward VDC_2. Although the mirror can be cleaned in place, it can be removed by removing 4 screws of the retaining ring with an Allen ball driver and removing the mirror with the retaining ring. There are vertical (top) and horizontal (side) alignment knobs for directing the beam. Two screws can be loosened to move the optic vertically, and 2 screws fasten the mount to the base plate.

VDC_2—(visible dichroic) transmits any residual visible wavelengths from the output beam from VDC_1, then directs the beam out of the *MOPO-HF* enclosure. Although the mirror can be cleaned in place, it can be removed by removing 4 screws of the retaining ring with an Allen ball driver and removing the mirror with the retaining ring. There are vertical (top) and horizontal (side) alignment knobs for directing the beam. Two screws can be loosened to move the optic vertically, and 2 screws fasten the mount to the base plate.

HW_1—(half-wave plate) used for attenuating power to the PO by rotating it.

$PO\text{-}TM_1$—(power oscillator turning mirror) provides adjustment to align the incoming beam from UVBS and direct it to $PO\text{-}TM_2$. The mount is fastened to the base plate by two screws, and the mount is slotted so it can be moved forward and backward. Although the mirror can be cleaned in place, it can be removed by removing 4 screws of the retaining ring with an Allen ball driver and removing the mirror with the retaining ring. The optic is flat so there is no set orientation, and it is spring-loaded against 3 balls for repeatability after removal. There are vertical (upper) and horizontal (lower) alignment knobs for directing the beam.

PO-TM$_2$—(power oscillator turning mirror) provides adjustment to align the incoming beam from PO-TM$_1$ and direct it to PO-TM$_3$. The mount is fastened to the base plate by two screws, and the mount is slotted so it can be moved forward and backward. Although the mirror can be cleaned in place, it can be removed by removing 4 screws of the retaining ring with an Allen ball driver and removing the mirror with the retaining ring. The optic is wedged so there is a set orientation, but there are no markings on the mirror for orientation. This rotation setting is set during the alignment procedure. The mirror is spring-loaded against 3 balls for repeatability after removal. There are vertical (upper) and horizontal (lower) alignment knobs for directing the beam.

PO-TM$_3$—(power oscillator turning mirror) reflects the incoming beam from PO-TM$_2$ back onto it but at a slightly different angle so that PO-TM$_2$ then reflects the bounced beam onto PO-RM$_1$. The mount is fastened to the base plate by two screws. Although the mirror can be cleaned in place, it can be removed by removing 4 screws of the retaining ring with an Allen ball driver and removing the mirror with the retaining ring. The optic is flat so there is no set orientation, and it is spring-loaded against 3 balls for repeatability after removal. There are vertical (upper) and horizontal (lower) alignment knobs for directing the beam.

PO-RM$_1$—(power oscillator routing mirror) provides adjustment to align the incoming beam from PO-TM$_2$ and direct it to PO-RM$_2$. The mirror is spring-loaded against 3 balls for repeatability after removal. There are vertical (upper) and horizontal (lower) alignment knobs for directing the beam. Two screws can be loosened to move the optic vertically, and 2 screws fasten the mount to the base plate.

PO-RM$_2$—(power oscillator routing mirror) provides adjustment to align the incoming beam from PO-TM$_1$ and direct it to the positive lens (PO-PL) of the power oscillator telescope. The mirror is spring-loaded against 3 balls for repeatability after removal. There are vertical (upper) and horizontal (lower) alignment knobs for directing the beam. Two screws can be loosened to move the optic vertically, and 2 screws fasten the mount to the base plate.

PO Telescope—is made up of the PO-PL and PO-NL (described below) and is used to set the diameter size of the beam.

PO-PL—(power oscillator positive lens) is the input end of the PO telescope (see above). It is mounted on a spring-loaded slide, and a micrometer provides fine adjustment for setting the separation between the two lenses. Although the lens can be cleaned in place, it can be removed by removing the 4 screws of the retaining ring with an Allen ball driver and removing the lens with the retaining ring. The lens is spring-loaded against 3 balls for repeatable seating. There are no vertical or horizontal adjustments for directing the beam. The mount is fastened to the base plate by 2 screws.

PO-NL—(power oscillator negative lens) is the output end of the telescope (see above). It is firmly mounted to the base plate by 2 screws, but the holes are slotted to allow for some minor horizontal adjustment. Two screws can be loosened for vertical adjustment. Although the lens can be cleaned in place, it can be removed by removing the 4 screws of the retaining ring with an Allen ball driver and removing the lens with the retaining ring. The lens is spring-loaded against 3 balls for repeatable seating. There are no vertical or horizontal adjustments for directing the beam.

MA—(Macor ceramic aperture) reduces the diameter of the beam from the PO-NL so the beam will fit through the clear aperture of the power oscillator BBO crystal. Two screws can be loosened to move the aperture vertically, and two screws fasten the mount to the base plate.

PO-TM$_4$—(power oscillator turning mirror) receives the beam from PO-NL and directs it to PO-TM$_5$ where the power oscillator beam is mixed with the seed beam. Although the mirror can be cleaned in place, it can be removed by removing 4 screws of the retaining ring with an Allen ball driver and removing the mirror with the retaining ring. There are vertical (top) and horizontal (side) alignment knobs for directing the beam. Two screws can be loosened to move the optic vertically, and 2 screws fasten the mount to the base plate. Slotted holes allow the mount to be moved forward and backward in the beam.

PO-TM$_7$—(power oscillator turning mirror) receives the residual beam from PO-TM$_6$ and directs it to beam dump MBD$_1$. The lens is spring-loaded against 3 balls for repeatable seating. There are no vertical or horizontal adjustments for directing the beam. Two screws fasten the mount to the base plate.

MBD$_1$—(mini beam dump) absorbs the residual PO beam from PO-TM$_7$. Two screws fasten the beam dump to the base plate. There are no adjustments.

Indicators

There are no indicators on the *MOPO-HF*.

Connections

There are three connections on the *MOPO-HF* side panel for attaching the unit to the MOPO controller (see Figure 4-2).

Optional FDO connector—provides control signals to and from the optional FDO frequency doubler. Refer to the *FDO User's Manual* for connection information.

MOPO AUTOTRACK connector—provides control signals to and from the *MOPO-HF* controller.

SINE-DRIVE connector—provides control signals from the controller to the sine-drive stepper motor.

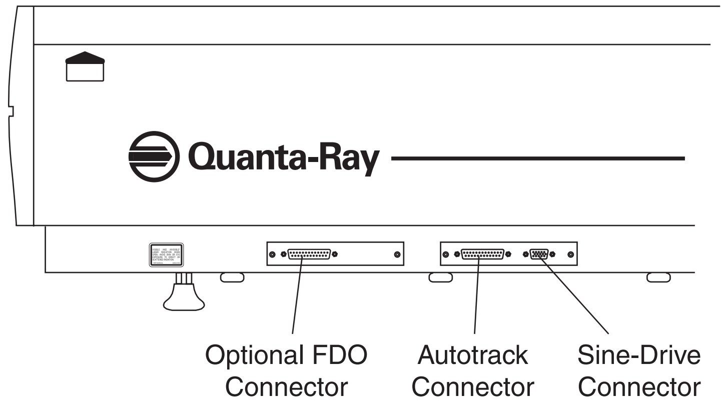


Figure 4-2: ***MOPO-HF*** **Connectors, Right Side View**

The MOPO-HF Digital Controller

The digital controller contains the CPU that controls the various circuits required to select wavelengths. Control and monitoring capability is provided via a front panel LCD display and 10 buttons. A structured menu system provides a logical means to control and monitor the system. Connectors on the back panel link the controller to the *MOPO-HF* head. Chapter 6 contains a complete description of the controller, its menus and its operation.

Front Panel

The digital controller is operated using an LCD display and ten buttons on the front panel (Figure 4-3). Each press of a button either brings up a different menu or modifies some variable.

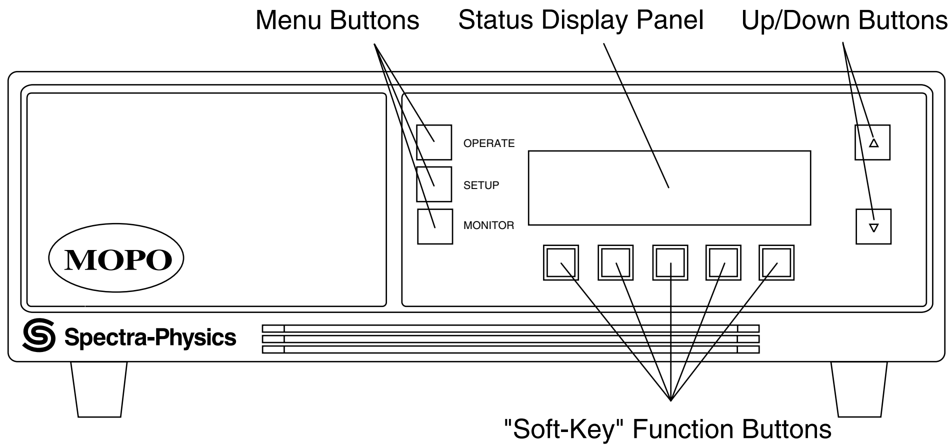


Figure 4-3: The Digital Controller Front Panel

LCD display—provides a visual means for accessing the system's menu-driven program. Depending on the menu displayed and the function key pressed, it shows the status of a variety of system parameters and allows you to follow the operation of the system as you input commands and change parameters. Help menus and instructions are shown from time to time to provide assistance.

To show which function or item is selected (prior to making it active), the button or associated window is highlighted with a box. To indicate which menu or function is active, it is shown in reverse video. To make it active, the associated key must be pressed and held in until it beeps. To change the data associated with a button, select the button (an outline box appears), use the up/down keys to toggle through the valid selections, then either (a) press and hold the key until it beeps to make it active, or (b) press and hold the SAVE button (when displayed) to save the data.

Mode buttons (3)—are the three buttons to the left of the display. They allow selection of the Operate, Service, Setup, Remote and Monitor menus. The first press of any button brings up the menu whose name appears next to the key. Further presses of that key toggles the selection to the next menu.

Soft keys (5)—the five buttons below the display, allow you to select a variable to change, implement an action, change to a sub-menu, etc. Their functions depend on (a) which menu is currently active and (b) which function key was previously selected (if any). These keys are referred to throughout this manual as function keys 1 through 5 (F_{1-5}).

Up/down push buttons (2)—to the right of the display, are used to either change the numerical value inside a selected function (a box appears around the selection) or to scroll through various pre-set selections.

Rear Panel

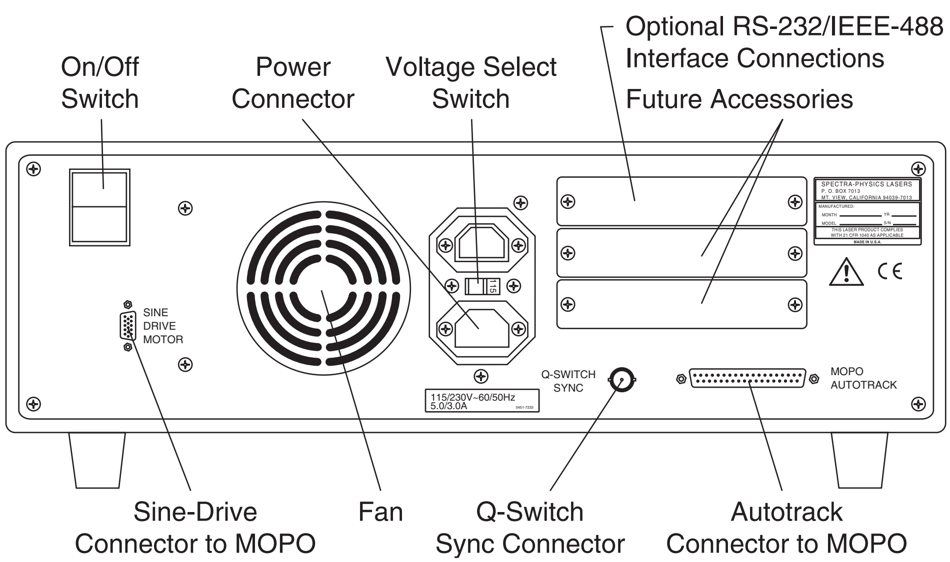


Figure 4-4: The Digital Controller Back Panel

On/Off POWER switch—turns on and off the *MOPO-HF* digital controller.

SINE-DRIVE MOTOR connector—provides connection to the sine-drive motor in the *MOPO-HF.*

Power cord connector—provides connection for the power cord.

Voltage selector—provides selection between 115 and 220 Vac.

Warning!

Verify this switch is set to the proper position before turning on your system for the first time. If not properly set, damage not covered by your warranty may occur to the controller and to various other voltage-sensitive components in the *MOPO-HF.*

Optional FDO interface connector—(not shown in figure) provides connection to the FDO interface on the side panel of the *MOPO-HF* for controlling the frequency doubler option. Refer to the *MOPO-HF FDO User's Manual* for connection information.

Optional RS-232/IEEE-488 connectors—(not shown in figure) provide connection to a remote control device for serial/parallel control of the system. Refer to Chapter 6, "Operation: The Remote Menu," for information on using these interfaces.

Future accessories bay—provides room for future options.

Q-SWITCH SYNC connector—provides connection to the Q-SW SYNC connector on the *PRO-Series* power supply, which supplies a sync signal to the controller.

MOPO AUTOTRACK connector—provides connection to the *MOPO-HF* interface on the side panel for command control.

Chapter 5 Installation and Alignment

The following installation procedure is provided for reference only; it is not intended as a guide to the initial installation and set-up of your *MOPO-HF*. Please call your service representative to arrange an installation appointment, which is part of your purchase agreement. Allow only personnel qualified and authorized by Spectra-Physics to install and set up your *MOPO-HF* system.

Danger! Laser Radiation

The use of controls or adjustments or the performance of procedures other than those specified herein may result in hazardous radiation exposure.

Installation

Danger!

Your *MOPO-HF* was aligned at the factory by specially trained professionals and should not require alignment in the field. Furthermore, the *MOPO-HF* generates an enormous amount of optical power that can cause damage and even injury. Therefore, do not attempt to align the laser yourself, you may void your warranty. Instead, call your Spectra-Physics service representative.

Materials Needed:

- Two alignment pinhole apertures*
- Black pinhole aperture*
- Three beam dumps (one large beam dump, e.g., *BD-5*; two small beam dumps* with an input port height at 9.21 cm (3.63 in.) above the *MOPO-HF* base plate).
- One (or more) white business cards

  In order to see the 355 nm beam in the following procedures, place a "viewing card" over one of the pinhole apertures. Do this by punching a 1 mm dia. hole through the center of a business card.Tape or glue the card over the aperture, allowing the beam through the alignment pinhole. Alternatively, place a white UV fluorescent label over the aperture and punch a hole in the center where the pinhole is.

**Provided with system*

- Right-angle turning prism assembly

  The assembly should include the necessary hardware to place the center of the optic approximately 3.5 in. off the base plate. See Figure 5-1 (e.g., Newport SP-2, and VPH-2).

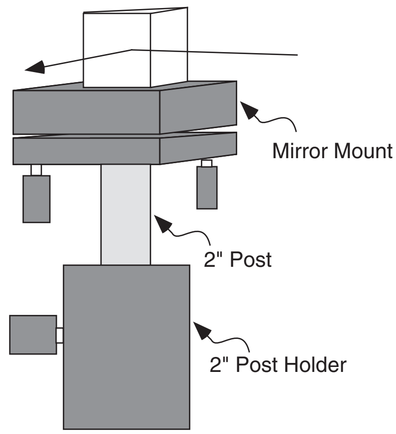


Figure 5-1: A Typical Right-angle Turning Prism Assembly

HeNe laser (>5 mW recommended)

- Hex wrench set
- 5/8 in. and 9/16 in. wrenches*
- Infrared (IR) card*
- Infrared high-pass/visible cut-off filter (e.g., Schott # RG695)
- *PRO-Series Model 230-10* (or higher) laser configured for 355 nm output
- Pen or pencil
- Ruler
- Uncoated beamsplitter (fused silica, *BK-7* or equivalent)

  Mounting hardware is required to locate the optic approximately 7 5/8 in. off the optical table.
- Polarizing material (e.g., Edmund Scientific sheet polarizer, P/N 71942)
- Potentiometer adjustment tool
- 0.25 cm^{-1} Fabry Perot etalon (e.g., Spectra Physics P/N 0100-8270)
- Power meter

Initial Setup

Setting up the PRO-Series Laser

1. Place the *PRO-Series* YAG laser in an appropriate location on the optical table and clamp the feet to the table. Figure 5-2 shows a typical table layout for a *PRO-Series* laser and *MOPO-HF.*

   The *MOPO-HF* may also be placed on the table, but do not place it in front of the *PRO-Series* laser at this time.

* *Provided with system*

Note

Set up the *PRO-Series* YAG laser in accordance to its *user's manual*. This should be done by a qualified individual only (i.e., someone who has received appropriate training)

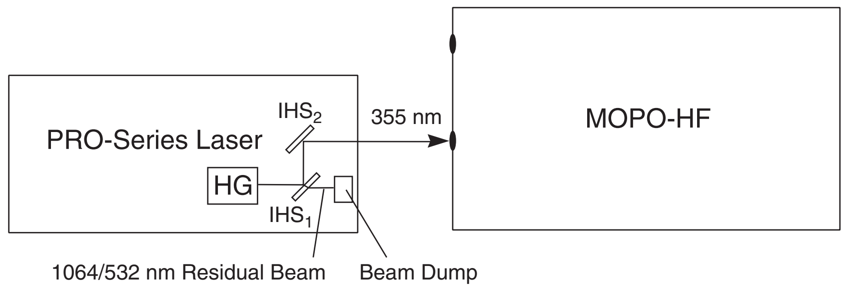


Figure 5-2: Typical Table Layout for a *PRO-Series* Pump Laser and the *MOPO-HF*

Caution!

Verify the alignment, mode, and seeding characteristics of the pump laser before you begin aligning the *MOPO-HF*

2. Turn on the *PRO-Series* laser and allow it to warm up a little.

   The spatial mode of the 355 nm output at 3 m should be uniform with no significant "hot spots" (localized regions of high intensity).

3. Set the *PRO-Series* fundamental beam height to 19.37 cm (7.63 in.) above and parallel to the table surface. This procedure assumes the *PRO-Series* seed beam is collinear with the fundamental beam.

   a. Change to Q-SWITCH OFF mode.

   b. Turn on the *PRO-Series* seeder unit.

   c. Use an IR card to locate the *PRO-Series* seed beam near the fundamental output port.

   d. Use $^5/_8$ and $^9/_{16}$ in. wrenches to adjust the two legs on the output end of the *PRO-Series* pump laser so the beam at the output port is 19.37 cm (7.63 in.) above the table.

      Use the $^5/_8$ in. wrench for the adjustment nut and the $^9/_{16}$ in. wrench for the locking nut.

   e. Adjust the back two feet until the beam is $7^5/_8$ in. above the table at a location 2–3 m from the laser.

   f. Repeat this step until the beam is $7^5/_8$ in. above and parallel to the table surface.

   g. Tighten the lock nut on each leg.

4. Set the 355 nm beam height so it, too, is $7^5/_8$ in. above and parallel to the table surface.

   a. Verify the system is still set to Q-SWITCH OFF mode.

b. Verify both the 2^{nd} and 3^{rd} harmonic crystals in the harmonic generator (HG) are in the beam path.

The 2^{nd} harmonic crystal arm should be in the "I" position for type I phase matching, or the "II" position for type II phase matching. The 3^{rd} harmonic crystal should be in the "T" position.

Eyewear Required

Laser radiation is present. Be sure to wear protective eyewear at all times!

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c. Place a beam dump in front of the *PRO-Series* seed beam so it is safely blocked.

d. Change to LONG PULSE mode.

e. Use a business card to locate the 355 nm pump beam near the output port of the *PRO-Series* laser.

Danger!

Avoid putting your hand or arm into the fundamental beam path.

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f. Perform a vertical adjustment of IHS_1 so that the beam is 7 $^5/_8$ in. above the table surface at this point.

g. Move the card 2–3 m away from the laser and perform a vertical adjustment of IHS_2 so that the beam is 7 $^5/_8$ in. above the table surface at that point.

h. Iterate adjustments of the IHS mirrors until the beam is 7$^5/_8$ in. above the table at both locations.

5. Change to Q-SWITCH OFF mode.

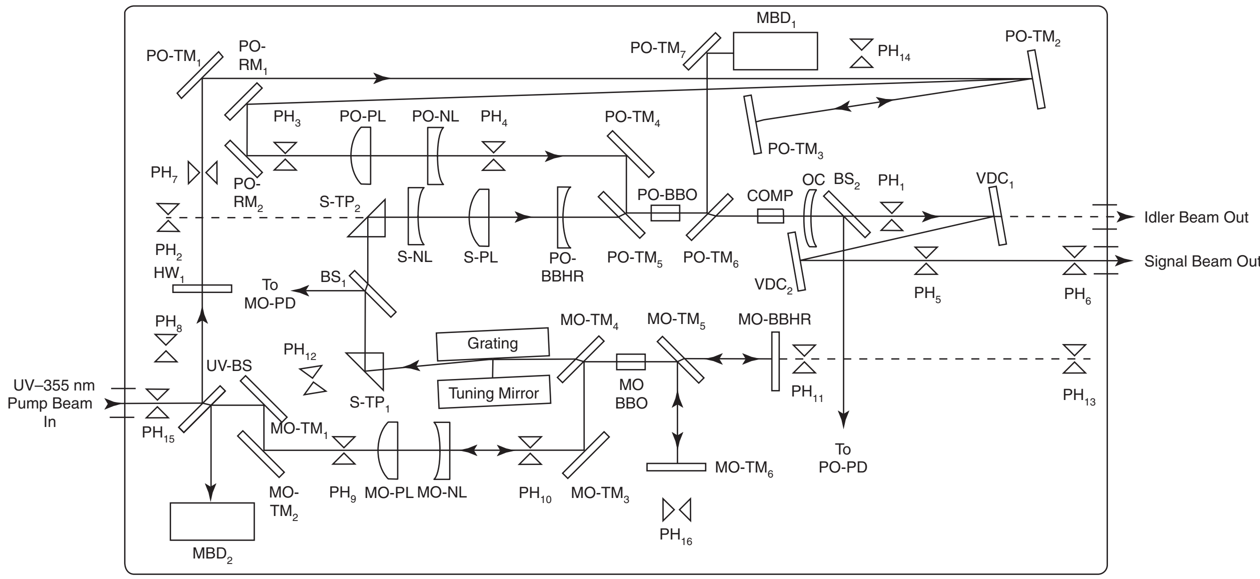
Setting up the MOPO-HF

6. Place the *MOPO-HF* in front of the *PRO-Series* laser. Figure 5-2 shows a typical table layout for this scheme.
7. If there is no internal beam dump, (BD_6), place an external beam dump in front of the fundamental output port. Use an IR card to ensure the *PRO-Series* seed beam is directed into the beam dump entrance hole, then securely fasten the beam dump to the table.
8. Change to LONG PULSE mode.
9. Adjust the position of the *MOPO-HF* so the 355 nm long pulse beam is directed into the appropriate entrance hole in the *MOPO-HF* cover, then adjust the IHS mirrors in the YAG laser to align the beam with the UVBS. The *MOPO-HF* optical layout is shown in Figure 5-3.

a. Place a pinhole mount on the dowel pins in front of UVBS.

b. Make minor adjustments to IHS_2 to center the beam onto the pinhole.

c. Remove the pinhole from in front of UVBS.



$BS_{1, 2}$	Beam Splitters	PO-BBHR	PO High Reflector
COMP	Compensating Crystal	PO-BBO	PO BBO Crystal
HW_1	Halfwave Plate	PO-PD	PO Photodectector
$MBD_{1, 2}$	Mini Beam Dumps	$PO\text{-}TM_{1-7}$	PO Turning Mirrors
MO-BBHR	MO High Reflector	$PO\text{-}RM_{1, 2}$	PO Routing Mirrors
MO-BBO	MO BBO Crystal	PO-PL	PO Positive Lens
MO-PD	MO Photodetector	PO-NL	PO Negative Lens
MO-PL	MO Positive Lens	S-NL	Seeder Negative Lens
MO-NL	MO Negative Lens	S-PL	Seeder Positive Lens
$MO\text{-}TM_{1-6}$	MO Turning Mirrors	$S\text{-}TP_{1, 2}$	Seeder Turning Prisms
OC	Output Coupler	UV-BS	Ultraviolet Beam Splitter
PH_{1-16}	Pin Holes	$VDC_{1, 2}$	Visual Dichroics

Figure 5-3: The *MOPO-HF* Beam Path and Optical Layout

d. The beam should pass through the UVBS without obstruction. If some clipping is present, make minor adjustments to IHS_2 to center the beam onto $MO\text{-}TM_1$ without clipping the UVBS.

10. Change to Q-SWITCH OFF mode.

11. Remove the two base plate shipping bolts on the *MOPO-HF*.

    This allows the base plate to expand and contract freely with changes in temperature. Otherwise, the *MOPO-HF* can misalign with temperature cycling.

12. Clamp the *MOPO-HF* to the table:

    If the base plate is not secured to the table, removing or replacing the cover or the *MOPO-HF FDO* might misalign it.

Caution!

Carefully lift each corner of the *MOPO-HF* base plate. Because the unit is secured to the top of the table, it should not move. If a particular corner moves, perform a counterclockwise adjustment of the foot until the corner is secure.

Verifying BeamLok Beam-pointing Sensor Alignment

13. Access the BeamLok Monitor menu (refer to the *PRO-Series User's Manual*) and verify BeamLok is off.

    This minimizes adjustment time when BeamLok is again engaged at the conclusion of the alignment procedure.
14. Change to Q-SWITCH mode.
15. Optimize the HG crystal settings to ensure the system is optimized for power. This step is very important for proper BeamLok operation.

Note Be sure to leave BeamLok off.

16. Verify the horizontal and vertical bars on the BeamLok Monitor menu are at the center of the "cross hairs." If the bars are not at the center:
    a. Change to LONG PULSE mode.
    b. Carefully remove the *PRO-Series* laser cover.
    c. Change to Q-SWITCH mode and verify the UV energy is within 2% of the specified peak value.
    d. Set the BeamLok controller for a screen gain level of 4 for optimal adjustment sensitivity, then use a $^{5}/_{64}$ in. hex wrench to adjust the pointing sensor so the horizontal and vertical bars are overlapped.
    e. Change to LONG PULSE mode.
    f. Place the cover back on the *PRO-Series* laser.
    g. Remove the beam dump (or power meter).
17. Remove the master oscillator (MO) and power oscillator (PO) half-wave plates (MO-HP and PO-HP). These will be reinstalled after setup is complete.

Electronics and Controller Setup

Initializing the System Settings

1. Connect the *MOPO-HF* to its controller (2 cables).
2. Verify the back panel line voltage switch matches your line voltage, then plug the controller power cord into an appropriate outlet.
3. Attach a BNC cable between the connector on the back of the controller box and the Q-Switch output on the front of the *PRO-Series* power supply

   This provides a trigger for synchronized functions within the *MOPO-HF* controller.
4. Turn on the controller.

   The power switch is on the back of the unit near the power cord.
5. Set the system for TABLE operation.
   a. Enter the Monitor1 menu.

b. Select M-OSC (F_4).

The border around the softkey highlights when it is selected.

c. Use the up/down keys to change the lower menu item of the key to TABLE (choices are: TRACK and TABLE).

d. Activate TABLE by holding the M-OSC key in until it beeps.

e. Repeat this procedure to set P-OSC to TABLE.

Caution!

If tables have been previously written for the system, *skip this next step* and proceed to the next section. Perform the following procedure only if a prior table has **not** been written or if the current table is no longer valid (e.g., if there has been a loss of table data, data corruption, grating re-calibration, movement or realignment of crystal potentiometers)

6. Load the default look-up tables for the MO and PO:

a. Enter the Setup2 menu.

b. Press the DEVICE key (it will highlight).

c. Use the up/down keys to set the device to MO-CRYS. To activate it, press the DEVICE key until it beeps.

d. Press the METHOD key (it will highlight).

e. Use the up/down keys to set the method to Y-SHIFT. To activate it, press the METHOD key until it beeps.

f. Access the ABORT button in the Setup 2 menu, then press it for several seconds until it beeps.

A "Delete?" message will appear.

g. Press the ABORT key again until it beeps. The MO default look up tables will load and become active.

h. In the same manner, select DEVICE: PO-CRYS and repeat this procedure to load the default tables for the PO.

This completes the installation phase. Continue to the next section to align the system.

Alignment

Establish the Reference Beam for the Master Oscillator

1. Place an aperture assembly on the dowel pins at PH_{13} (refer to Figure 5-3). Attach it to the base plate with a 10-32 screw.

2. Set up a HeNe alignment laser on the table as close to the *MOPO-HF* as possible (Figure 5-4).

   The HeNe laser output should be unpolarized. If it is polarized, orient the laser so the output is polarized at 45°. This allows the output beam to be horizontally or vertically polarized as required in subsequent steps in the alignment procedure. Appropriate polarization is achieved without misaligning the beam by placing a sheet polarizer in the beam path without misaligning the beam (Step 3).

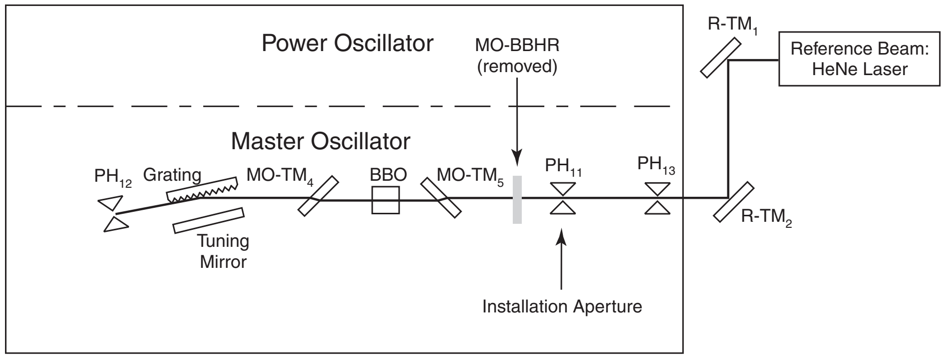


Figure 5-4: Reference beam alignment for the master oscillator. MO-BBHR is removed to allow the reference beam into the optical cavity. For purposes of clarity, some optical components have not been shown.

Unpolarized light from a HeNe laser that enters a birefringent crystal, such as BBO, will split into two separate beams referred to as ordinary (o-) and extraordinary (e-) rays (see Figure 5-5). The two beams are orthogonally polarized (i.e., the o-ray is horizontally polarized, while the e-ray is vertical). In a negative uniaxial crystal such as BBO, the e-ray will "walk off" the initial beam path in a direction that is away from the optic axis while the o-ray propagates through the crystal undeviated from the initial beam path.

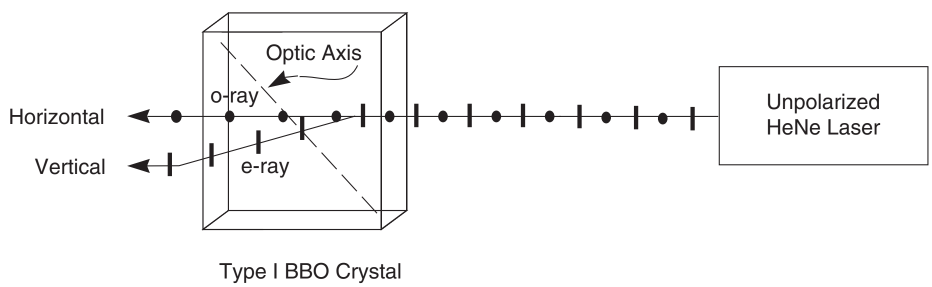


Figure 5-5: Unpolarized light from a HeNe laser shown entering a birefringent crystal, such as BBO.

The reference beam used to align the MO and PO cavities should be horizontally polarized (see Figure 5-6). This is necessary since the resonated signal wave generated in a type I BBO crystal has ordinary (horizontal) polarization. Appropriate orientation of the sheet polarizer in this case will eliminate the lower beam at the backside of the crystal.

3. Place a sheet polarizer in the output beam of the reference laser and orient it to obtain a horizontally polarized beam.
4. Set up two reference beam alignment mirrors, placing the first alignment mirror ($R\text{-}TM_1$) in front of the reference laser and the other ($R\text{-}TM_2$) in front of PH_{13} (Figure 5-4).

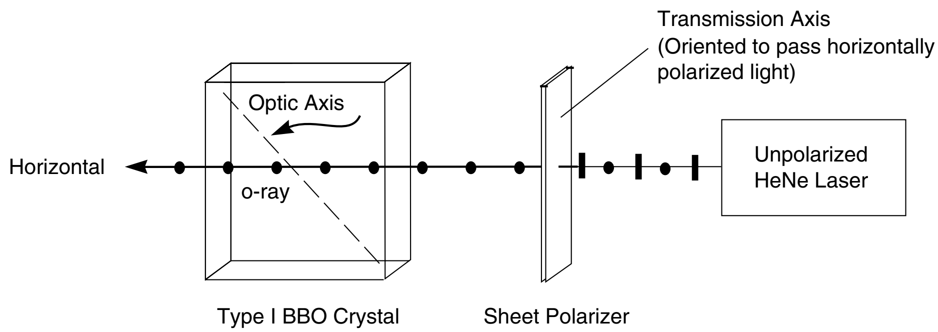


Figure 5-6: Horizontally polarized light passing through a birefringent crystal, such as BBO.

5. Establish alignment of HeNe beam to reference pinholes PH_{13} and PH_{11}:
   a. Adjust R-TM_1 to center the reference beam on PH_{13}.
   b. Adjust R-TM_2 to center the reference beam on the installation pinhole (PH_{11}) which is located just before MO-BBHR.
      i. Do not yet fasten R-TM_2 to the table surface.
      ii. Manually rotate R-TM_2 so the beam is directed through PH_{13}.
      iii. If the beam is to the right of pinhole aperture PH_{11}, move R-TM_2, toward the PO side of the *MOPO-HF*, and redirect the beam through PH_{13}. If the beam is to the left of PH_{11}, move R-TM_2 in the opposite direction.
      iv. Repeat the above steps until the beam is nominally centered in the two pinholes.
      v. Fasten R-TM_2 to the optical table.

Caution! Do not move or adjust the installation pinhole mount (PH_{11}) as it preserves the calibration alignment established at the factory.

   c. Iterate Steps a and b until the beam is centered through the two pinholes.
6. Remove the pinhole aperture from the PH_{11} mount.
7. Place the pinhole aperture on the other side of the PH_{13} mount so the flat side of the aperture faces the BBO crystal.

   This allows the reference beam retroreflections to be viewed on the flat side of the aperture during subsequent stages of the alignment procedure.
8. Remove MO-BBHR. Attach it to one of the available 10–32 holes on the base plate. Make sure that it does not interfere with the HeNe beam.
9. Remove the trigger cable from the Q-SWITCH output port on the power supply and attach it to LAMP SYNC.

This allows internal controller operation during the following steps without the need to run the *PRO-Series* laser. To operate the MO and PO monitors, the trigger must be changed back to the Q-SWITCH output port, which will be done at a later step.

10. If the crystal is not installed, skip to Step 11, otherwise:
    a. Use manual control (see Appendix D) to orient the crystal in the "face normal" orientation (surface of the crystal is perpendicular to the HeNe beam).
    b. Verify the retroreflections off the face of the crystal are on the back side of PH_{13}. The beams should be in one of the two locations described in Appendix A (i.e., the closest retro reflection to the pinhole should be either 10 mm to the left or 20 mm displaced to the right).
    c. If the retroreflections are not in one of the two orientations described above, take the crystal out and re-install it using the procedure described in Appendix A.
11. If the BBO crystal is not installed, install it now. See Appendix A, "Installing the BBO Crystal."
12. Remove $S\text{-}TP_1$.

    This allows the HeNe beam to pass onto PH_{12}.
13. Using the *MOPO-HF* controller, go to the wavelength of the reference beam (632.816 nm for a HeNe laser).
    a. Access the Operate menu and enter 632.816 nm in the GOTO key.
    b. Press the GOTO button down and hold it until a beep is heard.
14. The reference beam should travel through the middle of the crystal and intercept the central portion of the grating (Figure 5-4). Verify this.
15. Verify the beam reflected off the grating hits the center of PH_{12}. Due to alignment tolerances, the beam may not perfectly overlap the pinhole. If the beam is off-set from PH_{12} by less than one beam diameter (approximately 2 mm), perform the following:
    a. Adjust $R\text{-}TM_2$ to overlap the beam on PH_{12}.
    b. If necessary, adjust $R\text{-}TM_1$ to overlap the beam onto PH_{13}.
    c. Iterate these adjustments until the beam is centered in both pinhole apertures.
    d. Verify the beam is centered in the grating.
16. Place PH_{11} back into the beam path. If necessary, recenter the aperture on the beam.

Caution! Customers should contact a service engineer if there are difficulties in obtaining the desired alignment

17. The retroreflection from the tuning mirror should be centered on pinhole PH_{13}.

The retroreflection may be viewed on the flat side of pinhole PH_{13} by carefully rocking the tuning mirror plate that is attached to the sine bar mechanism. Note that the displacement is in the horizontal plane.

If the retroreflection is not overlapped with PH_{13}, perform one of the following:

a. If the beam is displaced by less than 2 mm from the pinhole, a slight vertical and/or horizontal adjustment of R-TM_2 may be necessary to overlap the retro reflection with the pinhole.

b. A beam displacement of less than 2 mm is most likely due to an inaccuracy in reproducing the reference beam alignment established during calibration. To re-establish the initial alignment, make minor adjustments of R-TM_2 while viewing the retro reflection on the pinhole. This should be sufficient to re-establish the initial alignment.

c. A beam displacement of more than 2 mm might be due to a minor misalignment of the tuning mirror and/or grating. In most cases, the error corresponds to a linear shift in the grating table. This may be compensated for by a slight vertical and/or horizontal adjustment of the tuning mirror (Figure 5-7).

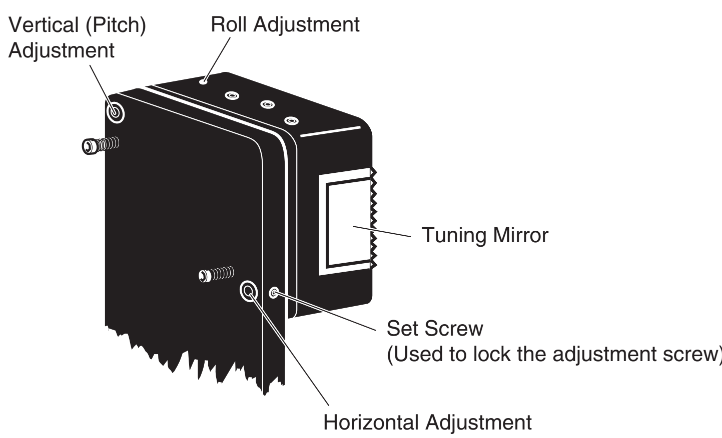


Figure 5-7: Tuning Mirror Adjustments

18. Adjust the HeNe sheet polarizer so the reference beam is vertically polarized.

    for overlap purposes, it is important to use a vertically polarized reference beam since the *PRO-Series* laser is vertically polarized.

    As explained in Step 2 of this procedure, changing the polarization of the reference beam will result in a displacement of the beam which exists the crystal. *Do not try to compensate for this with alignment.* This effect is a result of the birefringence of the BBO crystal and is taken into account in the alignment procedure.

19. Verify changing the polarization does not result in misalignment of the reference beam through the pinhole. If it does, direct the beam through a different portion of the sheet polarizer.

20. Place the PH_{11} aperture back into its mount. Orient it so that the flat side is facing the BBO crystal.
21. Place MO-BBHR in its "alignment" position on the left-hand side of the grating/tuning mirror pair (Figure 5-9). The mount should be oriented so that the front surface of the optic faces the BBO CRYSTAL. This set up will be used to retro-reflect the HeNe beam.

    This "alignment" position for MO-BBHR is used exclusively for assistance in the subsequent overlap procedure. It is distinct from its "standard" position in the MO cavity.

Note

Make sure the mount is at least 10 mm from the edge of the grating to prevent mechanical interference during the adjustments**.**

22. Adjust the MO-BBHR horizontal so that the HeNe beam is retro-reflected onto PH_{11}.
23. Verify the beam is also overlapped with PH_{13}. If not, the retro-reflected beam is missing the grating and is not folded back onto itself as desired. If so:
    a. While viewing the beam on PH_{11}, perform a clockwise adjustment on the MO-BBHR so that the retro-reflected beam is moving to the left.
    b. Continue this adjustment until the "left-going" beam disappears and a "right-going" beam becomes apparent.
    c. Overlap this beam with PH_{11} pinhole aperture and verify it is also overlapped with PH_{13}.

This completes the reference beam alignment for the master oscillator.

Master Oscillator Overlap Procedure

The following procedure assumes prior alignment of the reference beam through the MO.

Leave the pinhole aperture in PH_{13} to reduce the reference beam size.

The first two steps below determine which beam splitter (UVBS) is required. Perform these steps only if the *MOPO-HF* has not been previously aligned. If previously aligned and UVBS is already installed, skip to Step 5.

1. Measure the 355 nm output power from the *PRO-Series* pump laser.
    a. Turn on the *PRO-Series* laser to LONG PULSE mode.
    b. Locate the 355 nm beam with a business card at the output of the *PRO-Series* laser.
    c. Place a suitable power meter in the beam path.
    d. Change to Q-SWITCH mode.
    e. Record the power meter reading and determine the pulse energy.

2. Choose a beam splitter from the table below that will yield *transmitted* pulse energies in the range 65−75 mJ (values are given in% Transmission).

0451-1170	12%
0451-6440	14%
0449-1100	17%
0451-0670	20%
0449-1110	24%

The formula for calculating transmitted energy is: transmitted energy = (pump energy) x (% transmission of beam splitter)/100.

Example: Given 500 mJ of 355 nm output, a 14% beam splitter yields the following transmission value:

500 mJ x 14/100 = 70 mJ.

3. Change to LONG PULSE mode:
4. Install the chosen beam splitter in UVBS. Be careful not to touch the optical surfaces.

Note

In order to view the 355 nm (LONG PULSE) beam on an aperture in the subsequent steps, it is necessary to place a fluorescent (white) label on the flat side of the aperture. Alternatively, tape or glue the blank side of a business card to the aperture surface. Punch a hole in the label (or card) at the pinhole center. The pinhole must be free from material that might cause aberrations in the beam.

---

5. Verify the beam is propagating through UVBS without clipping.
6. In preparation for the PO alignment procedure, place a pinhole aperture on the dowel pins at PH_7, then adjust UVBS to center the beam on the pinhole.
7. Remove the pinhole from in front of UVBS. Verify the beam propagates cleanly through UVBS without clipping and onto the center of MO-TM$_1$. If the beam is clipped, make a horizontal adjustment of IHS-2, then re-adjust UVBS as necessary to re-center the beam on PH_7.
8. Place a beam dump in the beam path at a location between UVBS and PO-TM$_1$.

   Place MBD_1 on the dowel pins for PH_7 to safely block the PO pump beam during the MO alignment procedure.
9. Verify the 355 nm pulse energy in the MO optical leg is in the desired range of 60−75 mJ**.**
   a. Place the pick-off prism in the beam path were PH_9 would go and direct the beam out of the *MOPO-HF* (Figure 5-8).
   b. Locate the redirected 355 nm beam with a business card and place a power meter in front of it.
   c. Adjust the pick-off prism to direct the beam into the power meter.
   d. Change to Q-SWITCH mode.
   e. Record the power meter reading and determine the pulse energy.

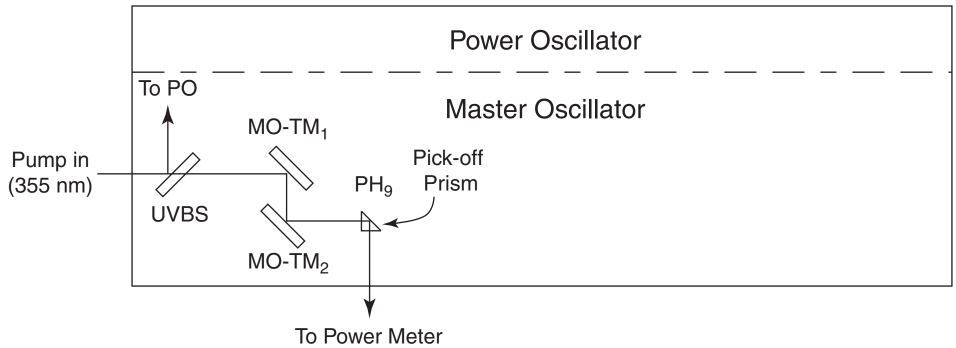


Figure 5-8: Placement of pick-off prism assembly for master oscillator pump energy measurement

f. If the energy is not in the desired range of 60–75 mJ, choose another beam splitter (see Step 2 above), install it, then verify the beam is still centered in PH_7. If not centered, adjust UVBS until it is.

g. Measure the pulse energy to see if its in the desired range.

h. Repeat this process until the required energy is obtained.

i. To minimize the possibility of optic damage later on, reduce the MO pump energy to about 60 mJ by adjusting the $\lambda/2$ plate on the *PRO-Series* HG.

Note

With a pencil, make a single mark at the 12 o'clock position on the half-wave plate knurled knob and on the clamp. This is so you can see how far off maximum the waveplate is detuned.

---

j. Change to LONG PULSE mode.

k. Remove the pick-off prism assembly.

10. Establish pump beam alignment through the MO telescope:

a. Remove the MO-NL lens mount.

b. Remove the positive lens from MO-PL mount.

c. Place pinhole apertures on the appropriate dowel pins at PH_9 and PH_{10}.

Note

PH_{10} is a single pinhole associated with the dowel pins in front of MO-TM_3 on the "double pass" assembly platform.

---

d. Adjust MO-TM_1 to center the beam on PH_9.

e. Adjust MO-TM_2 to center the portion of the beam that passes through PH_9 onto the PH_{10} pinhole aperture.

f. Iterate these two steps until the beam is centered through pinholes PH_9 and PH_{10}.

g. Verify PH_{10} is at its appropriate location.

PH_9 is used to limit the size of the beam. This is useful in the next alignment step.

h. Place the negative lens mount MO-NL back in its appropriate location in the pump beam line. The beam should be in the approximate center of the lens.

i. Make the necessary horizontal and vertical adjustments of MO-NL to direct the pump beam onto the center of pinhole PH_{10}.

j. Remove PH_9.

k. Place the positive lens back into the MO-PL mount. The distance between the positive lens and the negative lens should be approximately the difference in *absolute* focal lengths of the two lenses.

For example, the 2.5 reducing MO telescope typically consists of a +250 mm and a –100 mm focal length lens. These lenses should be separated by approximately (250–100=) 150 mm. In order to minimize the chance of damage, set the spacing initially about 10 mm closer. This should result in a slightly diverging beam. In this example, the lenses should initially be set at 140 mm.

l. Make the necessary horizontal and vertical adjustments of MO-PL to re-direct the beam onto the center of PH_{10}.

   i. Loosen the mount: Use a $^{3}/_{32}$ in. hex wrench to loosen the two screws on the front side of the lens mount.

   ii. Vertical adjustment: Use a $^{1}/_{16}$ in. hex wrench to adjust the two downward facing screws on the side of the mount.

   iii. Horizontal adjustment: Use a $^{1}/_{16}$ in. hex wrench to adjust the side facing screw on the side of the mount.

m. Remove PH_{10} from the beam path.

Warning!

Focused back reflection from MO-PL can easily damage MO-TM_2 or MO-TM_1. When finished aligning the MO telescope in this step, slightly adjust MO-PL horizontally just until the focused back reflection is directed to the teflon ring of MO-TM_2 or, if that is not possible, of MO-TM_1. It is not necessary to realign the beam to PH_{10}.

---

11. Establish collimation of the *PRO-Series* 355 nm MO pump beam.

a. Remove MO-BBHR from its “standard” location on the base plate and place it in its “alignment” location on the left-hand side of the grating/tuning mirror pair so it retro-reflects the reference beam back onto itself (Figure 5-9).

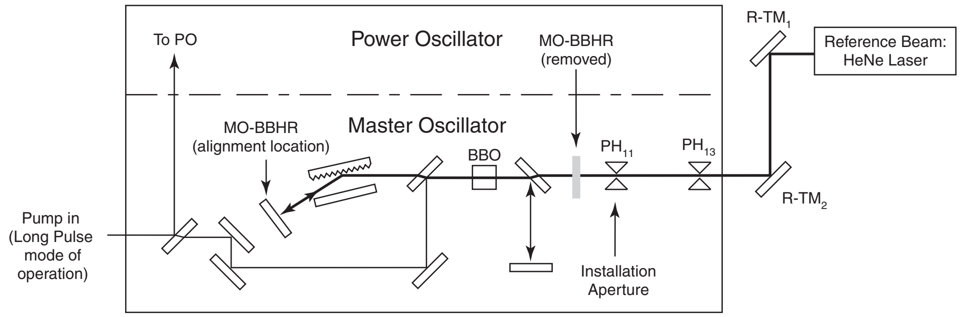


Figure 5-9: Placement of MO-BBHR for pump beam alignment.

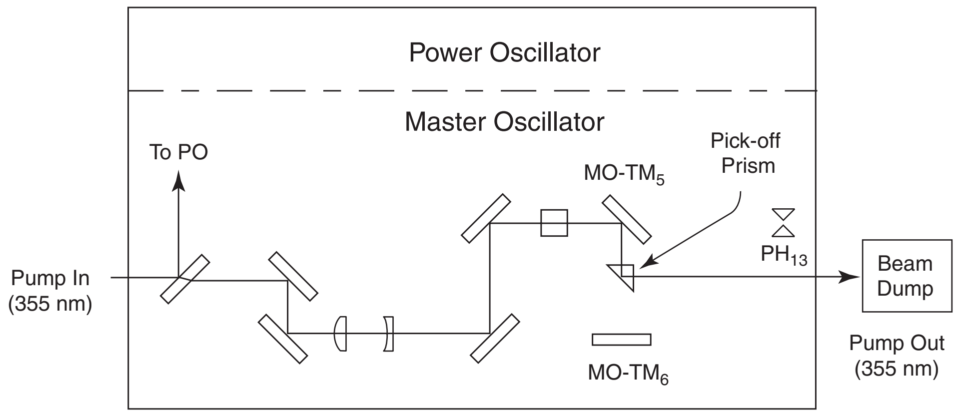


Figure 5-10: Placement of Pick-off Prism for Pump Collimation.

b. Place a pick-off prism in the long pulse beam path between MO-TM_5 and MO-TM_6 (Figure 5-10). It may be necessary to remove MO-TM_6.

c. Orient the prism so the long pulse beam is directed through the output port in front of PH_{13}.

d. Place a beam dump in the pump beam path approximately 0.5 m from the *MOPO-HF*.

e. Adjust the spacing between the positive and negative lenses so the beam appears nearly collimated but slightly diverging (in LONG PULSE mode).

   Perform a rough estimate of collimation by viewing the pump beam at two separate locations along the beam line. The beam may be viewed at a location just past the negative lens and also in front of the beam dump.

   Since the beam may have more convergence character when run in Q-SWITCH mode (due to thermal lensing in the YAG rods), we recommend the negative and positive lens displacement be adjusted so the beam appears slightly divergent.

Warning!

If the beam is converging it can cause damage to the optical components. Therefore, be sure the LONG PULSE beam is diverging initially. It should be approximately 1 mm larger at the beam dump than at the negative lens location.

f. Place PH_{10} back onto its dowel pins.

g. Make the necessary horizontal and/or vertical adjustments to MO-PL to re-center the beam onto the center of PH_{10}.

h. Remove PH_{10}.

i. Verify the long pulse beam is still going into the beam dump.

j. Change to Q-SWITCH mode.

k. Take mode burns just after the negative lens and in front of the beam dump.

Unexposed Polaroid film works well for mode burns. Place the film in a plastic bag to prevent ablated material from getting onto optical components.

l. Evaluate the relative sizes of the mode burns at the two locations. The mode burn at the beam dump should be slightly larger (up to about 1 mm) than the one at the negative lens. If the beam does not have the desired degree of beam collimation, follow the procedure outlined below.

   i. Change to LONG PULSE mode.

   ii. Tape a business card to the front of the beam dump, and mark the location of the beam with a pen or pencil.

   iii. Adjust the positive lens mount position in 1–2 mm increments in the desired direction

Note

If the beam exhibits too much divergence, move the positive lens away from the negative lens. If the beam is converging, move the positive lens toward the negative lens.

   iv. Make any necessary horizontal and/or vertical adjustments to MO-PL to re-center the beam onto the mark on the card.

   v. Repeat this step until the desired degree of collimation is attained.

12. Establish a 2° non-collinear alignment of the pump in the MO:

a. Locate the first surface-reflection of the HeNe beam from $MO\text{-}TM_5$. Two HeNe beam reflections should be noticed from the mirror. The first-surface reflection is the one which appears closest to the BBO crystal. If necessary, adjust the position of the pick-off prism so that it intercepts this reflection (Figure 5-11).

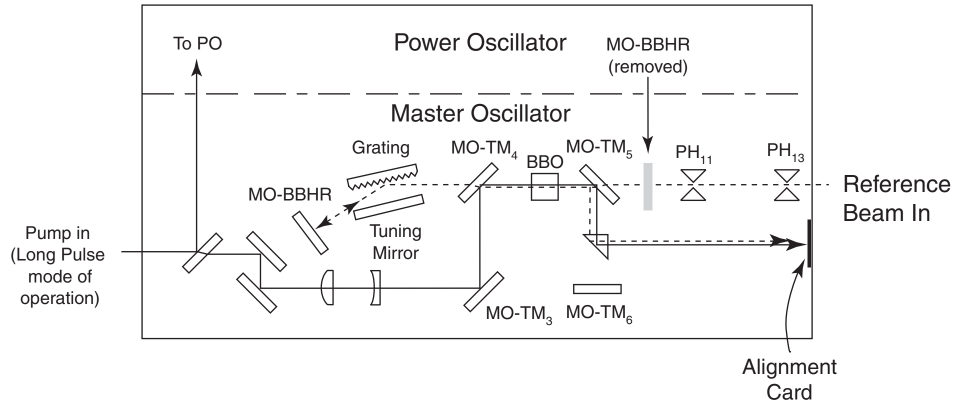


Figure 5-11: Overlap Location of HeNe Reference and Pump Beams

b. Adjust the prism position so the first surface reflection from the HeNe beam is directed onto the inside of the *MOPO-HF* lower cover approximately 5 cm to the right of the MO alignment porthole.

c. Using a pen or pencil, mark 2 lines on a business card that are spaced 2 cm apart (Figure 5-12). This will be referred to as the alignment card.

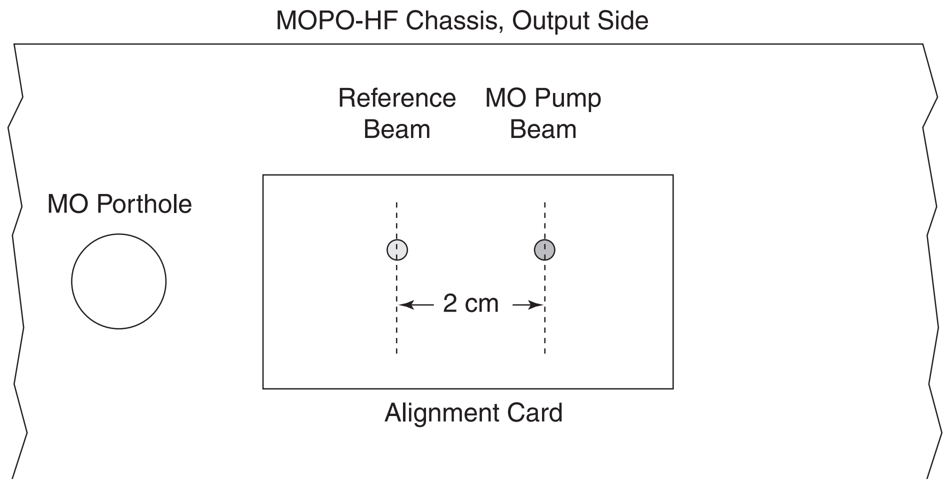


Figure 5-12: Overlap location for master oscillator overlap procedure.

d. Tape the alignment card to the inside of the *MOPO-HF* chassis so the left most mark is overlapped with the "first surface" HeNe reflection.

e. Using a business card (cut into a strip of approximately 10 mm), locate the pump beam in-between MO-TM_4 and the BBO crystal. Be careful not to touch the crystal surface. Adjust MO-TM_2 to overlap the pump and HeNe beams.

If necessary, block the reference beam periodically to estimate the relative positions of the two beams.

f. Locate the pump beam position on the alignment card. If it is not visible on this card, use a separate business card to locate it.

g. Adjust the MO-TM_3 horizontal and vertical so the pump and HeNe beams are overlapped on the alignment card. This step ensures that both beams are in the same horizontal plane (i.e., identical displacements from the base plate).

Note At this point the beams will not be overlapped in front of the crystal.

---

h. Adjust only the MO-TM_3 horizontal control so the pump is overlapped with the right-most mark on the alignment card.

i. Again, adjust MO-TM_2 to overlap the pump and HeNe beams in front of the BBO crystal.

j. Repeat Steps g–i until the *PRO-Series* pump beam is 2 cm to the right of the HeNe beam and overlap is achieved in front of the crystal.

k. As a final check of the alignment, adjust the MO-TM_3 horizontally so the beams are overlapped at the card. The pump beam may begin to clip the edge of the crystal, but do not be concerned about this. If the beams appear displaced in the vertical direction, make the necessary adjustments to MO-TM_3 to overlap them.

l. Finally readjust only the MO-TM_3 horizontal control so the pump beam is overlapped with the right most mark on the alignment card.

Note If the mirror adjustments are running out of range, loosen the MO-TM_3 base plate screws and rotate the mirror in the desired direction of adjustment. Re-tighten the screws. Alternatively, loosen MO-TM_4 and rotate it the desired amount. (The adjustment adds a negligible perturbation to the cavity alignment; therefore it should not alter the calibration.)

---

13. Remove the pick-off prism from its location between MO-TM_5 and MO-TM_6.
14. Place PH_9 onto its dowel pins. Place the flat side of the aperture so it is facing the positive lens.
15. If you removed MO-TM_6, replace it.
16. Adjust MO-TM_6 so the pump beam is retro-reflected onto the center of the PH_9 pinhole aperture (Figure 5-13).
17. Remove PH_9.

This completes the master oscillator overlap procedure.

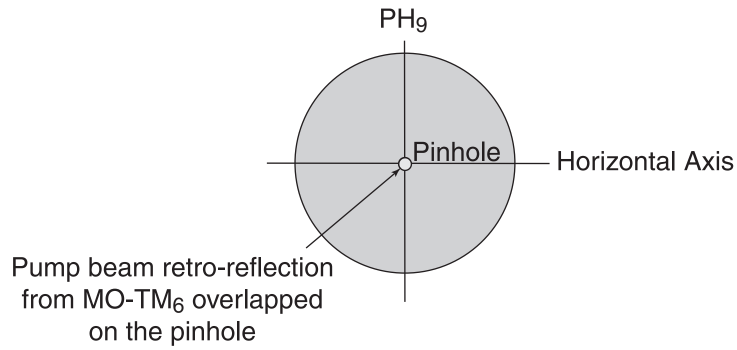


Figure 5-13: Retroreflection from MO-TM$_6$

Attaining Oscillation in the Master Oscillator

1. Change to LONG PULSE mode.
2. Place the pick-off prism assembly in a position to intercept the output beam from the MO (Figure 5-14). Direct the reference beam into a power meter. The meter should be on the 0.1 W scale.

   Be careful to prevent the Fresnel reflections from the surface of the prism from being reflected back into the MO. This may cause a parasitic oscillation.

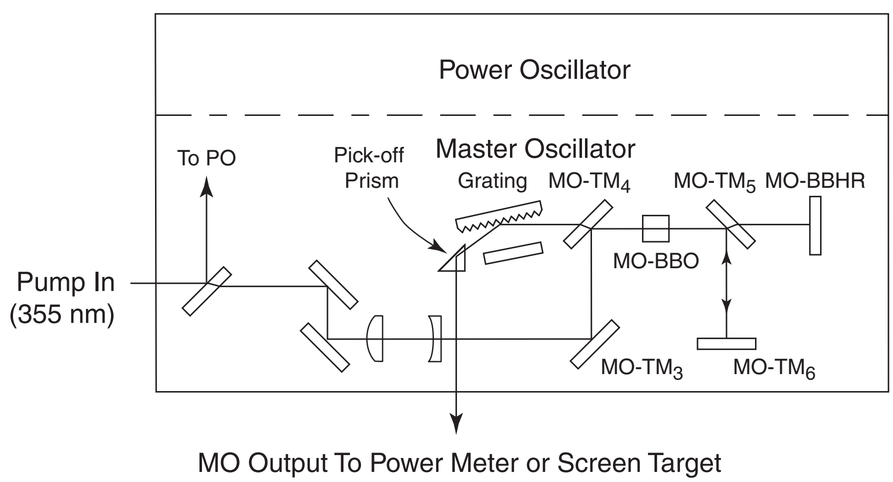


Figure 5-14: Placement for pick-off prism assembly for master oscillator output energy measurement

3. Remove the MO-BBHR from its “alignment” position and place it back in its “standard” position (Figure 5-9).

Note

In the following procedures, the MO output must be suppressed several times. This may be conveniently done by placing a business card over MO-BBHR to stop oscillation. To have room to do this, leave at least a 2-3 mm space between MO-BBHR and MO-TM$_5$.

a. Bend the short side of a business card so the bent portion is approximately 10 mm wide.

b. To see if it works, hang the card over the front side of the MO-BBHR optic (Figure 5-15).

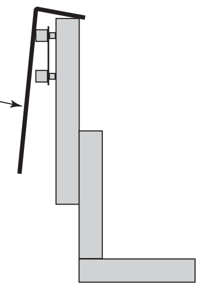


Figure 5-15: A business card folded and hung over the MO-BBHR.

c. Remove the card.

4. Align the retro-reflected reference beam (which originates from the backside of MO-BBHR) to a position approximately 2 mm to the left of the pinhole aperture in PH_{13}.

   Due to the wedge in the MO-BBHR optic, a series of retro-reflected spots are produced. It is important these reflections be in the horizontal plane. If this is not the case, rotate the optic in the mount to achieve the correct orientation. The primary reflection from the optical coating is the brightest. The wedge on the optic should be oriented so that the primary reflection is the second one from the right as shown in Figure 5-16. Use a card in order to view the weaker retroreflections (turning the lights out may help).

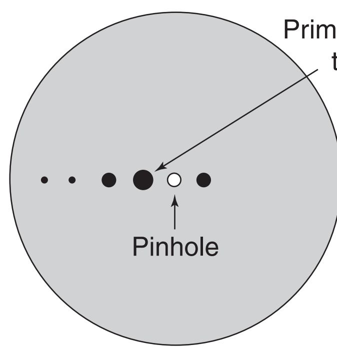


Figure 5-16: Retroreflections from the MO-BBHR shown in the correct horizontal orientation.

5. Verify the system is set to 500 nm.
6. Change to Q-SWITCH mode.
7. Use one of the procedures outlined in Appendix D to manually rotate the crystal until oscillation is attained.
8. **Important**. If oscillation is not observed, turn off the *PRO-Series* seeder. To do this:

a. Change to LONG PULSE mode.

b. Turn off the seeder.

c. Change to Q-SWITCH mode.

d. Manually adjust the crystal until oscillation is achieved.

e. Change to LONG PULSE mode.

f. Turn on the seeder.

g. Change to Q-SWITCH mode.

Turning the seeder off results in multi-mode output of the *PRO-Series* pump source for the *MOPO-HF*. As a consequence, the oscillation threshold for the MO is lowered and, thus, easier to achieve oscillation and to optimize it.

9. Once oscillation has been confirmed, perform a Y_SHIFT to the existing table at 500 nm:

   a. Confirm the system is at 500 nm.

   b. If necessary, confirm the autotrack board control switch is in the "computer" position (see Appendix D).

   c. Enter the Setup 2 menu.

   d. Press the DEVICE: OPO/MO_CRYS /PO_CRYS softkey.

   e. Press the up/down buttons until MO_CRYS appears in the menu box, then press the DEVICE softkey until it beeps.

   f. Select the METHOD softkey.

   g. Press the up/down buttons until Y_SHIFT appears in the menu box. Press the METHOD softkey until a beep it beeps.

   h. A menu should appear which displays the MO monitor.

   i. Use the up/down keys to maximize the output level on the power meter.

   j. Press the CONT. button.

   k. Press the SAVE? button.

Optimize the Master Oscillator

Optimizing Output Power

1. Turn off the *MOPO-HF* controller to allow the primary sine bar drive gear wheel to be rotated manually.

Note

For the next two steps, use your right hand to adjust the MO-BBHR and your left hand to rotate the gear wheel. This simplifies the adjustment sequence and minimizes the chance for putting a hand or arm in the beam path.

---

2. Note the output power on the power meter, then adjust the MO-BBHR vertical control clockwise just until power starts to fall.

3. Rotate the sine bar gear wheel manually to optimize output power.

   If the peak output power is lower than that noted in Step 2, repeat these last two steps, this time turning the MO-BBHR control counter-clockwise.

4. Repeat the above two steps until output power is maximized.

5. In order to ensure a maximum wavelength tuning range, the output should nominally be 5–6 mJ at 500 nm.

   If the system does not produce 5–6 mJ of output energy:

   a. Increase the pump energy by adjusting the HG $\lambda/2$ plate until 5–6 mJ of MO output energy is obtained.

   b. If it is still not possible to attain 5–6 mJ of MO output energy, perform the following steps.

      i. Turn the system to LONG PULSE mode.

      ii. Loosen the positive lens base plate screws.

      iii. Move the positive lens approximately 1 mm away from the negative lens. (This adds more convergence to the beam.)

      iv. Check beam collimation as described in Step 11 under “Master Oscillator Overlap Procedure” above.

      Important: make sure the beam is not converging.

      i. Verify the pump beam is still overlapped with the reference beam.

      ii. Attain oscillation as described above.

      iii. Measure the output energy and check the tuning range. If the system still does not tune over the specified wavelength range, repeat the above steps.

      iv. After the appropriate position of the positive lens is determined, tighten the positive lens base plate screws.

   c. If the desired MO output energy still cannot be attained, carefully check the following:

      i. Verify the retro reflection of the HeNe at 632.816 nm is overlapped with the PH_{13} pinhole aperture.

      ii. Verify correct alignment of the HeNe reference beam (refer to “Establish the Reference Beam for the Master Oscillator” above).

      iii. Verify the correct overlap of the pump and HeNe beams (refer to “Master Oscillator Overlap Procedure” above).

6. Verify the MO can be tuned over its specified operating wavelength range.

   a. Go to 450 nm.

   b. Use the manual crystal control (see Appendix D) to rotate the crystal until oscillation is observed.

   c. Go to 690 nm and repeat this procedure to verify oscillation can be achieved at this wavelength as well.

Note For optimal operation, the energies at the extremes of the tuning range should be 1–2 mJ.

Note Beware of multiple oscillations near 690 nm. These additional oscillations are at wavelengths that are shorter than the primary order. The correct order may be identified as being the last one observed as the crystal is tuned to the red.

Linewidth Measurement

1. Verify the time averaged linewidth (e.g., 50-shot average) at the FWHM is no more than three modes at 500 nm. One to two modes at FWHM is typical.
   a. Direct the MO output through a 0.25 cm^{-1} Fabry-Perot Analyzer (FPA).
   b. A concentric ring, or "Airy" diffraction pattern, should be visible (Figure 5-17).

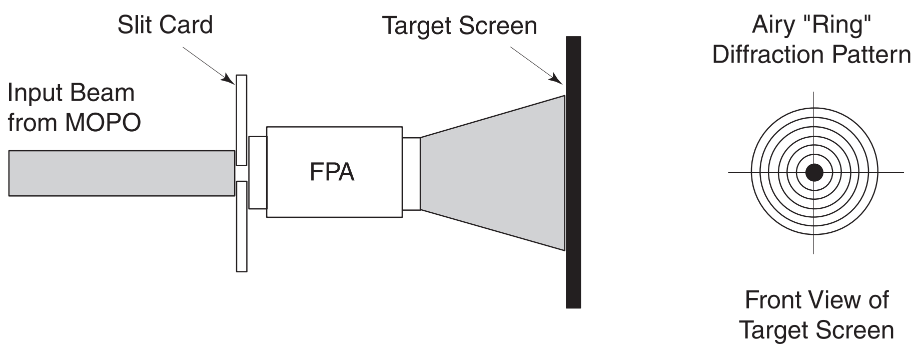


Figure 5-17: Airy Diffraction pattern by narrow linewidth radiation passing through a high finesse etalon.

   c. Place a linear diode array in the focal length plane of the FPA. The diode array should go through the center of ring pattern.
   d. A cross section of the fringe pattern may be recorded with a digital oscilloscope.
   e. Determine the ratio of the Full-Width-Half-Maximum (FWHM) of a particular fringe to the fringe spacing (Figure 5-18).
   f. The linewidth is obtained by taking the product of this ratio with the free spectral range of the etalon.
2. Turn down the lamp energy and remove the pick-off prism assembly.
3. Turn up the lamp energy. Oscillation in the MO should resume.

   The output beam should be directed onto S-TP_1.
4. Adjust S-TP_1 so the beam propagates unclipped through BS_1 and onto the center of S-TP_2.

   This completes the master oscillator alignment procedure.

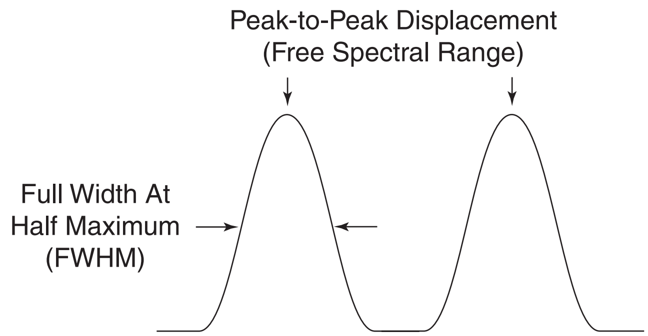


Figure 5-18: FWHM Ratio of a particular fringe to the fringe spacing.

Establish Reference Beam for Power Oscillator

Note If the PO has been previously aligned, establish the reference beam according to Method A below. Otherwise, use Method B.

Method A: PO has been previously aligned

1. Remove PO-BBHR, BS_2, S-TP_2, and the top half of the seed telescope assembly.

Note Use a 1/8 in. hex wrench to remove the two screws holding the assembly together.

2. Place a sheet polarizer in the output of the reference laser to obtain a horizontally polarized beam.

   It is important to use horizontally polarized light to establish an alignment reference for the optical cavity since the polarization of the resonated (signal) wave is horizontally polarized (Figure 5-6).
3. Align the reference beam to pinholes PH_6 and PH_5 (Figure 5-19):

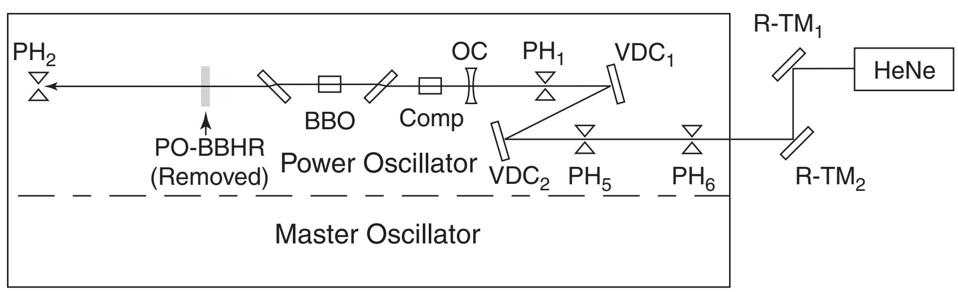


Figure 5-19: Reference beam alignment for the power oscillator. For clarity, some components are not shown.

   a. Place an aperture assembly on the dowel pins at PH_6 and secure it to the base plate with a 10–32 screw.

b. Place alignment mirror R-TM_2 approximately 1 foot (30 cm) in front of PH_6.

   The space between the *MOPO-HF* and the routing mirror leaves room for the placement of a power meter.

c. Place an aperture assembly on the dowel pins at PH_5.

d. Adjust R-TM_1 to center the reference beam on PH_6, then adjust R-TM_2 to center the reference beam on PH_5.

e. Iterate the last step until the beam is centered through the two pinholes.

f. Place aperture assemblies on the dowel pins at PH_1 and PH_2.

g. Adjust VDC_2 to center the beam on PH_1.

h. Adjust VDC_1 to center the beam on PH_2.

i. Iterate the last two steps until the beam is centered through the two pinholes.

4. Reverse the pinholes in PH_6 so the flat side faces the BBO crystal.

   This allows retroreflections from the oscillator optics to be seen during the following steps.

5. Use manual control (see Appendix D) to orient the crystal in the "face normal" orientation (where the surface of the crystal is perpendicular to the HeNe beam), then rotate the crystal until the Fresnel retroreflections off the BBO surface are the same distance above the *MOPO-HF* base plate as PH_1.

6. Verify the reflections from the BBO crystal and compensator are in the same horizontal plane. If they are not:

   a. Loosen the screw attaching the ribbon to the compensator mount.

   b. To identify the Fresnel retro reflection from the compensator, manually rotate the compensator mount while keeping the BBO mount fixed.

   c. Rotate the compensator mount until the retroreflections are in the same horizontal plane as the reflections from the BBO crystal and at the height of PH_1.

   d. Tighten the ribbon screw.

7. Verify the retroreflections from the BBO are directed onto the right side of the Teflon ring that surrounds the VDC_1 optic. If they are not:

   a. Loosen the BBO crystal holder.

   b. Rotate the crystal so its retroreflections are on the right side of VDC_1 (Figure 5-20).

   c. Verify the crystal is centered in the beam and make adjustments if necessary.

   d. Tighten the crystal holder.

8. Verify the retroreflections from the compensator are directed onto the left side of the Teflon ring surrounding the VDC_1 optic. If they are not:

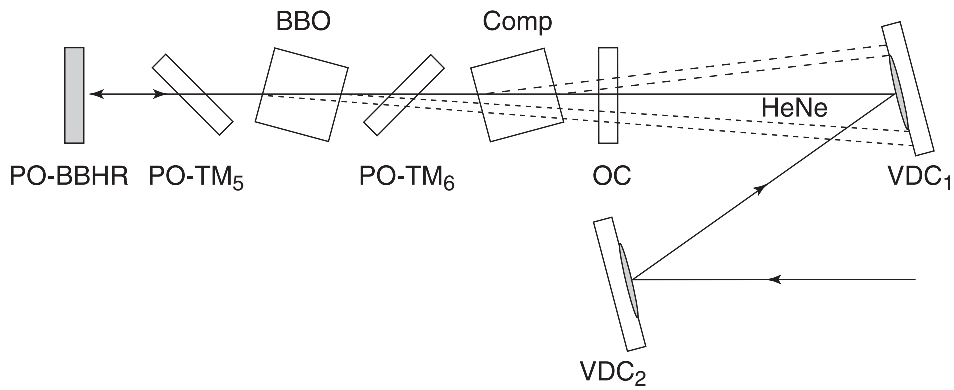


Figure 5-20: Orientation of the BBO Crystal

a. Loosen the compensator holder.

b. Rotate the compensator so that the retroreflection closest to the optic is on the left side of VDC_1.

c. Verify the compensator is centered in the beam. Make adjustments if necessary.

d. Tighten the compensator holder.

9. If necessary, re-adjust the OC so the primary retroreflection is directed back onto the PH_6 pinhole aperture.

10. Install the PO-BBHR in its standard location on the base plate. (The nominal separation between the OC and PO-BBHR is 13 cm.) Adjust the PO-BBHR so the retroreflections are directed onto the PH_6 pinhole.

Method B: PO *has not* been previously aligned

1. Remove all optics out of the beam path of the PO. This includes the PO-BBHR, PO-TM_5, PO-TM_6, BBO crystal, OC, compensator, and S-TP_2.

2. Place an aperture assembly on the dowel pins at PH_6 and secure it to the base plate with a 10–32 screw.

   The aperture will be used as an alignment reference.

3. Establish alignment of the reference beam.

   a. Place alignment mirror R-TM_2 approximately 1 foot (30 cm) in front of PH_6.

   The space between the *MOPO-HF* and the routing mirror leaves room for the placement of a power meter.

   b. Place an aperture assembly on the dowel pins at PH_5.

   c. Adjust R-TM_1 to center the reference beam on PH_6, then adjust R-TM_2 to center the reference beam on PH_5.

   d. Iterate the last step until the beam is centered through the two pinholes.

   e. Place aperture assemblies on the dowel pins at PH_1 and PH_2.

   f. Adjust VDC_2 to center the beam on PH_1.

g. Adjust VDC_1 to center the beam on PH_2.

h. Iterate the last two steps until the beam is centered through the two pinholes.

4. Reverse the pinhole in PH_6 so the flat side faces the BBO crystal.

   This allows retroreflections from the oscillator optics to be seen during the following steps.

5. Install the BBO crystal and compensator.

   a. Install the BBO crystal in its holder as described in Appendix A.

   b. Position the BBO so it is flush with the outside edge of the mount.

6. Use manual control (see Appendix D) to orient the crystal in the “face normal” orientation (where the surface of the crystal is perpendicular to the HeNe beam), then rotate the crystal until the Fresnel retroreflections off the BBO surface are the same distance above the *MOPO-HF* base plate as PH_1.

7. Adjust the BBO crystal so the retroreflections from its surfaces are directed onto the right side of the Teflon ring that surrounds the VDC_1 optic (Figure 5-20).

8. Install the compensator in its holder using the same technique used for the BBO crystal (again, refer to Appendix A). Position the compensator so that it is flush with the outside edge of the mount.

9. Adjust the compensator so its face is also in a face-normal geometry with respect to its front surface:

   a Loosen the screw attaching the ribbon to the compensator mount.

   b. To identify the Fresnel retro reflection from the compensator, manually wiggle the compensator mount while keeping the BBO mount fixed.

   c. Manually rotate the compensator mount until the retroreflections are in the same horizontal plane as the reflections from the BBO crystal and at the same height as PH_1.

   d. Tighten the ribbon screw.

   e. Manually rotate the compensator so the retroreflections from it are directed to the left side of VDC_1. The retroreflections should also be directed onto the Teflon ring surrounding the optic (Figure 5-20).

   f. If necessary, re-direct the retroreflections from the BBO crystal back onto the Teflon piece.

10. Notice that the HeNe beam at PH_2 has been displaced horizontally from the pinhole aperture. To compensate for this:

    a. Re-install the OC into its mount.

    b. Use a business card to identify the retroreflections from the OC, and adjust the OC so the largest and brightest retroreflection is directed onto the PH_6 pinhole aperture.

Note Improved accuracy is usually attained by directing the beam back into the laser. When a correct alignment is achieved, interference fringes should be noticed around the outside edge of the HeNe output aperture.

c. Rotate the OC so the HeNe beam at PH_2 goes onto (or very close to) the pinhole. This can be done by loosening the retaining ring and rotating the optic holder using a small hex wrench inserted into one of the set screws.

Note Keep the HeNe beam in the same horizontal plane as pinhole PH_2.

11. Install the 1 in. optic ($PO\text{-}TM_6$) and rotate it so the HeNe is displaced to the right of the PH_2 (i.e., in the same horizontal plane as the pinhole). See Figure 5-21.

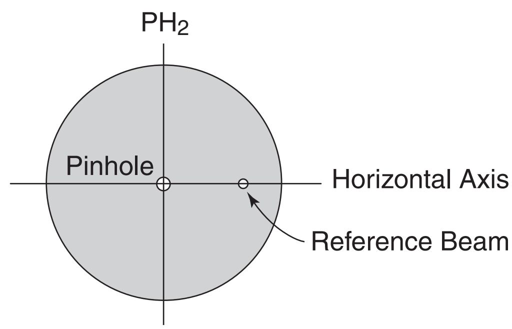


Figure 5-21: Horizontal displacement of reference beam from PH_2 pinhole.

12. Install the 1.5 in. optic ($PO\text{-}TM_5$). Rotate $PO\text{-}TM_5$ so the HeNe beam is directed onto the PH_2 pinhole.

    If you cannot direct the HeNe beam through the pinhole, at least make sure it is in line with it horizontally.
13. If the HeNe beam does not go through PH_2, realign the HeNe beam through PH_1 and PH_2 by adjusting VDC_1 and VDC_2.
14. If necessary, re-adjust the OC so the primary retroreflection is directed back into the HeNe laser.
15. Adjust the position of the BBO crystal and compensator, if necessary, to ensure they are centered in the HeNe beam.
16. Verify the retroreflections from the BBO and the compensator hit the Teflon ring surrounding the VDC_1 optic.
17. Place the PO-BBHR mount loosely on the *MOPO-HF* base plate at a location between PH_6 and PH_5, and orient the mount so the back surface faces the incident HeNe beam.

18. Observe the retroreflections from the back surface of the PO-BBHR on PH_6, and loosen the optic and rotate it so the retroreflections are in a horizontal line parallel to the base plate.
19. Install the PO-BBHR in its standard location on the base plate. The nominal separation between the OC and PO-BBHR is 13 cm. Adjust the PO-BBHR so the retroreflections are directed onto the PH_6 pinhole.
20. Loosen the $PO\text{-}TM_6$ base plate screws and rotate the mount slightly so the primary (brightest) retroreflection from the PO-BBHR is centered on $PO\text{-}TM_7$. Tighten the base plate screws.

Caution!

Verify the first surface reflection from $PO\text{-}TM_6$ is centered onto $PO\text{-}TM_7$ (Figure 5-22).

21. Loosen the $PO\text{-}TM_7$ base plate screws and rotate the mount slightly so the beam is directed into the beam dump. Cut a business card to an appropriate width to view the beam.

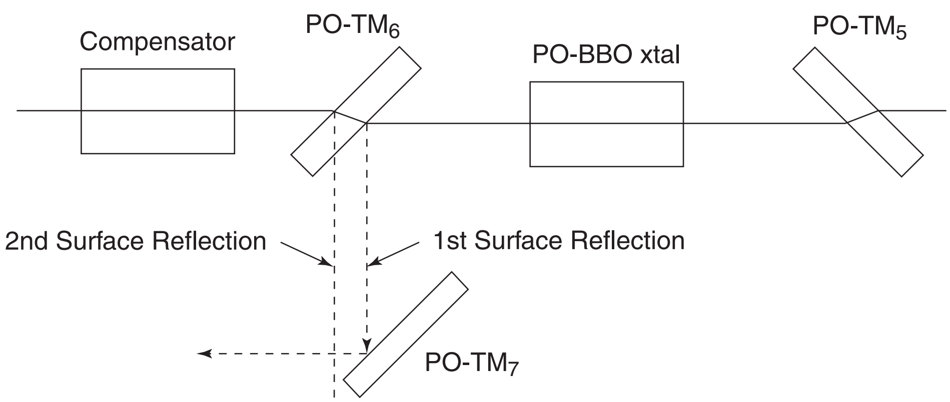


Figure 5-22: Alignment of the first surface reflection from $PO\text{-}TM_6$ onto $PO\text{-}TM_7$.

Power Oscillator Overlap Procedure

This procedure assumes prior alignment of the horizontally polarized reference beam through the PO. Leave an aperture in at PH_6 to reduce the reference beam size.

As described in the “Master Oscillator Overlap Procedure,” the overlap procedure requires that the HeNe beam have the same vertical polarization as the pump beam. This is necessary because both beams pass through a birefringent material and, therefore, experience a similar amount of Pointing vector walk-off. Because of unique geometrical constraints in the PO, the overlap procedure must be modified a little. For example, if a vertically polarized HeNe beam is used, the beam will walk onto a different portion of the high-reflector than does the horizontally polarized beam. Because the optic is curved, this results in an angular offset in the retroreflected beam. As a result, a slight angular error in the overlap procedure may occur if a vertically polarized reference beam is used. To avoid this error, we will overlap the pump with a horizontally polarized HeNe beam. Because the HeNe beam passes through the crystal twice, it will follow the same path the pump does on the output side of the BBO crystal. This enables the polarization of the pump and reference beams to be orthogonal.

Note If the *MOPO-HF* has *not* been previously aligned, establish the reference beam according to Method A below. Otherwise, use Method B.

Method A: MOPO-HF ***has not*** been previously aligned

1. Change to LONG PULSE mode.
2. Determine the combination of positive and negative lenses required for the telescope in the PO leg. Refer to Appendix E, "Determination of Telescope Lenses for Power Oscillator."
3. Obtain appropriate positive and negative lenses. Refer to the part numbers Appendix E.
4. Remove the PO-PL mount. (Leave PO-NL in its designated position on the *MOPO-HF* base plate.)
5. Place the positive lens in the PO-PL mount. Set the mount safely aside (in an unoccupied hole in the *MOPO-HF* base plate).
6. Orient the positive lens so its curved surface is directed away from the negative lens when it is placed in the beam line.
7. Do *not* yet mount the negative lens. Place it safely aside in an optic box or wrapped in a piece of optical tissue.

Method B: MOPO-HF has been previously aligned

1. Mark the location of the PO-PL mount on the translation stage with a pencil.
2. Remove the PO-PL mount. (Leave PO-NL in its designated position on the *MOPO-HF* base plate.)
3. Set the PO-PL mount safely aside (in an unoccupied hole in the *MOPO-HF* base plate).
4. Remove the negative lens from the PO-NL lens mount and place it safely aside in an optic box or wrapped in a piece of optical tissue.

Continuation of the Standard Procedure

1. The pump beam should be level and centered on PH_7. Verify this and remove the aperture from the base plate. Be sure to use an aperture with a fluorescent label or a business card taped to the flat side in order to view the beam.

   If necessary, center the beam on the pinhole by making make minor adjustments to UVBS. If these adjustments are performed, the beam must be re-centered on PH_3 and PH_4. Leave the telescope lenses in place during these adjustments.

2. Adjust the sheet polarizer so the reference beam is horizontally polarized.

   Verify the reference beam is still aligned PH_1, PH_5, and PH_6.

3. The pump beam should be roughly centered in $PO\text{-}TM_1$. Figure 5-23. If it is not, adjust the position of the mirror mount as necessary. The $PO\text{-}TM_1$ base plate should be roughly in the middle of its range of travel. This will allow necessary room for the pump to be directed by the mount and through the output port for diagnostic purposes.

4. Perform the following steps for proper height adjustment.

   a. Place the pinhole aperture in front of $PO\text{-}TM_2$.

   b. Adjust the $PO\text{-}TM_1$ to center the 355 nm pump beam on the pinhole.

   c. Remove the aperture.

   d. Adjust the $PO\text{-}TM_1$ horizontal so that the beam is to the left of the center of the $PO\text{-}TM_2$ optic Figure 5-23.

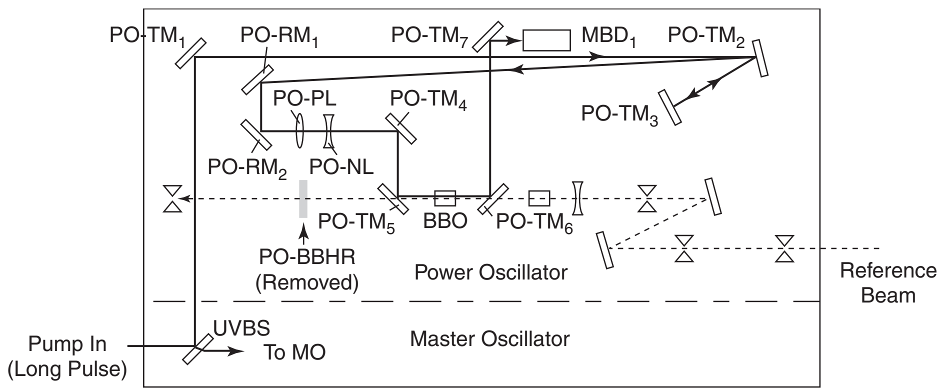


Figure 5-23: Overlap of HeNe Reference and Pump Beam for Power Oscillator

5. Place the pinhole aperture in front of $PO\text{-}TM_3$. Adjust the $PO\text{-}TM_2$ to center the beam on the pinhole. Remove the aperture to verify the beam is well centered on the optic.

6. Use a business card to locate the beam in front of $PO\text{-}RM_1$. Adjust $PO\text{-}TM_3$ to center the beam on the optic.

7. Place pinhole apertures on the appropriate dowel pins at PH_3 and PH_4.

8. Adjust $PO\text{-}TM_3$ to roughly center the beam onto PH_3.

9. Align pump beam to PH_3 and PH_4 apertures:

   a. Place a pinhole aperture into PH_7. Verify the beam is well centered the aperture.

      PH_7 reduces the beam diameter; thus, allowing more accurate alignment to the pinholes in the following steps.

   b. Adjust $PO\text{-}TM_3$ to center the “apertured” beam onto the PH_3 pinhole.

   c. Adjust the $PO\text{-}RM_2$ to center the beam on PH_4.

d. Iterate Steps b and c until the “apertured” beam is centered through the pinholes at PH_3 and PH_4.

e. Remove PH_7, PH_3 and PH_4.

Verify the beam is not clipping on $PO\text{-}RM_1$.

10. Overlap pump and HeNe beams:

a. Remove $PO\text{-}TM_7$.

b. Place a pick off prism on the base plate where $PO\text{-}TM_7$ was located. Orient the prism as depicted in Figure 5-24.

c. Locate the first surface reflection of the HeNe beam from $PO\text{-}TM_6$. Position the pick off prism to intercept this beam. Direct the beam out the diagnostic port hole closest to $PO\text{-}TM_1$ on the front side of the *MOPO-HF* Figure 5-24.

d. Place a beam dump on the side of the pump laser approximately 1 m in front of the port hole. Position the beam dump so that the HeNe beam is directed into the input hole.

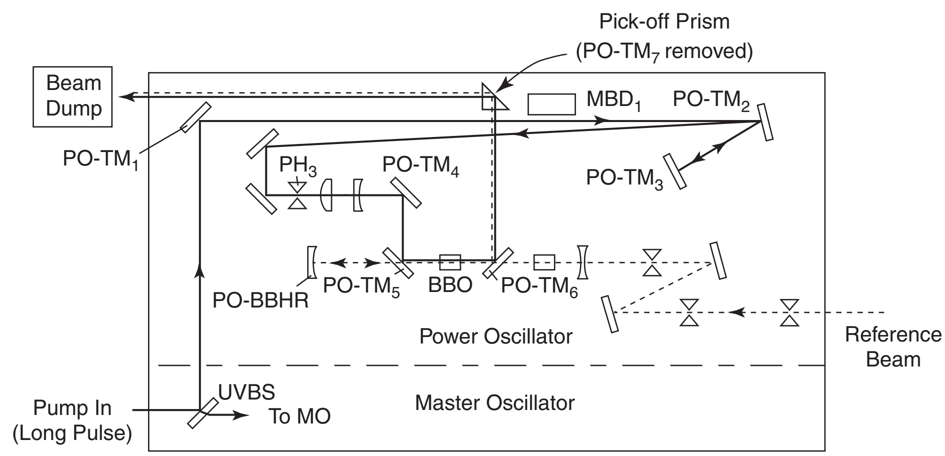


Figure 5-24: Power Oscillator Pick-Off Prism Placement

e. Place a pinhole aperture in PH_3. Verify the beam appears well centered on the pinhole.

Placing an aperture in the beam path reduces the beam size, thus, allowing more accurate overlap of the pump and HeNe beams in the subsequent steps.

f. Adjust $PO\text{-}TM_4$ to overlap the pump and HeNe laser beams at a location just outside the cavity near $PO\text{-}TM_6$. Use a business card (cut to a 15–20 mm width) to locate the beams. Make sure the first surface reflection of the HeNe beam from $PO\text{-}TM_6$ is used Figure 5-23.

Note

Due to walk off effects, it is important not to overlap the beams in between the crystal and $PO\text{-}TM_5$.

g. Adjust $PO\text{-}TM_5$ to overlap pump and HeNe laser beams at a location in front of the beam dump.

h. Reiterate Steps f and g until the beams are overlapped in the two locations.

Note

If it is difficult to attain overlap by iterating these adjustments (e.g. run out of travel on one of the mounts), perform the following steps.

---

i. Reset PO-TM$_4$ and PO-TM$_5$ adjustments to the middle of their ranges.

ii. Loosen the PO-TM$_4$ base plate screws. Note that PO-TM$_4$ is on a sliding base.

iii. Reposition PO-TM$_4$ in an arbitrary direction along the sliding base.

iv. Rotate PO-TM$_4$ until the pump and HeNe beams are relatively well overlapped near PO-TM$_6$.

v. Note the displacement of the two beams near the pick off prism.

vi. Re-iterate Steps iii–v until the beams are relatively well overlapped in the two locations. Note: if the displacement of the beams appears to be getting larger at the pick-off prism, reposition PO-TM$_4$ in the opposite direction along the sliding base.

11. Tape a business card over the PO pump diagnostic output port. Confirm the pump and HeNe overlap can be viewed easily on the card.
12. Place the negative lens into the PO-NL mount. The beam should be approximately in the center of the lens.

    The "plano-" (flat) side of the negative lens should be facing the positive lens location. This is important to prevent focused back reflections from damaging PO-PL.

13. Make the necessary horizontal and vertical adjustments of the PO-NL lens mount position to re-overlap the pump and HeNe beams on the business card at the diagnostic output port. Use the following procedure:

    a. Loosen the mount: Use a $^{3}/_{32}$ in. hex wrench to loosen the two screws on the front side of the lens mount.

    b. Vertical adjustment: Use a $^{1}/_{16}$ in. hex wrench to adjust the two downward facing screws on the side of the mount.

    c. Horizontal adjustment: Use a $^{1}/_{16}$ in. hex wrench to adjust the side facing screw on the side of the mount.

14. Place the positive lens back into position in the beam line.

    Verify the curved surface of the optic is directed away from the negative lens.

15. Adjust the position of the positive lens so that it is displaced from the negative lens by a distance that is approximately the difference in *absolute* focal lengths of the two lenses.

For example, a 1.2 x telescope which consists of a +240 mm and –200 mm focal length lenses should be displaced by approximately 40 mm.

16. Make the necessary horizontal and vertical adjustments of the positive lens mount position re-overlap the pump and HeNe beams on the business card at the diagnostic output port.
17. Remove PH_3.
18. Remove the business card at the diagnostic output port.
19. Place the macor aperture in its appropriate location on the base plate. Make sure it is centered on the beam.
20. Establish collimation of pump beam:
    a. If necessary, adjust the position of the positive lens until the beam appears collimated. Estimate the degree of collimation by viewing the pump beam at a position just past the negative lens and in front of the beam dump. Make sure the beam is still centered on the HeNe beam. It should not be clipping the edge of the BBO, compensator, or optical mount.

       Since the beam will have more convergence character when run in Q-SWITCH mode, it is recommended that the negative and positive lens displacement be adjusted so that the beam appears slightly divergent.
    b. Place a power meter at the signal output port. Place an appropriate beam block behind VDC_1. Also, remove any pinholes in the beam paths.
    c. Insert a suitably thick hex wrench (1/8 in.) or a 10–32 screw between the vertical adjust push plate and the main portion of the output coupler mount. This will suppress oscillation in the PO in the subsequent steps.
    d. Change to Q-SWITCH mode.
    e. Take mode burns just after the negative lens and in front of the beam dump.

       Unexposed Polaroid film works well for mode burns. Place the film in a plastic bag to prevent ablated material from getting onto optical components.
    f. Evaluate the collimation of the beam by comparing the diameter of the mode burns.
    g. Since the beam tends to spread out spatially with most of the energy in the central portion, it is recommended that the beam exhibit a slight amount of divergence. If the beam does not exhibit the desired amount of divergence character, perform the steps outlined below.
        i. Change to LONG PULSE mode.
        ii. Place a business card (target) in the beam path in front of the beam dump.

iii. Mark the location of the beam.

iv. Adjust the positive lens mount position in the direction necessary to attain the desired degree of collimation (see Note below).

Note

If the beam divergence is too great, move the positive lens away from the negative lens. If the beam is converging, move the positive lens toward the negative lens.

v. Verify the beam is roughly centered on the target in front of the beam dump.

vi. Remove the target.

vii. Turn to Q-SWITCH mode as described above and take mode burns again.

viii.Repeat this procedure until desired degree of collimation is achieved.

21. Change to LONG PULSE mode.
22. Place PH_3 back onto the base plate.
23. Re-check the overlap between the pump and HeNe beams.
    a. Remove the beam block placed in front of the signal output port in order allow the reference HeNe beam to pass unobstructed into the PO.
    b. Place PH_6 back onto the base plate.
    c. Remove the hex wrench from the OC mount.
    d. Verify the retroreflections from the OC and PO-BBHR optics are directed onto the center of PH_6. If they are not, make the necessary adjustments to center them on the pinhole. Be sure to place a card in front of PO-BBHR while checking the OC retroreflections.
    e. Using a business card, verify the pump and HeNe beams are still overlapped. Make any necessary adjustments to the positive lens (for course alignment) and the negative lens (for fine alignment).
24. Remove PH_3.
25. Remove the pick off prism. Place $PO\text{-}TM_7$ back onto the base plate.
26. Adjust the PH_{14} location to center the pinhole on the LONG PULSE beam.
27. Direct the beam into the mini-beam dump (MBD_1).

Attaining Oscillation in the Power Oscillator

1. Verify the pump laser is in LONG PULSE mode.
2. Prevent oscillation in the MO during subsequent steps in the procedure by placing a business card over MO-BBHR Figure 5-15.
3. Using the *MOPO-HF* controller, go to 500 nm.

a. Access the OPERATE screen and enter 500 nm in the GOTO menu.

b. Press the GOTO button down and hold it until a beep is heard.

4. Verify a power meter head is in the output signal beam path. This will be used to measure the signal output power, as well as to judge overall stability and seeding optimization.
5. Place a beam dump approximately 2–3 m from the idler output port.
6. Change to Q-SWITCH mode.
7. Oscillation in the PO should be observed. Allow a several minute warm up period.

Note

The oscillating wavelength may be somewhat different than 500 nm. The actual wavelength is determined by a default “look-up” table value in the MOPO operating system. The operating wavelength will be set to 500 nm when seeding is achieved.

---

8. Once the output from the PO has stabilized, place an IR card behind VDC_1. The idler should be visible along with some leakage from the signal beam. Make adjustments to the beam dump to ensure the beam is safely blocked.

Danger!

When viewing the idler, tilt the card downward to minimize the chance of directing the scattered light back toward the viewer

---

9. Assess the relative positions of the signal and idler. If the signal and idler beams are displaced from one another, adjust the vertical on $PO\text{-}TM_5$ to overlap them.

Warning!

If there is a horizontal displacement of the beams, a horizontal adjustment of $PO\text{-}TM_5$ is necessary. Set to LONG PULSE mode to avoid exposure to the beam. Make the adjustment.

Turn back to Q-SWITCH mode and assess the signal and idler overlap. Repeat until overlap is achieved.

Suggestions for viewing the signal/idler overlap:

- Use a visible cut-off/IR-pass filter in the beam path to view the relative positions of the two beams.
- If available place a 1–2 m positive lens in the idler beam path. View the signal and idler positions in the focus of the lens.

Note

Several idler output beams may be noticed in the far field. These are due to multiple Fresnel reflections from the surfaces of wedged optics in the PO. The main output beam is the largest one and contains most of the energy.

---

10. Use this procedure to *achieve collimation of the signal output beam.*
    a. Set to LONG PULSE mode.
    b. Remove R-TM$_1$ from signal beam output path.
    c. Place power meter or a beam dump 2–3 m from signal beam output port.
    d. Set to Q-SWITCH mode.
    e. Take mode burns of the signal at the output and 2 m away. Evaluate the collimation of the beam.
    f. Set to LONG PULSE mode.
    g. Adjust the position of PO-BBHR in the appropriate direction (see info-byte below) to *optimize collimation of the signal and idler output beam*.
    h. Set to Q-SWITCH mode.
    i. Evaluate the collimation of the signal beam.
    j. Repeat the above steps until the best possible degree of collimation is achieved.

Note Moving the PO-BBHR toward the output coupler will add more divergence to the signal beam. Moving it away from the output coupler will add more convergence character to the beam.

Note Additional optimization steps will be discussed in "Fine Tunning the MOPO Collimation."

11. Use the power meter to determine the output pulse energy of the signal beam. The signal output energy should be in the range 10–35 mJ at 490–510 nm wavelength range.

Note If the output energy is not in the desired range, a different PO telescope may be required.

Seeding the Power Oscillator

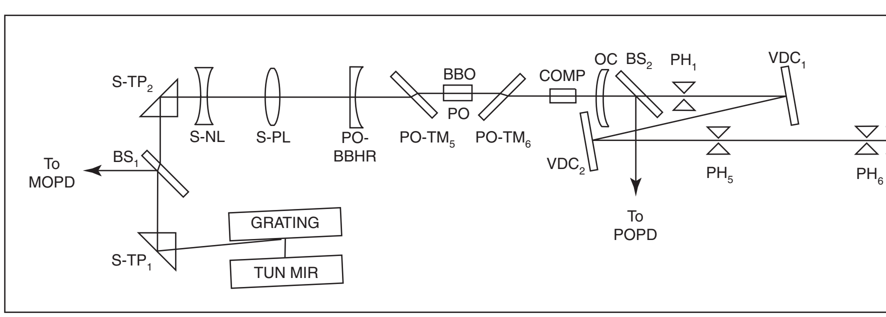


Figure 5-25: Seed Beam Alignment

Seed Beam Alignment (coarse alignment)

1. Change to LONG PULSE mode.
2. Place S-TP_2 back onto the base plate.
3. Verify the top half of the seed telescope assembly has been removed.
4. Place a beam block in the pump beam path at a location before PO-TM_1. Do this by placing MBD_1 over the dowel pins at PH_7.

   This prevents the PO from oscillating during the procedures described below.
5. Verify a beam dump is approximately 2 m from the idler output port. This allows the idler and (“leakage”) signal to be overlapped over sufficiently large distances.
6. Place PH_6 and PH_1 back onto the *MOPO-HF* base plate.

   Verify the flat side of the apertures are facing the BBO crystal.
7. Allow oscillation in the MO to resume remove the business card from in front of MO-BBHR.

   The MO output should be directed onto S-TP_1 Figure 5-25.
8. Change to Q-SWITCH mode.

   Oscillation in the MO should resume.
9. Adjust S-TP_1 to direct the seed beam onto the center of S-TP_2 Figure 5-25.
10. If necessary, adjust the position of BS_1 to direct the seed beam reflection into MOPD (master oscillator detector). Make sure the seed beam passes through the optic without clipping the sides of the mount. Adjust the position of the detector in order to maximize the signal.
11. The S-TP_2 base plate is slotted to allow translation. If necessary, adjust the base plate position to the center of these slots.
12. Coarse overlap procedure.
    a. Rotate S-TP_2 to overlap the signal beam onto PH_1 (see Figure 5-25).
    b. Note how far the leakage from PH_1 is displaced from the PH_6 aperture.
    c. If necessary, reposition the S-TP_2 mount (e.g., choose a new pivot location) and re-rotate to assess how well the beam is centered on the two pinholes. Repeat this step until overlap on the two pinholes is achieved.
13. Tighten the S-TP_2 base plate screws to fix the mount in position.
14. Adjust S-TP_1 to overlap the (leakage) signal beam on the PH_1 pinhole aperture.
15. Adjust S-TP_2 to overlap the beam on the pinhole aperture PH_6.
16. Repeat steps 14–15 until overlapped is achieved at both locations.
17. The MO beam should pass through BS_1.
18. Optimize the signal level on *MOPO-HF* using the following procedure:

a. Access the monitor menu on the *MOPO-HF* controller.
b. Note the signal levels on the MO monitor.
c. Maximize the signal level on the MO monitor by adjusting its position so that the Fresnel reflections from BS_1 are centered on the detector. If necessary, adjust the pointing of the BS_1 mount to maximize the signal.
d. Adjust the gain potentiometer on the monitor if signal levels are too low or high.

Optimizing Seed Beam Alignment

The following optimizes the alignment of the seed beam to the PO resonator. Part I describes the alignment of the seed telescope. In Part II the PO is converted into a low energy OPA (optical parametric amplifier). Adjustments are made to ensure collinear alignment of the seed beam to the PO pump beam. In Part III, the seed beam is blocked and the PO is converted back into an oscillator. Collinear alignment of the unseeded PO is verified.

Part I: Seed Telescope Alignment

Method A: PO has been previously aligned

1. Change to LONG PULSE mode.
2. Place the top half of the seed telescope assembly back onto its base assembly.
3. Use a $^1/_{16}$ in. hex wrench to remove the 1 in. optic barrel that contains the positive lens.
4. Change to Q-SWITCH mode.

   Oscillation in the MO should resume.
5. The seed beam should be roughly centered on the negative lens. If this is the case, proceed to Step 6.

   If the beam is clipping the lens mount, loosen the seed telescope base plate screws and slide the telescope base laterally to center the seed beam horizontally in the negative lens (coarse x-axis adjustment). Next tighten the telescope base plate screws.
6. Using a $^1/_{16}$ in. hex wrench adjust the x and y position of the negative lens (S-NL) to center the expanding beam on PH_6 and PH_1. Center the leakage light from PH_1 onto PH_6.
7. Place the 1 in. optic barrel that contains the positive lens back onto the seed telescope assembly.
8. Using $^1/_{16}$ in. hex wrench adjust the x and y position of the positive lens (S-PL) to center the expanding beam on PH_1 and PH_6. Center the leakage light from PH_1 onto PH_6.
9. Remove the PH_1 and PH_6 apertures.
10. Adjust the distance between the positive lens and negative lenses (z-position adjustment) to collimate the light that is coupled through the

cavity. Since the telescope expands the seed beam up to 6 times its initial size, the light will overfill the clear aperture of the crystal compensator. Thus the expanded seed light will have a rectangular appearance. Initial collimation is attained by making the size of the rectangular "cone" of light roughly the same at PH_1 and PH_6.

11. Place PH_1 and PH_6 back onto the base plate. Verify the leakage light from PH_1 is centered onto PH_6.

Method B: PO *has not* been previously aligned

1. Change to LONG PULSE mode.
2. Place the top half of the seed telescope assembly back onto its base assembly.

Note There should be no lenses in the S-PL or S-NL mounts.

---

3. Use a $^{1}/_{16}$ in. hex wrench to remove the 1 in. optic barrel that contains the positive lens.
4. Change to Q-SWITCH mode.

   Oscillation in the MO should resume.
5. Loosen the seed telescope base plate screws. Slide the telescope base laterally to center the seed beam horizontally in the S-NL mount (coarse x-axis adjustment). The beam should also be approximately centered on the S-PL "barrel" mount.
6. Tighten the telescope base plate screws.
7. Change to LONG PULSE mode.
8. Mount S-PL:
   a. Remove the S-PL optic "barrel".
   b. Remove the retaining spring.
   c. Insert the +75 mm fl optic.
   d. Insert the retaining spring.
   e. Set the S-PL assembly aside.
9. Mount the –12 mm fl lens in the S-NL mount.
10. Change to Q-SWITCH mode.

    Oscillation in the MO should resume.
11. Using a $^{1}/_{16}$ in. hex wrench adjust the x and y position of the negative lens (S-NL) TO center the expanding beam on PH_6 and PH_1. Center the leakage light from PH_1 onto PH_6.

Note If the intensity of the seed beam on PH_6 is too low, perform one of the following steps.

---

a. Turn out the room lights, or

b. Tune the MO wavelength 5–10 nm around 500 nm to find the transmission peak for the PO-BBHR coating. The peak may be verified by observing maximum brightness of the seed light on PH_6. The transmission peak is usually in the 500–505 nm region. The following procedure may be used to assess location of this peak.

   i. Write a table using MO-AUTO from 495–505 nm.

   ii. Perform a series of GOTOs in 1 nm increments from 495–505 nm. Note: if the peak cannot be found, increase the scan range to 480–520 nm.

   iii. Evaluate the brightness of the leakage seed light on PH_6.

   iv. After the scan is complete, go to the wavelength that results in maximum brightness on PH_6.

12. Place the 1 in. optic barrel that contains the positive lens back onto the seed telescope assembly.
13. Using 1/16 in. hex wrench adjust the x and y position of the positive lens (S-PL) to center the expanding beam on PH_1 and PH_6. Center the leakage light from PH_1 onto PH_6.
14. Remove the PH_1 and PH_6 apertures.
15. Adjust the distance between the positive lens and negative lenses (z-position adjustment) to collimate the light that is coupled through the cavity. Since the telescope expands the seed beam up to 6 times its initial size, the light will overfill the clear aperture of the crystal compensator. Thus the expanded seed light will have a rectangular appearance. Initial collimation is attained by making the size of the rectangular "cone" of light roughly the same at PH_1 and PH_6.
16. Place PH_1 and PH_6 back onto the base plate. Verify the leakage light from PH_1 is centered onto PH_6.

Part II: Seed beam alignment using an optical parametric amplifier (OPA)

1. Change the pump laser mode to LONG PULSE.
2. Remove the PO pump beam dump from in front of the $PO\text{-}TM_1$.
3. Place a power meter in the signal beam output path from the PO.
4. Insert a suitably thick hex wrench (or a 10–32 screw) between the vertical adjustment push plate and the main portion of the output coupler mount so that oscillation in the PO is terminated.

Note A hex wrench less than 1/8 in. thick may terminate unseeded operation, however, the oscillator may still be partially aligned. Thus, when the oscillator is seeded the operating characteristics may be more like that of an oscillator than an amplifier.

---

5. Change to Q-SWITCH mode.

   Oscillation in the MO should resume.

6. Wait several minutes for the MO output power to stabilize.
7. Adjust the PO crystal until amplification is observed:
   a. Access the crystal device menu.
   b. Press the PO XTAL softkey to activate it.
   c. Access the table writing options softkey. Toggle through the menu options until Y_SHIFT is obtained. Press and hold down the softkey to activate the option.
   d. Press the “up” and “down” arrow soft keys until parametric amplification is attained. Settle on the crystal position that results in the brightest output. Parametric amplification may be verified by observing idler behind VDC_1 using an IR card.
   e. Press the CONT softkey. A beep should be heard and the softkey label should change to SAVE?. Press and hold the softkey down until a beep is heard to store the new table values.
8. The signal and pump beams should also be visible on the IR card behind VDC_1. Use the x and y adjustments on S-PL to overlap the signal, idler, and pump beams.

Part III. Conversion to Unseeded OPO

1. Block the seed beam.
2. Remove the hex wrench (or other object) used to misalign the output coupler.

   The PO should be oscillating.
3. If necessary, make the adjustments to the OC to ensure the pump, signal and idler are overlapped. Check this with an IR card behind VDC_1. This is a collinear phasematching geometry.

OPO Seeding

4. Unblock the seed beam. Seeded operation should begin.
5. Make minor adjustments to the PO crystal to ensure optimal frequency overlap. Maximum power output should result. This may be accomplished by using the Y_SHIFT operation for the PO device in the SCAN SETUP 2 menu.

Initialize PO Detector

Throughout the alignment procedures, the PO beam splitter (BS_2) must be out of the beam line because it introduces an uncompensated wedge (see Figure 5-25). The final step in the procedure involves establishing PO detection.

6. Change to LONG PULSE mode.
7. Place BS_2 back onto the base plate. Use the HeNe beam to roughly center the optic on the output beam path. Leave the base plate screws loose.

   BS_2 should be oriented to reflect the output from the PO into POPD.

8. Block the seed beam from the MO.
9. Change to Q-SWITCH mode. Unseeded oscillation should resume.
10. Check to see if the BS_2 mount is clipping either the primary output beam or the Fresnel reflections directed onto POPD. Burn paper may be used to evaluate the primary beam. The Fresnel reflections may be viewed with a business card. If clipping is present do the following to correct it.
    a. Turn to LONG PULSE mode.
    b. Adjust the position of BS_2.
    c. Turn to Q-SWITCH mode.
    d. Evaluate beam clipping.

       If clipping is still present, repeat the above steps until it is eliminated.
11. Optimize the signal level on PO-PD.
    a. Access the monitor menu on the *MOPO-HF* controller.
    b. Note the signal levels on the PO monitor.
    c. Maximize the signal level on the PO monitor by adjusting its position so that the Fresnel reflections from BS_2 are centered on the detector.
    d. Adjust the gain potentiometer on the monitor if signal levels are too low or high.

    Optimal alignment of the seed beam to the PO is now achieved!

Engage BeamLok

1. Access the BeamLok menu on the *PRO-Series* controller.
2. Verify BeamLok is off.
3. If the vertical and horizontal bars in the display menu are not at the center of the cross-hairs, perform the following:
    a. Turn off the laser.
    b. Carefully remove the *PRO-Series* laser cover.
    c. Turn on the laser.
    d. Set the *PRO-Series* laser to Q-Switch mode, and verify the UV energy is at maximum.
    e. Use a $^5/_{64}$ in. hex wrench to adjust the pointing sensor so the horizontal and vertical boxes are overlapped.

       Use gain level 4 for optimal adjustment sensitivity.
    f. Turn off the laser.
    g. Place the cover back on the pump laser.
    h. Set the *PRO-Series* laser to Q-Switch mode.
    i. Engage BeamLok.

Optimizing MOPO Operation

Fine Tuning MOPO Collimation

Achieving well collimated pump, signal and idler beams is important to achieve best linewidth and beam propagation characteristics.

Note Use this procedure only if the signal and idler mode characteristics are not suitable.

---

1. Make a minor change (about 1 mm) to the PO telescope lens spacing (in an arbitrary direction) using the procedures outlined in the previous section. Verify the pump still appears reasonably collimated. Check to see if the signal and idler beam collimation has improved.
2. Make minor changes to seed beam divergence (e.g., ±1 mm changes in S-PL position). Check to see if the signal and idler beam collimation has improved.
3. Iterate Steps 1–2 until the signal and idler beam collimation is optimized.

Optimizing MOPO Stability

1. Passive (non-scanning) stability.
   a. Direct the *MOPO-HF* output into a power meter. Verify it is at a fixed wavelength (e.g. 500 nm).
   b. While observing the power meter reading, carefully apply a lifting pressure to each corner of the base plate.
   c. If the stability of the output improves while lifting a particular corner perform the following steps.
      i. Use the $^{5}/_{8}$ in. wrench to make a very slight adjustment on the foot belonging to the corner.
      ii. Adjust the foot to optimize the stability.
      iii *Do not* tighten the lock nut.
2. Scanning stability.
   a. Perform an x adjustment on S-PL to direct the leakage light from PH_1 1 mm to the right of PH_6. This eliminates potential "etalon effects" during a scan.

This completes the *MOPO-HF* alignment procedure.

Chapter 6 Operation

MOPO-HF/FDO Dos and Don'ts

Your system must be set up on an optical table to ensure mechanical stability, and steps must be take to ensure there are no air currents (e.g., heating and/or air conditioning registers or ducts directly over the table) and that there are no rapid changes in air temperature while the unit is running.

The following do's and don'ts should be made part of your standard laboratory procedures for operating the *MOPO-HF*. 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** remove a beam block from between the *MOPO-HF/FDO* and the pump laser while the laser is running.

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

- **Do not** vary the *PRO-Series* laser and/or *MOPO-HF/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 *PRO-Series* laser 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-HF* 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-HF 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 *PRO-Series* laser 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 *PRO-Series* laser SINGLE SHOT option when running the *MOPO-HF FDO*.

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

- **Do not** lean on the *PRO-Series* laser or *MOPO-HF FDO* units during operation, nor place items on them. Also, do not lean on the optical table.

  The entire *MOPO-HF* system is very sensitive to small amounts of movement in the beam. Leaning on the optical table, the *PRO-Series* laser, or the *MOPO-HF FDO* will compromise system performance by inducing beam movement.

- **Do not** remove the *MOPO-HF 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 service representative of the problem.

- Monitor the UV pump power on a daily basis.

  Important. As specified in the “Daily Start-Up” procedure of this *MOPO-HF* manual, a combined warm-up period of approximately 45 minutes is required before the UV power can be reliably read.

- Monitor the flash lamp lifetime of the pump laser.

  If performance is below specification and the flash lamp lifetime is greater than 30 million shots, replace the flash lamps.

Caution! Please note that UV performance begins to degrade at approximately 15 million shots for non-*BeamLok* systems.

Number of Shots as Function of Rep. Rate and Duration			
	1 Day (8hrs)	1 Week (40 hrs)	1 Month (160 hrs)
10 Hz	288,000	1.44 million	5.76 million
30 Hz	864,000	4.32 million	17.28 million
50 Hz	1.44 million	7.2 million	28.8 million

- 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.

Hints, Tips & Reminders for Daily Operation

MOPO stability

- For maximum stability, it is very important to verify the harmonic generator (HG) in the *PRO-Series* laser is peaked for maximum energy. Verify the output is stable.

PO alignment

- If most of the energy in the beam is "off center," align this portion with the pinholes as outlined in Chapter 5, "Installation and Alignment."
- Be sure to remove BS_2 when setting up (or checking) the HeNe beam alignment in the PO.

MOPO linewidth

- Be sure the vertical adjustment on MO-BBHR is adjusted for maximum output (see manual for details).
- If MO linewidth is greater than 3 modes, FWHM, (or has > 5 modes total), increase the angle of noncollinearity between the HeNe and the pump beam. This may be done by increasing the separation of the two beams in increments of 2 mm on the "alignment card" (see Step 12 of the "Master Oscillator Overlap Procedure" in Chapter 5).
- Occasionally linewidth from the MO may be improved by pumping closer to threshold. This may be achieved by adjusting the halfwave plate on the pump laser harmonic generator to reduce pump laser output energies.

Locking Issues

Appropriate locking in the PO requires that the ratio of seeded to unseeded output generally be greater than 1.2. In general, the larger this ratio, the better the system performs. This is related to the servo system's ability to discriminate between seeded and unseeded operation. As the power ratio increases, the error signal (discriminant) increases. Under these conditions the system should lock readily.

When the ratio is small, the error signal decreases. In this case, locking becomes more difficult. Threshold values are used by the system to assist in discriminating between local maxima and the absolute peak associated with a fully seeded system.

- If the PO has difficulty locking and it has been a day or more since the system has been operated, it may be necessary to refresh the threshold table. This is done by rewriting the base & peak table values (i.e., use the Set_Base and Set_Peak algorithms).
- If locking the PO is difficult after a threshold table has been written, the seeded/unseeded ratio may be too small. By adjusting the half-wave plate this ratio may be increased. Keep in mind the trade-off associated with this adjustment is a reduction in output energy.

General operation hints

- Optimal performance can be obtained by writing a small table over a region of interest shortly before an experiment is performed.
- On a daily basis, prior to operating the *MOPO-HF*, make sure the 355 nm output is peaked and stable. If necessary, adjust the HG.

Daily Start Up Procedure

This short procedure is provided to minimize your daily start up efforts. The *MOPO-HF* controls and display menus that are referred to here are discussed later in this chapter or are covered in your *FDO-970 User's Manual*.

This procedure assumes the system was used recently and has not been moved since that time. The *MOPO-HF FDO* controller should be off; do not turn it on until told to do so.

1. If frequency doubling, verify TP_1 is in its proper position for use with the FDO.

   If frequency doubling is not desired, make sure TP_1 is moved to its parking lot position so that it does not block the signal and/or idler beams from exiting their respective ports.
2. Verify the cooling water for the *PRO-Series* laser is on.
3. Verify the seeder on the pump laser is turned to ON and the piezo is set to AUTO.
4. Turn on the *PRO-Series* laser and set it to LONG PULSE mode. Allow the laser to warm up for 15 to 30 minutes.
5. Turn on the *MOPO-HF* controller.
6. Set the *PRO-Series* laser to Q-switch mode.
7. Verify the *PRO-Series* laser 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.
8. Use the Monitor1 menu to verify the master oscillator reads within 10% of the value it had at installation.

9. If the FDO is installed and you are frequency doubling, change the MODE to FDO, then use the Monitor1 menu to verify *MOPO-HF FDO* output is within 10% of the value it had at installation.
10. 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 7 to 10 for future use. If you have any problems following a reinstallation, refer to Chapter 5, "Installation and Alignment," or call your Spectra-Physics representative.

Daily Shut Down Procedure

Follow these steps to shut your system off between periods of frequent use. Instructions are given for using the analog controller on the *PRO-Series* laser system. Use the corresponding controls of the digital *BeamLok* controller if it is used.

1. Turn off the lamps.
2. Allow the system to cool off for 5 to 10 minutes.
3. Turn off the laser.
4. Turn the key switch on the *PRO-Series* 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 *MOPO-HF 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 *PRO-Series* power supply.

Operating the Control Electronics

Use the *MOPO-HF* controller to access *MOPO-HF FDO* operational, setup, monitoring and service functions. (Note: if you purchased the *MOPO-HF FDO* unit after the *MOPO-HF*, the Spectra-Physics service engineer that installed the *MOPO-HF FDO* also reconfigured the firmware to expand the control capability of the *MOPO-HF* electronics unit to include those for the FDO.) The *MOPO-HF* and *MOPO-HF FDO* functions are accessed in the same manner.

Ten buttons are used for operating the *MOPO-HF/FDO* controller (Figure 6-1). Three buttons to the left of the display allow selection of the Operate1, Operate2, Service1, Setup1, Setup2, Remote, or Monitor1 menus. The Setup menus allow you to set scan parameters and choose various table algorithms for controlling the position of system crystals.

The five buttons on the bottom are "soft-keys." 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 (up/down buttons) to the right of the display either to change the numerical value inside a highlighted box on the display or to scroll through the various selections.

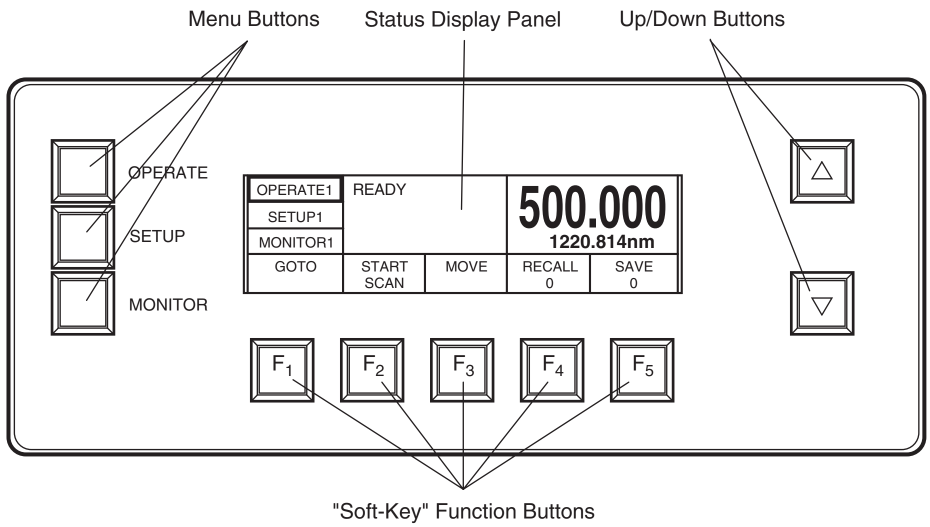


Figure 6-1: Initial configuration of the electronics panel

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

When operating the *MOPO-HF 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 (button) to select the type of operation to be performed, then use the up/down buttons 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 master oscillator (MO) crystal, you would first select the MO crystal as the device upon which to be operated (from the Setup2 menu which is covered later in this chapter), then select Y_DISP as the method. To do this, press the DEVICE button, F_1, to highlight it. Next, use the up/down keys to scroll to MO-CRYS. Finally, press the DEVICE button again and hold it in until it beeps to set the master oscillator crystal as the selected device. In the same manner, use the SSS process to select the Y_SHIFT function: press the METHOD button, F_2, to select it, then use the up/down buttons to scroll to the Y_SHIFT function, then set it by holding the METHOD button in until it beeps.

The MO-CRYS and the Y_SHIFT function will remain the active selections until you manually change it. Note that, although many procedures for the *MOPO-HF FDO* use the SSS process, not all require it. See "Setting Numeric Values" below.

Setting Numeric Values

The SSS procedure is not used with the Setup1 menu to set numeric values. Instead, press the function button whose value you want to change, then press that same button repeatedly to select the digit you wish to change (an underscore symbol moves under the digits) and use the up/down buttons to change the numerical value of that digit. Press the function button again to move to the next digit, etc. (the underscore rotates from left to right with each press). Do not press and hold the button to "set" it as outlined in the SSS procedure: the number is already "set." Note: you cannot set the BEGIN and END wavelength to a number outside the range allowed for the selected MODE (the SIGNAL, IDLER or FDO designated by the wavelength displayed in large digits). If by error you try to do so, the controller will beep and will not change the value of that digit. Make sure the wavelength settings desired matches the mode you selected earlier (via the OPERATE1 menu).

Please note: as the sole exception to the "setting numeric values" procedure, the GOTO function of the Operate1 menu requires that, after selecting the numeric value as outlined in this procedure, you "set" the value in order to initiate the goto function.

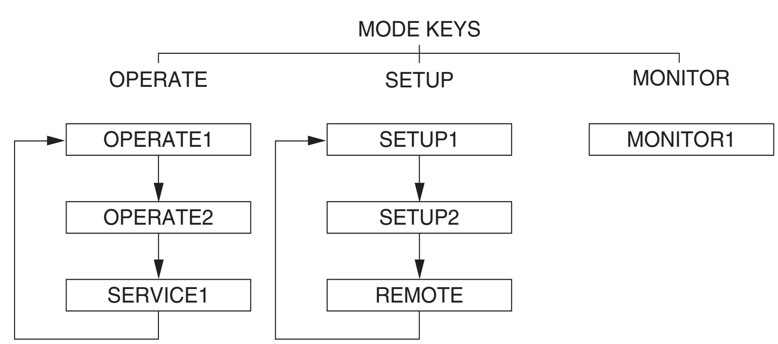
Powering Up the System

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 Operate1 menu is displayed. At this point, any of the menus listed below and shown in can be chosen.

The Menu Structure

The following is a description of the controller's layout and functions. The menus and commands that are necessary for operating the *MOPO-HF* are also listed here.

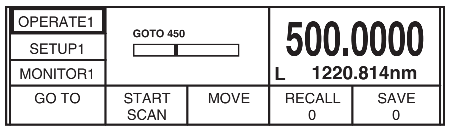
The illustration below shows the three mode buttons (the buttons to the left of the display) and the services that are available through them. The following sections give a brief description of the various menus that are displayed when these modes are selected and lists them in the order in which they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



A Brief Description

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

The Operate1 Menu (page 6-11): is displayed when the system is first turned on and any time the OPERATE button is pressed.



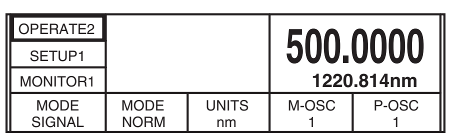
It displays:

- Signal (large) and idler (small) output wavelength if NORM is selected in the Operate2 menu, or
- Idler (large) and signal (small) output wavelength if IDLER is selected in the Operate2 menu, or
- *MOPO-HF FDO* (large) doubled output wavelength and *MOPO-HF* source wavelength (small) if FDO was selected in the Operate2 menu.
- The progression of the scan as a bar graph (left = start, right = done)
- The *MOPO-HF* mode setting: L = Track Lock

The function buttons allow initiation of:

- a GOTO: automatically goto a selected wavelength
- a SCAN: begin a scan from one wavelength to another
- a MOVE: manually move a selected wavelength using the up/down buttons
- a RECALL of the previous settings
- a SAVE of the present settings

The Operate2 Menu (page 6-13): is displayed when the OPERATE button is pressed once from the Operate1 menu.



It displays:

- Signal (large) and idler (small) output wavelength if SIGNAL is selected in the Operate2 menu, or
- Idler (large) and signal (small) output wavelength if IDLER is selected in the Operate2 menu, or
- *MOPO-HF FDO* (large) doubled output wavelength and *MOPO-HF* source wavelength (small) if FDO was selected in the Operate2 menu. Refer to your FDO user's manual for more information.

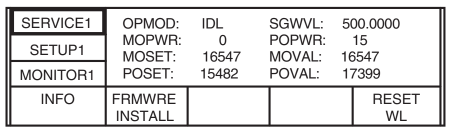
The function buttons allow you to set:

- the display and scan source. The following is displayed when set to:

Setting	Large Letters	Small Letters
SIGNAL	Signal	Idler
IDLER	Idler	Signal
FDO	FDO	Signal

- the display mode to NORM (6 digits) or MICRO (7 digits)
- the displayed wavelength units: either nm or cm^{-1}
- the master oscillator display gain: 1, 2, 4, 8, 16x
- the power oscillator display gain: 1, 2, 4, 8, 16x

The Service1 Menu (page 6-14): is displayed when the OPERATE button is pressed twice from the Operate1 menu.



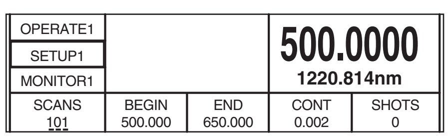
It displays:

- the *MOPO-HF* mode setting
- output wavelength
- master oscillator and power oscillator output power
- the relative set point and actual values for the MO crystal
- the relative set point and actual values for the PO crystal

The function buttons allow you to:

- display the system serial number, software version and track date
- update the operating system firmware (the PCMCIA card)
- causes the unit to perform a self-diagnostic reference check for wavelength/grating calibration

The Setup1 Menu (page 6-15): is displayed when the SETUP button is pressed.



It displays:

- Signal (large) and idler (small) output wavelength if SIGNAL is selected in the Operate 2 menu, or
- Idler (large) and signal (small) output wavelength if IDLER is selected in the Operate 2 menu, or
- *MOPO-HF FDO* (large) doubled output wavelength and *MOPO-HF* source wavelength (small) if FDO was selected in the Operate2 menu. Refer to your *MOPO-HF FDO User's Manual* for more information.

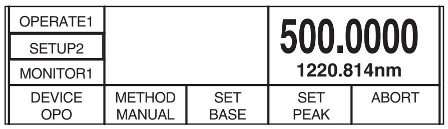
The function buttons provide a means to set up:

- the number of scans to be performed

- the starting and end wavelength for a SCAN
- the system for a CONTinuous scan at a user-defined rate or for an incremental scan with dwell points at user-defined pre-set wavelengths and a preset number of SHOTS given at each dwell.

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

The Setup2 Menu (page 6-17): is displayed when the SETUP button is pressed once from the Setup1 menu.



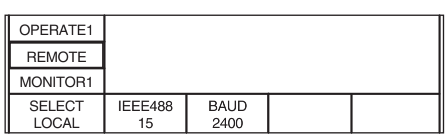
It displays:

- Signal (large) and idler (small) output wavelength if SIGNAL is selected in the Operate 2 menu, or
- Idler (large) and signal (small) output wavelength if IDLER is selected in the Operate 2 menu, or
- *MOPO-HF FDO* (large) doubled output wavelength and *MOPO-HF* source wavelength (small) if FDO was selected in the Operate2 menu. Refer to your *MOPO-HF FDO User's Manual* for more information.
- Once a device is selected and a table writing method is chosen, a second menu is displayed that shows master oscillator output power (PWR), requested power (SET) and crystal position (POS).

The function buttons provide a means to select:

- the device to set up: MO-CRYS, PO-CRYS, OPO or FDO. If FDO is selected, then several devices in the *MOPO-HF FDO* are available for display. Refer to your *MOPO-HF FDO User's Manual* for help in selecting FDO devices.
- the scan algorithm to be used for the selected device: MANUAL, Y_SHIFT, LIN_INT, LAGRANG, LSQ_MRG, MO_AUTO, or PO_AUTO.
- the base voltage for the noise filter (reference level)
- the peak voltage for the noise filter (optimum setting)

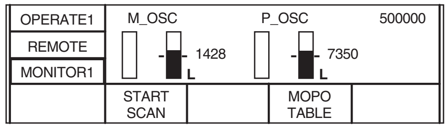
The Remote Menu (page 6-21): is displayed when the SETUP button is pressed two times from the Setup1 menu.



The function buttons allow you to select:

- the control source
  LOCAL: to return control to the *MOPO-HF* controller front panel
  RS-232: to provide a standard serial remote interface
  IEEE-488: a standard parallel remote interface
- the parallel interface port address: 1–32
- the serial interface baud rate: 300, 1200, 2400.

The Monitor1 Menu (page 6-23): is displayed whenever the MONITOR button is pressed.



It displays:

- the master oscillator power, numerically and graphically, and error tracking
- the power oscillator power, numerically and graphically, and error tracking
- the current chosen wavelength
- whether the *MOPO-HF* has been set to Track (L) mode or Table (no designator) mode

The function buttons allow you to:

- start, hold, resume and abort a scan
- set the *MOPO-HF* mode to: TRACK, TABLE, or TRK-TMO (track motor off)

The Operate1 Menu

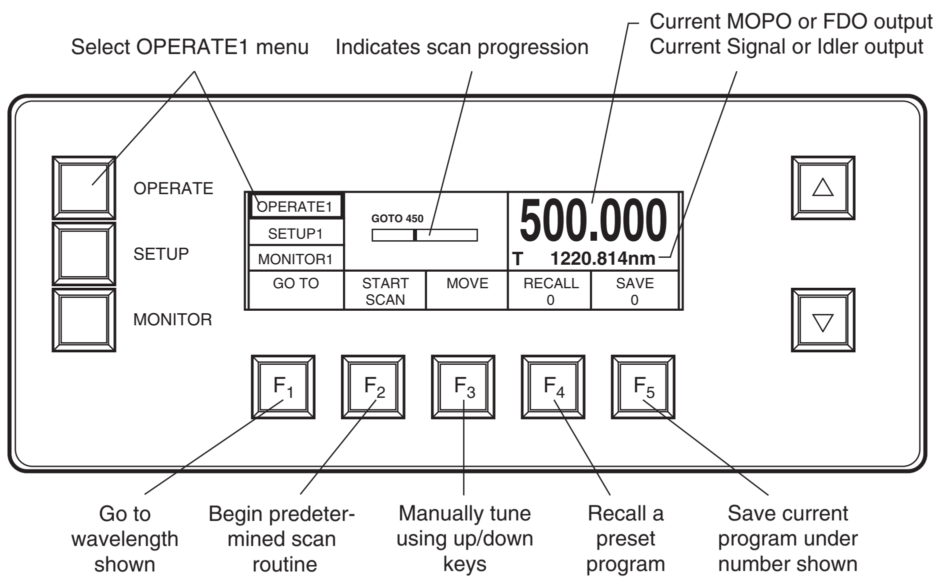


Figure 6-2: The Operate1 Menu

The Operate1 menu 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 Operate2 menu. A third push brings up the Service1 menu. Pushed one more time will return you to the Operate1 menu. This menu allows you to set the *MOPO-HF* wavelengths directly, to initiate 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:

When SIGNAL has been selected in the Operate2 menu, the large number in the upper right-hand box is the signal wavelength and the idler is the small number. If IDLER was selected, these numbers are reversed. If FDO was selected, the large number is the *MOPO-HF FDO* doubled wavelength and the small one is the signal.

The horizontal bar indicates the status of the current scan with "start" to the left and "end" to the right. This bar is displayed only when a scan is in progress.

An "L" in the right window denotes that *MOPO-HF* track mode is selected.

The Function Keys:

F_1: GOTO: XX—allows the operator to have the system automatically move to the wavelength displayed below GOTO. Press F_1 and use the "Setting Numeric Values" procedure on page 6-7 to set the wavelength value desired, then hold F_1 in until it beeps to initiate the operation. The *MOPO-HF* and *FDO* are automatically tuned for the proper signal, idler, or doubled 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 Setup1 menu. A scan is not allowed through the degeneracy range (between 345 and 366 nm).

F_3: MOVE: XX—allows you to tune the output wavelength manually using the up/down buttons. Simply select MOVE, then press the up or down button 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 *MOPO-HF FDO* needs to change the active crystal, there will be a pause while the proper crystal rotates into place.

F_4: RECALL: 0–19—recalls previously saved parameters, including the scan routine and the GOTO wavelength setting. Press the RECALL button, then use the up/down buttons to select the set of stored parameters you wish to use (0–19). Once chosen, hold the RECALL button in until it beeps to initiate the recall.

F_5: SAVE: 0–19—saves the SCAN settings and the GOTO wavelength setting. Press the SAVE button, then use the up/down buttons 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 Operate2 Menu

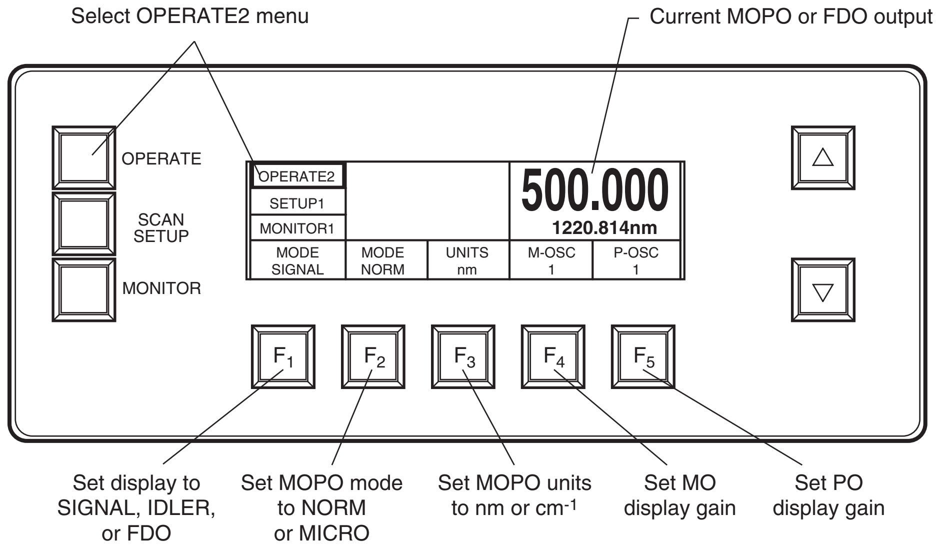


Figure 6-3: The Operate2 Menu

The Operate2 menu appears when the OPERATE button is pressed once from the Operate1 menu. This menu allows you to select the wavelength display format, set the display to normal (6 digits) or micro (7 digits), the wavelength display format (nm or cm^{-1}), and to independently set the display gain for the master and power oscillators (i.e., it increases the sensitivity of the bar graphs, it does not increase actual oscillator gain). The latter also amplifies the movement of the bar graphs in the Monitor1 menu.

Sometimes a higher display gain can be helpful, such as when calibrating the oscillator at a low-power wavelength. Lower resolutions are useful in most cases when simply monitoring system output and you want to see peak values. Available gain settings are 1, 2, 4, 8, or 16x. This feature is saved along with all other data when using the SAVE function from the Operate1 menu.

The Display:

When SIGNAL has been selected, the large number in the upper right-hand box is the signal wavelength and the idler is the small number. If IDLER is selected, these numbers are reversed. If FDO is selected, the large number is the *MOPO-HF FDO* doubled wavelength and the small one is the signal.

Under normal conditions, set the display to NORM. There are times, however, when more accuracy is required. In these cases, set the system to MICRO to display a 7th digit of accuracy.

For your convenience, you can have the display read wavelengths in nanometers (nm) or wavelength numbers (cm^{-1}).

The bar graph display gain can be set to 1, 2, 4, 8, or 16x, so that it is appropriate for the task. The current gain value for the MO and PO is displayed in the F_4 and F_5 button windows. A higher gain can be helpful, for example, when calibrating the oscillators at a low-power wavelength. Lower resolutions are useful in most cases when simply monitoring system output. This feature is saved along with all other data when using the SAVE function from the Operate1 menu.

The Function Keys:

F_1: MODE: SIGNAL/IDLER/FDO—allows you to select the wavelength display format.

Setting	Large Letters	Small Letters
SIGNAL	Signal	Idler
IDLER	Idler	Signal
FDO	FDO	Signal

F_2: MODE: NORM/MICRO—allows you to select a 6-digit (NORM) or 7-digit (MICRO) wavelength display format. The latter is used when more accuracy is required.

F_3: MODE: nm/cm^{-1}—allows you to set the wavelength display units as nm or cm^{-1}.

F_4: M_OSC: 1/2/4/8/16—allows you to set the display gain for the master oscillator to 1, 2, 4, 8, or 16 times to increase the sensitivity of the bar graphs.

F_5: P_OSC: 1/2/4/8/16—allows you to set the display gain for the power oscillator to 1, 2, 4, 8, or 16 times to increase the sensitivity of the bar graphs.

The Service1 Menu

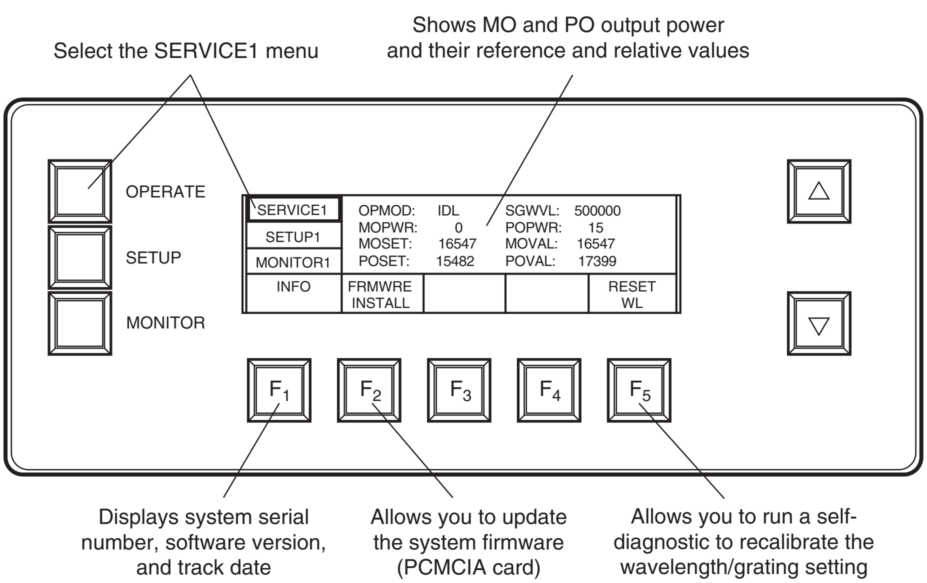


Figure 6-4: The Service1 Menu

The Service1 menu displays important status information regarding operation settings and system performance (refer to "The Display" below).

This menu allow you to identify your software revision number, which is required when determining whether or not to update the firmware and whenever you talk to your Spectra-Physics service representative.

The Display:

Displayed is the selected operating mode (OPMOD), the output wavelength (SGWVL), the master and power oscillator power (MOPWR and POPWR), and the setpoint and actual count value for both the master and power oscillators (MOSET/MOVAL and POSET/MPVAL). When the system is operating properly, the actual count should be fairly close to the setpoint value.

The Function Keys:

F_1: INFO—displays the software revision number.

F_2: FRMWRE: INSTALL—walks you through several steps that allow you to save your current table values while you update the system operating system. Use this function only *after* you have received a new PCMCIA card with the new operating system on it.

F_3: N/A

F_4: N/A

F_5: RESET: WL—performs a self-diagnostic reference check of the wavelength/grating calibration to look for gross calibration errors. Press this whenever you suspect a wavelength error (an error message is usually displayed on the screen).

The Setup1 Menu

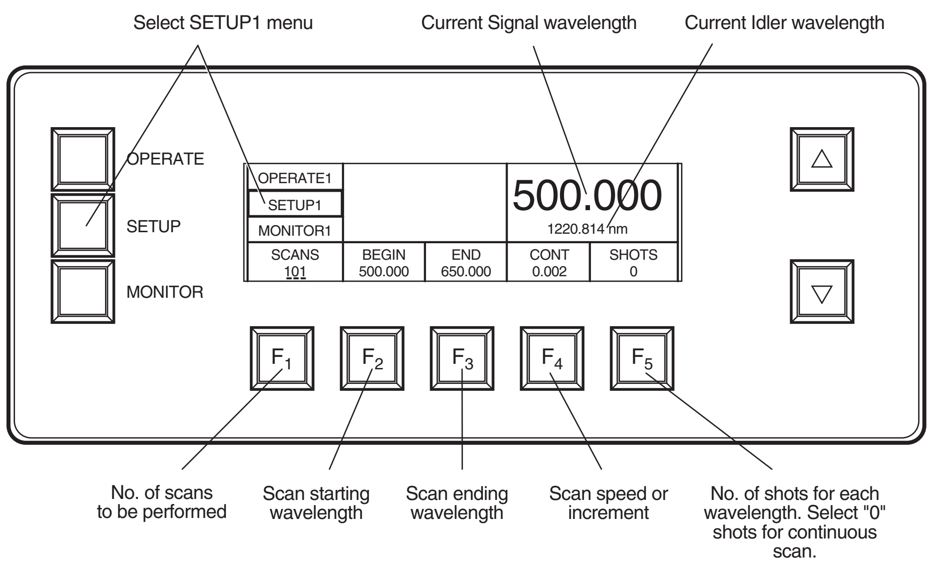


Figure 6-5: The Setup1 Menu

Press the SETUP button at any time to display this menu.

This menu allows you 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/s. 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, then moves 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.

The *MOPO-HF* scan rate is nonlinear because the it is dependent on the rotation of the *BBO* crystals and the beam angles, and beam angle vs. wavelength is a nonlinear function. The maximum scan rate is lower for scans in the blue end of the spectrum.

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

When present, a “DL” in the left window denotes the *MOPO-HF FDO* track mode is selected; “DT” denotes table mode is selected. An “L” in the right window denotes the *MOPO-HF* track mode is selected. No designation denotes *MOPO-HF* table mode is selected.

The SSS procedure is not used with this menu. Use the “Selecting Numeric Values” procedure on page 6-7 to set the various function values in this menu. Please note: you cannot set the BEGIN and END wavelength to a number outside the range allowed for the selected MODE (the SIGNAL, IDLER or FDO designated by the wavelength displayed in large digits). If by error you try to do so, the controller will beep and will not change the value of that digit. Make sure the wavelength settings desired matches the mode you selected earlier (via the OPERATE1 menu).

The Display:

When MODE: NORM has been selected in the Operate2 menu, the large number in the upper right-hand box is the signal wavelength and the idler is the small number. If IDLER is selected, these numbers are reversed. If FDO is selected, the large number is the *MOPO-HF FDO* doubled wavelength and the small one is the signal.

The Function buttons:

F_1: SCANS: XXX—sets the number of consecutive scans to be performed. Press this button to select it, then press it repeatedly to select the digit you wish to change and use the up/down buttons to set its numerical value. Press the button again to move to the next digit, etc.

F_2: BEGIN: XXXX—sets the beginning scan wavelength. The *MOPO-HF* beginning wavelength can be any number from 440 to < 1830 nm. The *MOPO-HF FDO* beginning wavelength can be any number from 220 to < 450 nm. Press this button to select it, then press it repeatedly to select the digit you wish to change and use the up/down buttons to set its numerical value. Press the button again to move to the next digit, etc.

F_3: END: XXXX—sets the end scan wavelength. The *MOPO-HF* end wavelength can be any number from > 440 to 1830 nm. The *MOPO-HF FDO* end wavelength can be any number from > 220 to 450 nm. Press this button to select it, then press it repeatedly to select the digit you wish to change and use the up/down buttons to set its numerical value. Press the button again to move to the next digit, etc.

F_4: INCR.—indicates the system 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 system 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: XX—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. Press this button to select it, then press it repeatedly to select the digit you wish to change and use the up/down buttons to set its numerical value. Press the button again to move to the next digit, etc.

The Setup2 Menu

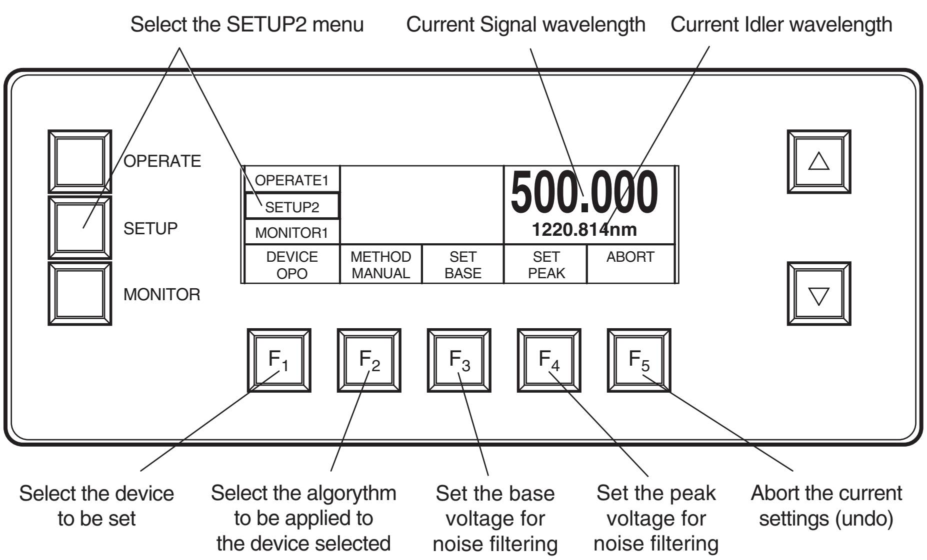


Figure 6-6: The Setup2 Menu

The Setup2 menu appears when the SETUP button is pressed twice. This menu allows you to manually manipulate the position of the MO or PO crystal separately by selecting MO or PO under F_1, or to operate them simultaneously by selecting OPO. You can also run one of seven table scan algorithms to optimize the position of the MO or PO crystal for best output power. Selecting the OPO_AUTO method under F_2 allows you to apply the same algorithm to both devices simultaneously. The values obtained during the scan are saved to the user table. The list of methods under F_2: METHOD below explain the differences between the various routines. "MOPO-HF Table-Writing Procedures" starting on page 6-27 explains how to select a method and write a user table.

From this menu, you can also set a base and peak value for the PO-PD (power oscillator pyrodetector) by selecting BASE or PEAK. Refer to the "Threshold Table-Writing Procedure" on page 6-31, for a description of how this works.

The Display:

Displayed are the current signal, idler, or *MOPO-HF FDO* wavelengths, depending on the MODE setting selected in the OPERATE2 menu.

The Function Keys:

F_1: DEVICE: MO_CRYS/PO_CRYS/OPO/FDO—selects the master oscillator (MO_CRYS) or power oscillator (PO_CRYS) individually or together (OPO), for the purpose of applying a scan algorithm to them. If FDO is selected, several devices in the *MOPO-HF FDO* are available for display. Refer to your *MOPO-HF FDO User's Manual* for help in selecting FDO devices. A device must be selected before you can select the table scan method you want to use (under F_2: METHOD below).

F_2: METHOD: XXXX—selects the scan algorithm to be applied to the selected device(s). In most cases, the chosen method will be used to create a user table to be used as a reference source.

The following describes each of the seven available selections:

MANUAL: allows you do perform what-if trials. You can manipulate the chosen DEVICE manually to see what happens. Once this method is chosen, a second menu appears with an ADJUST button. Press the ADJUST button, then use the up/down buttons to move the device and watch the results on the bar graph on-screen. When you are done, press the CONTinue button to return to normal operation. The current setting will not be saved and the device will return to its previous position.

Y_SHIFT: allows you to use the ADJUST button and the up/down buttons to shift up or down the entire data table associated with the selected device. This shift constitutes a single value point, yet the entire table is shifted by the same amount over the entire turning curve. This method is useful when you find something has shifted (an optic has moved slightly) and that a simple shift of all the points in the user table by a single value returns the system to optimal performance.

LIN_INT: performs a linear interpolation to find idealized (theoretical) values over a prescribed scan range (set up under the Setup1 menu). The beginning scan wavelength must be less than the ending wavelength, and, with regard to the *MOPO-HF FDO*, the wavelengths must be appropriate for the selected device.

This algorithm allows you to move the *MOPO-HF FDO* to the beginning and ending points for the scan range where you manually optimize beam power at each point. It then recomputes a theoretical curve between these points. This is an effective method for quickly optimizing small wavelength regions.

LAGRNG: (Lagrange) performs a curve-fitting algorithm over a large prescribed scan range (set up under the Setup1 menu). The beginning scan wavelength has to be less than the ending wavelength, and, with regard to the *MOPO-HF FDO*, the wavelengths must be appropriate for the selected device.

This algorithm cycles through 7 points within the scan range you specified, and it computes a higher order polynomial fitted curve to those points. 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. There is a minimum scan set-up range of 6 nm.

LSQ_MRQ: provides a least squares (Levenberg/Marquardt) fitting routine that includes values for 10 points. It is primarily intended for use with the *MOPO-HF FDO* PB prism to improve its pointing stability. You might have to experiment with this method and the LAGRANG method in order to determine the optimum curve fit for your application.

MO_AUTO: performs an automatic table-writing routine for the master oscillator based on the beginning and ending scan values set in the Setup1 menu. Starting with the beginning scan wavelength, the scan proceeds toward the ending wavelength, stopping every 1 nm along the way to sample the beam power. It then writes the best value to the table. This continues until the table is complete. This routine can take quite a while to run, depending on the size of the scan range. Please refer to the “Automatic Table-writing Procedure” on page 6-33 for a complete explanation of this method.

OPO_AUTO: performs an automatic table-writing routine for the power oscillator based on the beginning and ending scan values set in the Setup1 menu. If this routine detects that there is no similar table present for the master oscillator, it will create one for the MO as well. Starting with the beginning scan wavelength, the scan proceeds toward the ending wavelength, stopping every 1 nm along the way to sample the beam power. It then writes the best value to the table. This continues until the table is complete. This routine can take quite a while to run, depending on the size of the scan range. Please refer to the “Automatic Table-writing Procedure” on page 6-33 for a complete explanation of this method.

F_3: ADJUST—becomes available to allow activation of the appropriate adjustment environment once DEVICE and METHOD are selected. Displayed is the current device set point, the current device position, and the wavelength.

F_3: SET: BASE—allows you to run a routing that sets a base value for the PO-PD (refer to the “Threshold Table-Writing Procedure” on page 6-31). Once selected, the button display changes to ABORT to allow you to abort this process and keep the present value.

F_4: SET: PEAK—allows you to set a peak value for the PO-PD (refer to the "Threshold Table-Writing Procedure" on page 6-31). Once selected, the screen changes to show the master and power oscillator output as shown below. F_1 selects the master oscillator crystal and F_2 selects the power oscillator crystal for adjustment. F_4 moves the peak setting to the next 10 nm.

F_4: CONT—appears only after changing a table value and it allows you to continue on to the next point. Once all the values are entered for the selected method, the SAVE? button appears in this location so that you save the values you just entered. Neither the CONT nor SAVE? buttons appear when the MANUAL or MO_AUTO or OPO_AUTO methods are selected; all adjustments are only temporary when the MANUAL method is selected, and the movement between points, the calibration, and the final save are all automatic when the MO_AUTO or OPO_AUTO method is selected.

F_4: SAVE?—appears once all the values are entered for the selected table-writing method so that you can save these values in the user table. Neither the CONT nor SAVE? buttons appear when the MANUAL or MO_AUTO or OPO_AUTO methods are selected; all adjustments are only temporary when the MANUAL method is selected, and the movement between points, the calibration, and the final save are all automatic when the MO_AUTO or OPO_AUTO method is selected.

F_5: ABORT— appears if a change has been made to the menu (see the menu illustration under "Selecting a Table-Writing Method" below). A momentary press aborts the current action and returns you to the previous menu. Pressing the button until it beeps brings up the DELETE? key (see below).

F_5: DELETE?— appears only after ABORT has been pressed until it beeps. Caution! Pressing the DELETE? button until it beeps will delete the user-defined values for the selected device and will replace them with default theoretical values. A momentary press, on the other hand, unselects "delete" and returns you to the "abort" state.

The Remote Menu

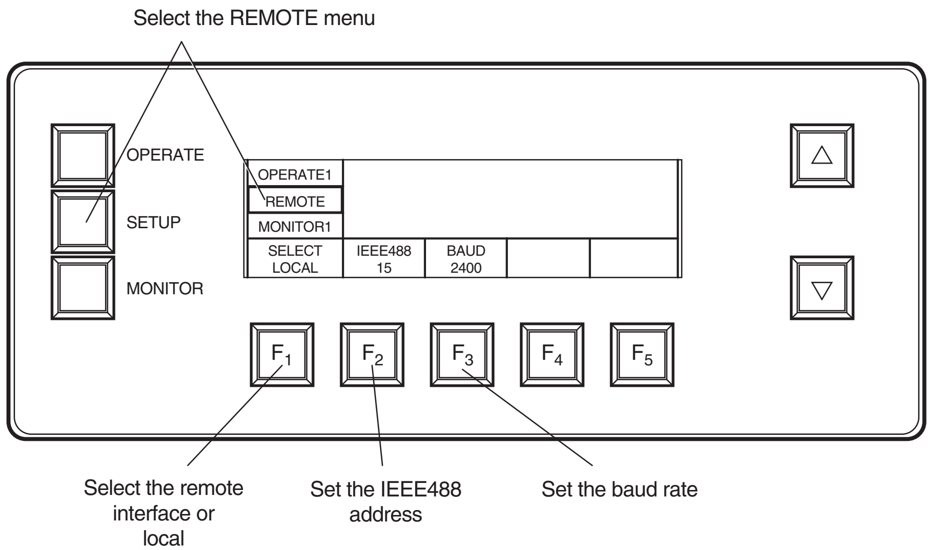


Figure 6-7: The Remote Menu

The Remote menu is accessed by pressing the SETUP button three times.

The Remote menu 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-HF 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.

Appendix B, “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 button 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 buttons 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, the Operator1 menu is displayed and LOCAL is displayed over F_5. Pressing F_5 returns the system to local operation (Figure 6-8).

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:

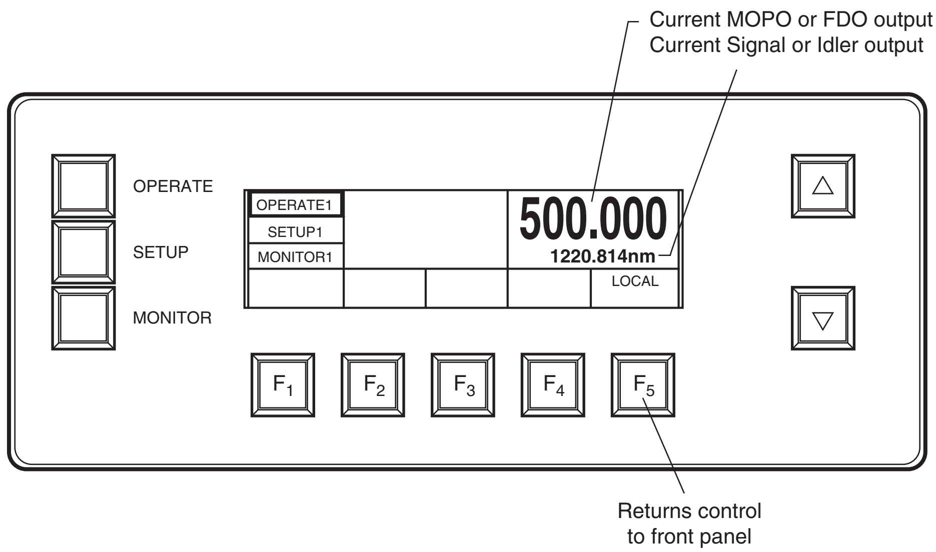


Figure 6-8: Returning Local Control to the System

1. Press F_2 to place the cursor under the digit to be changed.
2. Use the up/down buttons 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 buttons 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: IEEE-488/RS-232/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: 0–31—sets the address for the IEEE-488 parallel interface as shown in the display box. See “IEEE-488 Address Selection” above for information on changing this address.

F_3: BAUD: 300/1200/2400—sets the baud rate for the RS-232 serial interface as 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

The Monitor1 Menu

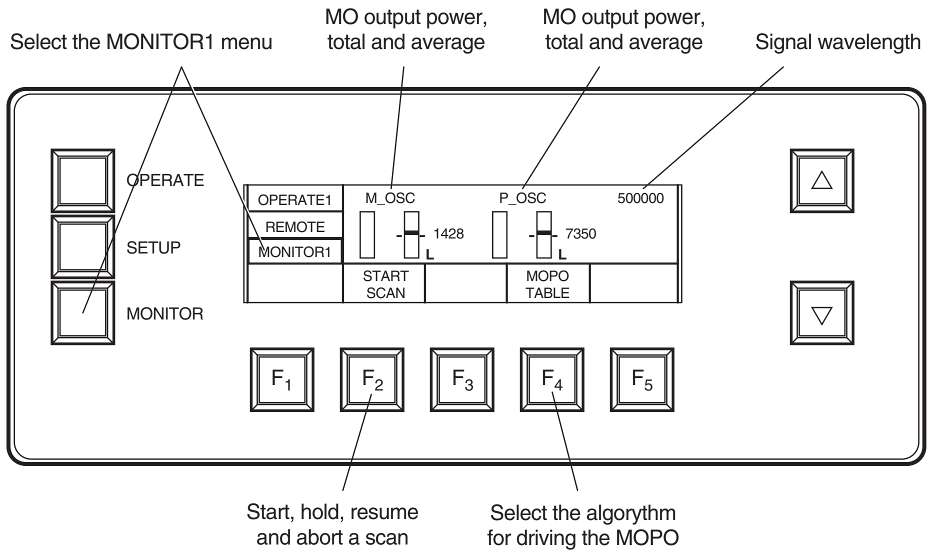


Figure 6-9: Monitor1 Menu

The Monitor1 menu is accessed by pressing the MONITOR button.

This menu provides a visual display of relative master and power oscillator output power, and the *MOPO-HF* 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 bar graphs can be increased up to 16 times via the Operation2 menu.

The Display:

The left-most bar graph expresses the master oscillator output power in relative terms of 0 to 100% of full power. The bar graph to its right shows the tracking error signal. This bar is ideally at the center of the graph, i.e., in its balanced position of minimum error signal. The number indicates a relative setting of the crystal angle. An "L" denotes track mode is selected.

To the right of these bar graphs is another set of bar graphs that indicate the output power and tracking error signal for the power oscillator. The number in the upper right-hand corner is the wavelength of the mode device selected from the Operate2 menu: SIGNAL, IDLER or FDO.

The Function Keys:

F_1: N/A

F_2: START SCAN—allows you to start a scan, then stop it (HOLD), resume it or abort it.

F_3: N/A

F_4: MOPO: TRACK/TABLE/TRK-TMO—selects the *MOPO-HF* operating mode: TRACK, TABLE, and TRK-TMO (track with motor off). The latter turns off the motor to reduce noise.

F_5: N/A

Switching Between MOPO and FDO Operation

Switching from MOPO to FDO Operation

1. Set system mode to FDO.
   a. From the Service1 menu, press the MODE button, then use the up/down buttons to select FDO.
   b. Press the MODE button until it beeps to activate this selection.
2. Set the *PRO-Series* controller to Q-SWITCH OFF.
3. Install the *MOPO-HF 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.

4. Set the *PRO-Series* controller to RUN NORMAL.
5. Once the *MOPO-HF* is operating, check the FDO UV output power. If UV output is at full power, the *MOPO-HF FDO* is ready to operate.

   If UV power is low, try increasing it by slightly adjusting TP_1. The vertical axis is most sensitive.

This completes the conversion from *MOPO-HF* to *MOPO-HF FDO* output operation.

Switching from FDO to MOPO Operation

1. Set the *PRO-Series* controller to Q-SWITCH OFF.
2. Move the FDO TP_1 turning prism from its normal position to its parked position near the crystal and PB prism turntables.
3. Set system mode to SIGNAL or IDLER, depending on the wavelength at which you will be working.
   a. From the Service1 menu, press the MODE button, then use the up/down buttons to select SIGNAL or IDLER.
   b. Press the MODE button until it beeps to activate this selection.
4. Set the *PRO-Series* controller to RUN NORMAL.

This completes the conversion from *MOPO-HF FDO* to *MOPO-HF* output operation.

Running a Scan

Figure 6-10 shows a scan being initiated from the Operate1 menu, and the following procedure explains how to perform a scan.

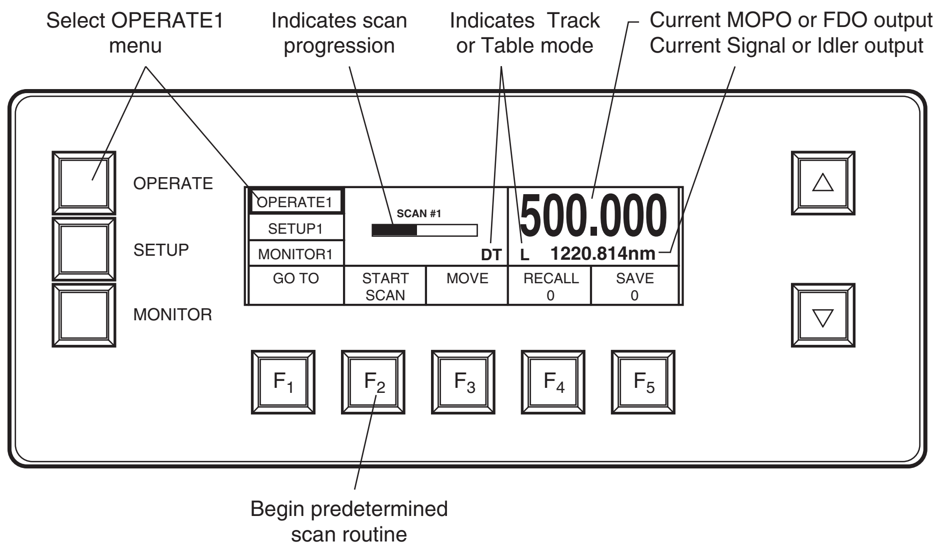


Figure 6-10: Initiating a Scan

1. Set the system set to TRACK mode.

   TRACK is selected via the Monitor1 menu. When TRACK mode is selected, an “L” is displayed in the lower right portion of the Operate1 menu.

2. Select SIGNAL, IDLER or FDO from the Operate2 menu for the desired output wavelengths.
3. From the Setup1 menu, set the scan BEGIN and END wavelengths.
   a. Press the BEGIN button, then use the procedure outlined under “Setting Numeric Values” on page 6-7 to set the BEGIN wavelength value.
   b. Press the END button, then do the same to enter the end wavelength value.
4. Set the number of scans desired.

   Press the SCANS button, then use the same procedure to set the number of scans desired.

5. 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/s.
6. If an incremental scan was selected in the previous step, set INCR to the number of nanometers desired between dwells.
7. Press the OPERATE button to return to the Operate1 menu.
8. Press the START SCAN button to begin the scan process.

   When the scan process begins, the Operate1 menu changes to indicate the progress of the scan (refer to Figure 6-11) and to provide you control of the scan as it progresses. A horizontal bar graph displays the percentage of scan completed, and the wavelength display shows the progress of the signal or idler output or, if MODE in the Operate2 menu is set to FDO, the doubled signal or idler output.

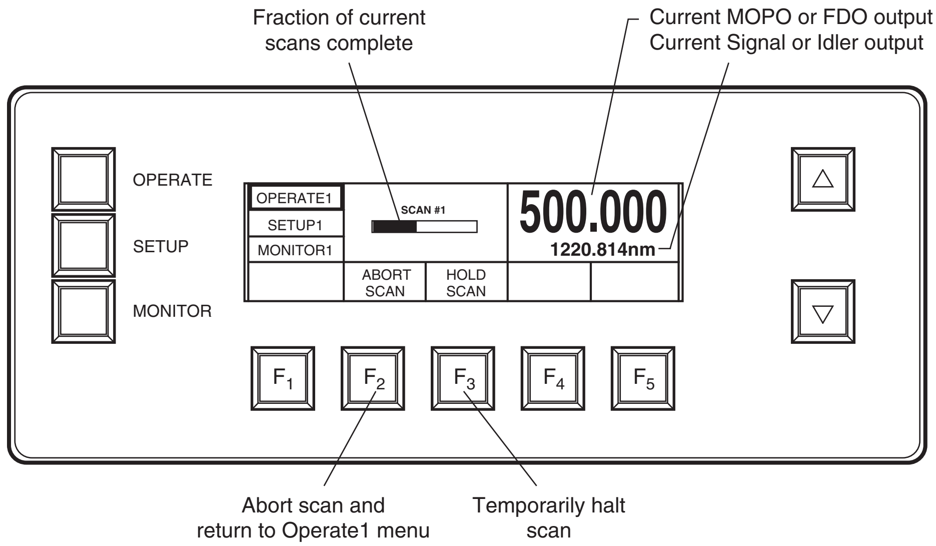


Figure 6-11: Scan in Progress

9. If you wish to pause the scan, press the HOLD SCAN button. To resume the scan, press the RESUME SCAN button.
10. If you wish to abort the scan altogether, press the ABORT SCAN button. You will be returned to the Operate1 menu.

When the scan completes, the system moves back to the starting wavelength and returns to the Operate1 menu. If you aborted the scan, the system will remain where is was when you pressed it.

Operating at Fixed Wavelengths

1. Set the system for track mode.

   If track mode is already selected (an “L” is displayed in the Operate1 menu), skip to the next step.

   a. From the Monitor1 menu, press the MOPO button, then use the up/down buttons to select TRACK.

   b. Hold in the MOPO button until it beeps to activate the TRACK setting.

2. Go to the desired starting wavelength.

   a. From the Operate1 menu, press the GOTO button, then use “Setting Numeric Values” procedure on page 6-7 to set the GOTO wavelength value.

   b. Hold in the GOTO button until it beeps to move the system to the chosen wavelength.

3. If output power does not appear optimized, i.e., the system is not locked (the “L” is not present on the display), use MANUAL or Y-DISP from the Setup2 menu to optimize output power. Remember, MANUAL does not save the values upon exiting that menu.

MOPO Table-Writing Procedures

Please read this entire section on table-writing procedure before you write a table for the first time.

For the *MOPO-HF* to operate properly, accurate "look-up" tables must be implemented. These tables are used to position the master and power oscillator crystals and other *MOPO-HF FDO* devices at angles necessary for optimal operation at every wavelength.

Your system was shipped from the factory with two tables: a non-volatile theoretical table and a factory-calibrated user table that was created during system test just prior to shipment. The theoretical table is provided as a backup that can be retrieved to rewrite the user table when there has been a loss of user table data, data corruption has occurred, a grating re-calibration has been completed, or there has been a movement or realignment of either or both of the crystals, i.e., when the current values no longer match your system and you cannot get your system running. Because only the user table can be "active," its values must be replaced with those from the theoretical table in order to use the latter.

The "General Table-Writing Procedure" below describes a typical table-writing routine and explains what you can expect from each table-writing method. The next two sections, "Reloading Default Table Values" and "Re-establishing User-Defined Tables" are special sections designed to get you out of trouble if your user table no longer matches your system (an optic was moved or realigned). These two sections plus the sections that follow them, the "Lagrangian Table-Writing Procedure" and "Automatic Table-writing Procedure," get you back up and running. The latter two sections, especially the "Automatic Table-writing Procedure," are the only routines normally used for day-to-day operation.

The "Reloading Default Table Values" procedure assumes the worst, that your table values are corrupted or that your system was so altered that it no longer matches your table values. This procedure will re-load the theoretical values into the user table and give you a starting point. *Please note, all your previous user values will be deleted if you perform this routine!*

The procedure for "Re-establishing User-Defined Tables" goes a step further, moving from general theoretical values to creating values that more closely reflect your system's alignment. It does this by establishing appropriate begin and end scan points, then runs a linear interpolation routine while performing a scan to establish realistic points on a theoretical curve. These values are then saved as the new user table.

The "Lagrangian Table-Writing Procedure" then refines these values, and the "Automatic Table-writing Procedure" fills in all the rest of the points. The latter runs an automatic table-writing routine that is based on the begin and end wavelength values you set for a scan, e.g., 440 and 690 nm if you performed the previous three procedures or, if you are using this procedure during normal operation, any other values you choose for a narrower area of interest. The scan stops and samples beam power every 1 nm then writes the best value to the table. It then moves on to the next nm until the entire scan is complete. This routine can take quite a while to run, depending on the size of the scan range.

For normal day-to-day operation, only use the "Automatic Table-writing Procedure." This will keep your user table optimized and up-to-date.

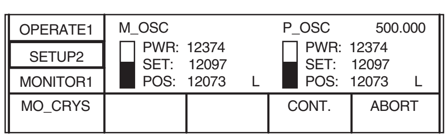
General Table-Writing Procedure

First, verity the system is in track mode, then select a device for which you want to write a set of user table values, then select the table-writing method you want to use. Although counter intuitive, selecting track mode instead of table mode when writing a table allows the system to automatically peak (track) performance for each value point.

1. Set the system to track mode.
   a. From the Monitor1 menu, press the MOPO button, then use the up/down buttons to scroll to TRACK.
   b. Press and hold the MOPO button until it beeps to activate your selection.
2. Select the device for which you will write a table.
   a. From the Setup2 menu, press the DEVICE button, then use the up/down buttons to scroll to the desired device.

      Note: If the FDO is present, several *MOPO-HF FDO* devices will also be available from which to choose. Refer to your *MOPO-HF FDO User's Manual* for help in selecting FDO devices.
   b. Press and hold in the DEVICE button until it beeps to activate your selection.
3. Select a table writing method.
   a. Press the METHOD button, then use the up/down buttons to scroll to the method you want to use. Refer to the descriptions of table-writing methods that start on page 6-18.
   b. Press and hold the METHOD button until it beeps to activate this selection.

When the METHOD button beeps, the menu shown below is displayed and the table-writing routine begins. Displayed are MO and PO output power (PWR), requested power (SET) and crystal position (POS). The "L" denotes the selected device is properly set to track mode; when absent, it is set to table mode. The number in the upper right-hand corner is the current wavelength for which a value is being computed. The wavelength range depends on the mode selected (SIGNAL, IDLER or FDO) from the Operate2 menu.



Your choices in the next steps depend on the table-writing method chosen, e.g., Y_SHIFT has only 1 value point, LIN_INT has 2, LAGRANG has 7 and LSQ_MRG has 10. MO-AUTO automatically determines a value for every 1 nm between the chosen beginning and ending scan points. MANUAL does not let you save values at all, but is used to perform "what if" trials.

If not already at the begin scan point, the system will move there first. Once at the begin scan point (note the wavelength shown on the menu screen), use the up/down buttons to modify the position of the selected crystal (except for OPO_AUTO which does this automatically). As the crystal moves, the bar graph showing the detected beam power moves upward as the system approaches the optimal position for highest power and downward when moving away from the ideal crystal position.

4. Optimize the crystal position at each value point.
   a. Use the up/down buttons to optimize the crystal position, then press the CONT button to write the corresponding position value to a temporary user table and to move the crystal to the next wavelength point for that table-writing method.
   b. In like manner, continue to optimize the position of the crystal at each point until all points for that method have position values.
   c. When the last value is written, the CONT button changes to SAVE? To save the values just obtained to the user table, press and hold the SAVE? button until it beeps. If you decide not to save these values, press the ABORT button (a momentary press) to allow the previous values to remain active.
5. If, before or after the table is written, you instead decide to start from scratch and load the theoretical values (*this will delete all your user values*), refer to "Reloading the Theoretical Table Values" below for instructions, otherwise, skip to the "Lagrangian Table-Writing Procedure" to continue enhancing your new table.

Reloading the Theoretical Table Values

Caution!

If tables have been previously written for the system, *this procedure will delete them!* Perform this procedure only if a prior table has *NOT* been written or if the current table is no longer valid (e.g., there has been a loss of table data, data corruption has occurred, a grating re-calibration has been completed, or there has been a movement or realignment of the crystals).

To load the theoretical factory values for a fresh start, perform the following (note—these are *not* the values originally shipped with your system):

1. Before you begin, the master oscillator should be well aligned and capable of oscillation (see Chapter 5, "Installation and Alignment").
2. Set the system to table mode.
   a. From the Monitor1 menu, press the MOPO button, then use the up/down buttons to scroll to TABLE.
   b. Press and hold the MOPO button until it beeps to activate your selection.
3. Set DEVICE to MO_CRYS.
   a. From the Setup2 menu, press the DEVICE button, then use the up/down buttons to scroll to MO_CRYS.

b. Press and hold the DEVICE button until it beeps.

4. Delete the existing tables.
   a. Press the METHOD button to select it, then press it again and hold it in until it beeps.
   b. Press and hold the ABORT button until it beeps.
   c. "DELETE?" should appear in the ABORT button box.
   d. Press and hold the DELETE button until it beeps.

   The user-defined tables are deleted and the theoretical tables are loaded and become active. *If you have second thoughts about deleting the current user table values, a* ***quick*** *press of the* DELETE? *button takes you back to the* ABORT *button, which allows you to retain the user table values.*

5. Perform the "Re-establishing User-Defined Tables" procedure below.

Re-establishing User-Defined Tables

Perform this procedure after you have reloaded the theoretical table values using the previous procedure.

1. Set the begin and end wavelength scan values to 460 and 660 nm.

   From the Setup1 menu, use the method described under "Setting Numeric Values" on page 6-7 to enter the begin and end wavelength scan values (F_2 and F_3).

2. Select the MO crystal for optimization.
   a. From the Setup2 menu, select the DEVICE button, then use the up/down buttons to scroll to MO_CRYS.
   b. Press and hold the DEVICE button until it beeps to activate your selection.
3. Select the linear interpolation method to write this table.
   a. Press the METHOD button, then use the up/down buttons to scroll to LIN-INT.
   b. Press the METHOD button until it beeps to activate the selection and to move the system to the begin wavelength.
4. With the system at the begin wavelength, watch the bar graph and use the up/down buttons to optimize oscillation at that point.
5. Press CONT. to move the system to the end wavelength.
6. Upon arriving at the end wavelength, watch the bar graph and use the up/down buttons to optimize oscillation.
7. Once optimized, press CONT. until it beeps.
8. Press SAVE? until it beeps.
9. Repeat this procedure for the PO crystal, starting at Step 2.

This sets two of the main values required to generate a new table. We will now write the base table for the entire tuning range, from 440 to 690 nm.

10. Perform the "Lagrangian Table-Writing Procedure" below.

Lagrangian Table-Writing Procedure

If oscillation of the master oscillator is not observed at 440 and/or 690 nm, use the following Lagrangian curve-fitting routine to “refine” the tables.

1. From the Setup1 menu, verify that 460 nm and 660 nm are entered for the BEGIN and END wavelength scan values.

   From the Setup1 menu, use the “Setting Numeric Values” procedure on page 6-7 to set the BEGIN and END wavelength values.
2. Select the MO crystal for optimization.
   a. From the Setup2 menu, press the DEVICE button, then use the up/down buttons to scroll to MO_CRYS.
   b. Press and hold the DEVICE button until it beeps to activate your selection.
3. Select the Lagrangian table writing method and move the system to the begin wavelength.
   a. Press the METHOD button and use the up/down buttons to scroll to LGRNG.
   b. Press the METHOD button until it beeps to to activate your selection and to move the system to the begin wavelength.
4. While watching the bar graph on the monitor, use the up/down buttons to maximize the output level for that value point.
5. Press the CONT. button to proceed to the next wavelength value.
6. Repeat the previous two steps to optimize each of the seven points in the scan range.
7. After the final point has been written, press the CONT. button again.
8. Press the SAVE? button until it beeps.

   Make sure you perform this step to save the table values you just entered.
9. Repeat this procedure for the PO crystal, starting at Step 2.

This completes the Lagrangian table-writing procedure. Now perform the “Threshold” Table-Writing Procedure” below followed by the “Automatic Table-writing Procedure” to complete this process.

Threshold Table-Writing Procedure

In the power oscillator, it is necessary for the servo system to be able to discriminate between an increase in signal due to noise or a fortuitous “bump” in the tuning curve (a false increase) and an increase that is due to seeded operation (a true increase). This challenge, which is caused by the system oscillating when unseeded, is addressed by using a “threshold” table. Signal increases that are above the threshold value are interpreted as “real” and the servo system is activated in order to find the peak. Signal levels below the threshold value are treated as “noise” and the system ignores them and the servo system remains inactive. For the master oscillator, the threshold serves to discriminate primarily between noise and oscillation signals.

Toward the red end of the spectrum the MO detector may register small leakage signals from the power oscillator that must also be detected and discriminated against.

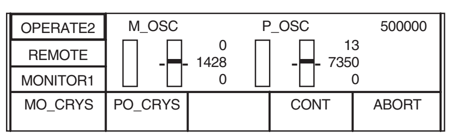
The system calculates the threshold using the following procedure. First, a baseline is created by recording the signal levels of the MO and PO detectors over the entire wavelength range, provided the MO is not oscillating. Second, a routine is run that allows the MO and PO to oscillate and they are independently optimized. These optimized values are stored in a "peak table" for various wavelengths over the entire tuning range. The threshold is calculated by taking a fixed percentage of the peak-baseline difference and adding that to the baseline value.

1. Set the system to track mode.
   a. From the Monitor1 menu, press the MOPO button, then use the up/down buttons to scroll to TRACK.
   b. Press and hold the MOPO button until it beeps to activate your selection.
2. From the Setup1 menu, set the begin and end scan wavelengths to the desired range, e.g., 450–690 nm.

   From the Operate1 menu, use "Setting Numeric Values" procedure on page 6-7 to set the BEGIN and END wavelength values.
3. Run the base line routine.

   From the Setup2 menu, press and hold the SET: BASE button until it beeps. This allows the routine to run until it is complete.
4. When the base line routine is finished, run the peaking routine.
   a. Press and hold the SET: PEAK button until it beeps.

   The following menu appears:



   b. Press the CONT. button at each "query" wavelength to move to the next wavelength.

   If the tables are accurate and tracking is active, the system should optimize the MO and PO crystal positions at each wavelength.
   c. After the CONT. button is pressed at 690 nm, a SAVE? button should appear.
   d. Press the SAVE? button until it beeps to save the settings.

If either the MO or PO crystal positions are not optimized, complete the rest of this procedure. If they appear optimized, you are done writing the threshold procedure and should continue with the "Automatic Table-Writing Procedure" below.

5. Set the system to table mode.
   a. From the Monitor1 menu, press the MOPO button, then use the up/down buttons to scroll to TABLE.

b. Press and hold the MOPO button until it beeps to activate your selection.

6. Press and hold the SET: PEAK button until it beeps to re-enter the peaking routine.
7. Press the CONT. button to go to the wavelength(s) for which the system does not appear optimized and independently optimize the position of the master and power oscillator crystals.
   a. Press MO-CRYS, then use the up/down buttons to optimize the output of the MO.
   b. Do the same for the PO-CRYS.
   c. Press the CONT. button to move to the next wavelength.
   d. Repeat until you are satisfied all the table points are optimized for both the MO and PO.
   e. When the SAVE? button appears at the end of the procedure, press it until it beeps to save these new values.

Note The best way to confirm you have seeded operation is to see if the *MOPO-HF* output drops when MO oscillation is terminated. Alternatively, the PO may be converted to an OPA to confirm wavelength overlap (refer to Chapter 5, "Installation and Alignment").

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8. Set the system for a wavelength scan range of 450 to 690 nm.

   From the Setup1 menu, use the method described under "Setting Numeric Values" on page 6-7 to enter the begin and end wavelength scan values (F_2 and F_3).
9. Run the automatic table-writing routine (refer to the next section).

   Note: if the table-writing procedure fails, do the following:
   a. Write a Lagrangian table (refer to the "Lagrangian Table-Writing Procedure" on page 6-31).
   b. Write a threshold table (refer to the "Threshold Table-Writing Procedure" on page 6-31).
   c. Rerun the automatic table-writing routine (see below).

Automatic Table-Writing Procedure

The automatic procedure is designed to minimize the amount of time a user is required to spend writing tables. It writes the master and power oscillator tables over an arbitrary scan range. To be successful, the current table must be close enough to optimal values in order for the search routines to find the appropriate "peak" signals.

Use this procedure whenever you need to update the MO and PO tables over a short scan range because they have either been realigned or one or both of the tables has drifted slightly.

To perform the OPO_AUTO automatic table-writing process (which includes both the MO and PO tables):

1. Verify the system is set to track mode.
   a. If necessary, from the Monitor1 menu, press the MOPO button, then use the up/down buttons to scroll to TRACK.
   b. Press and hold the MOPO button until it beeps to activate your selection.
2. From the Setup1 menu, verify that 440 and 690 nm are entered for the begin and end wavelength scan values (if you have performed the previous three procedures), or set them to the scan range of interest.

   This routine can take quite a while to run, depending on the size of the scan range.
3. Set DEVICE to OPO.
   a. From the Setup2 menu, press the DEVICE button, then use the up/down buttons to scroll to OPO.
   b. Press and hold the DEVICE button until it beeps to activate your selection.
4. Select the OPO_AUTO method to write this table.
   a. Press the METHOD button, then use the up/down buttons to scroll to OPO_AUTO.
   b. Press the METHOD button until it beeps to activate the selection and to move the system to the begin wavelength.

   A menu will appear that displays TRACK CALIB, and the automatic table-writing routine will begin.

   Upon completion, a message is displayed that indicates "calibration successful," the ending wavelength and that the data was saved. If the calibration is unsuccessful, the message will say "calibration unsuccessful," the wavelength at which the auto calibration routine stopped and that the data *up to that point* was saved.

   The auto routine aborts when there is not enough light to make a solid measurement. To continue the table-writing routine, you need to bring the system back within parameters for automatic table-writing. To do so, make the end wavelength the beginning point of a new scan (the end point remains the same as before), then run the "Lagrangian Table-writing Procedure" on page 6-31 to get the system back within the required parameters for automatic table-writing. Once this procedure is complete, re-run this automatic table-writing routine using the same scan setup that was used for the Lagrange routine.

This completes the automatic table-writing procedure.

Chapter 7 Maintenance

Preventative Maintenance

- The *MOPO-HF* top cover protects the internal components from outside contamination and prevents unwanted stray optical radiation from escaping the system.
- The *MOPO-HF* should always be operated with the top cover in place.
- Inspect daily all windows for contamination or damage. Windows should be cleaned with spectroscopic or electronic-grade methanol or acetone and lens tissue any time contamination is suspected or observed. Damaged windows should be immediately replaced.
- It is recommended the user annually check the safety features of the pump laser as well as the *MOPO-HF* optics to ensure safety is maintained (see Chapter 2, “Laser Safety,” for details).

Cleaning of Laser Optics

Losses due to unclean optics, which might be negligible in ordinary optical systems, can disable a laser. 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 term as nothing is ever perfectly clean; nor do cleaning operations ever completely remove contaminants. Cleaning is a process of reducing objectionable material to an acceptable level.

Since cleaning simply dilutes contamination to the limit set by solvent impurities, solvents must be as pure as possible. Use spectroscopic or electronic-grate 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 re-wiping a surface with the same swab; a used swab and solvent will redistribute contamination, it 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 small 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 0.01 nm, 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 and use finger cots when handling optics. Body oils and contaminants can render otherwise fastidious cleaning practices useless.
- Use dry nitrogen or a rubber squeeze bulb to blow dust or lint from the optic surface before cleaning it with solvent. Permanent damage may occur if dust scratches the glass or coating.
- Use spectroscope or electronic-grade solvents. Do not try to remove contamination with a cleaning solvent that may leave other impurities behind.
- Use photographic lens tissue to clean optics. Use each piece only once: a dirty tissue merely redistributes contamination.

Cleaning Optical Components

Warning! *Do not clean the crystals or the grating with solvent! This will damage them! Only use air!* Damage caused by cleaning is not covered by your warranty!

Equipment Required

- Dry nitrogen or rubber squeeze bulb
- Photographic lens tissue
- Spectroscopic or electronic- grade methanol
- Forceps
- Hemostat

Cleaning Prisms and Mirrors

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 (see Figure 7-1). Saturate the pad with methanol, shake off the excess, resaturate and shake again.

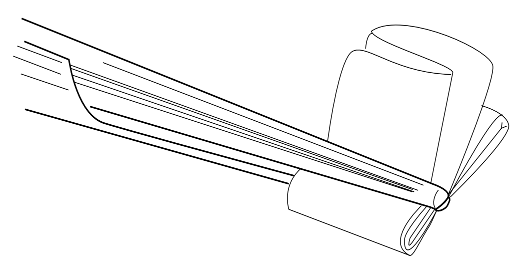

Figure 7-1: Lens Tissue Folded for Cleaning

3. Wipe one surface—bottom to top—in a single motion. Be careful that the tip of the hemostat does not scratch the surface.
4. Repeat this operation with a clean tissue on the second optic surface.

   Note: a clean optical surface will scatter little or no light when the laser is operating.
5. Install the optical assembly back into its base and adjust the mirror vertically and horizontally for maximum optical output power.

This completes the optical cleaning procedure.

Chapter 8 Service and Repair

Danger!
Laser Radiation

The Quanta-Ray *MOPO-HF* is a *Class IV—High Power Laser Product* whose beam is, by definition, a safety and fire hazard. Take precautions to prevent 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 when working on the laser and follow the safety precautions in Chapter 2, “Laser Safety.”

Troubleshooting Guide

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, please call your local service representative. A list of world-wide service sites is included at the end of Chapter 9, “Customer Service.”

This guide is divided into two parts, and each has two columns. In Part 1, the left column lists the various symptoms that might occur while using the system. On the right are the related possible causes of the symptom. In Part 2 (beginning on page 8-3), the causes are listed on the left and their corrective actions are on the right. In general, find the symptom first, then refer to its possible causes. Some corrections will be obvious. For those that are not obvious, refer to causes listed in Part 2 and note the corrective action(s) listed there. These lists are prioritized. Start at the top and work down.

Part 1

Symptom	Cause
No output from the MOPO-HF	Low pump power. Motor mike is at the end of its range. Damaged optics. Damaged crystal.
Low output power from the MOPO-HF	Low pump power. Master oscillator is not seeding the power oscillator. Power oscillator seeding is not optimized. Master oscillator is not operating. Master oscillator is not locking. Pump beam pointing is unstable. Optical misalignment due to temperature changes (i.e., room temperature changes, heat source under optical table etc.). Damaged optics. Damaged crystal. Dirty/contaminated windows.
Master oscillator is not operating	PRO-Series seeder is off. PRO-Series seeding is unstable. Master oscillator is not optimally seeding the power oscillator. The crystal surface is perpendicular to the pump beam. Damaged optics. Damaged crystal.
Output wavelength does not match display wavelength	Electronic “glitch” or error. Loose cabling. Electronics may be in MANUAL mode. Electronic component failure. Loose sine-drive mechanism. Unit out of calibration.
Poor mode quality	PRO-Series pump beam is misaligned. Master oscillator seed beam is misaligned. Poor Pro-series pump mode. Damaged optics. Damaged crystal. Harmonic generator is detuned. Power oscillator is misaligned.
Low doubling efficiency	Harmonic generation crystal is oriented to the wrong angle with respect to input polarization. Divergence of MOPO-HF output beam is not set properly. Output linewidth from MOPO-HF is too broad.

Symptom	Cause
Amplitude instability	PRO-Series pump source is unstable. Master oscillator seed beam is misaligned. Master oscillator output power is low. Master oscillator output is unstable. Power oscillator crystal angel is not optimized. There is excessive dither amplitude.
Master oscillator is not locking	Master oscillator output power is low. Master oscillator is not operating. Insufficient signal level on the MO detector. Unit is in INT mode instead of EXT mode.
Master oscillator is not locking	M-mike is in TABLE mode instead of TRACK mode. Controller is in HOLD mode.
"Wavelength Calibration Error" appears on control box display	Electronics "glitch" or software error. Loose cabling. An electronic component failed. Mechanical looseness in the sine-drive mechanism. Linear potentiometer is displaced greater than ¼ in. from an integral number of turns from the sine-bar reference point.
Wavelength does not change during a scan	Controller is in MANUAL mode. Motor mike has failed. Electronics "glitch" or error. Parasitic oscillation is present in master oscillator.
Controller display is "frozen" (it does not change as expected)	Q-switch trigger is absent. Electronics error occurred.
Divergent mode	Power oscillator high reflector (PO-BBHR) position is not optimized. Parasitic oscillation is present.

Part 2

Cause of Symptom	Corrective Action
Damage crystal and or optics.	Replace the damaged crystal or optic and realign the system as described in Chapter 5, "Installation and Alignment".
Electronics "glitch" or error.	Turn off the MOPO-HF controller, wait three seconds, then turn it back on.
Electronic component failed.	Identify the failed component and replace it or send the controller back to the factory for repair.
PRO-Series pump beam is misaligned.	Re-align the pump beam as described in Chapter 5, "Installation and Alignment."
PRO-Series seeding is unstable.	Verify the seeder is set to AUTO mode. With the PRO-Series in EXT mode, check the seeder mode. It should be well collimated and showing no break up. Optimize frequency overlap by adjusting the temperature potentiometer. (For trained personnel only). While viewing the seeded output pulse with a fast photodiode and oscilloscope, adjust the seeder routing mirror for optimum pulse stability. (For trained personnel only).

Cause of Symptom	Corrective Action
Harmonic generator detuned.	While viewing the pump power monitor, optimize the second and third harmonic crystal angles.
Insufficient signal level on MO detector.	Adjust the gain potentiometer on the back of the detector. Remove the ND filter from the filter stack.
Low pump power.	Check flash lamp lifetime. If greater than 30 million shots, replace lamps. Note: uv pump power begins to degrade after 15 million shots on non-BeamLok systems. Call a service representative for replacement of any damaged optics.
Master oscillator is not locking.	Verify MO output power is in the desired range (refer to Chapter 5, “Installation and Alignment”). Verify the beam splitter is directing the picked-off portion of the beam into the detector Adjust the gain potentiometer on the back of the detector. If necessary, remove an ND filter from the filter stack.
Master oscillator output power is low or non-existent.	Verify the pump power is in the desired range (refer to Chapter 5, “Installation and Alignment”). Check for damage optics or crystal and replace as needed. Verify the master oscillator alignment with a HeNe reference beam (refer to Chapter 5, “Installation and Alignment”). Verify the pump beam/reference beam overlap.
Motor mike failed.	Replace the motor mike.
Parasitic oscillation is present.	Tilt the face of the crystal in the horizontal plane as described in Appendix A.
Power oscillator seeding not optimized.	Adjust the PO crystal angle to optimize the frequency overlap (refer to Chapter 5, “Installation and Alignment”).
Power oscillator high reflector (PO-BBHR) position is not optimized.	Adjust the PO-BBHR position (refer to Chapter 5, “Installation and Alignment”).

Replacement Parts

The following list of parts can be purchased and installed by the user. They are offered here in the event an item becomes damaged or lost, or when an additional item is required that was not purchased with the system.

Table 8-1: Replacement Parts

Description	Part Number
Window 1 in.	0002-0061
Window, HA30, IR Cutoff, 1 in.	0005-0041-1
BBO Crystal, AR Coated PO	0447-9961
Compensator	0448-3690
Filter, RG695, Long Wave Pass	0448-8330
355 nm Dichroic, 1.5 in.	0448-8440
355 nm Dichroic, 1 in.	0448-8450
UV reflector, 0’, 355 nm	0448-8460
Visible Dichroic, 400–700 nm	0448-8470
High Reflector, 400–700 nm	0448-8480
Output Coupler	0448-8490
Beam Splitter, 355nm, 1%	0448-8500
Lens, +550 mm, PL/CVX	0452-2090
Lens, +500 mm, PL/CC	0452-2080
Lens, +300 mm, PL/CVX	0449-2340
Lens, +250 mm, PL/CVX	0448-8850
Lens, +200 mm, PL/CVX	0448-8860
Lens, +150 mm, PL/CVX	0448-8870
Lens, –150 mm, PL/CC	0448-8880
Lens, –100 mm, PL/CC	0448-8890
Grating 2700 Lines/mm	0448-8760
Mirror, Tuning, MO	0448-8770
Absorber	0449-0490
Beam splitter, 12%, 355 nm, 1.5 in.	0451-1170
Beam splitter, 14%, 355 nm, 1.5 in.	0451-6440
Beam splitter, 17%, 355 nm, 1.5 in.	0449-1100
Beam splitter, 24%, 355 nm, 1.5 in.	0449-1110
Beam splitter, 31%, 355 nm, 1.5 in.	0449-1120
Beam splitter, 38%, 355 nm, 1.5 in.	0449-1130
Beam splitter, 45%, 355 nm, 1.5 in.	0449-1140
Beam splitter, 52%, 355 nm, 1.5 in.	0449-1150
Rt. Angle Prism, AR 355 nm, 1.5 in.	0449-1530
Enhanced High Reflector	0449-1650

Table 8-1: Replacement Parts

Description	Part Number
Window, AR 355 nm	0449-1910
BBHR, 100 cm, CC/PL	0449-2670
Filter, ND, 0.1%	0449-4640
Filter, ND, 1%	0449-4641
Filter, ND, 3%	0449-4642
Filter, ND, 10%	0449-4643
Filter, Band Pass, 360 nm	0449-4670
Filter, Heat Absorbing	0449-4680
Mounted Turning Prism, AR 355	9800-0770

Chapter 9 Customer Service

Customer Service

At Spectra-Physics, 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 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. 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 (650) 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 parts and assemblies manufactured by Spectra-Physics are unconditionally warranted to be free of defects in workmanship and materials for a period of one year for mechanical and electrical components and 90 days for optics following delivery of the equipment to the F.O.B. point.

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. Spectra-Physics will provide at its expense all parts and labor and one-way return shipping of the defective part or instrument (if required). 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. When products manufactured by others are included in Spectra-Physics equipment, the original manufacturer's warranty is extended to Spectra-Physics customers. When products manufactured by others are used in conjunction with Spectra-Physics equipment, this warranty is extended only to the equipment manufactured by Spectra-Physics.

This warranty also does not apply to equipment or components that, upon inspection by Spectra-Physics, 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.

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 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.

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 containers.

Service Centers

Benelux

Telephone: (31) 40 265 99 59

France

Telephone: (33) 1-69 18 63 10

Germany and Export Countries*

Spectra-Physics GmbH
Guerickeweg 7
D-64291 Darmstadt
Telephone: (49) 06151 708-0
Fax: (49) 06151 79102

Japan (East)

Spectra-Physics KK
East Regional Office
Daiwa-Nakameguro Building
4-6-1 Nakameguro
Meguro-ku, Tokyo 153
Telephone: (81) 3-3794-5511
Fax: (81) 3-3794-5510

Japan (West)

Spectra-Physics KK
West Regional Office
Nishi-honmachi Solar Building
3-1-43 Nishi-honmachi
Nishi-ku, Osaka 550-0005
Telephone: (81) 6-4390-6770
Fax: (81) 6-4390-2760
e-mail: niwamuro@splasers.co.jp

United Kingdom

Telephone: (44) 1442-258100

United States and Export Countries**

Spectra-Physics
1330 Terra Bella Avenue
Mountain View, CA 94043
Telephone: (800) 456-2552 (Service) or
(800) SPL-LASER (Sales) or
(800) 775-5273 (Sales) or
(650) 961-2550 (Operator)
Fax: (650) 964-3584
e-mail: service@splasers.com
sales@splasers.com
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.*

Appendix A Installing the BBO Crystal

Due to cost and fragility, only a qualified spectra physics service engineer should perform the crystal installation described below.

Determining the Orientation of the Optical Axis in the Crystal:

Since BBO is a birefringent crystal, it exhibits a characteristic optical property known as double refraction. Polarized light passing through an appropriately oriented crystal may be observed to "walk off" its initial axis of entry. Since BBO is a negative uniaxial crystal, the direction of walk-off is away from the optic axis of the crystal. The steps below outline the set up and procedure for determination of the orientation of the optical axis based on this effect.

1. Place a piece of lined paper on a flat surface.
2. Hold the crystal approximately 25 mm (1 in.) from the paper in order to view one of the lines through the crystal.
3. With the line passing through the short axis of the crystal aperture, you should see a double image of the line (Figure A-1).

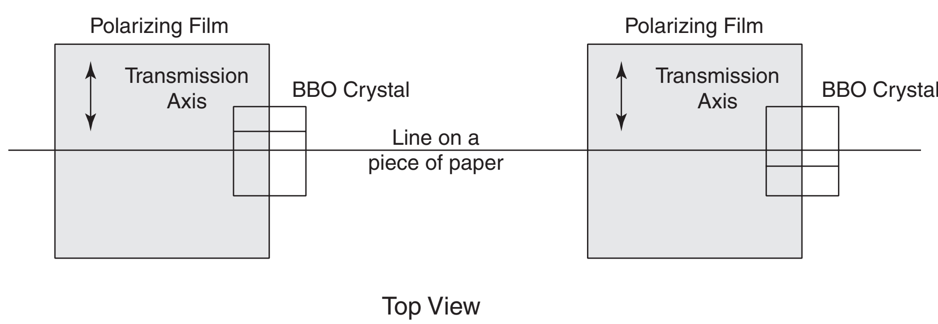

Figure A-1: Viewing the double image through the crystal.

4. Place a piece of sheet polarizer material on the paper with the transmission axis perpendicular to the lines as shown.
5. View one of the lines through the crystal at the edge of the polarizer where the lined paper is exposed.
6. The line passing through the polarizer and crystal should be displaced either above or below the line on the paper.
7. Since the polarized light walks away from the optic axis the following two situations can exist (as shown in Figure A-2):

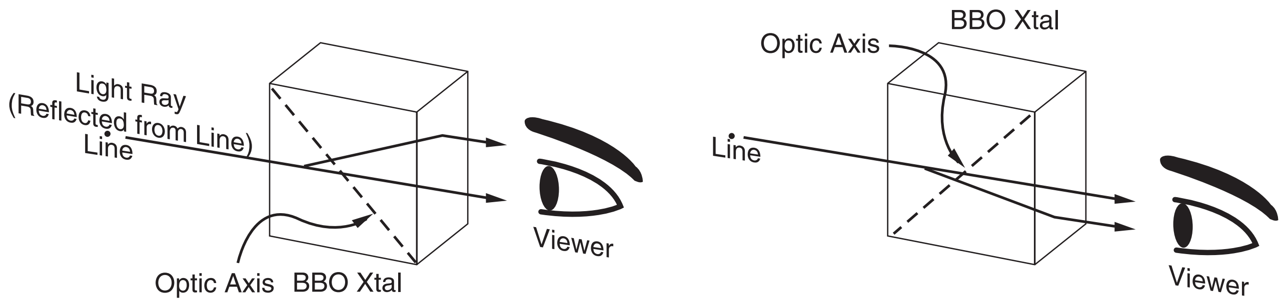

Figure A-2: The light walking away from the optical axis.

CASE I: If the line passing through the polarizer and crystal is displaced above the line on the exposed piece of paper, then the optic axis orientation may be visualized as beginning on the bottom corner of the viewer's side of the crystal and extending to the opposite corner.

CASE II: If the line passing through the polarizer and crystal is displaced below the line on the exposed piece of paper, then the optic axis orientation may be visualized as beginning on the top corner of the viewer's side of the crystal and extending to the opposite corner.

8. Using a pencil, draw a diagonal across the both sides of the crystal to indicate the optic axis orientation as shown in Figure A-3.
9. Now use a pencil to mark the master oscillator crystal with one dot in the upper right-hand corner. Mark the power oscillator crystal with two dots as shown in Figure A-3.

   A clockwise rotation of the master oscillator crystal results in a counterclockwise rotation of the power oscillator crystal. Such a rotation of the crystal shaft will tune the *MOPO-HF* to the red end of the spectrum.

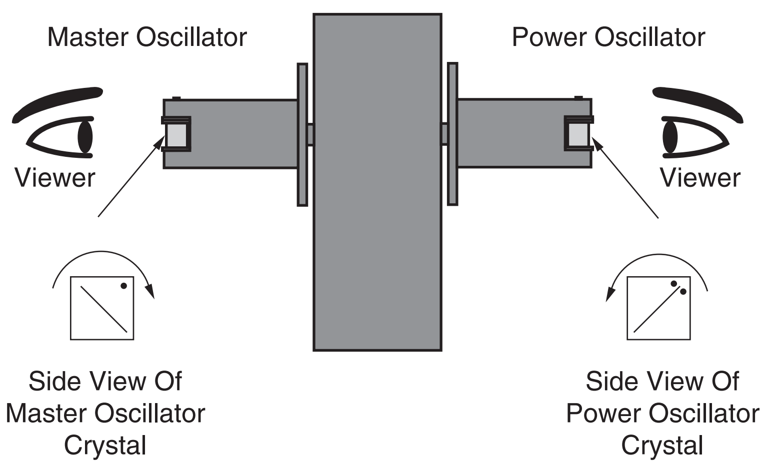

Figure A-3: Observing the master and power oscillator crystals.

A Quick Verification of the C-axis Direction

As described in Chapter 3, light that enters a birefringent crystal will, in general, decompose into two distinct light rays: the *extraordinary* (e-) and *ordinary* (o-) rays. This results in a double (or split) image of an object when it is viewed through the crystal. This phenomenon is known as *double refraction*.

The c-axis is a unique direction in the crystal. When light enters the crystal parallel to the c-axis it does not split into two distinct rays; therefore, no double image will appear. This fact may be used to quickly identify the c-axis direction.

1. Place the crystal over a thin line on a piece of paper.

   Notice that the image of the line is split.

2. Rotate the crystal in the direction that is perpendicular to the lines.

   Notice that the line merge at a particular orientation.

3. Use a pencil to draw a line from the corner of the crystal that is closest to the viewer to the opposite corner (Figure A-4). This line is along the c-axis.

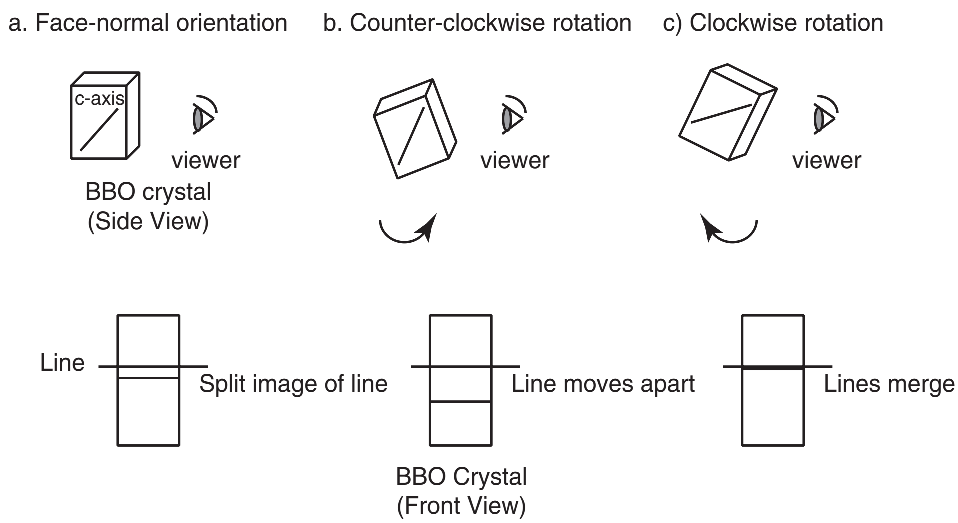

Figure A-4: Determining the C-axis.

Figure A-4 shows the case where the c-axis falls on the line that starts at the opposite lower corner and ends at the upper corner nearest the viewer. In “a,” the viewer observes the split image of a line through the crystal in a face-normal orientation. As the crystal is rotated counterclockwise, the lines are observed to move further apart as shown in “b.” When the crystal is rotated clockwise, the viewer observes the crystal in a direction that is parallel to the c-axis. In this case, the lines will merge as shown in “c.” A crystal with the c-axis starting at the nearest lower corner (as viewed by the observer) and ending at the opposite upper corner, causes the lines to merge when it is rotated counterclockwise.

This technique may be limited by the crystal’s clear aperture and the angle of the c-axis cut. In general, the technique is readily usable for crystals with large clear apertures and small c-axis angles.

Installing the Crystal in the Mount

Master Oscillator

1. Place the pinhole aperture on the other side of the PH_{13} mount so that the flat side of the aperture faces the interior of the base plate.

   This allows the reference beam retroreflections to be viewed on the flat side of the aperture during subsequent stages of the alignment procedure.
2. Insert the crystal assembly into the crystal mount (i.e., place the BBO crystal in between the two aluminum parts).
3. Turn the screw in the crystal assembly counterclockwise to "spring-load" the assembly in the crystal mount.
4. Use the manual control to rotate the crystal so that the crystal surface is approximately perpendicular to the incident reference beam.

   Retroreflections from the surface of the crystal should be noticeable on or near PH_{13}.

Because of safety considerations, the direction and degree of rotation may vary. Follow one of the procedures described below.

Case A: The crystal is marked "R" and there is an aluminum beam block flag attached to the upper part of the grating cage. The flag should be on the side of the grating that is closest to the crystal and extend toward the tuning mirror. Its purpose is to block the reflections from the crystal surface.

Loosen the crystal and rotate it by a small amount in the *counterclockwise* direction (as seen from the top). The two retroreflections from the crystal surface should be observed to move to the *left-hand* side of PH_{13}. Settle on a crystal orientation where the retroreflection closest to the center of PH_{13} is displaced to the left-hand side by about 10 mm (Figure A-5).

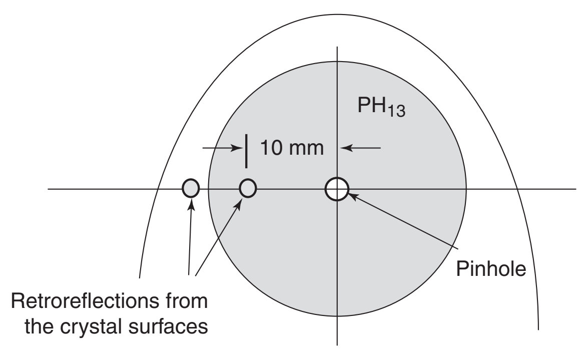

Figure A-5: The HeNe beam retroreflections from the crystal as seen on PH_{13} for cases A and C.

Case B: The crystal is marked "R" but there is no aluminum beam block flag attached to the upper part of the grating cage.

Loosen the crystal and rotate it by a small amount in the *clockwise* direction (as seen from the top). The two retroreflections from the crystal surface should be observed to move to the *right-hand* side of PH_{13}. Settle on a crystal orientation where the retroreflection closest to the center of PH_{13} is displaced to the *left-hand* side by about 30 mm. Note that both reflections miss the aperture mount completely (Figure A-6).

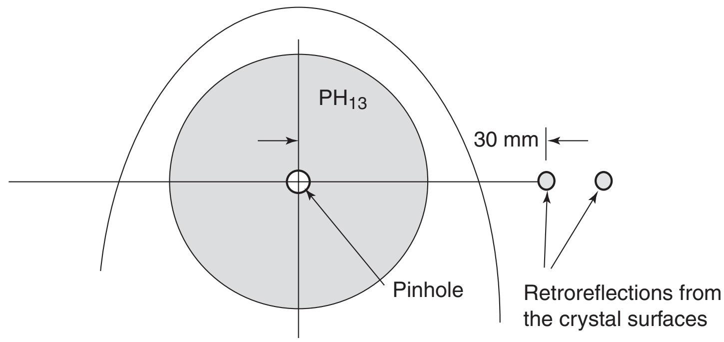

Figure A-6: The HeNe beam retroreflections from the crystal for case B.

Case C: The crystal is marked “L.”

Perform the same adjustments as in Case A.

Parasitic oscillations can be observed when the surface of the crystal is nearly perpendicular to the incident beam. Under these conditions, the crystal surfaces may provide enough reflection and feedback in the appropriate direction to induce oscillation within the crystal. Parasitic oscillations are undesirable as they have broad linewidths, cannot be tuned, and may cause optical damage.

This completes the master oscillator installation.

Power Oscillator

1. Insert the crystal assembly (the BBO crystal placed between two aluminum crystal holders) into the crystal mount.
2. Turn the screw in the crystal assembly counterclockwise to “spring-load” the assembly in the crystal mount.

Important: Make sure the power oscillator c-axis is oriented as depicted in Figure A-3.

This completes the power oscillator installation.

Appendix B The RS-232/IEEE-488 Interface

This appendix explains how to operate the *MOPO-HF* system from a remote source using either the optional RS-232 serial interface or 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-HF* 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-HF/FDO* controller.

Scope

This appendix describes how to install, set up, and use these interfaces. Chapter 6, "Operation: The 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-HF* 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-HF* controller.

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

Interface Commands

The following list of remote commands and queries provide full control of the *MOPO-HF* system through either the RS-232 serial or IEEE-488 parallel interface.

Effort has been made to create an interface that is compliant with IEEE-488.2. Refer to the IEEE-488.2 document for further information.

Setup Operations and Queries

Basic syntax

To setup or query the scan start wavelength, write the command using the following syntax:

Setup = :source:begin xxx.xxxx

Query = :source:begin?

Commands

:source:begin xxx.xxxx	scan start wavelength in nm
:source:end xxx.xxxx	scan end wavelength in nm
:source:shots xxxxx	shots to dwell for incremental scan
:source:incr xxx.xxxx	incremental scan increment
:source:scans xxxx	number of scans to perform
:source:rate .xxx	scan speed in nm/s (0.250 max)
:source:goto xxx.xxxx	goto wavelength in nm
:source:units x	0 = nm; 1 = cm^{-1}
:source:beginwn xxxxx.xx	scan start wavenumber in cm^{-1}
:source:endwn xxxxx.xx	scan end wavenumber in cm^{-1}
:source:wnincr xxxxx.xx	scan wavenumber increment in cm^{-1}
:source:gotown xxxxx.xx	goto wavenumber in cm^{-1}
:source:mmode x	0 = standard mode; 1 = micromode

Read Only Commands

Basic syntax

:read:wlen? gives the current wavelength in nm

Commands

:read:wlen?	current wavelength in nm
:read:moscpwr?	detector level of most recent shot
:read:moscavg?	16-shot rolling average
:read:poscpwr?	power oscillator detector
:read:poscavg?	rolling average
:read:count?	current scan count

Execution Commands

:scan	execute scan
:hold	hold scan or goto
:resume	resume scan or goto

:abort	abort scan, goto, or table-writing operation
:exegoto	execute goto
:recall x	recall parameter setting
:save x	save parameters to file number x
:movfwr	move forward l µm
:movbwr	move backward l µm
:mmovfwr	micro-move forward 2 µsteps
:mmovbwr	micro-move backward 2 µsteps
:wnmovfwr	move forward 0.0l cm^{-1}
:wnmovbwr	move backward 0.0l cm^{-1}
:setmode	set mode to micro or standard resolution
:setunits	set to nm or cm^{-1}
:trkenbl	enable closed-loop tracking
:trkdsbl	disable closed-loop tracking
:tmoenbl	enable "track time-out"
:wrttbl	write master oscillator crystal table
:abrttbl	abort master oscillator crystal table-writing operation

IEEE-488.2 Mandatory Commands

Basic syntax:

*SRE x	(to write a value, if allowed)
*SRE?	(to query a value, if allowed)

Commands

*CLS	Clear all IEEE-488.2 registers
*ESR	Query the ESR register. ESR Query is a destructive read.
*IDN	Query only, system ID string
*OPC	Operation complete, command or query
*RST	Command only, system reset
*SRE	Set or query the STB mask register
*ESE	set or quiry the ESE register
*STB	Query only, the IEEE-488.2 status byte
*TST	Command system self test
*WAI	IEEE-488.2 wait command

MOPO Implementation of the status byte

A query of the status byte can be used to determine when a measurement should be made.

bit 7	stable lock bit, set after successful track time-out
bit 6	IEEE-488.2 SRQ bit
bit 5	IEEE-488.2 ESB bit
bit 4	IEEE-488.2 MAV bit
bit 3	exec bit, operation (goto for example) in progress
bit 2	move bit, system is moving
bit 1	lock bit, active tracking enabled and successful
bit 0	dwell bit, at wavelength during incremental scan

Installation

RS-232-C Interface

The *MOPO-HF* RS-232 interface is configured as data communications equipment (DCE). Table B-1 at the end of this appendix describes 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-HF/FDO* (DCE device). Connection should be simple with no cross connections required.

MOPO/FDO Serial Interface Parameters

The parameter settings for the *MOPO-HF* 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-HF* serial interface baud rate can be set anywhere from 300 to 2400 bits per second. Chapter 6, "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-HF* system is configured as a talker-listener device (i.e., it can both send and receive 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-HF.*

The GPIB interface of the *MOPO-HF* system includes a National Instruments GPIB-PC II/IIA interface card that is installed inside the *MOPO-HF* controller. Table B-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 Table B-1.

The GPIB device address of the *MOPO-HF* 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-HF.* 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-HF* 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 or the IEEE-488 interface can be used, it must first be selected and its parameters set from the Remote menu. See Chapter 6, "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-HF* 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-HF* 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 RS-232 interface is used, send a null string to the *MOPO-HF*. Written in the BASIC programming language, this statement would look like:

   PRINT #1, "   "

After the interface is initialized, the *MOPO-HF* 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-HF* controller is easily and quickly tested. Simply send the query message to request the controller to send back a device identification message.

1. Send this query message to the controller:

   *IDN?

1. Receive this device identification message back:

   QUANTA-RAY, MOPO-HF, V2.06

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 controller. The system is now ready to receive commands for operation.

MOPO/FDO Firmware Revision

In the *MOPO-HF* ID message shown above, the last piece of data specifies the revision level of the *MOPO-HF* system firmware. The ID message should indicate that the *MOPO-HF* system firmware is Version 2.03 or a later revision.

Format and Syntax Rules

Format

All messages sent to the *MOPO-HF* must be transmitted in ASCII format. The *MOPO-HF* 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-HF*.

The *MOPO-HF* 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.

Programming Examples

The following program statements illustrate the correct format and syntax of *MOPO-HF* 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-HF 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-HF* 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

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
'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

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-HF,0,V2.06"

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$(Shots)
GOSUB WriteMopo
Cmd$ = ":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 B-1: IBM-PC/AT Serial Port Pinout

	Computer or Terminal			MOPO-HF/FDO	
RS-232-C Signal Name	**Signal**	**Pin No. (25-Pin)**	**Pin No. (9-Pin)**	**Pin No.**	**Signal**
Transmit Data	TXD	2	3	3	RXD
Receive Data	RXD	3	2	2	TXD
Request To Send	RTS	4	7	5	CTS
Clear To Send	CTS	5	8	4	RTS
Data Set Ready	DSR	6	6	6	DTR
Data Carrier Detect	DCD	8	1	8	DCD
Data terminal Ready	DTR	20	4	20	DSR
Signal Ground		7	5	7	
Protective Ground		1	SHELL	SHELL	

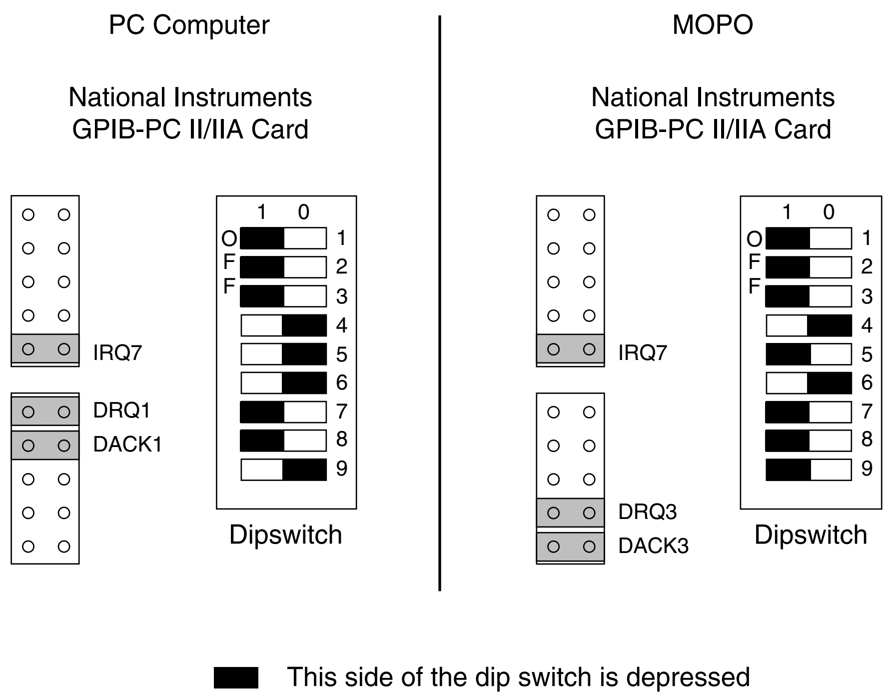

Figure B-1: IEEE-488 Dip Switch and Jumper Settings

Appendix C Replacing the PCMCIA Card Battery

The 512 kB PCMCIA memory card found in the *MOPO-HF* controller uses a small 3 V disk battery to maintain the data stored in it. The expected lifetime of the battery is approximately 2–3 years, so it is prudent to change the battery every 2 years regardless of use. *If the battery dies, the data is lost, and a full system recalibration is required.*

The different brands of PCMCIA cards used in these systems are described below. Following this description is a procedure for changing the battery without losing the data. Determine which card you have, then read the procedure completely through, making sure you understand it before you begin.

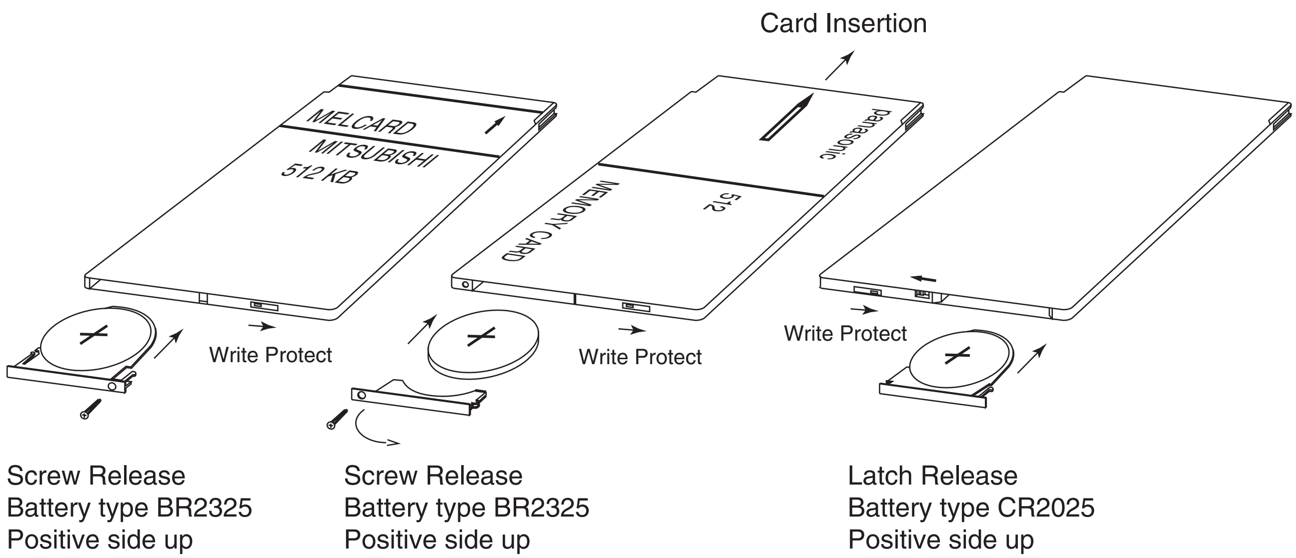

Figure C-1: Three examples of PCMCIA cards.

Card Description/Replacement Battery List

The following are the five types of 512 kB SRAM cards currently used.
3- volt batteries are used in all units, but size and part numbers vary.

Mitsubishi MF3513-LCDAT01

Silver with blue patch and white edge trim. Screw retains battery.
Battery: BR2325

Epson

Plain gray card with black edge trim. Latch retains battery.
Battery: CR2025

Epson

One side white, opposite side light blue. Latch retains battery.
Battery: CR2025

Epson

One side green/brown/copper, opposite side brown. Latch retains battery.
Battery: BR2325

Panasonic BN-512HMC

Gray and green with gray edge trim. Screw retains battery.
Battery: BR2325

Procedure

The idea is simple: leave the card in the controller and, with the controller on, replace the battery while the controller supplies power to the card.

Warning!

While performing this procedure:

- Do not turn off the power to the controller.
- Do not remove the card.

There are two types of battery holders. One type uses a small screw that secures the battery and holder in the card. The other type uses a sliding latch to secure the battery holder. Figure 1 shows memory cards from Mitsubishi, Panasonic and Epson. Note: the Epson card shown is the most common and is the first Epson type listed above and has no labeling.

Caution!

Note the write protect slide on each unit. Do not confuse this slide with the retaining latch on the Epson cards. These cards must NOT be write protected, or the system will not operate properly.

The Mitsubishi and Epson cards have battery holders which pull the battery out when they are removed. The Panasonic card simply has an end cap to keep it from falling out. The battery must be pulled out separately.

Warning!

The battery is not secured by the holder and *will fall out of the holder* as soon as it is no longer retained by the sides of the card. If it falls onto the controller motherboard, it can short traces or components and ruin the motherboard. *Be very careful — hang onto the battery as you pull it out!*

1. With the controller power on and the PCMCIA card in the unit, either loosen the screw (Mitsubishi or Panasonic) or slide the latch that retains the battery. *Do not drop the screw on the motherboard!*
2. Observe the polarity of the battery as you remove it (it is possible to install the battery backwards in the Panasonic card). There is a "+" sign on the battery on its positive side (the side without the seam). The "+" sign should face **away** from the front of the controller.
3. Install the new battery, observing its polarity.
4. Fasten the holder in place with the screw, or slide the retaining latch into place.
5. Place a piece of tape or Avery label on the PCMCIA card and mark on it the date of installation.

Remember to replace the battery approximately every 2 years.

Caution! Please dispose of the battery in accordance with local laws and regulations.

This completes the procedure for replacing the battery in the PCMCIA card.

Appendix D Manually Controlling the Crystal Stage

The Autotrack pc board in the *MOPO-HF* controller has two sets of four switches. One set controls the PO crystal, the other the MO crystal. Each set is identical in how it operates. The following outlines the operation of one of these sets.

1. Remove the cover of the *MOPO-HF* controller and locate the Autotrack pc board, then locate the control switches.

   The control switches are shown in Figure D-1. Reference the switches from the front panel as shown in the drawing. Switch designators are located near each switch.

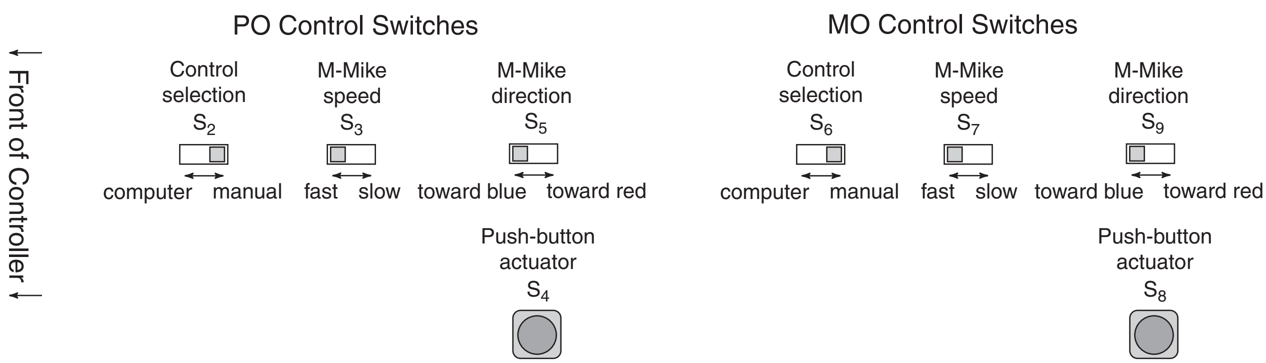

Figure D-1: The Autotrack control pc board motor mike switches.

2. Set S_2 or S_6 to the COMPUTER position (move it toward you), to place the crystal under computer control; set it to the MANUAL position (move it away from you) to place it under manual control. When set to MANUAL, switches S_3, S_7 and S_3 or S_7, S_3 and S_7 are active, when set to COMPUTER, they are inactive.
3. Set S_3 or S_7 to the FAST position (toward you) to make the motormike move quickly, or to the SLOW position (away from you) to make it move slowly for accuracy.
4. Set S_5 or S_9 to the BLUE position (toward you) to rotate the crystal toward the blue wavelengths, or to the RED position (away from you) to rotate it toward the red wavelengths.
5. When set to manual, once the slide switches are placed in the desired setting, press the black button, S_4 or S_8, to move the motormike.
6. When you are done moving the motormike(s) manually, remember to set switch(es) S_2 and/or S_6 back to COMPUTER before going back to normal operation.

Appendix E Determining Telescope Lenses for the PO

The following procedure is provided so you can select the proper lens combination for your power oscillator (PO) telescope if your system has *not* been previously setup and aligned or has had its configuration changed.

1. Measure the 355 nm energy in the power oscillator leg.
   a. Set the *PRO-Series* laser to Q-SWITCH OFF.
   b. If present, remove the PO beam dump from in front of PO-TM_1.
   c. Set the *PRO-Series* laser to LONG PULSE mode.
   d. Remove PO-TM_1.
   e. Remove the plug from the output diagnostic port.
   f. Place a power meter on the optical table in front of the diagnostic output port (left-most porthole on the input side of the *MOPO-HF*). Refer to Figure E-1.

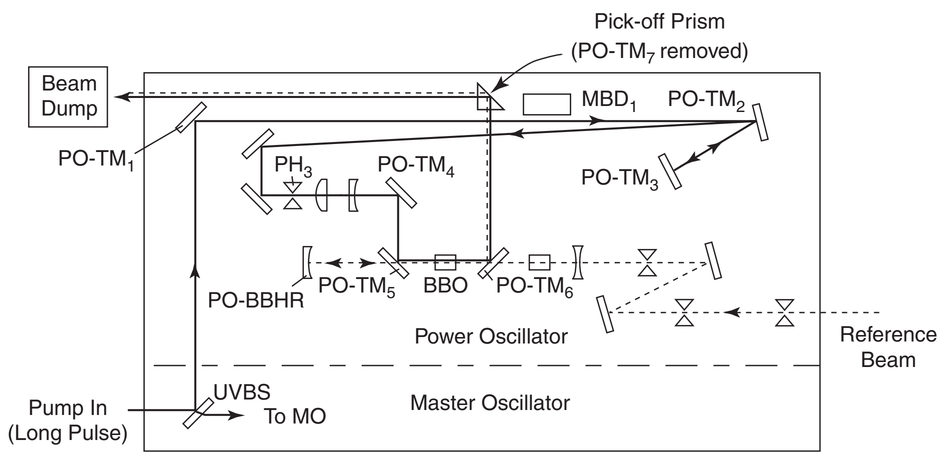

Figure E-1: Placement of pick-off prism for PO pump energy measurement.

   g. Place the pick-off prism assembly in the beam path at a location in front of the diagnostic porthole.
   h. Adjust the prism to direct the beam into the power meter.
   i. Set the *PRO-Series* laser to Q-SWITCH mode.
   j. Record the power meter reading and determine the pulse energy.
   k. Set the *PRO-Series* laser to LONG PULSE mode.
   l. Remove the pick-off prism assembly.
   m. Place the PO-TM_1 back onto *MOPO-HF*.

2. Choose from the following list of lens combination in accordance with the pump energy measured in Step 1j:

Energy Range (mJ)	Positive/Negative Lens (mm fl)	Part Numbers
≤200	+150/–100 (1.5x)	0448-8870
		0448-8890
200–300	+200/–150 (1.3x)	0448-8860
		0448-8880
300–350	+240/–200 (1.2x)	0451-5130
		0451-5140
>350	+550/–500 (1.1x)	0452-2080
		0452-2090

These are approximations only. Depending on the Gaussian nature of the beam profile, a different lens combination may be required. In general, more Gaussian beam profiles require less aggressive lens combinations for a given energy range (e.g., a 1.3 x instead of a 1.5 x). The opposite is true for the more flat-top beam profiles.

Note: in order to minimize beam clipping issues in the BBO crystal, a Macor aperture is typically implemented with 1.1 and 1.2 x telescopes.

Appendix F Installing a Software Upgrade

New releases of the *MOPO-HF* controller software might be issued that will upgrade your system to add new capabilities or increase its performance. If this occurs, use the following procedure to install the new software. This procedure is simple and straight-forward, but it must be followed precisely to prevent any loss of any data already stored in your unit.

You will swap your current PCMCIA card in the controller with a new one, and will have to do this a couple of times. If the two cards are from the same manufacturer, it may be prudent to mark the old one to identify it so that you do not inadvertently insert the wrong card. *If this happens, you will lose your original data.*

1. Verify the *MOPO-HF* controller is off.
2. Remove the cover from the controller.
3. Remove the old PCMCIA card.

   It is plugged into the mother board just behind the front panel (see Figure F-1). Pull it straight up and out.
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—the illustration shows the card as viewed from the rear of the controller).

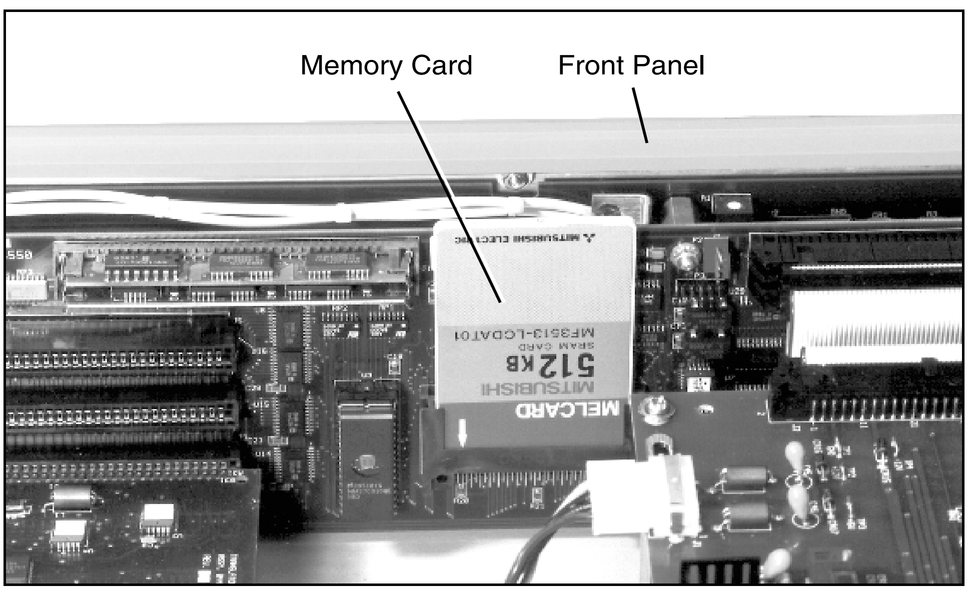

Figure F-1: Electronics unit showing location of removable PCMCIA memory card.

5. Turn on the controller. The new software will boot.
6. Once the opening menu is displayed, press the OPERATE button until the Service1 menu is displayed.
7. *Leaving the system on*, replace the new PCMCIA card with the original card.
8. Press the FRMWRE UPDATE button, then hold in the LOAD button until the system beeps. Observe the various messages that indicate the status of the loading operation. This loads your old data.
9. When the loading is complete, replace the original PCMCIA card with the new one.
10 Hold in the SAVE button until the system beeps. This saves the old data with the new software.
11. When the save process is completed, leave the new PCMCIA card plugged in and replace the cover.
12. Turn the system off, then back on to reboot the unit with the original data values and new firmware software.

All the settings that were in place using the original card, including the IEEE address, the baud rate, and the local or remote mode setting should still be evident using the new card. If you have just upgraded your system to include the FDO, you will need to select the appropriate operating mode.

Notes

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): ______________________________

____

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Mail To:

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FAX to:

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(650) 961-7101