Quanta-Ray

MOPO

Quanta-Ray MOPO-700
Optical Parametric Oscillator

Instruction Manual

Spectra-Physics Lasers, Inc.
Quanta-Ray
1330 Terra Bella Avenue
Post Office Box 7013
Mountain View, CA 94039-7013

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Spectra-Physics

Preface

This manual describes installation, operation and preventive maintenance of your MOPO-700 series optical parametric oscillator (OPO). The manual also contains information about OPO theory, options and accessories.

While this manual contains an installation and alignment procedure, it is not intended as a guide to the initial installation and set-up of your MOPO. Please wait for the Spectra-Physics service engineer who has been assigned this task under your service agreement. Allow only qualified and authorized Spectra-Physics service personnel to install your laser system.

The Quanta-Ray MOPO-700 series is designed for use with Quanta-Ray GCR-100 and GCR-200 series of pulsed Nd:YAG lasers. This combination provides continuously tunable radiation from 410nm to over 2000nm. Proprietary broad-band optics, designed and manufactured by Spectra-Physics, mean that no mirror change or realignment is necessary when scanning across the visible or near IR spectrum.

The MOPO-700 series' tuning range can even be further extended from 200nm to beyond 3000nm through nonlinear processes in the Quanta-Ray FDO-800 harmonic generation system and the EWO-1 wavelength extender.

The MOPO-700 is compact and easy to work with. The MOPO design incorporates two coupled OPO's, a master OPO and a power OPO. This design provides the flexibility to easily change and upgrade the output linewidth from tens of wave numbers to below 0.02cm^{-1}, while maintaining consistent output energies. All units come standard with control electronics which allow the user to set all necessary operating parameters. Optional RS-232 and IEEE-488 interfaces allow easy connection with existing laboratory control and data collection systems.

The MOPO series emits radiation that can permanently damage eyes and skin, ignite fires, and vaporize substances. Moreover, focussed back-reflections of even a small percentage of its output energy can destroy expensive internal optics. To minimize the risk of expensive repairs, injury, or death, carefully follow these instructions.

We welcome your comments on the content and style of the manual. The last page is a form to aid in bringing such problems to our attention. Thank-you for your purchase of a Spectra-Physics instrument.

Table of Contents

SI Units

The following System International units, abbreviations and prefixes are used in Spectra-Physics Lasers manuals:

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

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

Introduction

1

The principal of operation for the optical parametric oscillator (OPO) is quite different from that of a laser system. A laser derives its gain from the spontaneous and stimulated emission generated by atomic transitions. These atomic transitions have inherent linewidths which define the maximum tuning range of the laser. For example, a dye laser tunes over 20nm per dye while Ti:sapphire lasers can tune over 200nm. 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 355nm, BBO based OPO can tune continuously from 410nm to wavelengths greater than 4000nm. An OPO's gain is derived from a nonlinear frequency conversion process rather than by stimulated emission.

OPO Theory of Operation

The gain of an OPO system is derived from the nonlinear interaction between an intense optical wave and a crystal having a large nonlinear polarizability coefficient.

OPO operation can be most easily understood as the inverse of the familiar nonlinear frequency mixing process used to generate odd harmonics of the Nd:YAG laser (for example the 3rd, 5th etc harmonic). The third harmonic of Nd:YAG is 355nm, and is generated by mixing the fundamental output at 1064nm with the second harmonic at 532nm in a nonlinear material such as BBO or KDP.

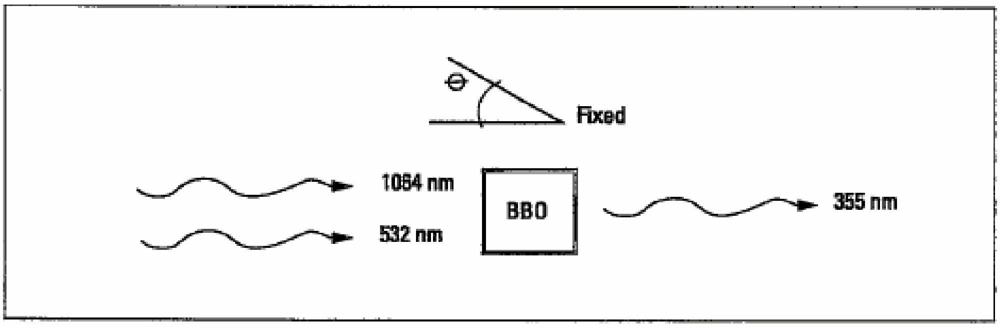

Figure 1-1: Frequency mixing to generate the third harmonic of Nd:YAG

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:

$$1/\lambda_p = 1/\lambda_s + 1/\lambda_i \quad (2)$$

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-700 series is designed such that both cavities (that is the master and power oscillator) are singly resonant over the signal wavelength range.

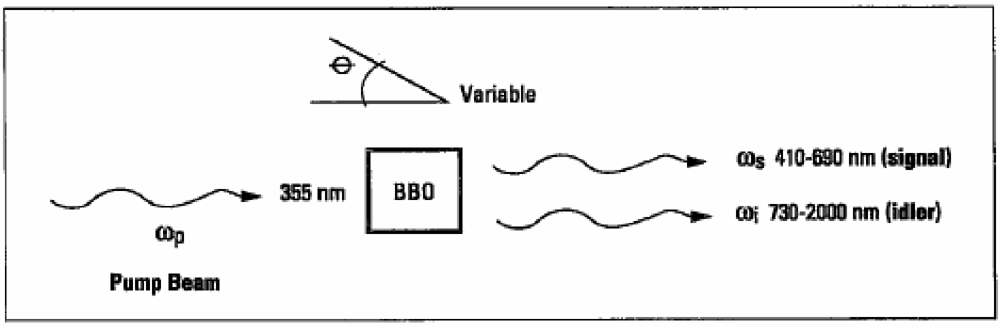

Figure 1-2: Parametric Amplification to Generate Tunable Output from 410nm to Beyond 2000nm.

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.

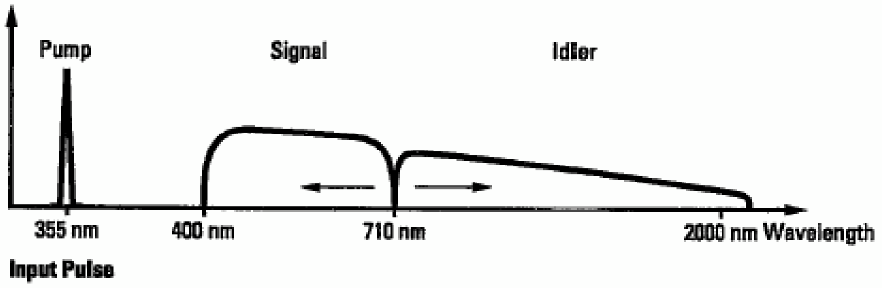

Figure 1-3: Signal and Idler Output wavelengths for 355nm Pump

In the MOPO system, the pump wavelength λ_p is always 355nm. 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.

Power Oscillator Design Used in the MOPO-710

The MOPO-700 series is based on the parametric gain in BBO pumped by the 355nm third harmonic of either a GCR-100 Series or a GCR-200 Series Nd:YAG laser. The MOPO design incorporates two coupled OPOs, a master OPO and a power OPO. The master oscillator/power oscillator (MOPO) design provides the flexibility to easily change and upgrade the system.

The heart of the MOPO-700 series is the high energy power oscillator. The unique design delivers greater than 100mJ of energy over most visible wavelengths, with typical conversion efficiencies in excess of 20% at a single wavelength.

The key to 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-700 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.

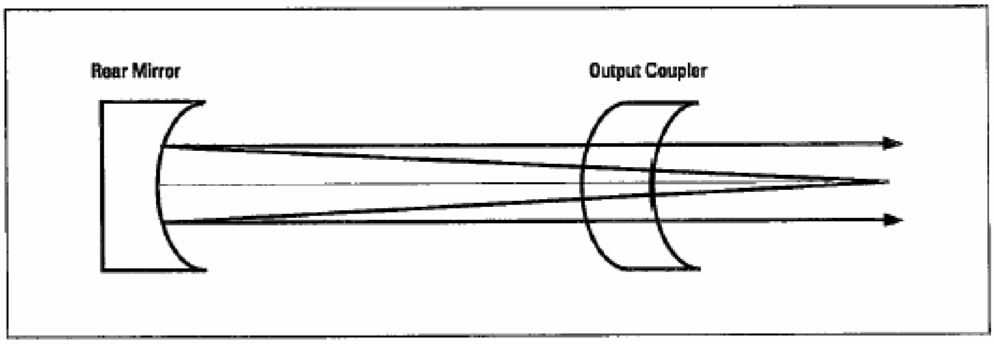

Figure 1-4: Schematic of an Unstable Resonator Design used in the MOPO-700 Series

MOPO-710 Description and Principle of Operation

The MOPO-710 is the basic version of the MOPO-700 Series, and includes the power oscillator and control electronics. It is designed for use with Quanta-Ray GCR-100 and -200 Series Nd:YAG lasers. This combination provides tunable laser radiation from 410nm to 2000nm. The tuning can be even further extended by using the Quanta-Ray FDO-800 harmonic generator system and the EWO-1 wavelength extender. Figure 1-5 shows a schematic of the MOPO-710 laser system.

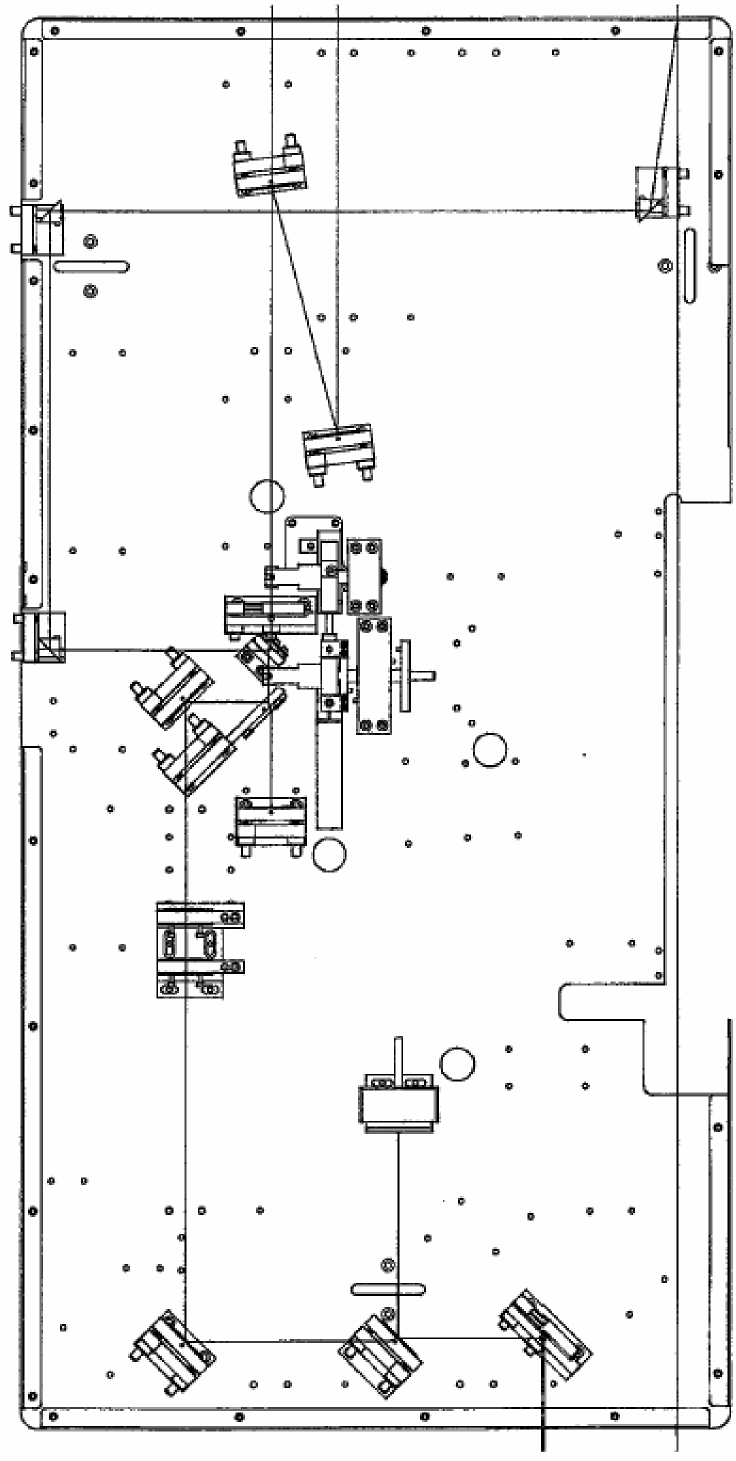

Figure 1-5: Schematic diagram of the MOPO-710

Two 45° turning mirrors, coated to reflect 355nm direct the 355nm pump beam through a collimating telescope which is used to reduce the pump beam's diameter by approximately a factor of two. This telescope has no user adjustments and ensures correct pump power density on the face of the BBO crystal for efficient operation. This design provides a non-focussing, parallel beam for optimum phase matching throughout the length of the crystal.

The 355nm pump beam is then directed into the BBO crystal using two additional 45° UV high reflectors. After a single pass through the BBO crystal, the residual 355nm beam is routed out of the OPO resonant cavity by another small UV high reflector, and directed to a beam dump external to the MOPO.

Previous OPO designs pump the BBO crystal through the cavity high reflector. Such high reflector coatings are typically unable to sustain the high UV pump fluence levels required to achieve efficient OPO operation. To eliminate these coating damage issues, Spectra-Physics designed the MOPO oscillators with 45° intracavity 355nm pump beam high reflectors. This scheme allows the use of pump fluence levels much higher than any other design, and consequently for the first time OPO energies in excess of 100mJ.

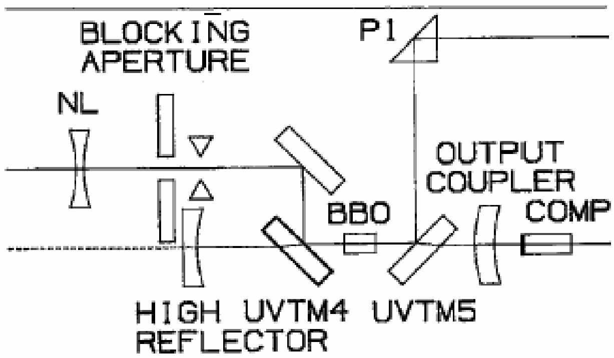

Figure 1-6: Location of the 45° 355nm intracavity turning mirrors

The resonant cavity used for the amplification of the signal wavelength is composed of a convex broadband visible high reflector and a concave broadband visible output coupler. A quartz compensator block is positioned right in front of the output coupler and is used to correct for vertical walkoff resulting from angle tuning of the BBO crystal.

The linewidth of the MOPO-710 is driven by a combination of the pump Nd:YAG laser linewidth and the gain bandwidth within the BBO crystal. Typical linewidths from 8cm^{-1} to greater than 50cm^{-1} are observed when pumping with an injection seeded Nd:YAG. For non-injection seeded Nd:YAG pumping linewidths vary from 15cm^{-1} to greater than 60cm^{-1} as degeneracy is approached.

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-700 systems contain a broadband dichroic pair to separate the two beams. The use of two dichroic optics ensures >97% spectrally pure beams. The final outputs are parallel and 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 410nm to 2000nm. This means that no mirror realignment or change is necessary when scanning across the visible or near IR spectrum.

Automated Control Electronics

The MOPO-700 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. Push button controls provide simple access to menus which allow the user 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, IEEE-488 interfaces and even a fax modem allow easy connection with existing laboratory control and data acquisition equipment.

The electronics contain a UL compatible computer style internal power supply, a microprocessor based controller board, and a main drive board for crystal rotation. The BBO crystal is tuned by rotating the crystal to a known angle for each wavelength by this main drive board.

MOPO-700 Series Specifications

Model[1]	MOPO-710	MOPO-730
Pump beam parameters[2]		
Laser type	Nd:YAG	Nd:YAG
Laser wavelength	355 nm, 3rd harmonic	355 nm, 3rd harmonic
Spatial mode	>70% Gaussian fit	>70% Gaussian fit
Pointing stability	<100 μrads	<100 μrads
Beam divergence	<0.5 mrads	<0.5 mrads
Linewidth[3]	<0.01 cm^{-1} at 355 nm	<0.01 cm^{-1} at 355 nm
Repetition rate[4]	1-50Hz	1-50Hz
Pulse width	5 – 10 ns	5 – 10 ns
Pump energy by oscillator		
Master Oscillator	n/a	150 mJ
Power Oscillator (min)[5]	100 mJ	100 mJ
(max)[5]	450 mJ	450 mJ
Pump energy in total		
Minimum	100 mJ	250 m J
Maximum	450 mJ	600 m J

Tuning Characteristic[7]		
Signal tuning range (typical)	410 to 690 nm	440 to 690 nm
Idler tuning range (typical)	735 to 2200 nm	735 to 1800 nm

Other Output Characteristics	MOPO-710	MOPO-730
Polarization	Horizontal > 97%	Horizontal >97%
Beam diameter (typical)[8]	5 mm	5 mm
Beam shape (typical)[9]	Round ± 20%	Round ± 20%
Beam profile[10]	>70% Gaussian fit	>70% Gaussian fit
Beam divergence[11]	<1 mrad	<1 mrad
Pointing stability[12]	< 200 μrad	< 200 μrad
Pulse width (typical)	2 ns less than pump	2 ns less than pump
Resettability	<1 x linewidth	<1 x linewidth
Electronic readout accuracy (typical)	<10 x linewidth	<10 x linewidth
Long term stability	< 1 x linewidth/°c/hr .	1x linewidth/°c/hr
Pulse to pulse stability[13]	± 8%	± 8%
Timing jitter[14]	< 2 ns	< 2 ns
Linewidth	Varies with wavelength,[15] values shown in figure 1 are typical only	< 0.2 cm^{-1}

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.

2. All GCR-100 and 200 series Nd:YAG lasers will meet the pump beam requirements. Older GCR's can be upgraded to meet the pump conditions. Please contact our local service center for upgrade prices. DCRs and most Nd:YAGs manufactured by other manufacturers will not satisfy the pump beam profile and pointing requirements. MOPO operation with such unqualified pump sources is entirely at the user's risk. Spectra-Physics will not cover any optical damage under warranty unless an approved pump Nd:YAG laser is used.

3. Assumes use of single mode diode pumped, solid state injection seeder with Nd:YAG laser.

4. Assumes fixed repetition rate between 1 and 50Hz, not a variable repetition rate.

5. Pump energies below 100mJ are too close to threshold to ensure all other specifications can be met.

6. Pump energies above 450mJ are too high to ensure long term reliable operation.

7. We are continually optimizing our optical coatings to bring superior performance. This may affect the limits of the tuning ranges.

8. Beam diameter is measured at the FWHM points and can vary depending on the pump source energy level.
9. Measured at 1 meter from output.

10. Measured at 1 meter from output.

11. Full angle measured at the FWHM points.

12. Over an 8 hour period with temperature variation of <±3°c

13. Pulse to pulse stability for >99% of pulse, measured over 1 hour.

14. rms jitter from the Q-switched sync pulse in the pump Nd:YAG laser, using an injection seeder.

15. Energy output and conversion efficiency vary with pump pulse energy and repetition rate. Since there are over 20 different model GCR-100 and 200 pump Nd:YAG lasers it is impossible to show exact energy specifications for all systems at all wave lengths in this data sheet. Please contact your local sales representative for specific configuration energy specifications.

16. MOPO-710 linewidths can vary ±20% for any given wavelength depending on the exact collimation of the Nd:YAG pump beam in the BBO crystal.

2

The Quanta-Ray MOPO-700 series laser accessory is designed for maximum wavelength coverage from 410nm to >2000nm. The laser output may be visible or invisible.

DANGER

The Quanta-Ray MOPO-700 is a high power laser accessory whose beam is a safety and fire hazard. Take precautions to avoid accidental exposure to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye or skin damage.

Precautions For The Safe Operation Of Class IV High Power Lasers

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

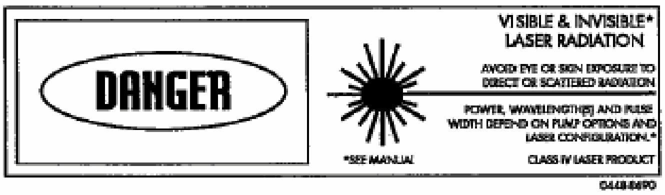

Figure 2-1: Standard Safety Warning sign

CAUTION

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

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

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

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

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

This laser product complies with Title 21 of the United States Code of Federal Regulations, Chapter 1, Subchapter J, parts 1040.10 and 1040.11, as applicable. The MOPO 700 series is a passive laser accessory. As such, it has no inherent interlock devices. For verification of CDRH safety compliance including interlocks, verify pump laser safety features. To maintain compliance, verify the operation of all features listed in your Nd:YAG pump laser manual, either annually or whenever the product has been subjected to adverse environmental conditions (eg. fire, flood, mechanical shock, spilled solvents). The features are identified on the radiation control drawing (figure 2-2).

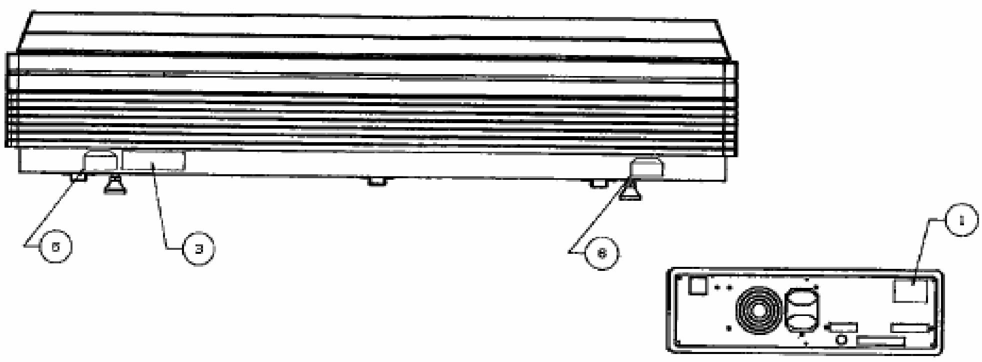

Figure 2-2: MOPO-710 Radiation Control Drawing

Sources Of Laser Safety Standards

Safe use of Lasers (Z136.1)
American National Standards Institute (ANSI)
1430 Broadway
New York, NY 10018

A Guide to Control of Laser Hazards
American conference of Governmental and Industrial Hygienists (ACGIH)
1014 Broadway
Cincinnati, OH 45202

Occupational Safety and Health Administration (OSHA)
US department of Labor
400-1st Street NW
Washington, DC 20001

KEY TO RADIATION CONTROL DRAWING

Item	Description	
1	Identification and Patent Labels	( )
2	Warning Logotype Labels	( )
3	Aperture Labels	( )
4	Noninterlocked Protective Housing Label for adjustment Access Plugs	( )
5	Electronics ON Indicator	
6	Danger Label	

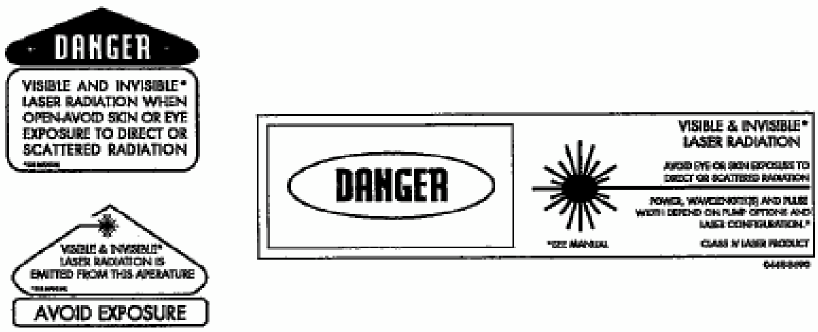

Figure 2-3: Quanta-Ray MOPO-710 Warning Labels

Focussed Back Reflection Safety

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

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

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

Electronics Safety

DANGER

Voltages present in this unit can cause serious or fatal injury. Only qualified personnel should install or perform service procedures on this equipment.

Voltage is present on unprotected pins when the unit is operational.

No short circuit protector for motor outputs is provided in the unit. The ac input is internally fused.

When power is applied, all parts of the circuit should be considered hazardous.

Allow at least ten minutes for capacitors to discharge. Capacitors remain at high voltages for several minutes after the power is removed.

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

WARNING

Do not connect or disconnect motor or signal cables while ac power is applied.

Do not apply ac power until all the connections have been made correctly.

Do not exceed specified input voltages.

Installation

3

Unpacking Your Laser Accessory

Your MOPO-700 was carefully packed for shipment; if its crates arrive damaged, have the shipper's agent present when the laser is unpacked. Inspect each unit as you unpack it: look for dents, scratches, or other damage. If you discover any damage, immediately file a claim against the carrier and notify your Spectra-Physics Lasers representative. Spectra-Physics Lasers will correct the problem without waiting for settlement of your claim.

KEEP THE SHIPPING CRATES. If you file a claim, you will need them to show that shipping caused the damage. If you must return the unit for service, these special crates provide maximum protection.

WARNING

Spectra-Physics Lasers considers itself responsible for the effects on safety, reliability, and performance of the Quanta-Ray MOPO-710 laser accessory only under the following conditions:

(A) Field installable options, modifications or repairs are performed by persons authorized by Spectra-Physics Lasers;

(B) Electrical service complies with International Electrotechnical Commission (IEC) requirements;

(C) The equipment is used only according to instructions provided in this manual.

Required Utilities

The MOPO-700 is designed to accept either 90-130VAC single phase 50 or 60Hz input or 180-260VAC single phase 50 or 60 Hz input. No other utilities are required.

Installing The Pump Laser

The MOPO-700 is compatible with selected GCR-100 and GCR-200 Series Nd:YAG lasers.

1. Set up the pump laser according to the instruction manual.
2. Verify that the pump laser meets specifications for energy and pulse width.
3. The MOPO-700 is pumped with 355 nanometer output from a Quanta Ray YAG with HG harmonic generator and IHS internal harmonic separator.
4. Verify that the pump laser beam is approximately 7.5" to 7.7" above and parallel to the optical table. The 355nm and 532nm beam should be parallel to each other.
5. See figures 3-1 and 3-2 for orientation of MOPO with respect to GCR pump lasers.

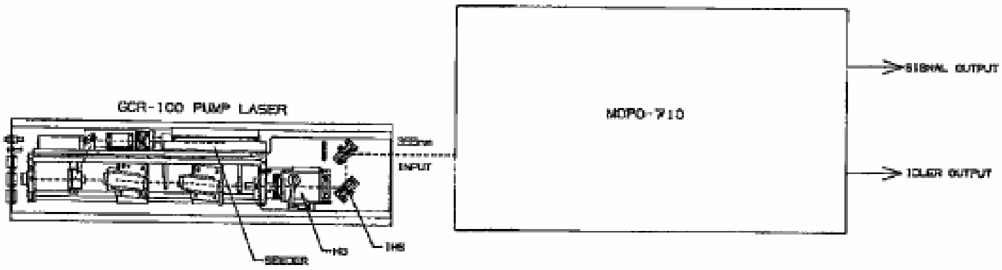

Figure 3-1: MOPO-710 system layout diagram configured with a GCR-100 Series pump laser

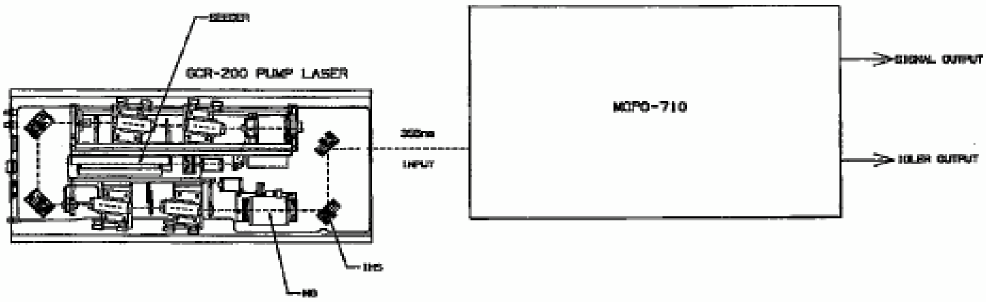

Figure 3-2: MOPO-710 system layout diagram configured with a GCR-200 Series pump laser

Installing The Electronics

Controls and Indicators

FRONT PANEL

"OPERATE": Allows wavelength to be changed or routines to be stored and recalled.

"SCAN": Allows changes to be made to the scan routine.

"MONITOR": Allows monitoring of the GCR 355nm pump energy without needing any alterations in the operation of the MOPO.

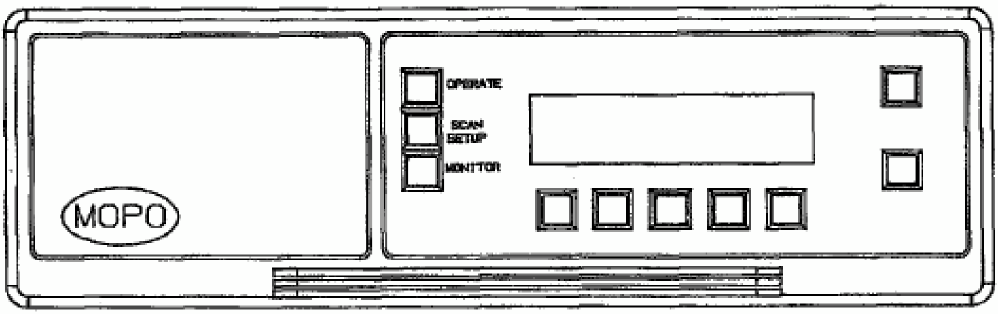

Figure 3-3: electronics front panel component identification

BACK PANEL

Voltage Selector Switch: Selects 115V or 230V ac. The switch position must match the available line voltage.

115/230VA.C. Input: power cord connection.

1/0 switch: turns the electronics module on or off. 1 is ON, 0 is OFF.

Q-Switch Sync: BNC cable which connects the GCR Q-switch sync output signal to the electronics module.

MOPO Autotracker™: 37 D-sub cable which connects the MOPO electronics unit to the back side of the MOPO head.

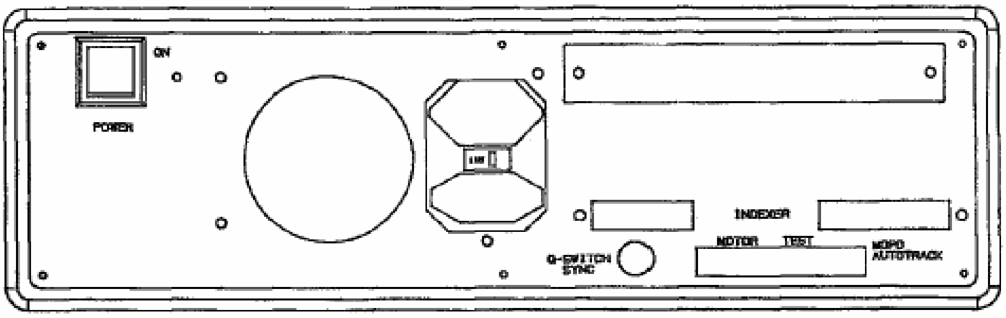

Figure 3-4: Electronics back panel component identification

Installation Instructions

Select the appropriate line voltage range ("115" = 90 - 130VAC range; "230" = 180 - 260VAC range.)

Connect the power cord.

Connect the BNC cable from the Q-switch output on the GCR laser to the Q-switch sync connection on the rear panel of the MOPO electronics.

IMPORTANT NOTE REGARDING Q-SWITCH SYNC. SIGNAL: *The MOPO 710 may not operate correctly if the Q-switch sync. cable is not connected properly and the Q-switch signal of the pump laser is not being generated before the MOPO controller box is turned on. If the "ERR1" message appears when the controller is turned on, make sure the Q-switch cable is conneted and a sync. pulse is present, then turn the controller off and back on again to ensure proper synchronization. If this does not occur, although the laser may still operate, the user's experiment may be adversely affected.*

Connect the 37 pin D-sub cable from the rear panel of the MOPO electronics to the MOPO head.

Installing The MOPO-700

Controls and Indicators

All status indicators and controls for the MOPO-710 are located on the Electronics Control Unit.

Installation of the MOPO-710

> **WARNING**
>
> **When following the procedures below, always operate the pump laser at low levels to prevent optical damage to the MOPO-710. For pumping with the third harmonic, this would be oscillator only, un-Q-switched, about 1-2 increments above threshold on the lamp energy adjustment.**

Place the MOPO-710 in the appropriate position on the table, relative to the pump laser, as shown in figure 3-6.

Select the long-pulse mode of operation of the GCR pump laser, and slowly increase the lamp joules until a small amount of green, 532nm light is visible.

Align the MOPO-710 base plate such that the 532nm beam are centered through the two outermost window ports of the MOPO-710. Both horizontal and vertical adjustments to the MOPO-710 may be required.

Use levelling indicators to ascertain that the MOPO-710 remains horizontal following any height adjustment.

Secure the MOPO-710 to the optical table by using the four foot clamps provided.

Remove the MOPO-710 cover.

> **WARNING**
>
> **At high energy, these pulses can cause permanent eye damage. Always wear appropriate eye protection when making adjustments to the MOPO-700.**

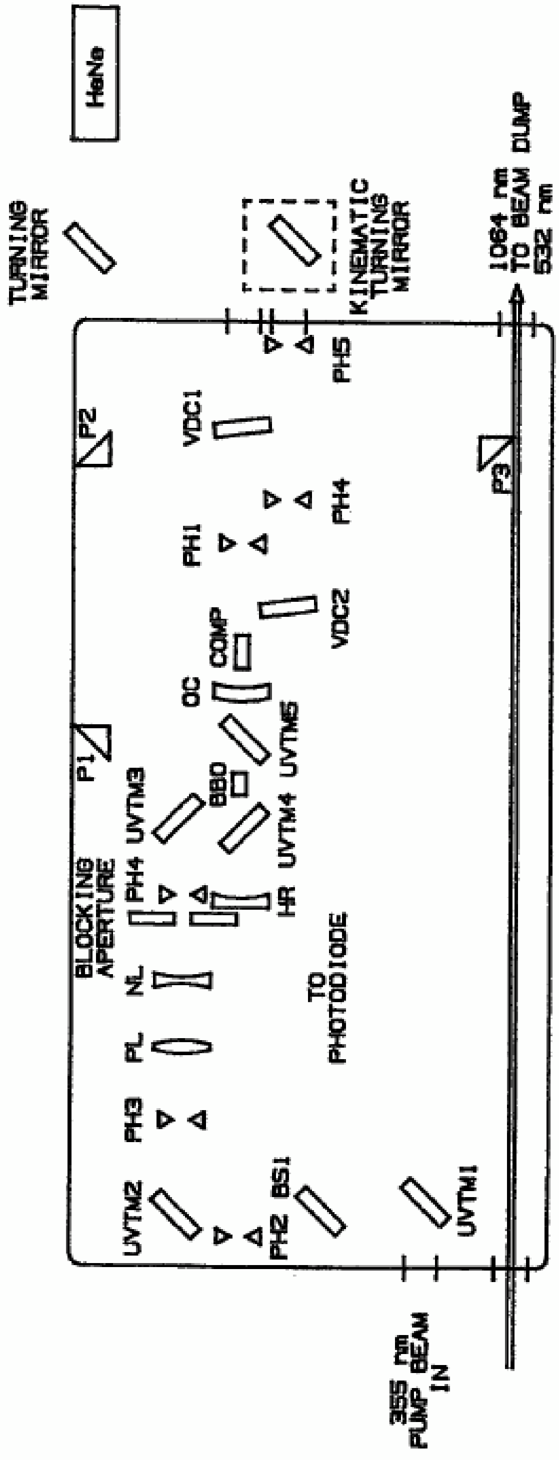

Figure 3-6: Initial alignment of the 532nm GCR beam through the MOPO-710.

Center the first IHS-355 on the pump beam. Adjust this IHS-355 to center the pump beam on the second IHS-355. Adjust this second dichroic so that the pump beam passes unobstructed through the center of the input port of the MOPO-700 and the alignment port situated in line with the input port. Please refer to figure 3-7 to identify various MOPO-700 components.

Designators

UVTM	UV tuning mirror (HR @ 45°, 355 nm)
BS	Beamsplitter (for UV diode)
PH	Pinhole
PL	positive lens
NL	negative lens
P	prism
HR	high reflector (visible HR 400-700 nm)
OC	output coupler
BBO	BBO crystal
Comp	compensator block
VDC	visible dichroic mirror

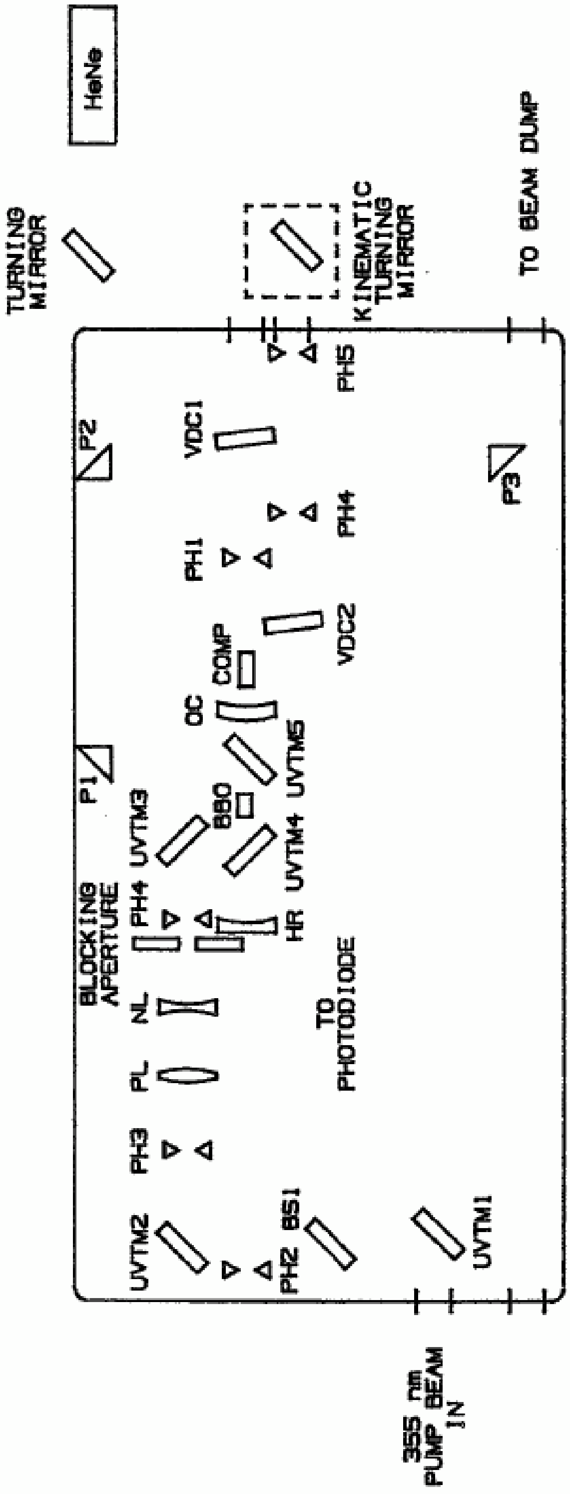

Figure 3-7: MOPO-710 Internal component identification

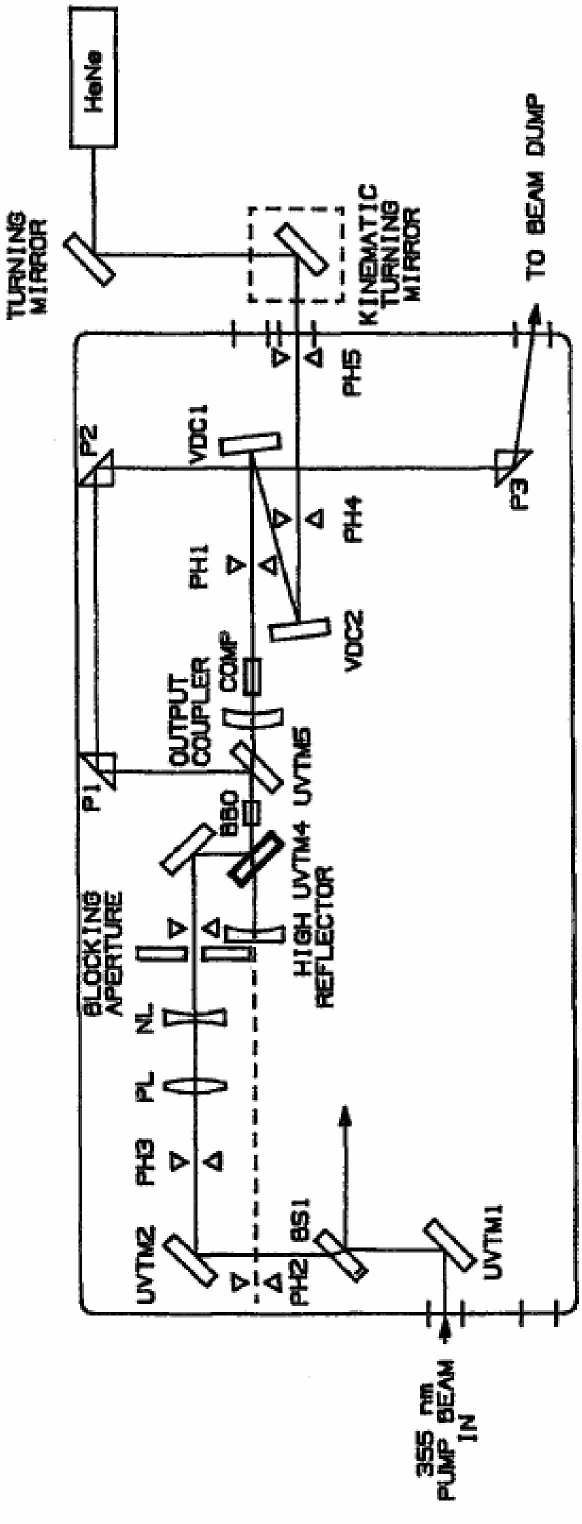

Figure 3-8: MOPO-710 Beam Path

Part 1: HeNe alignment

Required materials

- HeNe
- 2 HeNe routing mirrors
- 2 pinhole mounting apertures with UV paper mounts (provided in the accessories shipped with the MOPO-710)
- leveling device

1. Set up a low energy alignment HeNe laser (0.5-2mW). Use one fixed and one kinematic HeNe mirror to steer the beam into the MOPO-710, as shown in figure (3-8).
2. Align the HeNe beam on the center of the visible dichroic mirror 2 (VDC2)
3. Install pinholes PH1 and PH2 into the baseplate, at the locations shown in figure (3-9).
4. Remove the high reflector (HR) of the resonator cavity of the power oscillator.
5. Align the HeNe beam though pinholes PH1 and PH2 using the adjustments on VDC1 and VDC2.
6. Using a white card, check the position of the HeNe beam on both faces of the BBO crystal and the compensator block. Translate the BBO crystal and the compensator horizontally to center the HeNe beam on both crystals.
7. Verify that the HeNe beam is approximately centered on the OC, UVTM4 and UVTM5. Make sure that the HeNe beam is not clipped by any of the optics.
8. Adjust the position of the output coupler (OC) of the power oscillator's resonator cavity such that weak surface HeNe back reflections are collinear with the original HeNe beam path.
9. Install the high reflector (HR) optic and mount onto the baseplate.
10. Adjust the position of the HR so that weak surface HeNe back reflections are collinear with the original HeNe beam path. Secure all mounting screws on the HR mount.

This completes the HeNe alignment of the system.

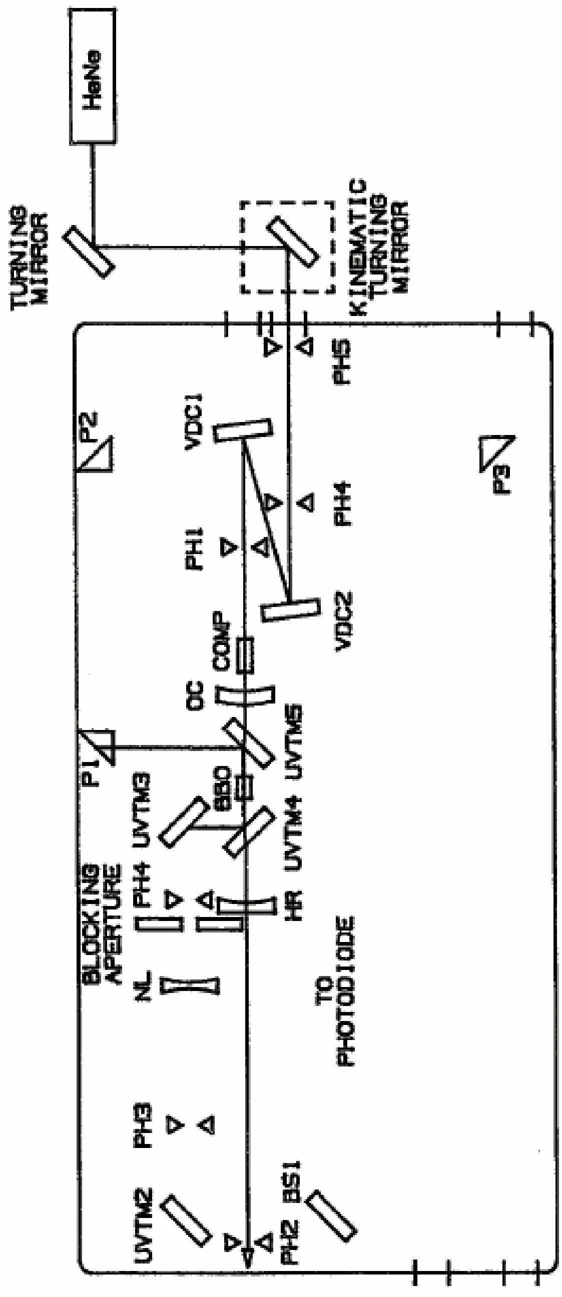

Figure 3-9: Location of the alignment HeNe beam and alignment pinholes in laser cavity

PART 2 : Power Oscillator Alignment

1. Place UVTM1 in the mount. Adjust the position of the UVTM1 such that the pump beam is centered on the UVTM2. After proper adjustment, the pump beam will pass through the center of BS1. (See figure 3-10).
2. Adjust the position of BS1 to steer the pump beam pickoff onto the photodiode detector.
3. Remove telescope lenses NL and PL out of the beam path. Use the adjustments on UVTM 1 and 2 to center the pump beam through pinholes PH 3 and 4. After this alignment, the pump beam will be centered on UVTM3.
4. Fine tune the position of BS1 to recenter the pump beam pickoff onto the photodiode detector.
5. Remove the two pinholes, PH3 and PH4
6. Adjust the position of UVTM3 to overlap the pump beam and the HeNe beam on the face of the BBO crystal. This is a crucial step for proper alignment.
7. Adjust the position of UVTM4 to overlap the position of the pump beam and HeNe beam on the front face of NL.
8. After this adjustment, the two beams will no longer be overlapped on the face of the BBO crystal. Reiterate step (6) and (7) until both beams simultaneously over lap on the face of the BBO crystal and on the negative lens.
9. Adjust the position of UVTM5 base to center the pump beam onto the turning prism, P1.
10. Position the pump beam onto the second turning prism, P2, by making adjustments to the position of P1. Likewise, position the pump beam onto the third turning prism, P3, by making adjustments to the position of P2.
11. Steer the pump beam through the output aperture using P3. Tape a white card over this output aperture and mark the position of the center of the pump beam.
12. Install the negative lens of the telescope (NL) into the path of the pump beam. Adjust its horizontal position in order to overlap the center of the expanded pump beam with the HeNe beam on the blocking aperture. Tighten all mounting screws on the NL mount.
13. Install the positive lens of the telescope (PL) in front of the negative lens. Adjust its horizontal and vertical position to reduce the pump beam diameter by a factor of 0.75 and to overlap the center of this beam with the HeNe beam at the input face of he BBO crystal.
14. Note the position of the pump beam on the white card taped to the output aperture. Fine tune the horizontal position of the PL to recenter the beam to its initial position on the white card.
15. Verify the size of the pump beam at the output of the telescope, just past NL. Translate PL in the vertical direction to achieve the same beam size as that present at the output of P3 as well as NL.

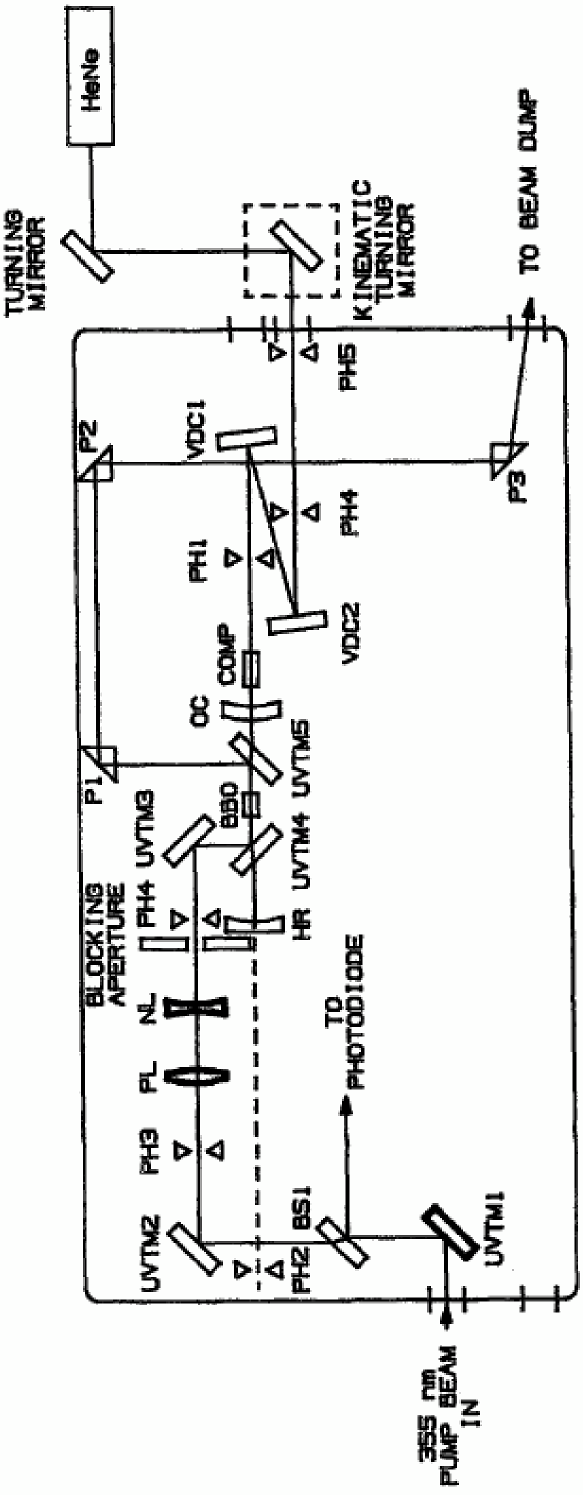

Figure 3-10: Location of UVTM1 and telescope optics.

4

Operation of the MOPO-710

Once the MOPO-710 has been installed, day to day operation is straightforward.

System start-up

Turn on the GCR pump laser, and set the lamp energy one to two full increments above threshold in the un-Q-switched mode.

Verify that the pump beam is properly aligned into the MOPO-710. Make any necessary adjustments.

Set the pump laser for Q-switched operation. Make any necessary adjustments for proper alignment.

Slowly bring the pump beam to the desired energy level. For best stability, operate the laser at maximum pump energy.

Do not change the pump laser operation dramatically while pumping the MOPO-700 due to risk of damage to optical train.

IMPORTANT NOTE REGARDING Q-SWITCH SYNC. SIGNAL: *The MOPO 710 may not operate correctly if the Q-switch sync cable is not connected properly and the Q-switch signal of the pump laser is not being generated before the MOPO controller box is turned on. If the "ERR1" message appears when the controller is turned on, make sure the Q-switch cable is conneted and a sync. pulse is present, then turn the controller off and back on again to ensure proper synchronization. If this does not occur, although the laser may still operate, the user's experiment may be adversely affected.*

Operation of the electronics

Turn the power switch on. The blue display on the front panel will light up after a 10 second wait.

There are a total of 10 buttons with which to control the electronics box for the MOPO as shown in figure 4-1. The three buttons on the left side change the **mode** between OPERATE, SCAN SETUP and MONITOR. The five buttons on the bottom are "soft-keys" and control various functions depending on which mode has been selected. The two arrow keys on the right side adjust the numerical value inside the highlighted box.

When the unit is initially turned on, the OPERATE mode is automatically selected. A bright box surrounding the function OPERATE is visible on the screen. Note that if "ERR1" shows up on the screen, this indicates the Q-switch sync from the pump laser is not connected to the controller.

Any of the three mode settings can be chosen at any time by using the three labeled buttons. A highlighted box will appear around the chosen setting.

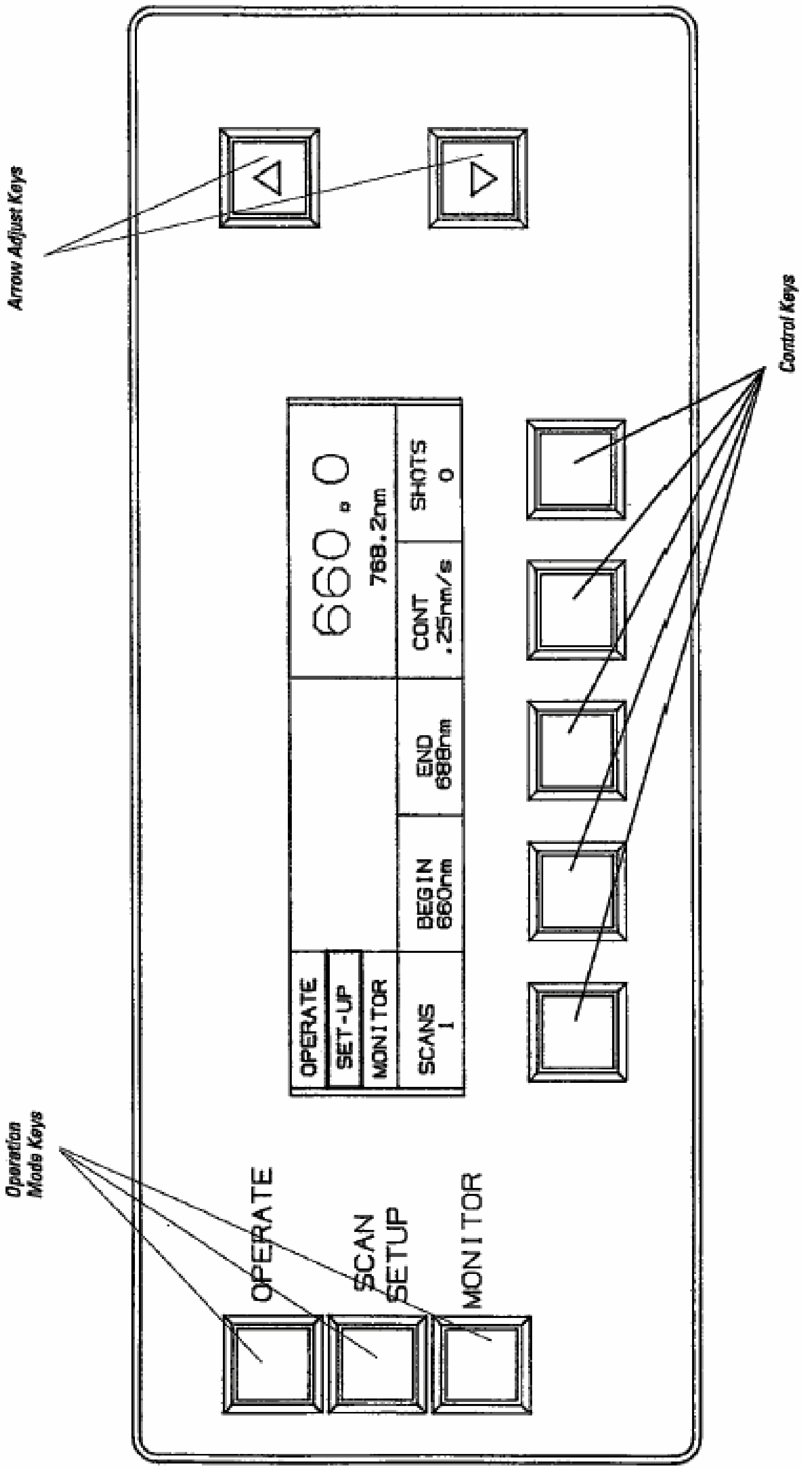

Figure 4-1: Initial configuration of the electronics panel

OPERATE Mode

The operate mode allows one to control the laser wavelength directly or to initiate a previously defined scan (See SCAN SETUP Mode).

Upon activating the operate button, the following display appears on the blue backlit screen shown in figure 4-2.

The number in the top right hand box indicates the present operating wavelength of the MOPO-710.

The control functions in the OPERATE mode are: GOTO, START SCAN, MOVE, RECALL, and SAVE and are accessed using the five lower buttons.

Any function can be chosen by depressing the black key situated just below the function on the screen. A highlighted box will appear to indicate your choice.

By pressing the GOTO key, a wavelength number in nm appears in the goto box. This wavelength can be changed to any number between 400.0nm and 700.0nm in 0.1nm increments by using the two arrow keys on the right side of the front panel. The goto function is then activated by depressing the GOTO key for ***at least 1.5 seconds.***

For a scan to be accessed, it must first be programmed in the SCAN SETUP mode (See SCAN SETUP Mode). Once this has been done, a scan is initiated by depressing the START SCAN key. Before the scan actually begins, the laser must first tune to the beginning point of the scan. This will be indicated on the screen by a message reading "Move to _____". The line graph will indicate the laser's approximate position relative to the total tuning range of 400-700 nm.

Once this move is completed the scan will begin. A bar graph appears indicating the fraction of the scan that is complete.

Throughout the duration of a scan routine, the screen displays two different functions: ABORT SCAN and HOLD SCAN. See figure 4-3.

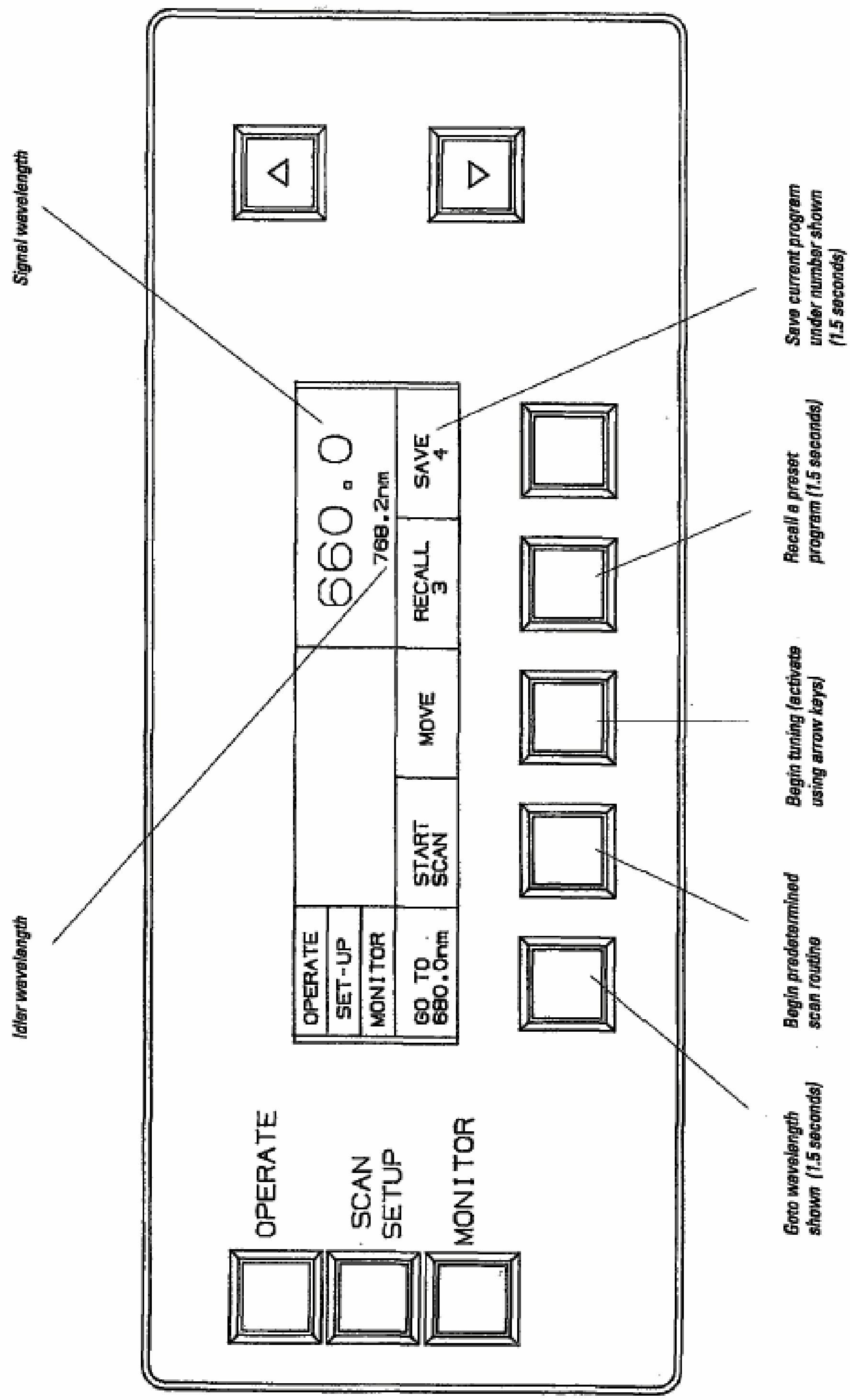

Figure 4-2: Choice of settings available in the operate mode.

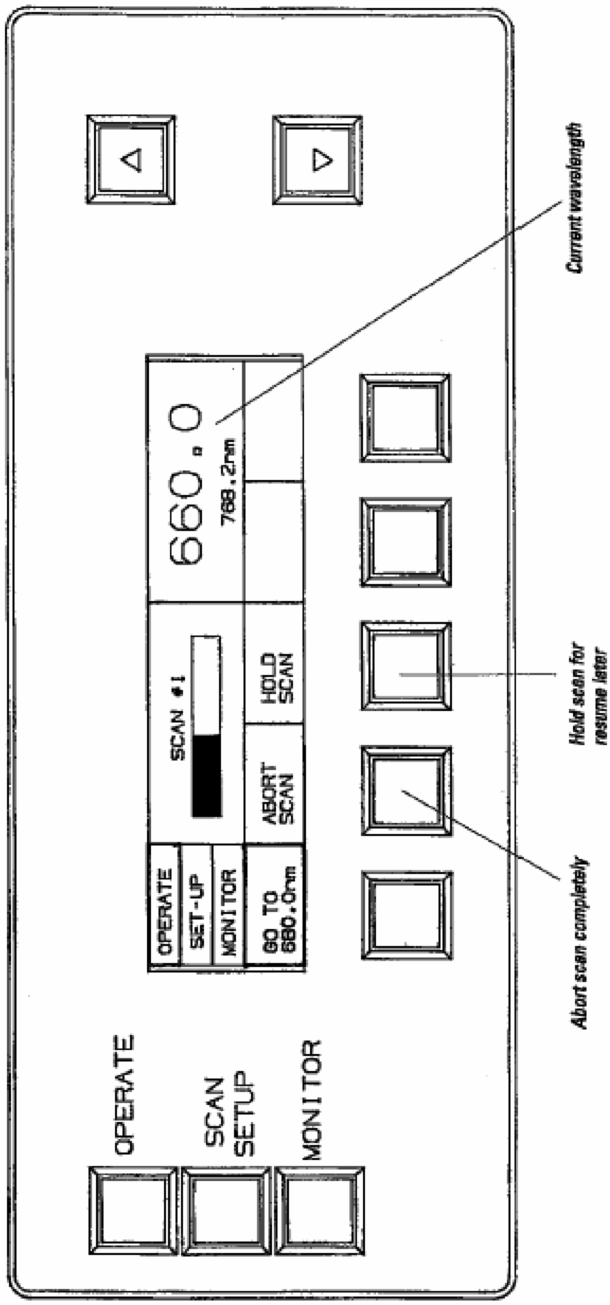

Figure 4-3: Backlit panel options displayed throughout the duration of the scan.

If the HOLD SCAN function is depressed, the scan is stopped at the current wavelength. RESUME SCAN appears as a function on the screen in the place of HOLD SCAN as shown in figure 4-4. The scan can be continued by depressing the key now labeled RESUME SCAN.

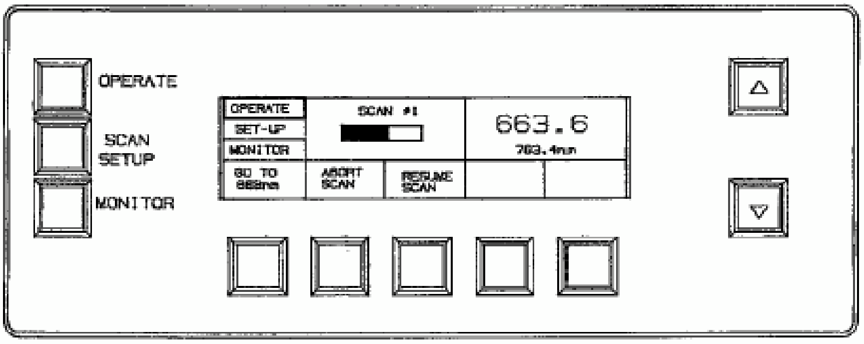

Figure 4-4: Backlit panel options displayed after holding a scan

If the ABORT SCAN function is chosen the scan will terminate and the wavelength will remain in its current position. The screen will return to its original mode as shown in figure 4-5.

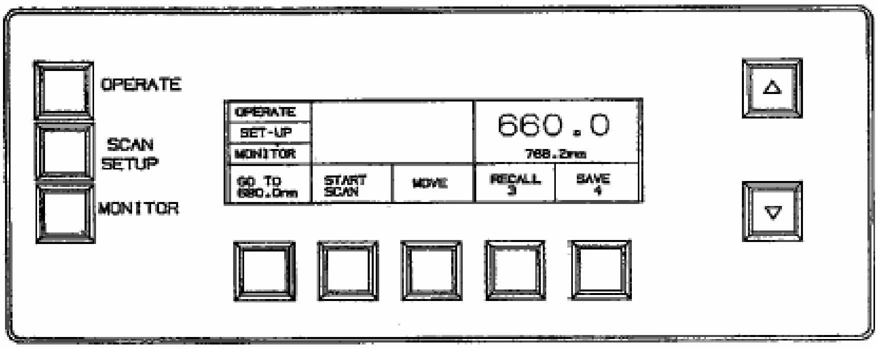

Figure 4-5: Backlit panel options displayed after aborting a scan.

The MOVE key allows you to directly tune the laser system using the arrow keys. To use this feature, simply press the move key, then tune the laser to shorter or longer wavelengths using the up or down arrow keys.

The RECALL function allows one to recall a previously saved group of settings including the scan routine and a GOTO wavelength. Depress the RECALL key and select the number of the parameter file to be recalled (0-9). Recall the file by depressing the RECALL key for 1.5 seconds.

Likewise, the SAVE function allows one to save a full set of parameters associated with a scan as well as a GOTO setting. Depress the SAVE key and select the number of the parameter file (0-9) under which the parameters are to be saved using the arrow keys. Save the present parameters to this file by depressing the SAVE key for 1.5 seconds.

SCAN SETUP Mode

This mode of allows the user to define exactly the desired scan routine. Upon choosing this mode, the screen displays the choice of options shown in figure 4-6.

The number of desired consecutive scans is chosen by selecting the option box labeled SCANS and using the arrow keys to increase or decrease the number shown in this option box.

The initial wavelength of the scan is chosen by selecting the BEGIN option box. The choice of initial wavelength can be any number from 400.0nm to 700.0nm. Again, the desired wavelength is selected by using the arrow keys to arrive to the appropriate number.

The scan ending wavelength is chosen by selecting the END option box using the arrow keys to select any number between 400.0nm and 700.0nm.

Two types of scans are available: continuous scanning (which is accessed by selecting 0 shots on the "shots" function), or incremental scanning (accessed via the shots setting).

The scan rate is variable within certain constraints for a continuous scan. Because the wavelength angular tuning sensitivity changes significantly between 400nm and 700nm, the maximum scan rate for a continuous scan changes accordingly. For example, at the and of the spectrum (400nm) a change of 1° in the BBO crystal angle corresponds to a 10nm change in signal wavelength. At the red end of the spectrum (700nm) only a change of .01° in the crystal angle is required to produce a 10nm change in signal wavelength. This nonlinearity affects the fastest scan rate achievable. At the blue end, the fastest scan rate is 0.07nm/s while at the red end, the fastest scan rate is 2.2nm/s. Thus, the wavelength range of the scan predetermines the fastest scan speed allowed.

Incremental scans are also possible. These are scans where a chosen number of shots are taken at one wavelength, the BBO crystal is then tuned to the next wavelength, and the same number of shots are taken at this new wavelength. This process is repeated at all chosen wavelengths comprising the scan.

Incremental scans are defined by determining the wavelength extremes of the scan, the number of shots to be taken at each wavelength as well as the wavelength increments.

To set up the incremental scan mode, depress the shots key, and choose the number of shots at each wavelength using the arrow keys. The display will read as shown in figure 4-7.

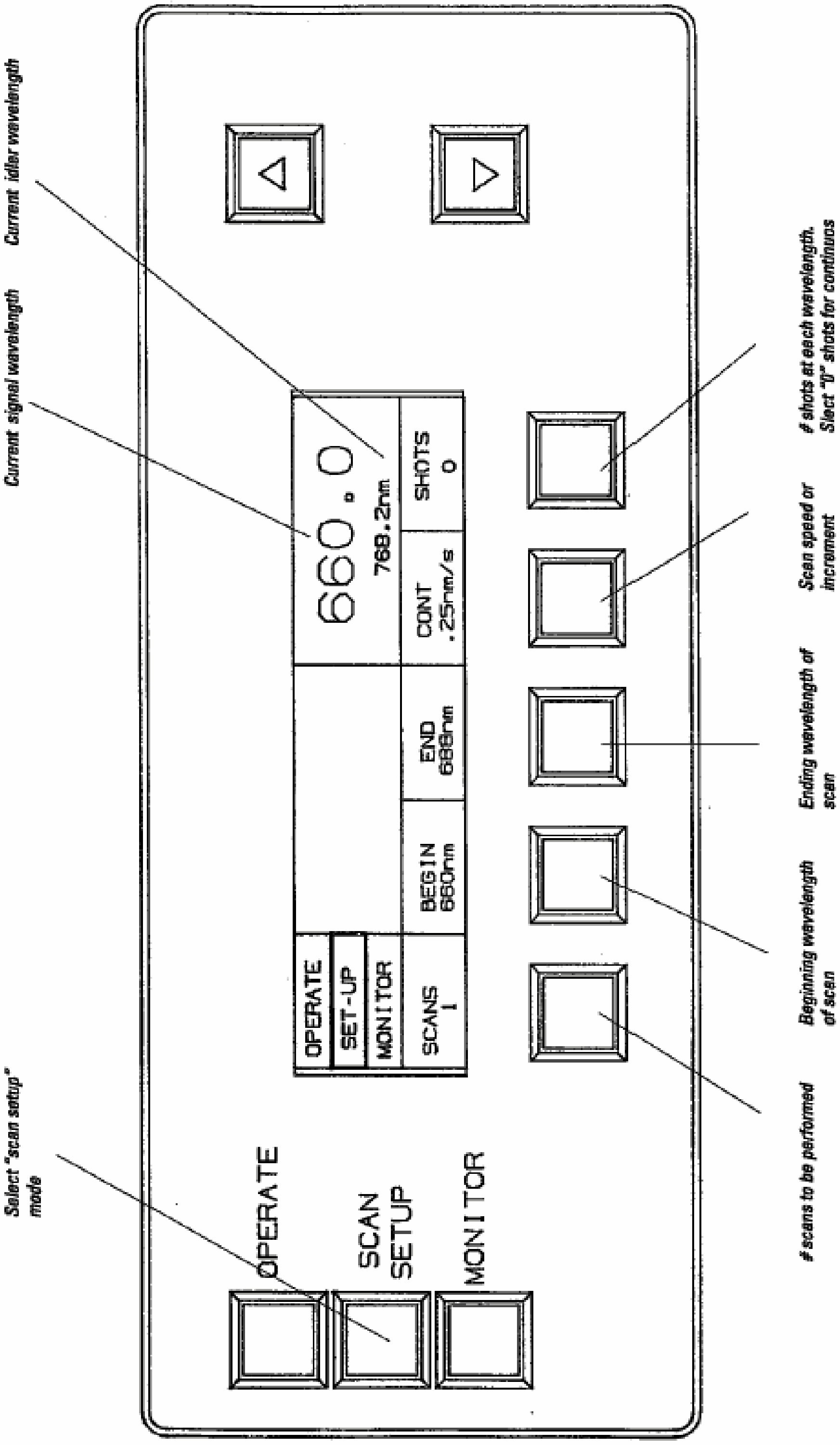

Figure 4-6: Backlit panel options displayed in the set-up mode.

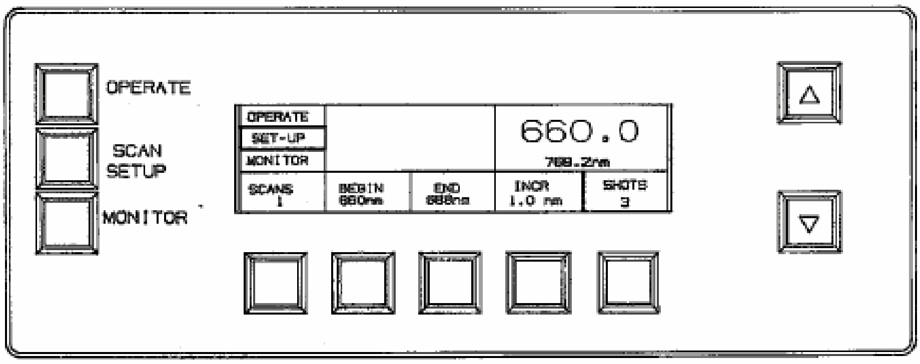

Figure 4-7: Backlit panel options displayed in the incremental scan mode.

Wavelength increments of the scan can be chosen by depressing the INCR key. The initial and final wavelengths of the scan can be chosen exactly as in the continuous scan mode; that is by using the begin and end keys.

Note on SAVE and RECALL of programs created in SCAN SETUP mode: Scan routines created or changed in the SCAN SETUP mode but can only be accessed in the OPERATE mode. To save a program, create it in SCAN SETUP, then switch to OPERATE mode. Press the save key, adjust the arrow keys until the desired number (program label number) is obtained, then depress the save key for 1.5 seconds.

To amend a previously-created program, retrieve the program in the OPERATE mode using the recall key (note that whatever was on the screen will be lost if not already saved), then switch to the SCAN SETUP mode, make changes, switch back to the OPERATE mode, select save, obtain the correct program label number which was recalled (using arrow keys) then depress the SAVE key for 1.5 seconds.

MONITOR Mode

This mode allows the GCR energy to be monitored for diagnostic purposes at any time during the operation of the MOPO without any disruption to the proper functioning of the system. A beamsplitter, inserted in the 355nm pump beam's path, directs a small percentage of its total energy into a photodiode. The energy of the pump laser can thus be monitored.

Upon choosing this option, the display shows:

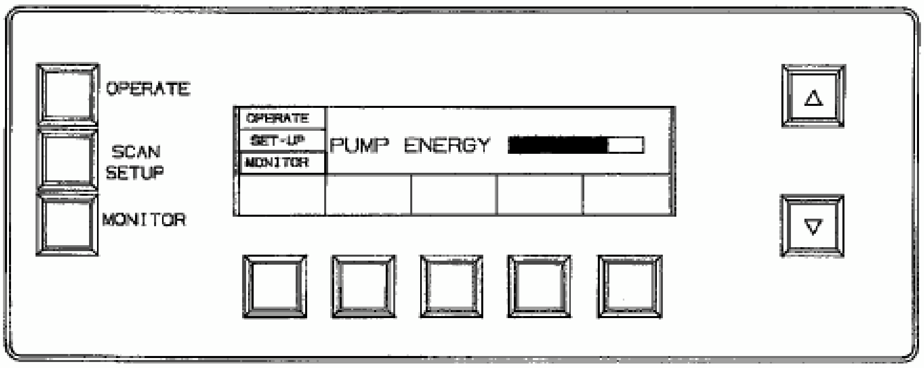

Figure 4-8: Backlit panel options displayed in the monitor mode.

Pump energy is shown as a bar graph and its level can be monitored periodically to ascertain the proper functioning of the GCR laser as compared to a baseline level.

5

Preventive Maintenance

The MOPO-710 has been designed for "hands-off" operation, requiring minimal maintenance.

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

The MOPO-710 should always be operated with the top cover in place.

Inspect daily all windows for contamination or damage. Windows should be cleaned with 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 optics to ensure safety is maintained (See Laser Safety section for details).

Customer Service

At Spectra-Physics Lasers, we take pride in the durability of our products. Considerable emphasis has been placed on controlled manufacturing methods and quality control through the manufacturing process; nevertheless, even the finest precision instrument will break down occasionally. We feel that our instruments have excellent service records, compared to competitive products, and we hope to demonstrate in the long run, that we can provide above average service to our customers-not only in providing the est equipment for the money, but in addition, service facilities that get your instrument back into action as soon as possible.

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

Replacement parts should be ordered directly from Spectra-Physics Lasers. For ordering or shipping instructions or for assistance of any kind, contact your nearest sales office or service center, and provide them with your instrument's model and serial number. Service data or shipping instructions will be promptly supplied.

Warranty

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

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

This warranty does not apply to any instrument or component not manufactured by Spectra-Physics Lasers. When products manufactured by others are included in Spectra-Physics Lasers' equipment, the original manufacturer's warranty is extended to Spectra-Physics customers. When products manufactured by others are used in conjunction with Spectra-Physics Lasers equipment, this warranty is extended only to the equipment manufactured by Spectra-Physics Lasers.

Spectra-Physics Lasers will provide at its expense all parts and labor, one way return shipping of the defective part or instrument (if required), and one half of the "zone charge" travel expense for on-site repairs.

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

The above warranty is valid for units purchased and used in the United States Only. Product 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 Lasers.

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

Service Centers

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Spectra-Physics Pty. Ltd.
25 Research Drive
Post Office Box 141
Croydon, Victoria 3136
Telephone: (03) 761-5200
Fax: (03) 761-5600

Belgium
Spectra-Physics BVBA
North Trade Building
Noorderlaan 133
2040 Antwerp
Telephone: (03) 541-7515
Fax: (03) 541-8202

Latin America and Pacific Regions
Spectra-Physics Lasers
1330 Terra Bella Avenue
Post Office Box 7013
Mountain View, CA
94039-7013
Telephone: (800) 456-2552
(415) 961-2550
Telex: 348-488
Fax: (415) 969-4084

France
Spectra-Physics SARL
Avenue de Scandinavie
ZA de Courtaboeuf
BP 28-91941 Les Ulis Cedex
Telephone: 1 69186310
Fax: 1.6907 60 93

Germany and European Countries Not Listed Separately
Spectra-Physics GmbH
Siemensstrasse 20
D-64289 Darmstadt
Germany
Telephone: (06151) 2708240
Fax: (06151) 79102

Japan
Spectra-Physics KK
15-8 Nanpiedai-cho
Shibuya-ku, Tokyo 150
Telephone: (03) 3462-4531
Fax: (03) 3462-4530

The Netherlands
Spectra-Physics BV
Prof Dr Dorgelolaan 20
Post Office Box 2264
5613 AM Eindhoven
Telephone: (040) 45 18 55
Fax: (040) 43 99 22

United Kingdom
Spectra-Physics Ltd
Boundary Way
Hemel Hempstead
Herts, HP2 7SH
Telephone: (0442) 258100
Fax: (0442) 68538

United States
Spectra-Physics Lasers
1330 Terra Bella Avenue
Post Office Box 7013
Mountain View, CA
94039-7013
Telephone: (800) 456-2552
Telephone: (415) 961-2550
Fax: (415) 964-3584

User Manual Feedback

Spectra-Physics Lasers User Manual Problems and Solutions

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

Thank you.

Name:____

Company or Institution:______________________________

Department: ____________________________________

Address:______________________________________

Instrument Model Number:____________ Serial Number:____________

Problem:______________________________________

Suggested Solution(s):______________________________

Mail or Fax To:

Spectra-Physics Lasers, Inc.
Quanta-Ray Quality Manager
1330 Terra Bella Avenue
Post Office Box 7013
Mountain View, CA 94039-7013
USA
Fax: (415) 961-7101