Operation and Maintenance Manual for the ND6000 Series Dye Laser

Continuum®

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996-0198 Revision K

System Operation Data Sheet

Project #:

Date:

User:

WARNING

The voltage setting on the PU6000 A&H Series power units at the time of installation may NOT be exceeded without consulting the Continuum Service office first. Exceeding the designated voltage can result in free-running (see manual for additional information), thermal focusing and optical damage. Failure to follow these precautions will result in voiding the warranty (see manual for additional information on your pump laser)

<table>
<tr><th>Energy Measured</th><th>Spec Energy</th><th>Wavelength</th><th>Pump Energy</th></tr>
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<tr><td colspan="2">Oscillator</td><td colspan="2">First Amplifier</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Final Amplifier</td></tr>
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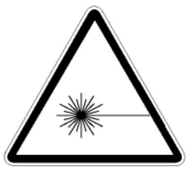
Grating Option Optics and Calibrations

Option	Grating P/N	Ang/turn	Zero Reset (nm)
STD (S2400)	199-0012		
UVG (S3000)	199-0078		
IRG (S1800)	199-0046		
DGO1 (D2400)	199-0012		
DGO2 (D1800)	199-0046		
DGO3 (D3000)	199-0078		

Table of Contents

Preface

The internationally recognized warning symbols shown here are used throughout the manual to alert the user of potential hazards when operating this laser.



LASER RADIATION:

The radiation symbol is to alert the user to the danger of laser radiation when performing certain operations and when the danger of exposure is the greatest. It is also used when the optical hazards are present.

DANGER VOLTAGE:

The lightning or thunderbolt indicates the presence of high voltage, which may pose a danger to the user or the equipment.

CAUTION:

The exclamation point symbol is to draw attention to other potential hazards not included under the optical or electrical categories. The user should be aware of special care that needs to be taken when performing potentially hazardous procedures.

WARNING: PERSONAL INJURY

The Safety section is placed as the first chapter of the manual to emphasize its importance and the need for everyone to read it before working with the laser.

The installation section includes a copy of the installation instructions for future reference. The site requirements are listed, as is the initial installation process step by step.

The Troubleshooting chapter presents common problems that are encountered and ways to solve them in both the electronic and optical areas. It is here that the more complicated procedures such troubleshooting stepper motor electronics are discussed.

The Appendix lists the Continuum warranty and gives Service telephone and FAX numbers for further help. The Operator Notes gives the user a convenient place to keep maintenance records and other information.

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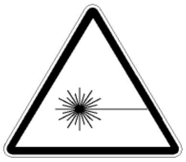
Préface

Les symboles de danger reconnus internationallement présentés ici sont utilisés tout au long du manuel pour avertir l'utilisateur des risques possibles lors de l'utilisation de ce laser.



Le symbole de radiation sert à avertir l'utilisateur du danger d'exposition à la radiation laser lors de l'exécution de certaines opérations et lorsque ce danger est le plus grand. Il est aussi utilisé en cas de risques optiques.

Le signe d'éclair indique la présence d'une haute tension qui peut représenter un danger pour l'utilisateur ou l'équipement.

Le point d'exclamation sert à attirer l'attention sur d'autres risques possibles non inclus dans les catégories optique et électrique. L'utilisateur devrait être conscient des mesures de protection particulières à prendre lors de l'exécution de procédures potentiellement dangereuses.

La section Sécurité est en tête du premier chapitre de ce manuel afin de souligner son importance et la nécessité incombant à chaque utilisateur de la lire avant de commencer à utiliser un laser.

La section Installation comprend une copie des instructions de montage pour future référence. Les exigences de site sont énumérées comme l'est le processus d'installation initial, étape par étape.

Le chapitre Dépannage présente les problèmes couramment rencontrés et indique les mesures à prendre dans les domaines de l'électronique et de l'optique. C'est aussi dans ce chapitre que les procédures plus complexes telles que l'élimination du fonctionnement libre sont expliquées.

L'Annexe décrit la garantie Continuum et fournit les numéros de téléphone et de fax du service après-vente. Les Notes de l'Utilisateur offrent à l'utilisateur un endroit pratique pour conserver les rapports d'entretien et d'autres informations utiles.

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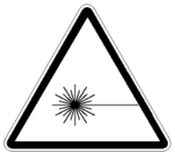
Vorwort

Die hier abgebildeten, international verständlichen Warnsymbole werden in der gesamten Anleitung dazu verwendet, den Benutzer auf mögliche Gefahrenquellen beim Laserbetrieb hinzuweisen.



Das Strahlungssymbol warnt den Benutzer vor gefährlicher Laserstrahlung bei bestimmten Betriebsverfahren und bei den stärksten Strahlengefährdungen. Es wird auch für optische Gefahrenquellen verwendet.

Das Blitzsymbol weist auf das Vorliegen von Hochspannung hin, die eine Gefährdung für Benutzer oder Gerät darstellt.

Das Ausrufezeichensymbol soll auf weitere Gefahren aufmerksam machen, die nicht unter die Kategorie Optik oder Elektrik fallen. Der Benutzer sollte auf besondere Maßnahmen achten, die bei evtl. gefährlichen Verfahren anzuwenden sind.

Das erste Kapitel dieser Anleitung ist der Sicherheitsabschnitt, da dieser äußerst wichtig ist und vor dem Betreiben des Lasers von jedem Benutzer gelesen werden sollte.

Der Abschnitt zur Installation enthält für den zukünftigen Bedarf ein Exemplar der Installationsanleitung. Hier sind sowohl die Standortanforderungen als auch eine schrittweise Erläuterung der Erstinstallation enthalten.

Das Kapitel Fehlersuche und -behebung beschreibt bekannte Probleme (Elektronik und Optik), die auftreten können, sowie Abhilfemaßnahmen. Hier werden auch kompliziertere Verfahren, wie das Verhindern von “Freischwingern”, erörtert.

Der Anhang enthält die Continuum-Garantie sowie Service-Rufnummern und -Faxnummern, unter denen weitere Hilfestellung verfügbar ist. Unter “Benutzernotizen” kann der Benutzer bequem Wartungsdaten und sonstige Informationen aufbewahren.

Manual Organization

Chapter I, Safety, provides all the appropriate safety procedures and warning labels. These instructions must be followed to ensure safe operation of the laser equipment.

Chapter II, Installation, provides a list of site requirements and supplies required.

Chapter III, System Operation /Software describes operating instructions for the ND6000 series lasers. Routine startup and shutdown procedures are given here. Software instructions are also included in this chapter.

Chapter IV, System Description is a overall description of the laser and the control module commands.

Chapter V, Maintenance describes the routine maintenance procedures to keep the equipment operating properly. Only those procedures listed may be performed by the operator.

Chapter VI, Troubleshooting describes troubleshooting procedures should the equipment malfunction.

Chapter VII, contains warranty information and Continuum's Customer Service Department telephone number. The Appendix has detailed information on remote operation.

Related Documents

Continuum Documents:

Operator's Manual for the Continuum Powerlite Series PL8000/PL9000 Pump Laser, COM 996-0255.

Operator's Manual for the Continuum Surelite Series, COM 996-0207.

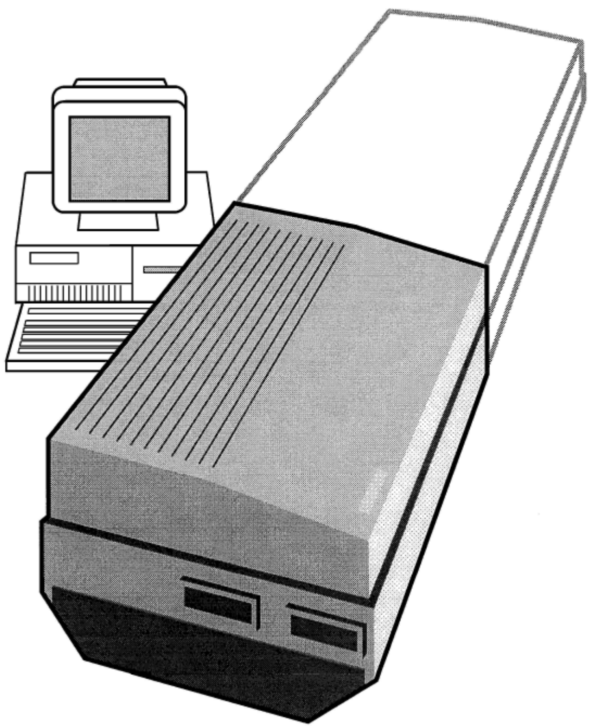
Operator's Manual for the Continuum Ultra-Violet Tracker (UVT), COM 996-0199.

Laser Safety:

American National Standard for the Safe Use of Lasers, Laser Institute of America. (www.laserinstitute.org)

Laser Safety Guide, Laser Institute of America.

A guide for Control of Laser Hazards, American Conference of Governmental Industrial Hygienists.



The ND6000 Laser System

Chapter I Laser Safety Precautions

Caution:
Only operators experienced in working with lasers and trained by a Continuum service engineer should use and service the ND6000 laser. Otherwise, the warranty may be voided.

A. Class IV Laser Safety Precautions

The following summary of general safety precautions must be observed by everyone working with this Class IV laser. For a complete listing of safety standards see the ANSI booklet or other references listed at this chapter's end.

General Safety Rules

1) This laser equipment must be located in a locked area with access only by authorized personnel. The area must be marked by well-defined warning signs, and off limits to unauthorized personnel.

2) Provide interlocks for all doors.

3) This laser equipment must be operated only by qualified personnel who have also been trained by a Continuum Customer Service Engineer.

4) Laser equipment must be shut off when not in use.

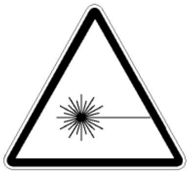
5) Place a fire resistant background behind target areas.

6) Coat surrounding work areas with a material that absorbs scattered radiation.

7) Be sure there are no volatile substances in the area which the laser beam could ignite.

8) Tracking of individuals, vehicular traffic, aircraft or airborne objects with laser radiation is prohibited.

Optical Safety Rules



1) Eye safety is the greatest concern. Be aware at all times that this is a Class IV laser, the highest and most dangerous classification. Main beam reflection from a polished surface can cause severe and permanent eye damage.

2) Turn off all power to the laser before beginning maintenance or repair of the ND6000 Tunable Dye Laser.

3) Be sure that the light from the flashlamps of pumping source is obscured from the eyes; it is dangerous if viewed directly.

4) Always wear laser goggles appropriate for the wavelength and beam intensity generated.

5) Do not wear or use any object that may reflect laser light such as a watch, ring, pen, etc.

6) Mark the lab well with warning signs when the laser is operating and provide interlocks for all doors.

7) Light the area around the laser so that the operator's pupils are constricted normally.

8) Operate the laser without its covers ONLY when aligning it; replace covers promptly.

9) Close beam exit shutters when laser is not in use.

Electrical Safety Rules

1) Discharge all power capacitors and turn off all power of pumping source before beginning maintenance or repair operations.

2) Avoid the high voltages that are present in the laser head whenever ac power is supplied to it.

B. Safety Procedures for Dyes & Solvents

All personnel in areas where dyes and solvents are used must be informed about the hazards of exposure to dyes and solvents. The project supervisor must give each employee a copy of these safety rules and ensure that all safety precautions are observed.

Handling Dyes and Solvents

1) Never smoke, eat or drink in any laboratory or storage space containing any dye or solvent. Post warning signs stating these prohibitions on each door leading into every such laboratory and storage space.

2) Store and handle dyes and solvents to current OSHA or Federal standards and in ways minimizing the possibility of accidental spillage or exposure of personnel.

3) Store and handle solvents only in rooms provided with a fast air exhaust system that vents outside.

4) Inform all persons working in the ventilated space where they can locate the exhaust system control switch.

5) Actuate this exhaust system whenever any solvent is spilled until all vapors are exhausted.

6) Report any accidental exposure to toxic (or possibly toxic) dyes or solvents to a supervisor.

7) At least two people should be present at all times when dyes or solvents are being handled or used.

8) Ensure that the system is turned off before leaving the room, or lock the room.

Personal Protection

1) Wear approved gloves using the MSDS sheets as a guide whenever skin contact with dyes or solvents may occur.

2) Wear goggles whenever solvents or dye solutions may splash.

3) Wash promptly whenever skin becomes wet with solvents or dye solutions. Remove clothes wet with solvent to avoid a flammability hazard.

4) Be prepared to use an air respirator or self-contained breathing apparatus if exposure to high solvent vapor concentrations (2000 ppm for methanol) is possible.

Material Safety Data Sheets

Material Safety Data Sheets meeting OSHA standards are found in the Appendix of this manual. They include the common dyes and solvents listed in Figure 1.1. These Data Sheets describe the physical and chemical properties of each compound. Also listed are health hazards, signs of exposure, first aid and preventative practices. Each user of these materials should be familiar with this information.

Figure 1.1
Types of Dyes Used in the ND6000

Coumarin 440	LDS 698	Rhodamine 590 tetrahydroborate
Coumarin 460	LDS 750	Rhodamine 590 chloride
Coumarin 480	LDS 751	Rhodamine 590 perchlorate
Coumarin 500	LDS 765	Rhodamine 610 chloride
DCM	LDS 821	Rhodamine 610 perchlorate
Fluorescein 548	LDS 867	Rhodamine 640 perchlorate
Kiton Red 620	Rhodamine 575	Stilbene 420
LD 390		Sulforhodamine 640
LD 489	Solvent: Methanol	

Note: Material Safety Sheets are provided in Appendix of this manual. Appropriate care must be exercised when handling these materials.

Symptoms of Methanol Exposure

The following exert from methanol's Material Safety Data Sheet highlights both the special danger of volatile solvents and the usefulness of these sheets.

Warning!
Exposure to methanol may result in eye irritation, headache, drowsiness, light-headedness, nausea, vomiting, visual disturbances, blindness, eye burns, digestive disturbance and failure of vision. It may enter the body through inhalation, ingestion, through the skin and/or eye contact.

C. ND6000 Safety Features

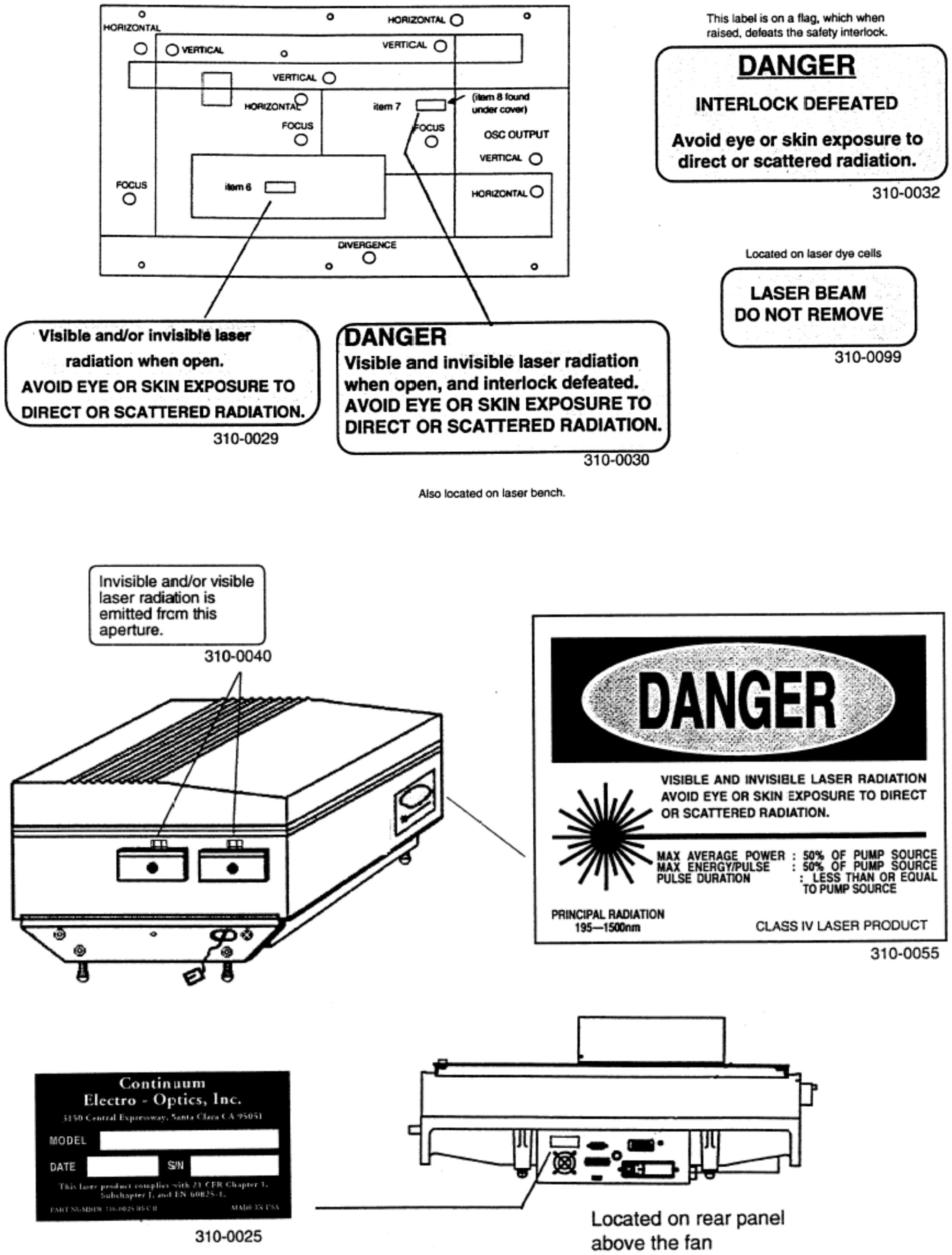


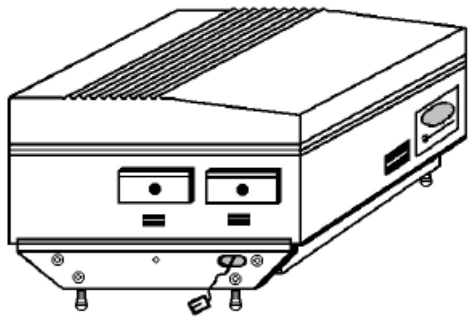
Figure 1.2
ND6000 Warning Labels

Laser Covers

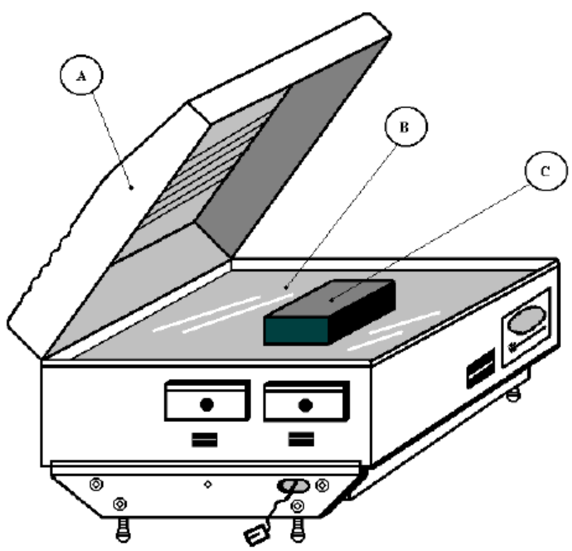
Three covers protect against stray laser radiation from the ND6000. Opening the hinged top cover **A** reveals a smoked plastic plate **B** covering the optical path. The oscillator cover **C** beneath plate **B** encloses the dye cell. See Figure 1.3.

Safety labels attached to the ND6000 warn of specific dangers. Figure 1.2 shows the safety labels. Locations of these labels are described in Figures 1.4 and 1.5.

Figure 1.3
ND6000 general cover



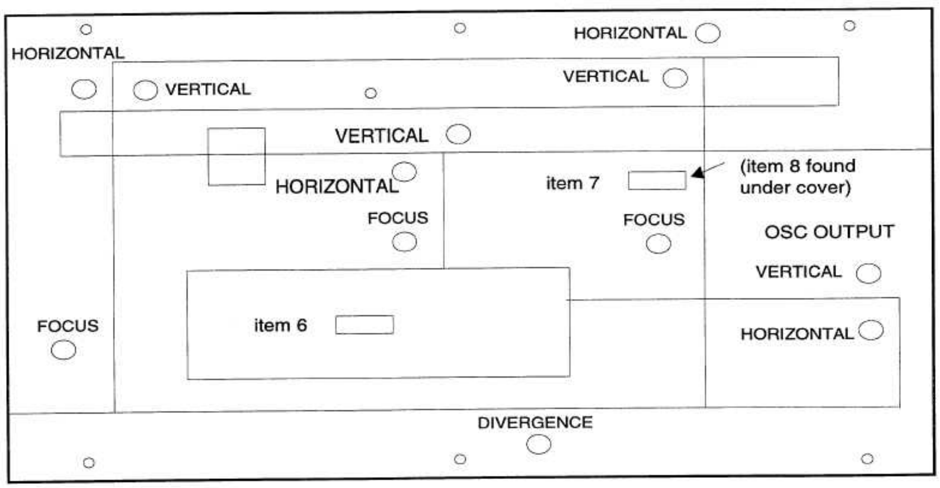
A. Hinged top cover
B. Optic area cover
C. Oscillator cover



Safety Interlocks

The ND6000 contains two safety interlocks. The main interlock is activated when the smoked plastic plate **B** is removed (see Figure 1.3). This interlock can be daisy-chained to a similar interlock on Continuum Powerlite™ or Surelite™ pump lasers, so that opening either laser shuts both off. When the ND6000 is pumped by another laser, the interlock protects the ND6000 only.

Figure 1.4
Smoked Plastic Internal Cover



This interlock can be defeated by raising the actuator switch, marked by the "DANGER: Interlock Defeated" sign under the smoked plate **B** about 25 cm from the pump beam entrance (see Figure 1.3). This figure also locates the interlock connection plugs.

Warning!
Do not operate the ND6000 without its covers. When plastic cover B must be removed during use (for alignment or maintenance) wear goggles, and strictly observe all safety precautions. Replace cover as soon as work is completed.

To prevent dye from being burned onto the dye cell surfaces an interlock between the ND6000 and its dye circulator, the DCP6100, is installed. This main safety interlock is part of the 110/220 Vac cable connecting the two units and cannot be defeated.

Figure 1.5
DCP6100 Front & Rear Panels

Rear View

Front View

Exit shutter

The ND6000 has beam shutters located outside the laser housing at the exit ports of both the dye laser output and the pump laser mixing output (for wavelength extension options only). Closing the beam shutter merely prevents the beam from exiting; it does not shut down the laser.

Beam dump

A beam dump (located in the pump laser path just after part of the pump beam is directed toward the oscillator cell) blocks pump energy from reaching both amplifier stages. Pushing this beam dump down into the pump beam results in a greatly attenuated dye laser beam.

D. Government and Industry Safety Regulations

Continuum strongly suggests that all customers purchase a copy of the **American National Standard for the Safe Use of Lasers** (ANSI Z136.1-1986) in order to read and implement necessary precautions. The American National Standards Institute (ANSI), a member of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), issues this booklet. Write or call the publisher listed below for information on obtaining a copy of ANSI Z136.1-1986.

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

Continuum's user information complies with section 1040.10 of 21 CFR Chapter I, Subchapter J concerning Radiological Health published by U.S. Department of Health & Human Services Center for Devices & Radiological Health, 1988.

E. Additional Safety References

- *Regulations of the Administration and Enforcement of the Radiation Control for Health and Safety Act, 1968*. US Dept. of Health and Human Services, Public Health Service and Food and Drug Administration. (http://www.fda.gov/; http://www.os.dhhs.gov/)
- *American National Standard for the Safe Use of Lasers*. Laser Institute of America. (www.laserinstitute.org)
- *Laser Safety Guide*. Laser Institute of America.
- *A Guide for Control of Laser Hazards*. American Conference of Governmental Industrial Hygienists.

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Chapter II Installation

Continuum will perform the initial installation of the ND6000 and train operators. Information in **Chapter I** will assist installation and troubleshooting. We recommend contacting Continuum Service Department prior to moving or reinstalling the ND6000 Dye Laser.

A. Supplies Required

Please have the following supplies on hand for the dye laser installation; they are also necessary for operation. The welcoming letter sent on receipt of your order lists these items as well. They include supplies needed for a Continuum YAG laser.

- Kodak IR phosphor card
- 208-220 Vac, 3 phase, 20 A, with a plug that fits your receptacle
- 3 standard 110 Vac receptacles
- 1 gallon methanol, reagent grade or better
- Distilled water, 3 gallons
- Cold tap water source and drain, with 15-70 psi and 2 gal/min flow
- 100-500ml glass beaker
- Kodak linagraph direct print paper, type 1895 (cat. 1986009)
- Laser goggles (1 pair per person in the room)
- Power meter, 10-30 watt, with a volume absorber detector
- Rhodamine 590 perchlorate, 1 gram
- Tektronix 2467 oscilloscope or equivalent which shows nanosecond pulses in room light
- Photodiode with response time of less than 1 nanosecond.

Initial Installation

Follow the instructions given in this chapter to prepare the equipment for first-time installation, but **do not** install.

Warning!
Do not connect the cables or power up the ND6000 before the Continuum service engineer arrives at the installation site or the warranty will be voided.

A Continuum customer engineer must connect cables, turn the system on, and perform all initial system checks and adjustments. The Continuum engineer will also demonstrate the operation of the ND6000, and provide training for the system operators.

Note:
If the ND6000 is relocated after its initial installation, Continuum strongly recommends that the installation procedure at the new location be performed by Continuum.

Please perform these steps in advance of the Continuum customer service engineer arrival:

- **Step 1** Schedule the Continuum customer service engineer for your installation when the equipment arrives.

- **Step 2** Prepare the site for the equipment, following the safety rules given in Chapter I, Safety, and in ND6000 site requirements in this chapter.

- **Step 3** Inspect the crates upon arrival for shipping damage and notify the shipper if any damage is visible.

- **Step 4** Unpack the system and check that all parts are present as listed in the packing list. The ND6000 is shipped in two crates:

  - The ND6000 laser crate.

  - The CCM (CPU, keyboard and monitor) crate. This crate, if ordered, includes a power supply, stepper motor control cables, the DCP6100 and a customer tool kit.

Note:
Notify Continuum Customer Service if any parts are missing.

- **Step 5** Check all parts for shipping damage. Any shipping damage is the responsibility of the shipping company and buyer. Be sure to open the ND6000 cover and check for loose parts.

Note:
If any damage is found, notify the shipper and Continuum customer service immediately.

- **Step 6** Set the equipment in place; refer to *Positioning the Laser* in this chapter.

- **Step 7** (Optional) If intending to use a remote computer to control the system, or supplying an external timing signal for operation, fabricate the interconnect cables (see the Appendix).

B. ND6000 Site Requirements

Warning!
Please read all lasers safety regulations before choosing a location for the ND6000.

Laser Position

The ND6000 must be located in a locked area with access only to authorized personnel. Clearly label the entrance with laser warning signs. The room should be totally enclosed, without windows or apertures where a laser beam can escape. Aim the laser towards the back of the room, never towards a doorway.

Room Air

Locate the ND6000 in a clean area, where the temperature is stable during the working day. If the room is air conditioned, place the equipment away from the effects of the ducted air.

Wall Covers

Mount a fire-resistant cover on the walls behind the laser target areas. All other areas surrounding the work location should be coated with a material that absorbs scattered radiation.

Place the ND6000 on a solid bench that allows access from all sides, and directly next to the pump laser. Figure 2.1 gives the external dimensions of the ND6000. Leave space at the ND6000 output for a UVX/UVT Harmonic Generator (if required) and any customer-supplied equipment.

Electrical Power

Three standard 110 VAC, 15 amp, 3-prong electrical outlets are needed for the:

- ND6000
- Computer monitor
- Computer Control Module (CCM)

Pump Laser

The Continuum pump laser normally requires a 208 volt 3 phase 15A ac power source and a water cooling system (Refer to **Supplies Required**, Chapter II and to your specific **pump laser manual** for details.)

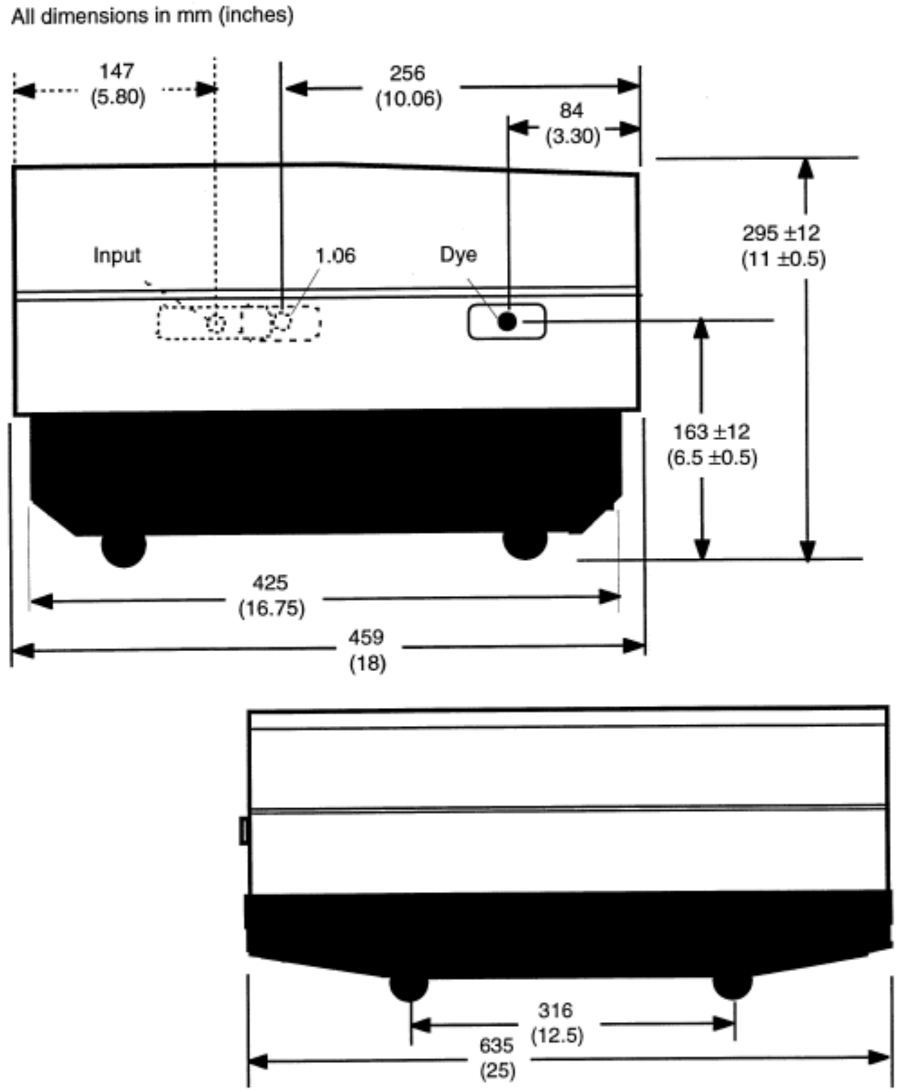


Figure 2.1
External Dimensions of ND6000

C. Positioning the Laser

The following steps may be performed only by a Continuum service engineer.

Note:
If a different type of pump laser is installed, output must conform to Continuum specifications.

- **Step 1** Position the Continuum YAG pump laser as described in the pump laser manual.

Caution:
The sine drive has been secured for shipping. It must be released from the restraint prior to use or permanent damage will occur.

- **Step 2** Remove the sine drive shipping tie-down, and the tissue between the glass plate and the ball.

- **Step 3** Position the ND6000 input in line with the pump laser output shutter. Note the alignment of the locking pins on both units (refer to Figure 2.1). Be sure that sufficient space remains on the bench for a UVX/UVT, a IR option (if ordered) or any other equipment needed at the ND6000 output.

- **Step 4** Position the Computer Control Module (CCM) within 6 feet of the ND6000 to allow for the length of interconnecting cables. The CCM and keyboard are standard desktop PC/AT configurations and the monitor sits on the CCM. Figure 2.2 shows CCM/ND6000 cable connections.

- **Step 5** Position the DCP6100 in a place which allows easy access to the dye reservoirs, drain bottles and control. Be sure that it is also in a location in which accidental contact (e.g. from being dislodged) is minimized.

Continuum recommends that a large, shallow metal tray (e.g. for film developing) be placed under the DCP6100 to prevent damage from spills.

Warning!
Do NOT connect the cables or power up the ND6000 before the Continuum service engineer arrives at the installation site or the warranty will be voided.

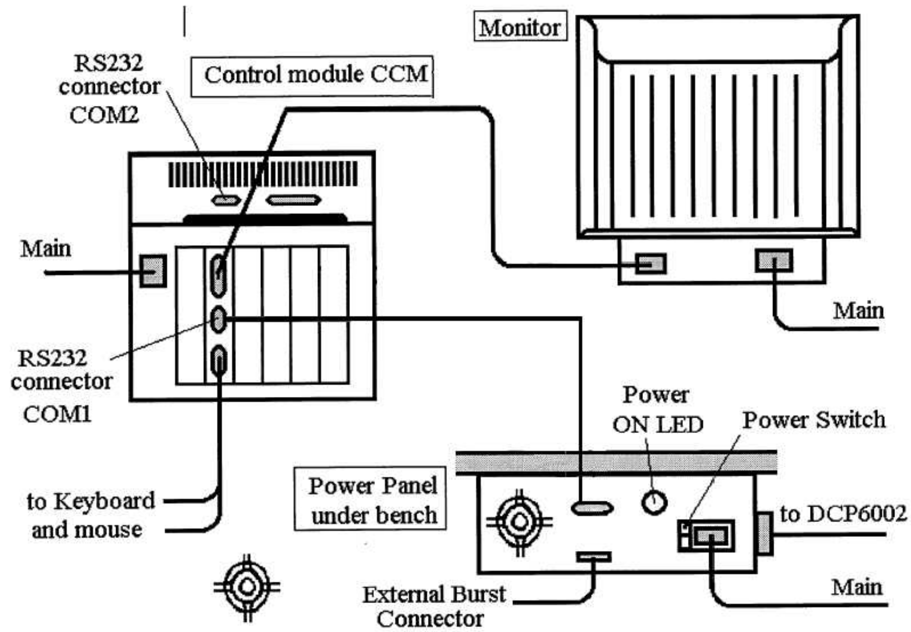
D. CCM Installation

Continuum is responsible for cabling the CCM to the ND6000 as part of the initial laser installation. Users may reinstall the CCM. Figure 2.2 illustrates a representation of the necessary connections between the ND6000 and CCM.

Position the CCM (a PC/Pentium clone) within 6 feet of the ND6000 so that its cables will reach the laser's power panel. The CCM monitor normally sits beside the CCM.

- **Step 1** Be sure the ND6000, CCM computer and monitor are OFF.
- **Step 2** Attach the monitor cable to the CCM.
- **Step 3** Plug in the CCM AC power cable.
- **Step 4** Start the computer. (Follow instructions for your specific computer model to start Windows. Refer to the manual that comes with your computer for specific guidelines. You may double-click on the ND6000 icon to start the program).

Figure 2.2
CCM and ND6000 connections



Note: The standard ND6000 system does not include a computer. Because computer models and manufacturers have different system configurations, you may have to refer to the manual that comes with your specific computer to ensure your connections are in the right place.

Warning!
The program diskettes have program settings unique to your system. It is important that you keep the originals in a secure location so that you can make copies at any time.

- **Step 5** **(Reinstallation only)** With CCM power off, attach the communication cable (Figure 2.2) between the CCM and laser.

E. DCP6100 Installation

Continuum is responsible for DCP6100 installation as part of the initial laser installation. The supplied 3/16" Teflon tubing is 5' long. Tubing lengths may be increased to 10' without voiding the warranty.

- **Step 1** Attach the 4 Teflon hoses between the DCP6100 and ND6000 with the supplied connectors. Tighten each connector finger-tight plus an additional 1/2 turn.

Note:
The connections on both modules are labeled Oscillator or Amplifier, IN or OUT. In addition, the hose connector ends are similarly coded. Figure 2.3 shows the hose connection plates of the DCP6100 and ND6000, respectively.

- **Step 2** Remove the reservoir bottle caps and fill the reservoirs with about 250ml of clean methanol (1/4 full), washing down the sides in doing so. Replace the caps and install a drain bottle.

- **Step 3** Connect the umbilical power cord between laser and dye circulator.

- **Step 4** Turn on the ND6000 and DCP6100 ac power, but not the pump laser. Allow methanol to circulate. Turn off and check for leaks at the 8 tubing connections, re-tightening slightly if necessary.

- **Step 5** Drain the methanol from both paths (use both drain valves) and fill both reservoirs with dye solutions (refer to Chapter V for details on flushing the DCP6100 and replacing dye solution).

F. Connecting the Safety Interlock

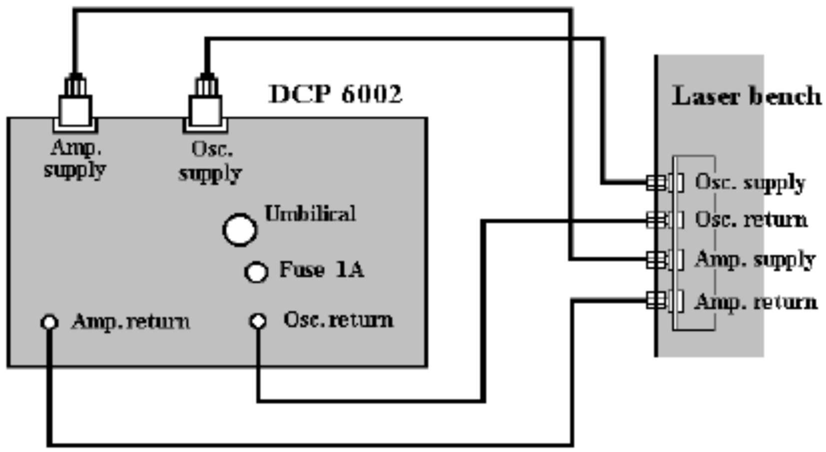


Figure 2.3
DCP6100 and ND6000 plumbing connections

Purpose

The only electrical connection between the ND6000 dye laser and the YAG laser is with a safety interlock; a twisted wire pair with a 3-prong connector. (The outer 2 pins of the connector are used.)

The safety interlock will shut off both lasers whenever:

1) the ND6000 smoked plastic dust cover is removed (unless the interlock defeat bar is in use), or

2) the DCP6100 circulator is not pumping, or

3) any other equipment that is daisy-chained to this safety interlock opens the interlock circuit loop. There will be a warning to the user that operation with the safety interlock defeated is extremely dangerous.

Warning!
Operation of the laser with the safety interlocks defeated is extremely dangerous. Observe all safety procedures carefully.

To the Pump Laser

To link the ND6000 safety interlock with a Continuum pump laser, remove the three-pin jumper plug from its connector under the YAG chassis near the control electronics box. Connect it to the matching security plug of the dye laser. This joins the dye laser security system and the YAG security, which in turn, is part of the YAG's control/power supply console security.

To the DCP6100

The security connection between DCP6100 and ND6000 is made when the ac power cord between them is attached.

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Chapter III System Operation / Software

A. System Overview

The ND6000 is a nanosecond Dye Laser that is capable of emitting a tunable radiation when pumped by the second or third harmonic beam of a Neodymium YAG laser. It includes an optical bench, a dye circulator and a computer controller (see below).

The ND6000 laser system controller schematic is provided in Figure 3.1.

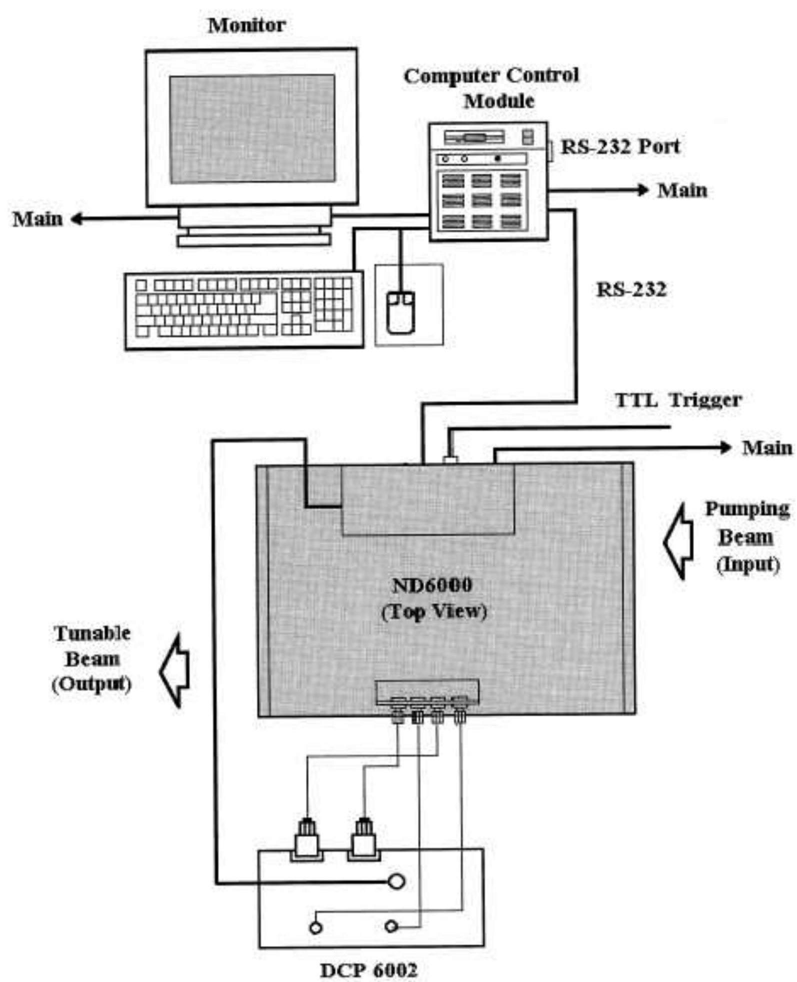


Figure 3.1
ND6000 System Overview

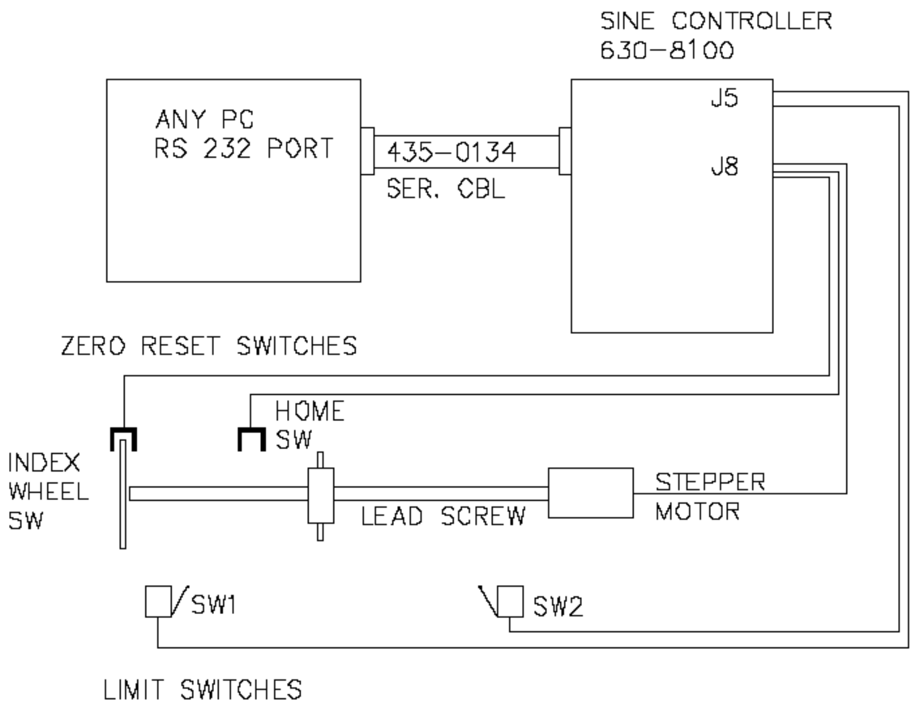


Figure 3.2
ND6000 System Block Diagram

Motor Driver Stepper Motor: The dye oscillator includes a grazing incidence grating and a tuning mirror. Wavelength tunability is achieved through a sine drive mechanism that tilts the mirror in the desired position. A matched motor and power driver pair give precise control of that mechanism.

EOT SW1, SW2: Two end of travel limit switches prevent the system from being driven past the end of travel thereby preventing damage to the system.

Index Wheel, Home SW: An index wheel and home SW allows the system to find home upon command or system power-on. The index wheel is coupled to the sine drive lead screw thereby providing a vernier to the home SW.

Indexer Controller: A microprocessor based indexer card is used for precise control of the motor driver. That card receives acceleration, velocity, and position information from the controller's CPU and generates the appropriate pulses to step the motor. Additional logic provides
other necessary functions, such as monitoring the end of travel limit switches, interface with a homing circuitry, and control of an external TTL trigger to allow external motion commands without the intervention of the computer.

ND6000 Computer Software: The system's controller is an IBM-PC based clone computer which provides precise calculation of the desired wavelengths. The wavelength information is provided by the user and is converted to motor steps and sent to the Indexer micro-stepper board. The micro-stepper board provides the position and velocity control to the motor driver. Backlash and other second order issues associated with the sine drive are calculated by the CPU and added to the wavelength/position command, and then sent to the Indexer controller making them transparent to the user.

Local Control: There are two separate user interfaces in the system. The primary interface is a local interface consisting of a monitor, keyboard and mouse. This interface allows control of wavelength settings, dithering between two wavelengths and configuration of the system.

Host Serial RS232C: Remote operation of the system by a host computer using this standardized interface allows operation of the ND6000 from a host computer. A simple command sequence sets the system into motion.

TTL Trigger: Allows remote triggering of scan.

Computer control

The ND6000 computer controller can be used in two different ways in order to control the movements of the dye laser internal sine drive mechanism.

- The **Software** delivered with the ND6000 is the easiest way to control the wavelength emission of the dye laser. It is a user-friendly interactive program with windows and pull down menus. It is not necessary to be familiar with programming of an IBM PC.

- The **Microprocessor-based Indexer** mounted in the computer controller can be programmed directly. The responsibility for creating a computer program in that case lies with the user. Although creating an interactive program should pose no problem for an experienced programmer, the program needs to integrate all the handlers for a good control of the sine drive characteristics, backlash compensation, end of travel switches, calibration, wavelength display and tracking).

Continuum does not recommend programming of the Indexer card. For fast response of the dye laser, the external burst mode operation allows the user to run the dye laser at the limit of the Indexer's response time. See Figure 3.24 *External Burst Scan Window*. Select scan mode.

Disk Contents

The ND6000 program has been specially designed to operate the Continuum ND6000 Tunable Dye Laser. The ND6000 program was written with several assumptions about the computer literacy of the user. They are listed below.

- The user is familiar with Microsoft Windows operation, the concept of an operating system, and the specific Windows functions of opening Windows, starting applications and using disk drives.

- When buying a new ND6000, the software necessary to run the system comes on a CD. It will be loaded on the hard drive of your computer during installation. The software will be stored in the main drive in a folder called **C:\ND6000.** These files are listed in Table 3.1.

Table 3.1
ND6000 Software Files

File Names	**Description**
ND6000.EXE	The Main Executable program file.
ND6000.POS	The program file that stores the main operating parameters.
Sxxxx.VAR	The parameter library file that restores the operating parameters for the configuration using a single grating with "xxxx" lines per millimeter.
Dxxxx.VAR	The parameter library file that restores the operating parameters for the configuration using a dual grating with "xxxx" lines per millimeter.

NOTE:
The ND6000 can be configured in a single or dual grating arrangement, and with three different grating options, 1800, 2400 or 3000 grooves per millimeter.

An additional set of files is also necessary to run the software. These other files are listed in Table 3.2. They are Window and Visual Basic system files.

Table 3.2
Additional Software Files

File Names	**Description**
Comdlg16.ocx	Visual Basic ActiveX control files
Mscomm16.ocx	
Threed16.ocx	
Dynamic library files.	
VB40016.dll	
OC25.dll	
Ftltlt.ttf	
ND6000.bmp	Continuum bitmap file

NOTE:
One additional disk labeled "ND6000 for Windows" containing all the files required to operate the ND6000 is also provided with the system. This disk is a backup copy to be used only in case the files located in the Computer hard drive have been corrupted.

B. System Operation

Daily Startup

Tools Needed:

- Safety glasses
- Red fluorescent paper
- Burn paper
- Power meter

Warning!
WEAR GOGGLES. Observe all safety precautions. Be sure the output beam aims into a safe area (e.g. beam dump or energy meter).

1) Engage (lower) the dye amplifier beam dump.

2) Turn on the pump laser, dye laser electronics and dye circulator. Allow the YAG to stabilize and the dye to flush the cells for 20 minutes.

3) Turn on the CCM. Self-calibrate if software warns that the system is un-calibrated. (see figures 3.39, 3.40, and 3.41)

4) Set wavelength to peak of the dye in use.

5) Open the dye laser output port.

6) Admit the pump beam using single shot mode. BE SURE TO PUMP ONLY THE DYE OSCILLATOR AT THIS STAGE. Verify with red paper placed at the output of the dye laser that the output beam is not dangerously aimed.

7) If using wavelength extension options, verify with red paper that the beam passes through its optics without being clipped. If there is clipping, perform routine alignment explained in that option's manual.

8) BE SURE THAT THE DYE LASER BEAM IS NOT STOPPED BY ANY PAPER OR OTHER BEAM BLOCK INSIDE THE ND6000 COVERS, AND CONTROL WHERE THE BEAM IS AIMING. Remove (raise) the dye amplifier beam dump and check the beam using burn paper in a clear plastic bag. If quality or power is unacceptable, perform a routine alignment (See Chapter V: **Routine Alignment**.)

9) The system is now ready to run.

Shutdown

Follow this procedure to ensure that the self-calibration will not be lost while powering the ND6000 down.

1) Return to the main window closing all other application tasks.

2) Click the Quit menu and wait until the stepper motor is safely parked at one of its poles and the screen message proposing to exit the program is displayed. Click the Ok button and wait for the software to shut down the ND6000 application.

3) Exit Windows.

4) Turn the CCM OFF.

5) Turn OFF the ND6000, DCP6100 and pump laser.

6) Shut the dye laser output port and lower the beam dump.

NOTE:
Turning OFF the computer switch while the ND6000 software is still active could corrupt the files necessary for the system to perform correctly.

355 nm Operation

This manual assumes that the ND6000 pump beam is 532 nm green light. Other wavelengths are acceptable. Another common pump beam is 355 nm. When using a 355 nm pump beam, make these changes to the ND6000 before beginning operation.

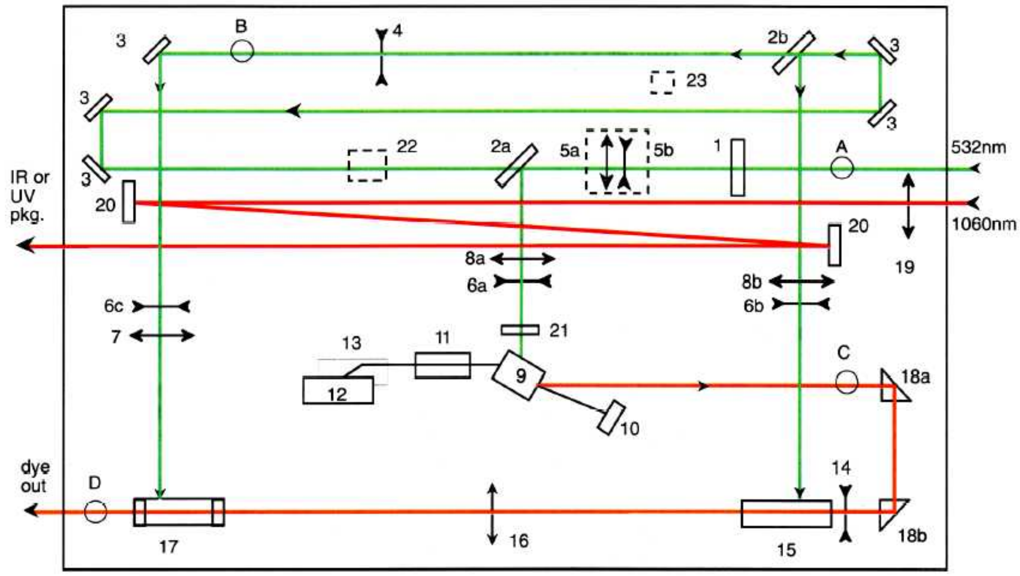


Figure 3.3
ND6000 layout options, optics
Key: ***Numbers refer to optical elements, letters to alignment jig stations.***

Standard ND6000 Optics	
1. Half wave plate	108-0002
2a. Beam splitter	105-0157
2b. Beam splitter	105-0158
3. Mirror, dichroic	105-0022/0023
4. Lens, spherical, -1000 mm	102-0055
5a. Lens, cylindrical, +200 mm, AR355/532	101-0080
5b. Lens, spherical, -150 mm, AR 355/532	102-0046
6. Lens, spherical, -70 mm	102-0031
7. Lens, cylindrical, +70 mm	101-0095
8. Lens, cylindrical, +50 mm	101-0041
9. Dye cell, oscillator	199-0080
10. Moya mirror, oscillator	105-0026
11. Beam expander, NPB-3	618-0810
12. Sine drive mirror	105-0027
13. Grating, 2400 lines	199-0012
14. Lens, -70 mm	102-0027
15. Dye cell, preamp	199-0084
16. Lens, +300 mm, spherical	101-0040
17. Dye cell, amp, windows	110-0010
5 mm capillary for above	199-0013
18. Prism, 90 degrees	109-0008
22. Beam dump	618-3900
Beam dump filter	107-0061
23. Safety interlock defeat	
A-D. Alignment test points	

High energy pump beam options	
3. 2 dichroic mirrors	105-0160
5. Dichroic mirror	105-0160
Optics for UVX options	
19. Lens for 1064 nm beam	varies
20. Mirror, 0 degree	105-0001
21. Filter, neutral density	varies
Pump beam diameter options	
7 mm pump beam telescope	618-3100
17. Amp dye cell window for 3 to 5 mm capillaries	110-0010
3 mm capillary for above	199-0074
4 mm capillary for above	199-0073
5 mm capillary for above	199-0013
6 mm capillary for above	618-3200
355 mm pump beam options	
1. Half wave plate	108-0002
2a. Beam splitter	105-0156
2b. Beam splitter	105-0159
Grating options (2 if dual option)	
13. Grating, 1800 lines	199-0046
13. Grating, 3000 lines	199-0078
13. Grating, 2400 lines	199-0012
Dual wavelength options	
12. Sine drive mirror	105-0073
9. Osc. Cell windows	110-0037

1) Flush the dye system, clean its filters, and change the dye to the appropriate, fresh dye (see Chapter V).

2) Rotate the half wave plate (1) (Figure 3.3) into the pump beam path.

3) Remove beam splitters 2a and 2b with their kinematics mounts from the optical bench. Each mount is secured with a single M5 bolt.

4) Replace both beam splitter mounts on the optical bench.

5) Exchange each pair of mirrors (P/N 105-0022) with their kinematic mount: undo the M5 bolt holding the mount to the optical bench and install the mount holding a pair of 355 nm dichronics (P/N 105-0160).

6) Similarly, exchange the final amplifier pump mirror (P/N 105-0022) in position (3) in its kinematic mount (see above step) with a mount holding a P/N 105-0160 dichroic.

7) Perform a routine alignment (Chapter V) to realign the pump beam. Also make the dye beam pass through the amplifier cell close to the edge where the pump beam strikes, rather than through the center of the cell. This will increase dye beam power, but may degrade its quality.

8) Optimize the dye concentration (see Chapter V, Figure 5.6, and section **Optimizing Dye Concentration Levels**)

Re-Calibration Procedure

If the ND6000 software is not properly terminated, a warning message will be displayed, suggesting proceeding to a zero reset calibration. (See **Zero Reset** in this chapter)

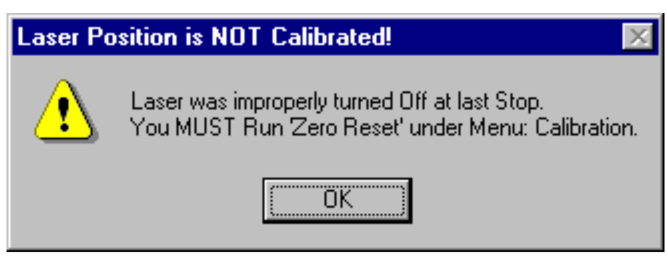


Figure 3.4
Out of Calibration Window

After clicking the Ok button, a permanent message will be displayed in the main current wavelength display window (Figure 3.5.)

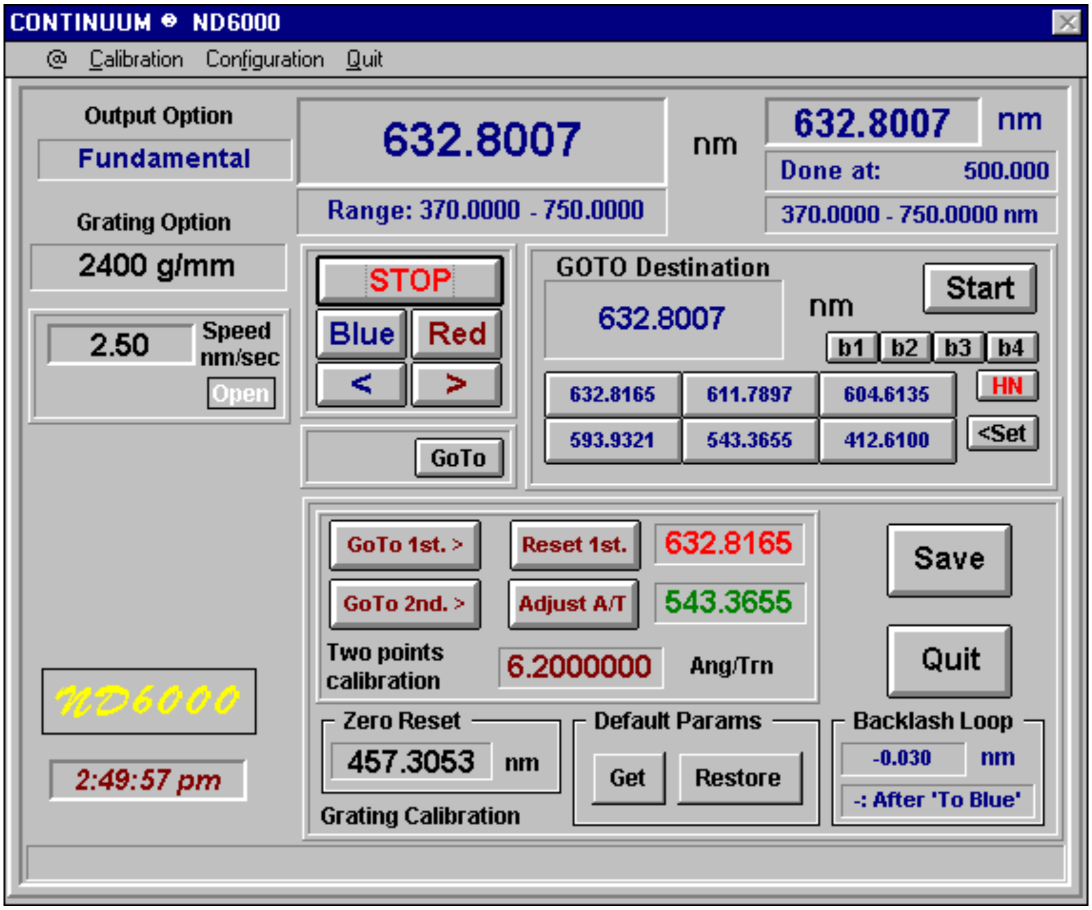


Figure 3.5
Calibration Status Message

In order to re-calibrate the system i.e. re-adjust the accuracy of the displayed wavelength, the operator will need to execute the **Zero Reset Calibration** procedure described later in this chapter.

NOTE:
If you exit improperly from an action, the message “Need Zero Reset” (Figure 3.5) will appear in the GOTO wavelength box.

C. Software Organization

General Description

This chapter describes the ND6000 computer interface. It is based on the same principles as Microsoft Windows based programs. If the user is unfamiliar with these types of programs, refer to the Windows User Manual included with the computer.

Windows and Menus

The next figure (Figure 3.6) is an overview of the basic ND6000 screen.

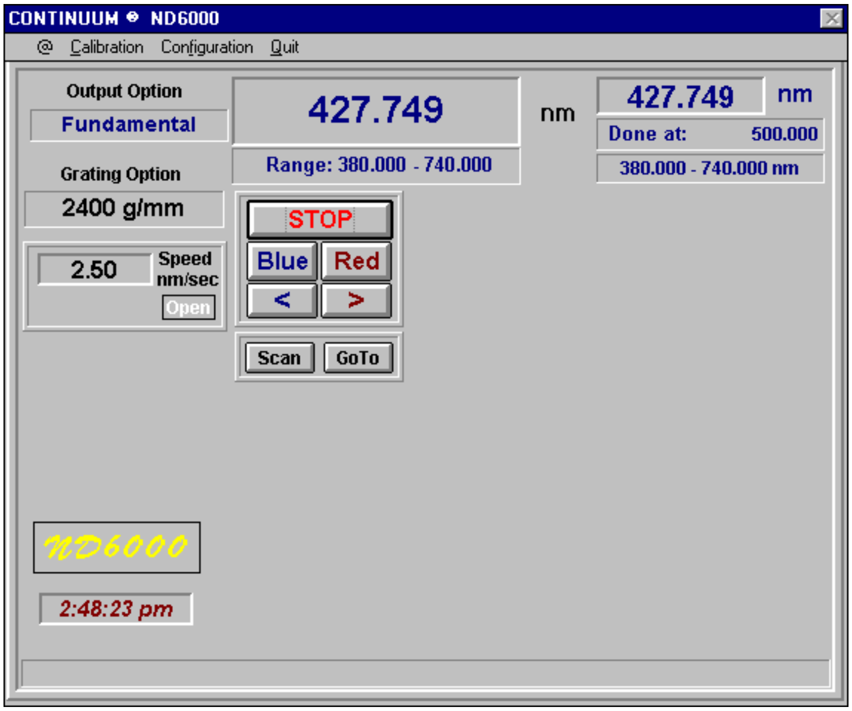


Figure 3.6
Overview of the ND6000 Program Window

This screen is divided into several fixed windows for ease of use. Clicking on these screens controls the ND6000 software operations. When necessary, other windows appear to allow further parameter display and configurations setting, as well as calibration of the laser. The ND6000 basic screen contains five different areas or windows that are illustrated in the following figures.

Signal Displays Window

The Signal Displays window (Figure 3.7) shows in the top center of the screen, the current signal wavelength at all times (except during the zero reset calibration procedure). That display window shows output values listing the unit of measure. You may toggle between units of either nanometers (nm) or wave numbers (cm^{-1}) by clicking on the label. The system defaults to the last unit of measure the user selected. The top left corner of the screen shows the chosen output option and grating option.

The top right part of the screen displays information on the fundamental wavelength generated by the dye oscillator as well as the wavelength scanning values (destination and scans limits).

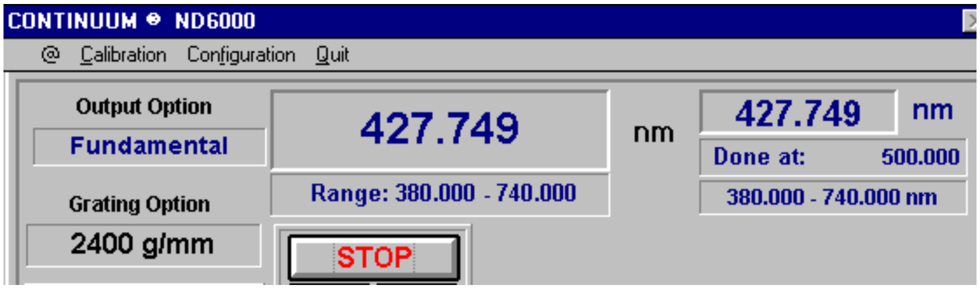
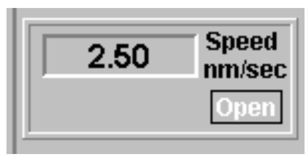


Figure 3.7
Signal Display Window

Speed Window

The speed window (Figure 3. 8) displays the current GOTO speed and allows changes.

Figure 3.8
Speed Window (minimized)



See **Speed Window** section for a description of how to change all speeds.

Help Window and RS232 Status

This window (Figure 3. 9) where the ND6000 logo is displayed contains a panel reporting remote Commands received through the RS232. It contains also a panel where error messages and help messages are displayed as well as a clock.

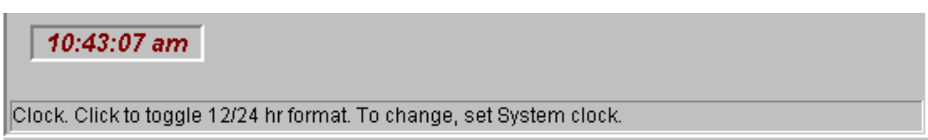


Figure 3. 9
RS232 Status/Help Window

Motion Control Window

This window located in the center of the screen, (Figure 3. 10) contains buttons to start and stop all wavelength movements: GOTO, Scan, Displacements (move) in the chosen direction, continuing until stopped or reaching a calibration limit.

Figure 3.10
Motion Control Window

The **Blue** and **Red** buttons start motion toward the respective blue and red ends of the spectrum. The Stop button stops all motion. The **Red** and **Blue** buttons and the <Esc> key on the computer keyboard can also stop motion.

The ‘ **<** ‘ and ‘ **>** ‘ buttons are used to make small wavelength movements. The laser will move as long as the button is depressed and will stop when the button is released. The speed used by these buttons is displayed on the bottom of the speed Window. Larger wavelength movements are made using the **Numeric Keypad.**

Pull Down Menu Windows

The top part of the ND6000 screen (Figure 3. 9) offers four different pull down menus respectively a Calibration menu, a Configuration menu, a Quit program menu and an Information menu (@).

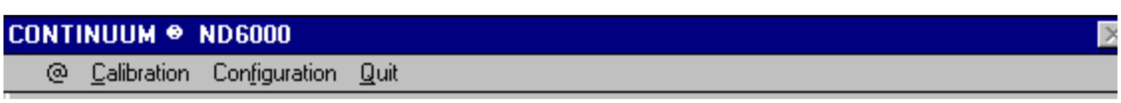


Figure 3. 11
Pull Down Menus

Calibration Menu

Clicking on the Calibration Menu allows access to two Calibration Windows (Figure 3. 12). The Grating calibration Window and the Zero Reset Calibration

Window. The Grating Calibration function will be explained in more detail in section called **Grating.** The Zero Reset function allows to recalibrate the ND6000. For more detailed operation see **Zero Reset** section.

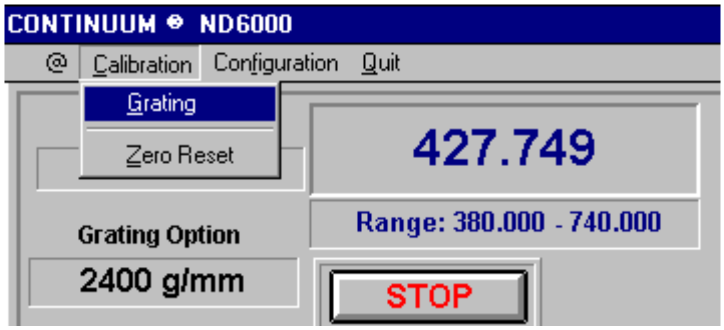


Figure 3.12
Calibration Pull Down Menu

Configuration Menu

Clicking on the Configuration Menu (Figure 3. 13) allows to change the wavelength display units (nm or cm-1) and/or operating conditions (fundamental wavelength display or harmonics). It allows also to change the serial port parameters, the grating option used in the dye oscillator and choose the shape of the triggering pulse when operating the laser in external burst mode. The help menu controls the appearance of the help messages. For more detailed operation see **Windows and Menus for Scanning** section of this chapter.

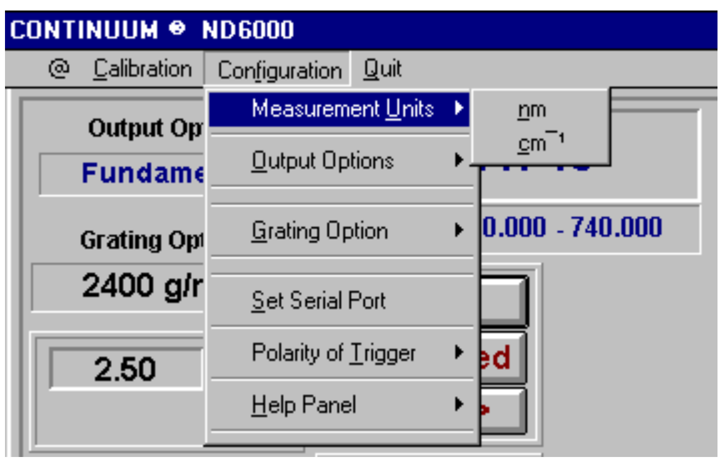


Figure 3.13
Configuration Pull Down Menu

Quit Menu

To quit the ND6000 software, the operators should always click the quit function in the menu area. A second level of security is displayed before quitting the program under the form of an optional display panel (Figure 3.14).

Figure 3.14
Quit Pull Down Menu

Information Menu

Displays system information including part number and software revision level (Figure 3.15).

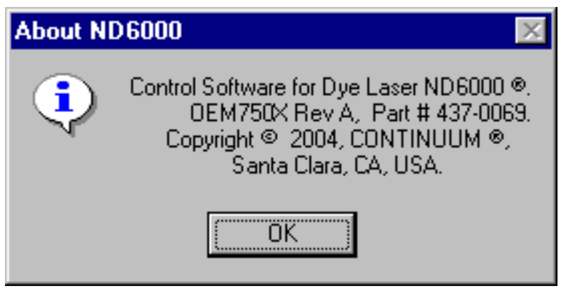


Figure 3.15
Information Menu

"Hidden" Windows

The **Open/Hide** button opens and hides windows. Several windows only appear on an as needed basis. These include the GOTO window, Scan window, RS232 window, part of the speed window and the Numeric Pad.

GOTO Window

The GOTO window (Figure 3.16) open when clicking on the GOTO command button. It displays the destination wavelength for a GOTO movement and allows modifications to be made. For a more detailed operation see **GOTO Window** section.

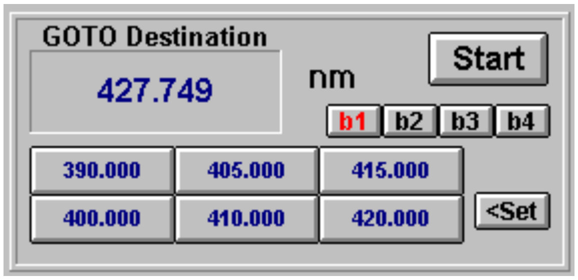


Figure 3.16
GOTO Window

Scan Window

The Scan window (Figure 3.17) opens when clicking on the Scan command button. It displays current scan mode and parameters. It also allows the user to change the values for a scan and between four different scan modes. For more detailed operation see Figure 3.21.

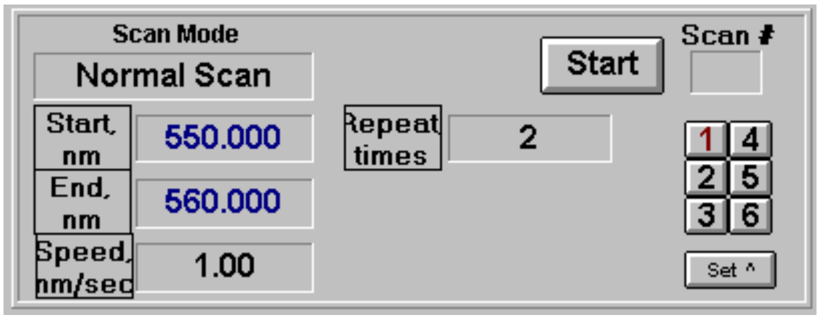


Figure 3.17
Scan Window

Speed Window

The speed window (Figure 3. 18) opens when clicking on the open button of the speed window. It displays the current GOTO speed and allows changes.

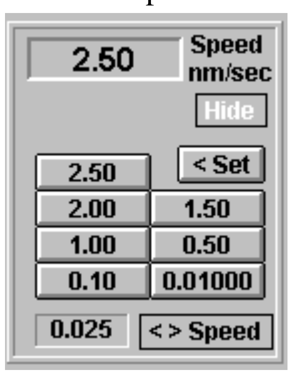


Figure 3.18
Speed Window (maximized)

Numeric Keypad

If the mouse pointer changes into a "black box" when placed over a display, clicking on that display opens a Numeric Keypad (Figure 3.19)

Figure 3.19
Numeric Keypad

The user may enter a new value using the numbers and decimal point on the Numeric Pad or the keyboard. Use the **Backspace (<)** key on the Numeric Keypad or the numbers on the keyboard to correct an entry error. To complete the entry, click on the **Enter** button on the Numeric Keypad or the **Enter** key on the keyboard to complete the entry. Limits for current values are displayed at the bottom of the Numeric Keypad. If the entered value exceeds limits, it will be automatically changed to the nearest limit and a beep will sound. To cancel an entry, click on the target display and close the Numeric Keypad without changing the original value.

D. Windows and Menus for Scanning

There are five methods of moving the laser to a new wavelength:

- GOTO: Move to a GOTO destination using the current GOTO speed. Use the Red and Blue buttons to start movement. To stop movement, click on the Stop button. Refer to GOTO Window for more details.

- Manual tuning: Move to a wavelength at a slower speed, Use the left (<) and right (>) arrow keys on the keyboard to tune the laser.

- Normal scan: Scan a selected wavelength range at a programmed velocity for a specified number of scans. Enter the scan parameters in the Scan Window.

- Burst Mode (There are two forms of burst mode):

- Internal Burst Mode: In this mode, the laser will jump to a selected wavelength, pause, and then scan a preset distance. The system pauses for a defined period of time and scans the preset distance to the next paused wavelength position. This pattern is then repeated over the range.
- External and Fast External Burst Mode: This is a typical burst mode with the scan segment length and start controlled by external pulses.

- Displacement: This feature is available for Remote Operation only. The user may Displace (move) the wavelength by a specified amount. Refer to Remote Operation for more details.

The following windows control the above actions and work as indicated:

Speed Window

The Speed Window (see Figure 3.18) displays the current GOTO speed. The user can change the speed from the Speed Window as well. The **OPEN/HIDE** button displays or hides the bottom part of the window to control the functionality of the Speed Window.

The Speed Window has a Speed Display and saving buttons that are used to save and recall the currently displayed speed. When the display is in nanometers, the laser has a constant speed in nm/sec. To move the laser at slower speeds, click on ONLY the < > buttons.

To change the speed, use the mouse and click on the button of the speed desired. The GOTO speed serves as the reverse scan speed during all scans and as the step speed during all *Burst Scans*.

Note:
If you select any Dual Grating, Mixing Option, and/or combination of those, the speed will NOT be linear. This means that the speed will be different at different points of the wavelength range. The display ONLY shows average speed of the current range, instead of the exact speed.

GOTO Window

In the **Control Window**, select the **GOTO** button to display the GOTO window (Figure 3.20)

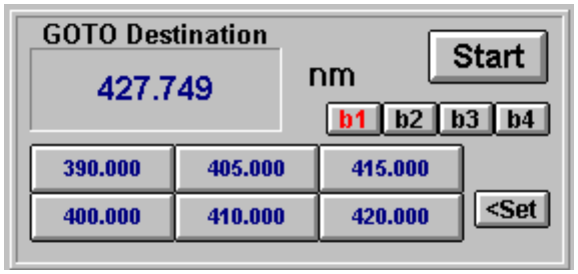


Figure 3.20
GOTO Window

The GOTO destination display window displays the currently selected destination. New values are set in the **Numeric Keypad**. Four banks of saving buttons are used to save and recall current GOTO destinations.

Note:
For details on Numeric Keypad functionality, refer to Figure 3.19.

The GOTO destination is displayed in units of nm or cm^{-1} for both the current Grating Option and Output Option. Clicking on a nm or cm^{-1} label will toggle between these units in the destination display window; as well as the values currently stored in the saving buttons. If a displayed value is out of range, the system will adjust the GOTO destination and the destination display to the nearest limit.

The **Start** button is used to starts movement toward the destination point using the GOTO speed. It can also be used to stop motion. The **STOP** button, **Red and Blue** buttons, and the **<Esc>** key, located on the keyboard, will also stop the GOTO motion.

Scan Window

Scans are the main method of using the ND6000 laser. Selecting the scan button will display the scan window (Figure 3.21)

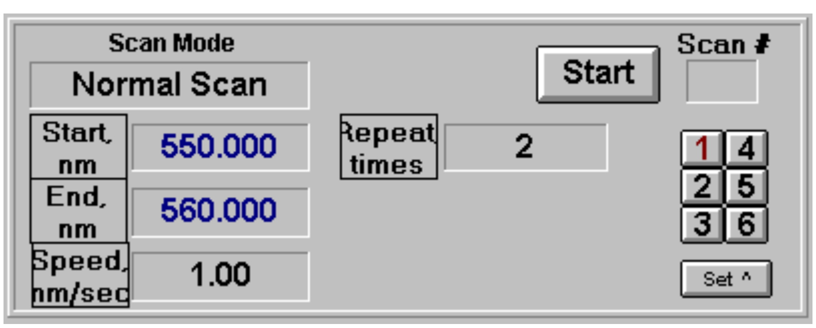


Figure 3.21
Scan Window

The user may use the following functions in the Scan Window:

Select Scan Mode
Selecting the Scan Mode display will toggle modes between Normal, Internal Burst, External Burst, and Fast External Burst (Fast Ext. Burst) Modes. Corresponding scan windows are displayed in Figures 3.22 through 3.25.

Note:
For details on Numeric Keypad functionality, refer to Figure 3.19.

Start and End Wavelengths
For all scan types, select a Start wavelength and an End wavelength. Selecting either of these displays opens the **Numeric Keypad** for entering the new wavelength value. Clicking the label toggles measurements (see Figure 3.21)

Speed
For **ONLY** the Normal Scan mode, enter a value for the measurement speed (in nm/sec) in the Speed nm/sec display. The reverse scan speed of all scans and the step speed of all Burst scans is the same as the current GOTO speed.

Number of Scans
In Normal or Internal Burst mode, enter the number of scan repetitions in the Repeat Times display.

Step Size
The step size is the distance the laser wavelength will be tuned by each burst. For **ALL** Burst modes, set the Step distance. When you toggle between measurement units, the value of the step is not converted because it has different values at different points of range.

Delay Time
In Internal Burst mode, enter the desired time to pause between burst steps in the **Delay, sec** display.

Save Scan Values
Click the **Set ^** key, followed by one of the six numbered saving buttons.
This saves the current scan mode and all its parameters in that button.
Previously saved values in the button will be lost. The parameters displayed on the screen are the current values.

Recall Scan Values
Choosing one of the six numbered buttons selects the saved scan mode and all parameter values. Currently displayed scan parameters will be lost unless the parameters are stored in a saving button.

To recall a set of scan parameters, select the numbered button associated with the values. When selected, the color of the button will change from white to red. This indicates that the current scan values have been stored with this red number. If you change any of the current scan parameters, the color of the button changes from red to white. This indicates that the current scan was originally stored under the white number, but has changed.

When recalling or initiating new scan parameters you have three options to recall or change parameters: 1) You can do nothing and will lose the new parameter; 2) You can save new scan parameters to a specific number by selecting the Set button followed by the appropriate color (white or red) button, saved parameters will be updated to reflect the current scan parameters; or 3) You can restore values that have been recalled from a numbered button (if they are current), by selecting only the numbered button.

Start

The **Start** button begins the current scan. From the Control Window, click on the **Scan** button to open the Scan Window. Close the Scan Window by clicking on the **Scan** button.

Normally Invisible Buttons

The Resume and Control buttons appear only when needed.

Resume

The Resume button appears if a scan is stopped prior to its normal completion. It is used to resume scanning, despite the fact that several measurements near the point of Stop/Resume will be incorrect. When Stop is selected a second time or any parameter is changed, Resume mode is cancelled and the Resume button disappears.

Continue Button

The Continue button, which appears only in External Burst mode while waiting for external trigger to start the next step, can be used to manually start the next step.

E. Different Scan Modes and Windows

There are four different scan modes:

- A ‘Normal scan’ where the laser is programmed to repeat a scanning between two positions in the spectrum at a preset speed and a defined number of times.

- Three different Burst scan modes where the laser is programmed to repeat a scanning between two positions in the spectrum a defined number of times but by preset moving Step distances. These Burst scan modes can be started internally through the mouse or externally triggered by an RS232 commands or a TTL signal.

Normal Scan

When the Scan Mode is in “Normal” mode, pushing the Start button in the scan window starts a normal scan. The displacement to the Start position will occur at the reverse scan speed. It is the same as the GOTO Speed. Then the laser will scan from Start nm to End nm wavelengths at the designated Speed nm/sec. When the number of repeats of scans is greater than one, the wavelength returns to the Start nm wavelength at the reverse speed, then immediately starts the next scan, repeating the scan cycle (refer to Figure 3.22).

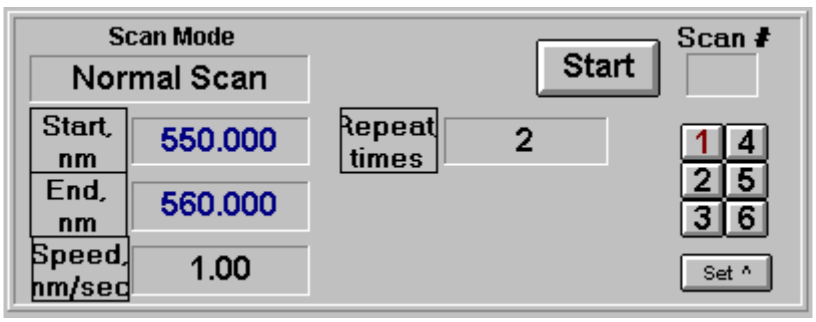


Figure 3.22
Normal Scan Window

Burst Scan Modes

There are three Burst scan modes: Internal (Figure 3.23), External (Figure 3.24) and Fast External (Figure 3.25). All motion occurs with GOTO speed normally set to maximum.
When using one of the Burst modes, pushing the Start button in the Scan Window starts a burst scan. The laser will move from its current position to the start position in reverse speed. The reverse speed is the same as GOTO speed. It will then scan from the Start to End positions at the reverse speed in preset “step” distances or increments. The step direction is shorter than the “Start, nm” to “End, nm” range. After moving the Step distance, the laser waits for the next trigger to go another step distance. This process continues until the laser reaches or exceeds the End position. **Internal Burst Scans** sets can also be repeated a number of times.

Burst scans differ only in how they are triggered. An **Internal Burst Scan** is triggered by internal timer. An **External Burst Scan** is triggered by external RS232 commands. This is accomplished by clicking the Continue button, or by sending a TTL signal. Refer to **Direct TTL Port** in this chapter. Fast **External Scans** are triggered only by TTL signals (see Appendix for more setup details).

Internal Burst Scan

When the Scan Mode is in "Internal Burst" mode, pushing the Start button in the scan window starts an internal burst scan (see Figure 3.23). The delay, in seconds, is set with a resolution of .1 sec. The range is .1 sec to 1000 sec. The laser will repeat the entire Burst cycle as many times as is set in the 'Repeat' parameter. During the final cycle, the laser will stop at the 'End' of the wavelength.

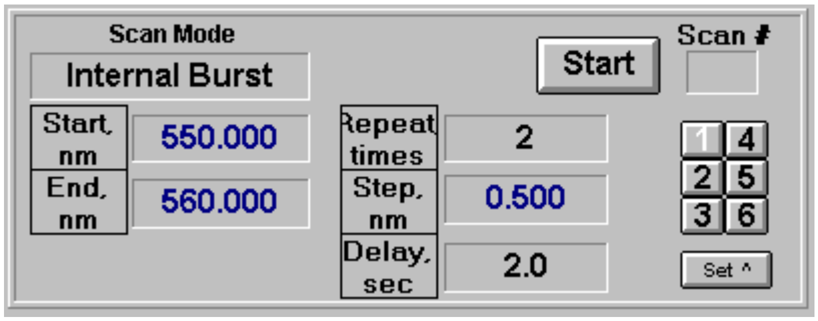


Figure 3.23
Internal Burst Scan Window

External and Fast External Burst Scans

The External Burst Mode can be used with any of the following triggers.

- An RS232 command X@. There is a delay (~200 ms) between sending the X@ command and the start of the next step.

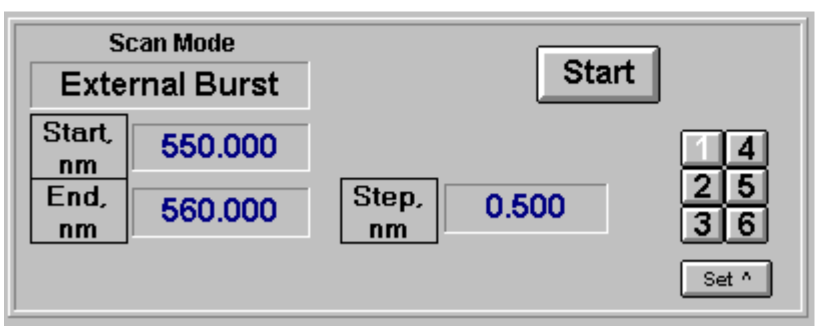


Figure 3.24
External Burst Scan Window

- The Continue button. This button can trigger a step. It appears in the SCAN window only in **External Burst** Mode while it is waiting for a trigger.

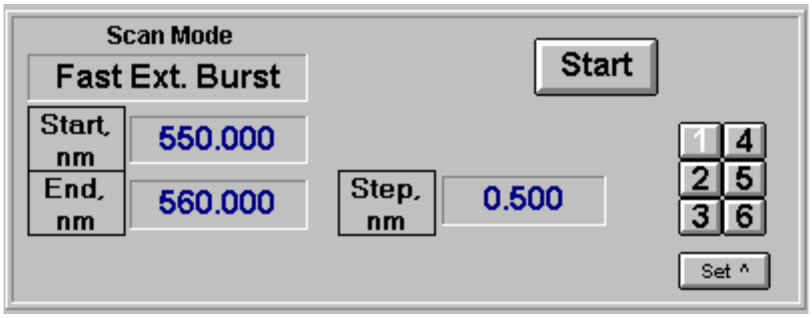


Figure 3.25
Fast External Burst Scan Window

- A direct TTL trigger. In the **External Burst** mode, this trigger uses pulses sent through the Direct TTL port to start a step. In this mode, there is also some delay (~100ms) between the triggering edge and the start of movement. The Direct TTL signal must have a pulse duration that is shorter than the time required by the laser to move the step distance.

  The Fast External Burst mode can be used only with a Direct TTL trigger. The advantage of the **Fast External Burst scan** is its very short delay between the trigger and the start of movement (see Section L, Fast Triggering of Burst Modes, found later on in Chapter III for details and setup).

Backlash Compensation
In order to have repeatable scans, the software includes a loop, which compensate for Sine Drive mechanical backlash. When scanning from red to blue, each scan will overshoot the destination wavelength by a **Backlash Loop** in nanometers and return from the opposite direction. This parameter is set during the Grating Calibration process.

Warning!
Backlash should be adjusted only by Continuum.

Backlash Loop

Overshoot the destination wavelength by Backlash Loop nanometers and return from the opposite direction. This parameter is set in the Set Parameters window, selected from the Grating Calibration menu. It is applied after all GOTO, Displacement, Normal scan and the **end** of a Burst scan in the red direction. Not used **during** Burst scans.

Backlash Speed

This parameter, also set in the Set Parameters window, sets the speed of the backlash correction. To instead apply the corrections in the blue direction, click the **+ After to Red** button; its label will change to **+After to Blue** and **Backlash Loop** will become negative.

Wavelength Motion Range Limits

Each crystal calibration and the grating calibration have a minimum and maximum calibrated wavelength, which appear at the top of the **SIGNAL DISPLAYS** window during **Grating Calibration** and **Files**. No wavelength change is possible beyond the most restrictive of these four limits, except during calibrations. In addition, the **Set Parameters** window contains these absolute values, which limit all motions:

Min Limit: the smallest signal wavelength ever allowed for any motion
Max Limit: the largest signal wavelength ever allowed for any motion

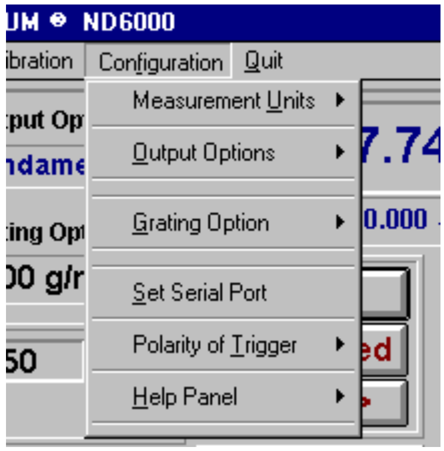
Warning!
Minimum and Maximum Limit are hardware limitations; expanding their range may cause mechanical or crystal damage.

F. Configuration and Calibration Menus

Configuration Menu

The Configuration menu choices are illustrated in Figure 3.26.

Figure 3.26
Configuration Menu Option

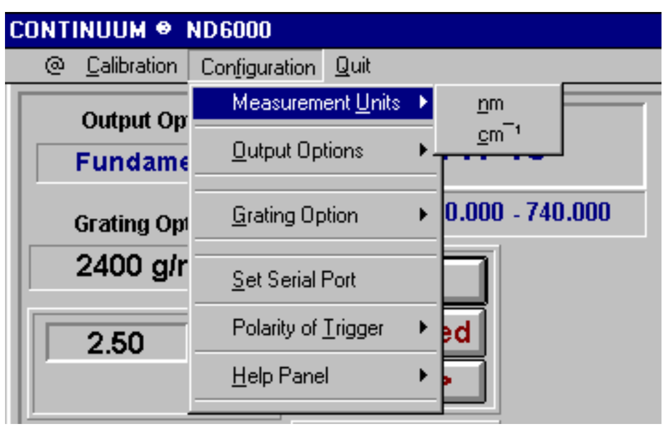


Descriptions of these options follow.

Measurement Units

This function allows the user to toggle between measurement units of nm and cm^{-1} for all applicable displays. The displays may be changed individually by selecting the labels with nm or cm^{-1}. All wavelength displays default to nm after the start of the program.

Figure 3.27
Measurement Units Menu Option

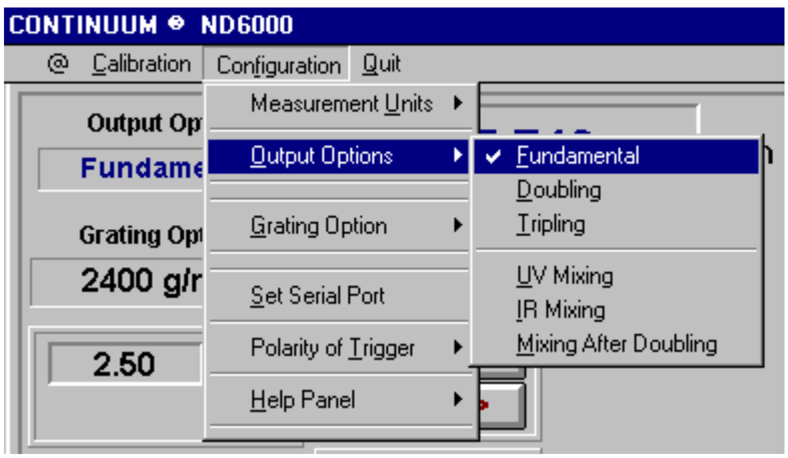


Output Options

This function allows the user to select between several Output Options. The user can toggle between the Fundamental Mode and the selected output Option at any time by clicking the corresponding area (Figure 3.28).

From the **Configuration** menu, choose Output Option to select the system's mode of operation. The selected mode will be indicated with a check mark in the menu list, indicating the current output mode. The system will toggle between Fundamental Mode and one additional mode **ONLY**. Menu choices are illustrated in Figure 3.28. The system will default to the last mode of operation selected by the user.

Figure 3.28
Output Option Menu



Grating Options

This function allows the user to toggle between the six Grating Options. Changing the Grating Option will save the current overall configuration, read saved configurations, set new wavelength range, and display output for new

Grating Options (see Changing Gratings in this chapter).
From the Configuration menu, choose Grating Option to select the grating option. The selected mode will be indicated with a check mark in the menu list, indicating the current grating option. Menu choices are illustrated in Figure 3.29 (refer to Chapter V, Switch Grating Procedure for more details).

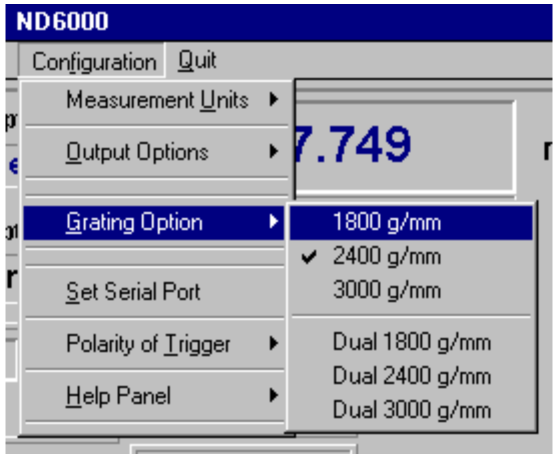


Figure 3.29
Grating Option Menu

Polarity of Trigger

This function allows the user to select a rising-edge or falling-edge trigger start for External Bursts. Select **Configuration > Polarity of Trigger** to set the rising-edge of trigger (0V to 5V) of falling-edge of trigger (from 0V to 5V).

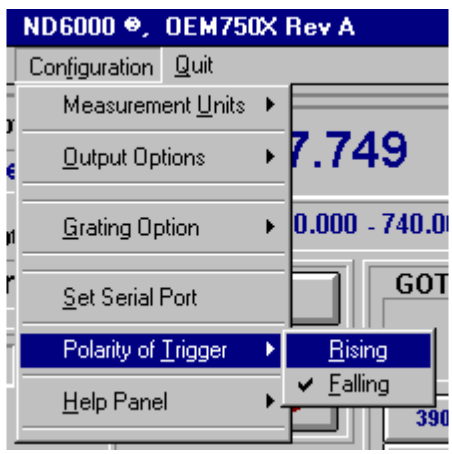


Figure 3.30
Polarity of Trigger Configuration Window

Set Serial Port

This function allows the user to access the Set Serial Port window to set Serial Port parameters and to turn the Serial Port ON or OFF. ND6000 serial communication adapts to many formats. Select **Configuration > Set Serial Port** window to choose the desired serial protocol parameters. The following figure (Figure 3.31) shows the settings. Set the Port to ON to activate serial communication.

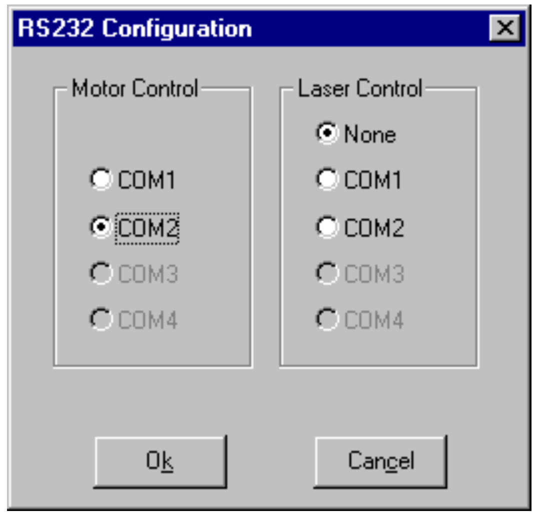


Figure 3.31
Serial Port Configuration Window

Note: When the Serial Port is ON, the RS232 display appears at the bottom of the Main Window (Figure 3.9). It will display incoming Remote commands.

Help

Displays help information on how to use the system. **Configuration > Enable in Grey** or **Enable in Black** to display help information. Select neither to disable the help feature (refer to Figure 3.32). Comments appear in the bottom portion of the Control Window when the mouse pointer is placed over an object for several seconds. If you move quickly through the menu options, you will notice help comments are not displayed. Help comments will remain on the screen long enough to give the user an opportunity to read the comment and perform an action. Messages disappear as you move the mouse to perform an action.

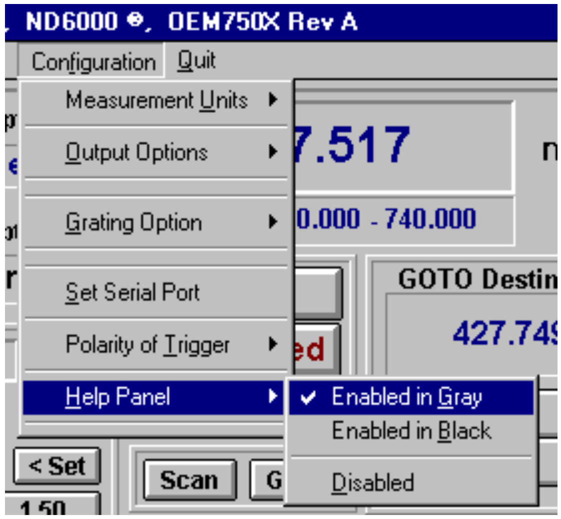
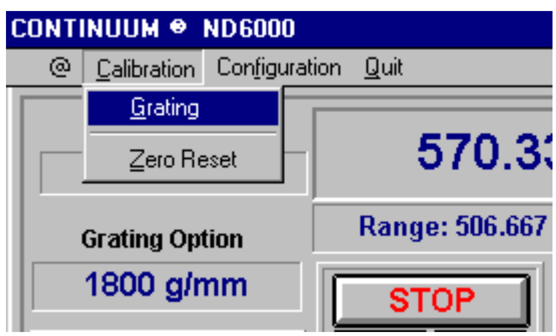


Figure 3.32
Help Menu Option

Calibration Menu

The Calibration menu choices are illustrated in Figure 3.33.

Figure 3.33
Calibration Menu Option



Descriptions of these options follow:

Grating
Displays the Grating Calibration Window.

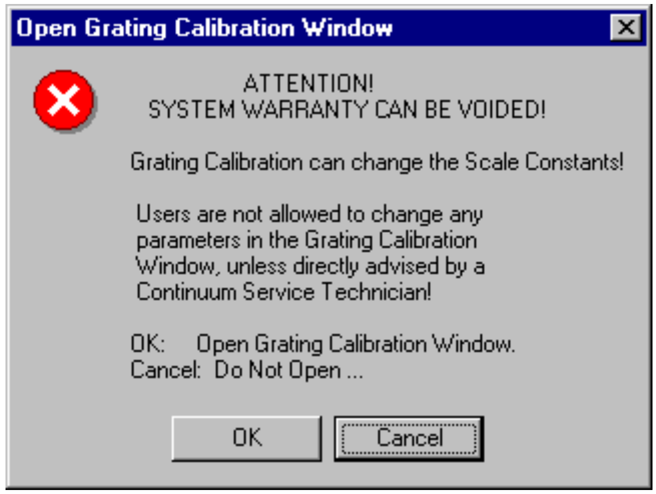


Figure 3.34
Calibration Menu Warning Message

The user is allowed only to read parameters. Making changes to the parameters in the Grating Calibration window without direct advice from the Continuum Service Department will void your warranty.
To open the Grating Calibration Window click the OK button. Figure 3.35 illustrates the grating calibration window and some typical values of the calibration as an example system preceding a re-calibration of the ND6000.

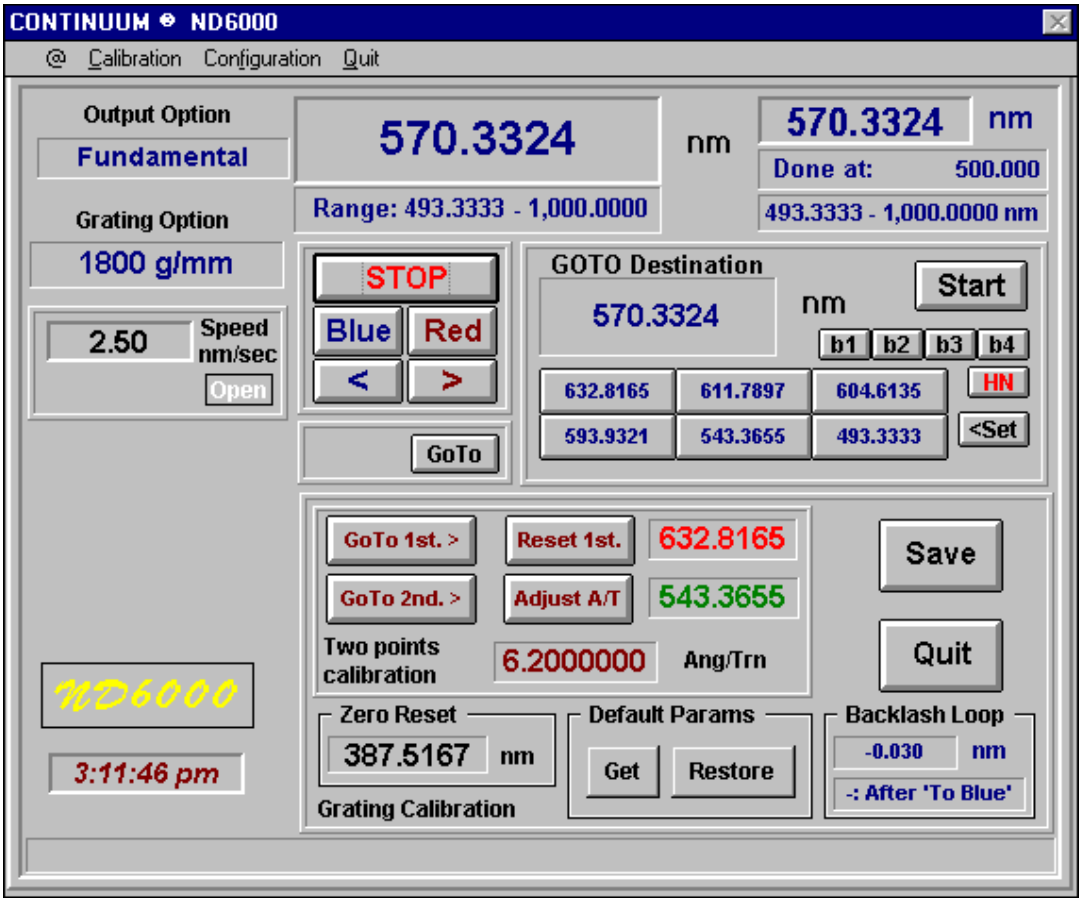


Figure 3.35
Grating Calibration Menu Option

Note:
The GOTO window opens systematically when entering the calibration window. Both are operational simultaneously.

Several Options and corresponding Windows are offered at the end of the Calibration or to Exit that mode. They are given below:

1) Window displayed when clicking in the Quit button

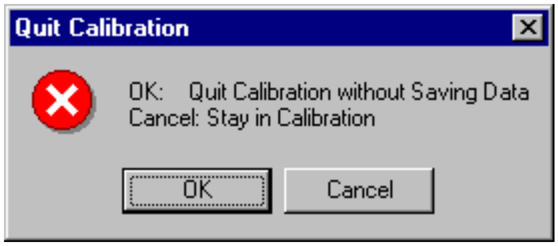


Figure 3.36
Window to Quit Calibration without Saving Calibration Parameters

2) Window displayed when clicking in the Save button

Figure 3.37
Window to Exit Calibration after Saving Calibration Parameters

3) Window displayed when trying to exit the ND6000 software program while the calibration is active.

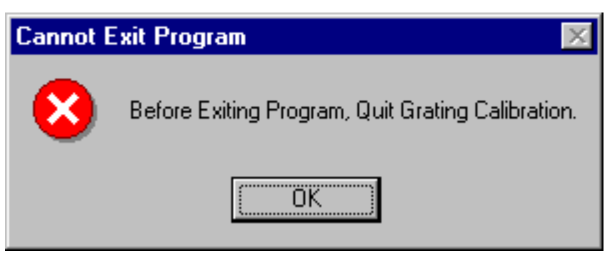


Figure 3.38
Warning Message When Exiting Grating Calibration

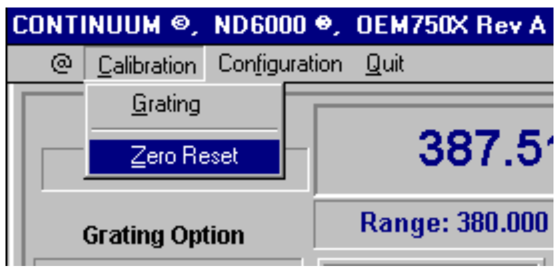
Zero Reset

Calibrates the starting position of the tuning mirror. Zero Reset must be performed during the first installation, after the laser or computer were turned off and left without supervision for any length of time, or if there is any doubt about the calibration. The Zero Reset function is recommended after the ND6000 or Laser Power supply is restarted.

In order to re-calibrate the system i.e. re-adjust the accuracy of the displayed wavelength, the operator will need to execute the following Procedure:

1) Click in the **Calibration menu > Zero Reset** Option (Figure 3.39).

Figure 3.39



Zero Reset Menu Option

2) The Start Zero Reset command panel will offer the possibility here to start the process of Wavelength Calibration. Click the Ok button on the Zero Reset Calibration Start window (Figure 3.40).

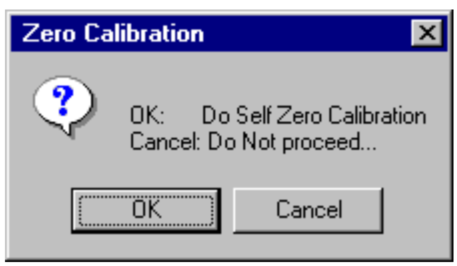


Figure 3.40
Zero Reset Calibration Start Window

The turning mirror mechanics of the ND6000 will be driven to a known position, which corresponds to a known wavelength. Calibration finds this position and relates it to the known wavelength; this position is the **Zero Reset Point**. While the mechanics moves and the system search for this point, the Main wavelength display window freezes, the message “Z-RESET” is displayed in the top left window and the Zero Reset wavelength is shown in the adjacent window “Looking for Z ….” A typical window is given Figure 3.41.

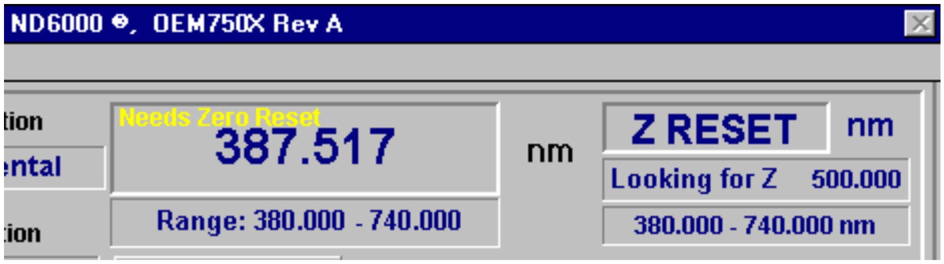


Figure 3.41
Zero Reset Configuration Display

G. Remote Operation Overview

Software supports external control of the ND6000 through a serial port on the ND6000 computer. ASCII control commands may be sent to the ND6000 over an RS-232 serial line, and the ND6000 echoes these commands and provides scan status information.

The remote operator may:

- Send commands to the ND6000 and receive its status
- Interpret the ND6000 status to interactively control the ND6000
- Send multiple commands at once. (macros)

Setting up the serial interface is the user's responsibility. Continuum recommends Labview, a high level programming language (from National Instruments, Austin, Texas). Refer to section *Remote Commands* found later in this chapter for more information and examples of common commands.

H. Using the Computer Control Module Serial Interface

The ND6000 Computer Control Module (CCM) can be controlled via a PC remote computer by sending ASCII characters through its RS-232C port. The remote computer may be used to:

- Send commands to the CCM and receive feedback data from it.
- Interpret data from the CCM to interactively control the CCM.

Responsibility for creating hardware connections and computer programs lies with the user. Creating an interactive program should pose no problem for an experienced programmer.

The CCM stepper motor controller may also be programmed directly, but Continuum does not recommend this approach. Any such program must contain drivers, which consider specific characteristics of the sine drive, such as backlash compensation and limit switches. Continuum does not provide assistance for writing such programs.

The examples in this chapter are designed to illustrate the approach used to communicate with the ND6000 CCM.

The basic steps required are:

- Prepare the proper cable
- Choose serial communication parameters
- Establish communication between the remote computer and CCM
- Write software using embedded CCM commands to control the CCM or receive CCM data and interactively control the CCM

The section that follows treats these 4 steps in more detail.

Preparing Cables for Remote Computer Control

Serial interface pin assignments

The pinouts for the ND6000 serial port are given in Figure 3.42. The serial port signals are available below.

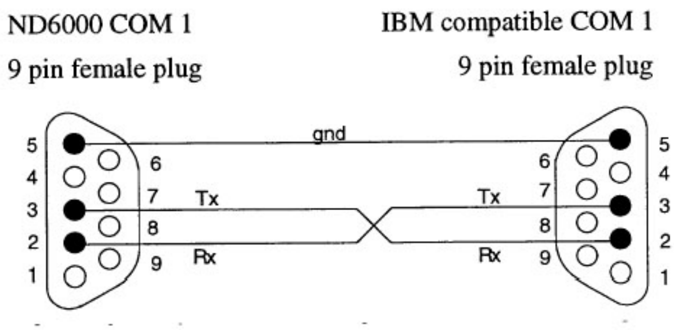
Serial Port Pinout for a Male 9-Pin Connector

Pin #	**Signal**	**Name**	**Signal Direction***
1	DCD	Data Carrier Detect	Input
2	RX	Receive Data	Input
3	TX	Transmit Data	Output
4	DTR	Data Terminal Ready	Output
5	SG	Signal Ground	
6	DSR	Data Set Ready	Input
7	RTS	Request to send	Output
8	CTS	Clear to send	Input

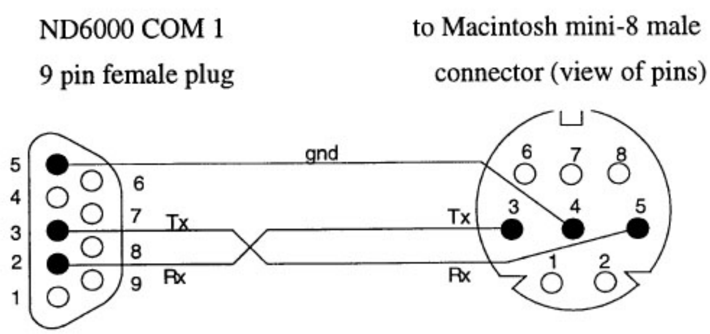
Pin 9 is unused. (*) Signal direction at ND6000 controller.

Notes on Serial Interfacing (Cable Connections)

Only a few of the pins listed are needed for normal operation of the ND6000. In order to simplify the "handshaking" needed between the ND6000 controller and the host computer, only three pins are used: the Frame ground, the Transmit data line and the Receive Data line. Serial signals should be conditioned so that high = +12 Vdc max, and low = -12 Vdc max. The following connections are typical (see Figure 3.42).



RS-232 interface cables: ND6000 to IBM PC



RS-232 interface cables: ND6000 to Mac

Figure 3.42
Remote Control Interface Cable

Procedure for Hardware Connections:

Step 1: Make up the indicated Host cable. Cable should be shielded and length should not exceed 10 feet (6 meters) and made of at least 22 gauge wire. These cables can also be made by combining commercially available cables and a null modem.

Step 2: Turn off both computers and connect the host cable between the host computer and the 25 pins (or 9 pins) Serial Port of the ND6000 controller.

Serial Data Format and Protocol

To use the communication line, you must make sure the asynchronous communication parameters (baud rate, parity, data bits and stop bits) of the sending and receiving devices are properly set. Furthermore each computer (CCM and Host computer or terminal) should be configured with the same parameters given below:

Serial Data Format

9600 Baud rate

8 data bits
1 stop bit
no parity
no flows control

NOTE:
See Figure 3.31 to set serial port parameters

Procedure for Testing

- Load and test a modem terminal program such as Terminal (provided with Windows), Quickmodem or equivalent software in both the ND6000 controller and the host computer.

- Configure both computers with the same serial data format.

- Refer to your programmer or computer manuals to send information to the ND6000 controller via the RS232 serial port.

- Once you have successfully tested the Interconnection between the host computer and the ND6000 controller, quit the communication program used in the ND6000 computer and reload the ND6000 software.

- Configure the serial port parameters of the ND6000 with the same parameters that these tested (same serial data format).

- Send the following command from the host computer: **R@**

The ND6000 should acknowledge the command by displaying it in the RS232 window (see Figure 3.9, page 3-12). The ND6000 should echo back the message to the host computer.

Connecting the CCM to a Macintosh

Establish the hardware link using the Mac modem port (the printer port may be used if necessary).

The remote cable diagram necessary to connect the CCM to a Macintosh is shown in Figure 3.42

Set the Macintosh modem port communication parameters (baud rate, data bits, etc.) using any modem terminal program or communication program (e.g. Z-term, Microphone, or Red Ryder).

J. Writing Programs

External Computer Control Module Commands

This section describes the commands that are used to control operation of the ND6000 CCM.

The ND6000 CCM commands are sequences of ASCII characters using the character “@” as delimiter. Any command or string of commands received by the ND6000 CCM is BUFFERED. After receiving the delimiter character, the command is echoed to the remote computer and sub-commands are analyzed and executed in their input order. Commands which have missing characters or have improper parameters values are ignored. The ND6000 CCM will send an error message (Z Message@) through the serial port and resume the proceeding sub-commands.

Delimiter

All individual commands end with a delimiter that signifies that the command is complete. The character “@” is used as delimiter in all messages sent to the ND6000 CCM. Spaces are not recognized.

Functional External Commands

The Software supports external control of the ND6000 through a serial port on the ND6000 computer. ASCII control commands may be sent to the ND6000 over an RS232 serial line, and the ND6000 echoes these commands and provides scan status information.

Sending commands initiates the same control-software response as entering the command directly with the mouse. The remote operator may:

- Send commands to the ND6000 and receive its status
- Interpret the ND6000 status to interactively control the ND6000
- Send multiple commands at once (macros)

Programming the serial interface is the user’s responsibility. The following section describes the protocols and commands used for remote control of the ND6000.

NOTE:
When you want to start an External Burst scan without the (up to 100 msec) delay of the RS232 signal protocol, you can use the Direct TTL port on the ND6000 laser. Refer to Section L of this Chapter, Fast Triggering of Burst Modes for more details. This provides a much faster response. Fast External Burst can use only Direct TTL and has the least delay time of the three burst modes.

Remote Command Syntax

All remote commands begin with one or two letters (not case sensitive) and terminate with the "@" or with another command in the macro. No other delimiter is recognized. Spaces are not allowed inside a command and are ignored before or after one. In the following tables, xxxx.xxx refers to a wavelength in nm, x.xxxx refers to a scan speed in nm/sec, x.xxx refers to the Burst Delay in seconds [n] or [n] refers to the scan number. The symbol [ ] meaning that inside is optional, brackets should not be part of the command..

The optional argument 'n' ($0 < n < 6$) refers to the one of six numbered (1 to 6) Scan window buttons and to its set of saved parameters. When n is specified and non-zero, only the value stored in scan button n, and not the current value, is changed (or used). This is used to prepare saved scans for later use. A comma must precede 'n' when it is sent directly after a number or the comma is optional.

Command Buffer

Remote Commands can be two types: 1) those that execute immediately, and 2) those that wait for prior commands to be completed. The command buffer stores up to 50 waiting commands. Commands may be sent to this buffer singly or in strings. Individual command strings (macros) may have commands delimited by spaces, but the spaces are optional. Use the delimiter @ only at the end of a macro, not after each command in it. Waiting commands remain in the buffer until executed, when they are cleared from the buffer. The ND6000 CCM External Commands can be subdivided into four categories: Motion commands, Motion Parameters Set commands, Stop Move commands, and General Purpose commands.

K. Remote Commands

Motion Commands

Gxxx.xxx @GOTO: This command instructs the Controller to Go to the wavelength which value is given by “xxx.x:xx” in nanometers. The velocity of the movement will be determined by the goto velocity that reside in the controller at the time the GOTO command is read.

Typical Commands:

G562.4@	Goto 562.400 nm
G600@	Goto 600 nm
G510.234@	Goto 510.234 nm

D[s]xxx.xxx@ Displacement: This command instructs the Controller to execute a displacement. The displacement value is given by “xxx.xx” in nanometers and it is either added or sub-tracted to the starting wavelength depending on the signed specified (s = + or -). The velocity of the movement will be determined by the goto velocity that resides in the controller at the time the Displacement command is read.

Typical Commands:

D56@	Displacement of 56 nm
d-6.01@	Displacement of -6.01 nm

P[,n] @ Programmed Scan (set in button n). This command instructs the Controller to execute a scan with values specified in the Scanning Parameters stored in the button "n" displayed in the Scanning Window (see Figure 3.22).

Typical Commands:

P@	Start Programmed Scan with values specified in last scan window opened
P,2@	Start Programmed Scan with values specified in button 2

NOTE:
This command relates to the six different scans memorized through button 1 to 6. If one of the Scan Windows (Figure 3.22) is open, the command P@ will execute the corresponding scan.

If the Scan Window is not opened when the command P@ is send, the Controller will open the Scan Window that was the last opened. For example if the last command executed from the CCM was an Internal Burst memorized in button 4, and if the Scan Window was closed at the end of the scan, sending the command P@ through the serial port will open the Scan Window and start the Internal Burst scan memorized in button 4.

X@ Step to next when in TE[,n] (External Burst) scan mode. This command instructs the Controller to execute a step with value specified in the External Burst Scanning Parameters stored in the related button displayed in the Scanning window (see Figure 3-25).

Typical Commands:

X@	Start step in External Burst mode.

Motion Parameter set Commands

Bxxx.xxx[,n]@ Set Beginning wavelength of Scan (set in button n): This command instructs the Controller to set the beginning of the scan set in button n at a wavelength which value is given by “xxx.xxx” in nanometers.

Typical Commands:

B560@	Set Begin scan of button 1 or Scan mode displayed if Scan Window is opened at 560 nm
b606.012,3@	Set Begin scan of button 3 at 606.012 nm

Exxx.xxx[,n]@ Set Ending wavelength of Scan (set in button n): This command instructs the Controller to set the Ending of the scan set in button n at a wavelength which value is given by “xxx.xxx” in nanometers.

Typical Commands:

E517@	Set End scan of button 1 at 517 nm
E606.012,5@	Set End scan of button 5 at 606.012 nm

Lxxx.x[,n]@ Set Length of Burst Scan (set in button n): This command instructs the Controller to set the Length of the Burst Scan set in button n at a value given by “xxx.x” in seconds.

Typical Commands:

L1,3@	Set Length of Burst Scan of button 3 at 1 second

Nxxx[,n]@ Set Number of Scans (set in button n): This command instructs the Controller to set the number of scans set in button n at a value given by (xxx).

Typical Commands:

N5@	Set Number of scans of button 1 equal to 5
n66,4@	Set Number of scans of button 4 equal to 66

Sxxx.xxx[,n]@ Set Step Width for Burst Scan (set in button n): This command instructs the Controller to set the Step Width for the Burst Scan set in button n at a value given by “xxx.xxx” in nanometers.

Typical Commands:

S10,2@	Set Step Width for Burst Scan of button 2 at 10 nm

TN[,n]@ Set a Normal Scan for button: This command instructs the Controller to set a Normal Scan for button n.

Typical Commands:

TN,1@	Set Normal Scan for button 1

TI[,n]@ Set an Internal Burst Scan for button: This command instructs the Controller to set an Internal Burst Scan for button n.

Typical Commands:

TI,2@	Set Internal Burst Scan for button 2

TE[,n]@ Set an External Burst Scan for button n: This command instructs the Controller to set an External Burst for button n.

Typical Commands:

TE,5@	Set an External Burst Scan for button 5

TF[,n]@ Set a Fast External Burst Scan for button n: This command instructs the Controller to set a Fast External Burst Scan for button n.

Typical Commands:

TF,4@	Set Normal Scan for button 4

VPxxx.xxx[,n])@ Set Scanning Velocity of Programmed Scan (set in button n): This command instructs the Controller to set the velocity of the programmed scan set in button n at a value given by “xxx.xxxx” in nanometer per second.

Typical Commands:

Vp.006@	Scan velocity set at 0.006 nm/s
vP1@	Scan velocity set at 1 nm/s
vp0.45@	Scan velocity set at 0.45 nm/s

VGxxx.xxxx[,n]@ GOTO/ Reverse / Displacement Velocity (set in button n): This command instructs the Controller to set the velocity of the GOTO, Reverse, Displacement moves and / or Burst moves(set in button n) at a value given by "xxx.xxx" in nanometer per second.

Typical Commands:

vg.007@	GOTO velocity set at 0.007 nm/s
VG8@	Displacement velocity at 8 nm/s
vg0.245@	Reverse velocity at 0.245 nm/s
VG2,5@	Burst velocity of scans of button 5 set at 2 nm/s.

NOTE:
When the scan Window is opened (Figure 3.22 to 3.25), the parameters set through the serial port are preferentially those displayed in the open window, unless specified in the command. If no button number is specified in the command, the default button is button 1.

Stop / Restart Move Commands

The following commands can be used in the following modes:
GOTO, PROGRAMMED SCAN and DISPLACEMENT.

H@ Halt: This command instructs the Controller to Halt (Pause) the processing movement. When the ND6000 move have been initiated with a GOTO command, this command will abort the processing movement. When the ND6000 move have been initiated with a Scan command, , this command will pause the processing movement until either a Continue command or a Reset or Abort command is send to the CCM.

R@ Reset: This command instructs the Controller to Reset the ND6000 software and the stepper motor control board. When the ND6000 is processing a move this command will not be executed. The CCM will send the following error message "ZLaser in Motion@".

A@ Abort: During a move, this command instructs the Controller to Abort the processing movement.

C@ Continue: This command instructs the Controller to Continue a Scan movement that has been paused by a Halt command. The movement will resume with the same scanning parameters. This command works only in Scans, not in moves initiated with the GOTO command.

General Purpose Commands

A@ Parameters query: While not scanning, this command instructs the Controller to send back the present scanning parameters for a programmed scan. The ND6000 software will send a string of ASCII parameters separated by the “I” delimiter (‘1ex number FCH). See next paragraph for more detailed information on answer format.

V*@ Velocities query: This command instructs the Controller to send back he present velocities values (GOTO/Displacement, Reverse and Scan).

R@ Reset: This command instructs the Controller to Reset the ND6000 software and the stepper motor control board.

Q@ Quit: This command instructs the Controller to QUIT the ND6000 RS232 Program and exit to Windows.

Fx@ Serial port report Flag: This command instructs the Controller to turn ON - F1@ - or OFF - F0@ - the wavelength position report. While scanning, if the Flag is ON, the ND6000 controller will report the displayed wavelength through the Serial port each time the wavelength is updated and displayed in the Fundamental Current Wavelength position.

RC(s)x.xxx@ Initialize wavelength: This command instructs the Controller to recalibrate the present fundamental the wavelength by an offset which value is given by x.xxx in nanometers with (s) = + or -. The value of the offset cannot force the value of the Zero Reset Wavelength to be out of the range [375,390] nm.

NOTE:
The only commands which execute immediately (and so are not stored in the command buffer) are H@, A@, R@, C@, X@ and V*@.

- H@, A@ and R@ also erase the command buffer when executed.
- V*@ and X@ do not erase the command buffer.

Echoes and Status Reports

All received commands are echoed when executed, as the following examples illustrate. Fill zeroes and commas are always added.

Scan Mode Report

The P@ command echoes the type of scan as well as starting it:
Command to Echo and report Meaning ND6000 from ND6000

P@	Start scan of current mode.
Pn@	Report scan mode: N (Normal); I (Internal); E (External; F (Fast)

NOTE:
See note below (in Remote Commands paragraph) for the different moves initiated based on whether the Scan Window is opened or closed.

Reports While Moving

The additional echoes N@, X@, and Y@ appear during each scan, while X@ and Y@ echoes confirm the start and stop points of all other moves. This example assumes the current scan has been set to Normal, between 600 and 602nm and repeating 2 times:

Command to ND6000	Echo and report from ND6000	Meaning
P@	Pn@	Start current scan (mode n)
	N1@	Scan 1
	X600.000@	At 600nm
	Y602.000@	Scan has ended at 602nm
	N1@	Scan 1 has completed
	N2@	Scan 2 (final scan) starting
	X600.000@	600nm
	N2@	Scan 2 has completed
	X602.000N2@	Scan has ended at 602nm

Intermediate Wavelength Reports

Intermediate wavelength echoes (lxxx.xxx@) appear during motion if F1@ was issued. This example is otherwise the same as the one above:

Command to ND6000	Echo and report from ND6000	Meaning
F1@	F1@	Issue intermediate l reports
P@	Pn@	Start current scan (mode n)
	N1@	Scan 1 is starting
	X600.000@	At 600nm
	l600.512	Intermediate l report
	l601.023	Intermediate l report
	l601.678	Intermediate l report
	Y602.000@	Scan has ended at 602nm
	N1@	Scan 1 has ended
	N2	Scan 2 is starting
	X600.000@	At 600nm
	l600.589	Intermediate l report (not made at same moment as scan N1)
	l601.0231...	...etc.
	l601.678	Intermediate l report
	Y602.000@	Scan has ended at 602nm

Speed Status Report

The V@ command returns 2 speed values; its echo is:

Command to ND6000	Echo and report from ND6000	Meaning
V*@		Issue report of scan speeds
	VPx.xxxx@	Scan speed of last Scan selected
	VGx.xxxx@	Current GOTO scan speed (same as Step, Return scan speeds)

Displacement Reports

The Dxxx.xxx@ command echoes itself and gives the start and end of its motion. This example assumes a current GOTO ending at 600nm and a starting wavelength at 600 nm:

Command to ND6000	Echo and report from ND6000	Meaning
D10@		Wait for end of any current motion, then start a (Displacement)
D010.000@		Report displacement in nm
X600.000@		Report l at (Displacement) start
Y610.000@		Report absolute nm at motion end (Reverse scan occur without a report)

Scan Report

The A@ command echoes and returns 8 more status echoes if no scan is in progress. The format of its status return is:

Command to ND6000	Echo and report from ND6000	Meaning
A@	A@	Abort the current motion
A@	A@	No motion, so give scan status:
Mxxx.xxx@		Main (right) display l (Fundamental only) wave length
Fn@		"Format label of Auxiliary (left) display (n= harmonic output for ND6000) ""Fundamental"" = n ""Doubling"" = n ""Tripling"" = n

		“”UV Mixing””= n “”IR Mixing””= n “”Mix After Doubl””= n”
Axxx.xxxx		Auxiliary (left) display l
Pn@		Last scan mode: n = E (External) n = N (Normal) n = I (Internal) n = F (Fast)
Bxxx.xxxx@		Start of last l motion
Exxx.xxxx@		Start of last l motion
Sx.xxx@		Current Scan step (if last motion was Burst Scan PI,PE or PF)
VPx.xxxx@		Current scan speed (or if last motion was GOTO)
VGx.xxxx		
Lx.x@		Scan delay (if last motion was Internal Burst PI)
Nxxx@		Number of scans (echoed on Normal or Internal Burst only)

Zero Reset Report

When proceeding a re-calibration, after the Mechanics found the Zero Reset point, the CCM send the Zero Reset wavelength value preceded by an Xxxx.xxx@ and execute the move to position the mechanics at the wavelength where the re-calibration was called. At the end of this move, the CCM send the typical end of displacement report Yxxx.xxx@.

Echo and report from ND6000

Re Calibration	Meaning
X384.0431@	Zero Reset wavelength
Y562.000@	Report absolute nm at motion end

Examples of Control Command Sequences

This simple example shows the remote control of an **External Burst mode,** sent one command at a time:

Command to ND6000	Echo and report from ND6000	Meaning
TE@	TE@	Select External Burst mode
B510.1@	B510.100@	Begin Burst scan at 510.1nm
E512.6@	E512.600@	End Burst scan at 512.6nm
VG.5@	VG0.500@	Step speed set to 0.5nm/sec
S.1@	S.100@	Move 0.1nm each Burst step
P@	PE@	Start scan (echoes scan mode)
X@	X510.100@Y510.200@	Step to 510.2nm and pause (echoes l before and after move)
X@	X510.200@Y510.300@	Step to 510.3nm and pause
X@	X510.300@Y510.400@	Step to 510.4nm and pause... … (Repeated X commands sent)
X@	X512.500@Y512.600@	Step to 512.6nm and pause
X@	X512.600@Y512.700@	Step past end, pause and return
X@	PE@	Start next scan
X@	X510.100@Y510.100@	Step to 510.1nm and pause
X@		... ...etc.

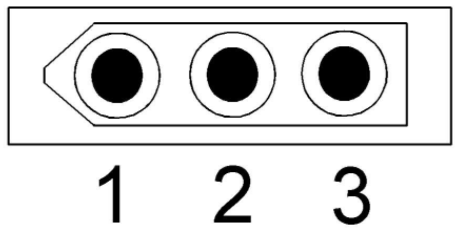
This example shows how to store values in a scan button, and how the effect of a macro (F0B510.1,5TN,5E512.6,5VP.25,5P,5@) is integrated. If F1 replaces F0, the report will include additional wavelength positions, sent as lxxx.xxx between each Xxxx.xxx and Yxxx.xxx (see example above).

Command to ND6000	Echo and report from ND6000	Meaning
F0@	F0@	Do not report intermediate 1's
B510.1, 5@	B510.100@	Set scan button 5 start l value
TN,5@	TN,5@	Set button 5 mode=Normal
E512.6,5@	E512.600@	Set scan button 5 end l value
VP.25,5@	VP0.25000,5@	Set scan button 5 scan speed
P,5@	PN,5@	Wait for end of any current motion, then start scan with button 5 (and already chosen Scan reverse)
	N1@	Beginning of first scan
	X510.100@	Starting l (scan time now elapses)
	X512.600@	Ending wavelength report
	N1@	End of scan report
	N2@	Beginning of second scan
	X510.100@	Starting l (scan time now elapses)
	X512.600@	Ending wavelength report
	N2@	End of scan and macros report, assuming scan button 5 already has number of scans set to 2

L. Fast Triggering of Burst Modes

TTL Connections

To trigger a Burst step directly without using the RS-232 interface, use the 3-pin Direct TTL connector, located on the ND6000 power module near its ON/OFF switch. Pin 2 of the Direct TTL connector triggers a step only in Fast Burst and External Burst scans (scan types TF@ and TE@). Pin 3 goes high during motion after using the Blue, Red, < , >, buttons, the GOTO start command, and when measurements are taken in all scan modes (scanning in normal scan, waiting for trigger in Burst scans). See Figure 3.43.



Pin 1 Ground
Pin 2 Step Start
Pin 3 Motor Run Status

Figure 3.43
Direct TTL Cable Pin Definitions

Pulse Polarities

The Configuration menu contains the Polarity of Trigger choice; set here whether you wish to trigger on the rising or falling edge of your TTL pulses. Select Configuration>Polarity of Trigger to set the rising-edge of trigger (0V to 5V) of falling-edge of trigger (from 0V to 5V).

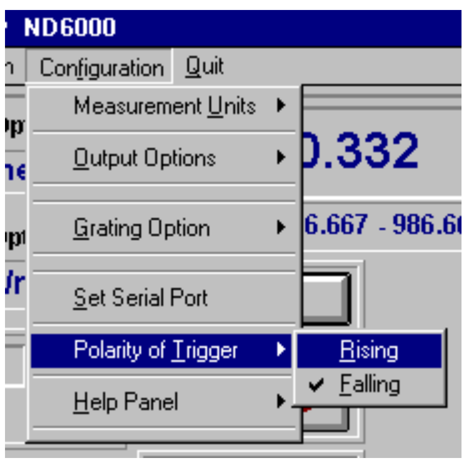


Figure 3.44
Polarity of Trigger Configuration Window

External Step/Start Pulse and Step Motor Response

Burst/External mode step start and motor status waveforms are shown above. The start pulse on pin 2 is a positive-going TTL pulse which must have a minimum width of 5 msec. The motor starts 2 msec after the rising (or falling) edge of this pulse. While it is running, pin 3 goes high; it goes low again when the move ends. Start commands given while the motor is stepping are ignored, so do not send another start pulse until the motor has finished the previous move. Use pin 3 to detect the move's end. Table 5.1.1 gives the approximate time needed until the motor accepts the next pulse. A 10 Hz system (100 msec period) cannot step more than 300 steps between each shot.

Motor Steps	Stepping Time (ms)	Motor Steps	Stepping Time (ms)
10	42	200	85
25	51	250	92
50	61	500	125

Table 3.1
Minimum Times Between External Burst Trigger Pulses

The external device generating the start signal can be a TTL circuit that produces the pulse on command, or a manual switch connected between pins 1 and 2. When the switch is opened, the ND6000 will begin to step, stopping after the number of steps previously entered into the external burst window.

Note: The correspondence between the rotation between the stepper motor shaft and the wavelength displacement is given by the formula:

dR/dL = 25000 / AngTrn in microsteps per Angstrom.

Where AngTrn is equal to the number of Angstrom per turn of the sine drive.

For example if AngTrn = 6.25 Angstrom per turn, then dR/dL = 400 microsteps per Angstrom.

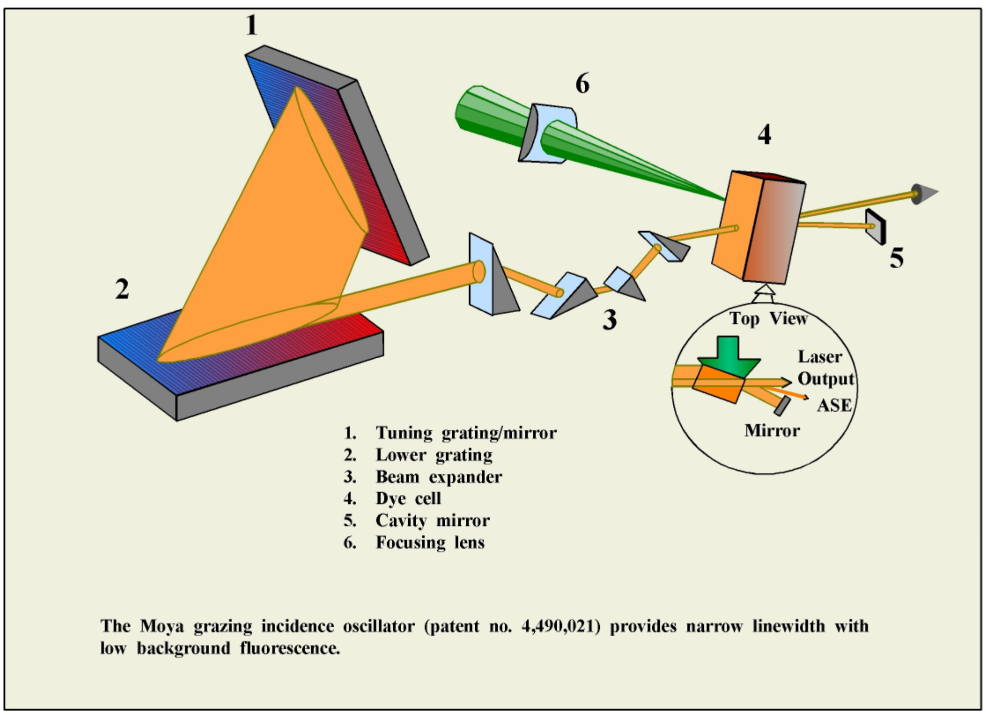
Chapter IV System Description

A. General Description

Introduction

The ND6000 is Continuum's latest evolution of pulsed dye laser technology representing over 20 years of experience producing dye lasers. The ND6000 showcases Continuum's fourth generation of dye laser design. Continual improvements to our products give us a quality and reliability advantage.

The core of the ND6000 is a dye oscillator and two dye amplifier cells, all of which are pumped by an external Nd:YAG laser. The dye oscillator contains an improved Moya Dye Laser Cavity.



The Moya grazing incidence oscillator (patent no. 4,490,021) provides narrow linewidth with low background fluorescence.

Figure 4.1
Moya Oscillator

The Moya oscillator provides narrow linewidths with low background fluorescence.

B. Moya Oscillator

Better Tuning

The Moya Dye Laser Cavity design improves the grazing-incidence grating tuning method by first expanding the beam (to fully utilize the grating) and using higher resolution gratings (or optional dual gratings) for better wavelength selectivity.

Output Coupling

The laser oscillation takes place between two totally reflecting mirrors, and also undergoes total internal reflection from a dye cell window. Energy is coupled out of the lasing path by diffraction around an edge of this window. In this design, neither the laser oscillation path nor the main direction of fluorescence emission (parallel to the cell axis) coincides with the direction of the output beam.

Lower ASE

Because the main path of fluorescence emission is different from the laser oscillation path and the output beam path, fluorescence of the Moya Oscillator is greatly reduced. Also, the little fluorescence coming back from the amplifiers is dispersed by the grating before striking any reflective surface. Thus amplifier fluorescence is dispersed and attenuated to very low levels.

C. Other Features

Modules

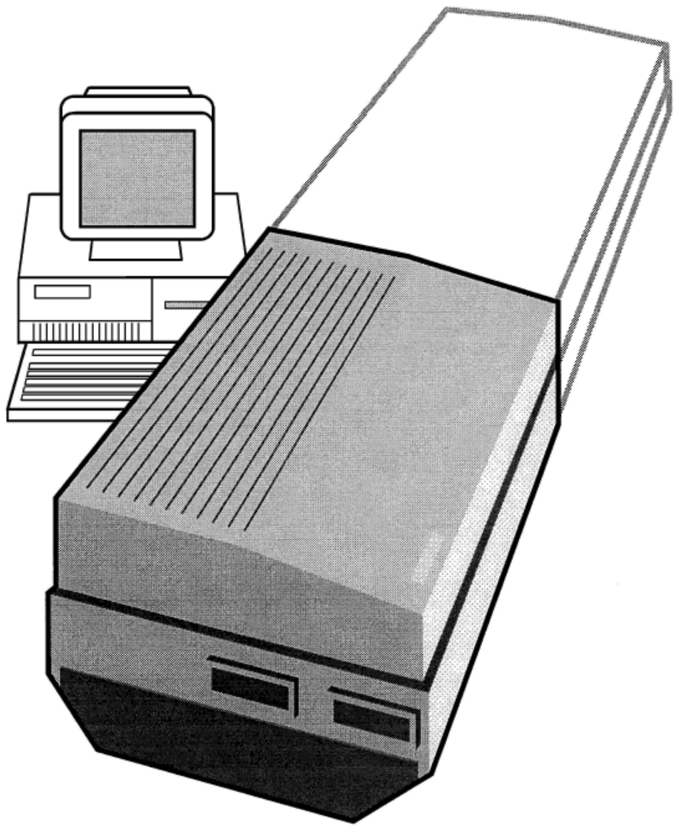
A standard ND6000 consists of the laser head, pump laser, dye circulator and control computer. Figure 4.2 shows a typical ND6000 package.

Options

ND6000 options include extensions into the IR and UV regions. With its UV and IR extensions, the ND6000 covers a wide scanning range: 0.2 to 4.5 μm. Automatic crystal tracking maintains optimal performance while scanning extended wavelength regions.

Pump Lasers

The ND6000 dye laser is designed to be pumped by any Continuum Powerlite Precisions™ or Surelite™ series Nd:YAG laser over a wide range of pump energy.



Left to right: CCM and ND6000 dye laser.
The DCP6100 dye circulator is not shown.

Figure 4.2
Continuum's Tunable Dye Laser Package

Other options include double gratings to decrease linewidth and a high energy option which handles the output from the highest energy commercial Nd:YAG's available. Easy mating and unified safety interlocks add to the compatibility of all combinations. Figure 4.3 gives the performance specifications for the ND6000 and its options.

Figure 4.3
ND6000 Performance Specifications

	Fundamental	**UV Package**	**IR Package**
Range (nm)	420-900	206-425	1500-4500
Option	IRG (740-900nm)	UVX-1,-2 & -3	IRP
Crystal	N.A.	KDP, BBO	LiNbO3
Technique	Fundamental	Doubling/mixing	Difference frequency mixing

Option (NBP required)	**Linewidth (cm-1)**	**Energy (mJ)**	**Tuning Range (nm)**
Standard (Single 2400 l/mm grating)	0.08 at 560nm 0.10 at 515nm	>200 >35	420-740
DGO-1 (Dual 2400 l/mm grating)	0.05 at 560nm	10% energy reduction	510-715
IRG (Single 1800 l/mm grating)	0.10 at 750nm	>100	510-900
DGO-2 (Dual 1800 l/mm grating)	0.08 at 750nm	10% energy reduction	680-900
UVG (Single 3000 l/mm grating)	0.07 at 515nm	10% energy reduction	305-590
DGO-3 (Dual 3000 l/mm grating)	0.05 at 515nm	25% energy reduction	415-570 420-570

(pumping with 750mJ @ 532nm, 280mJ @ 355nm)

Resettability	±0.02Å
Absolute Accuracy	±0.5Å
Super-radiance (ASE) center of dye	
@ 560nm	<0.2%
edge of dye band	<0.5%
Frequency stability (lasing at a fixed wavelength)	
Standard	$0.05 cm^{-1}$/°C/hr
FSO Option	$0.05 cm^{-1}$/5°C/7hr
Spatial Characteristics	
Nominal beam diameter	3-6mm
Beam divergence	<0.5mrad
Beam polarization (with NBP, Vertical)	>98%

Figure 4.4a
ND6000 Performance Specifications Diagram

(pumped at 532 nm and at 355 nm)

Powerlite 8010 pumping ND6000 with 532nm - Fundamental

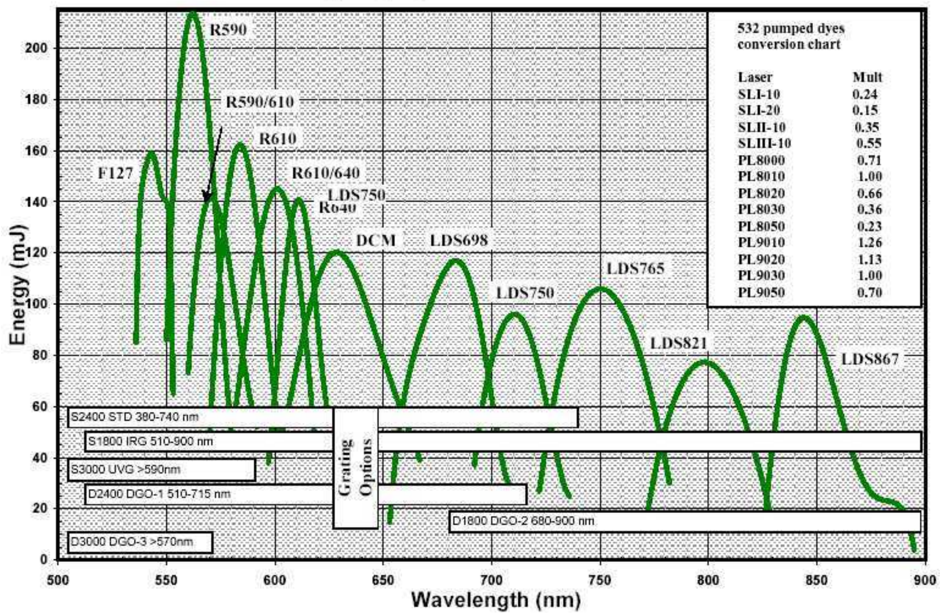
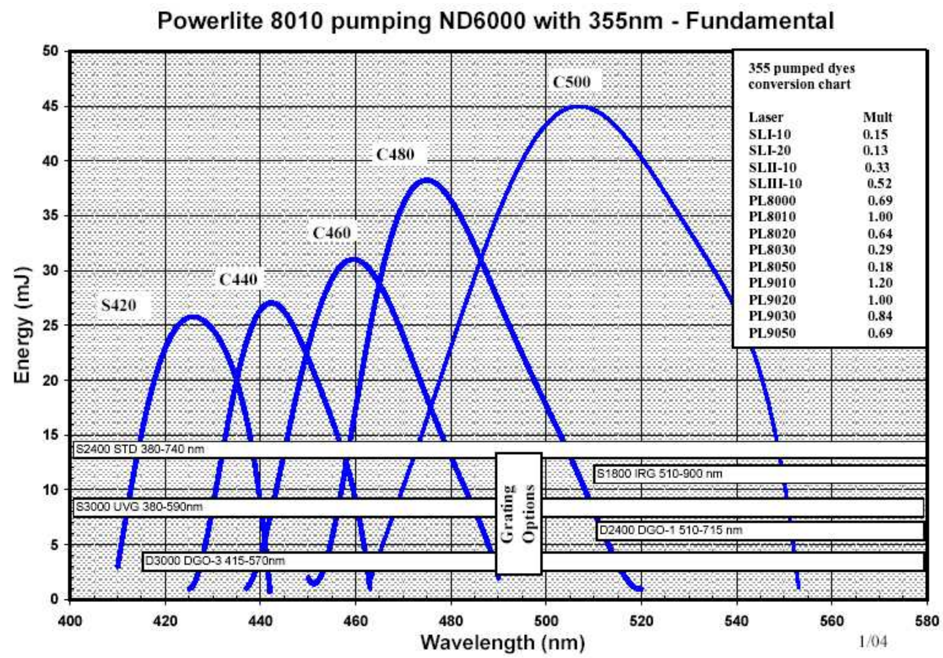


Figure 4.4b
ND6000 Performance Specifications Diagram
(in the IR range)



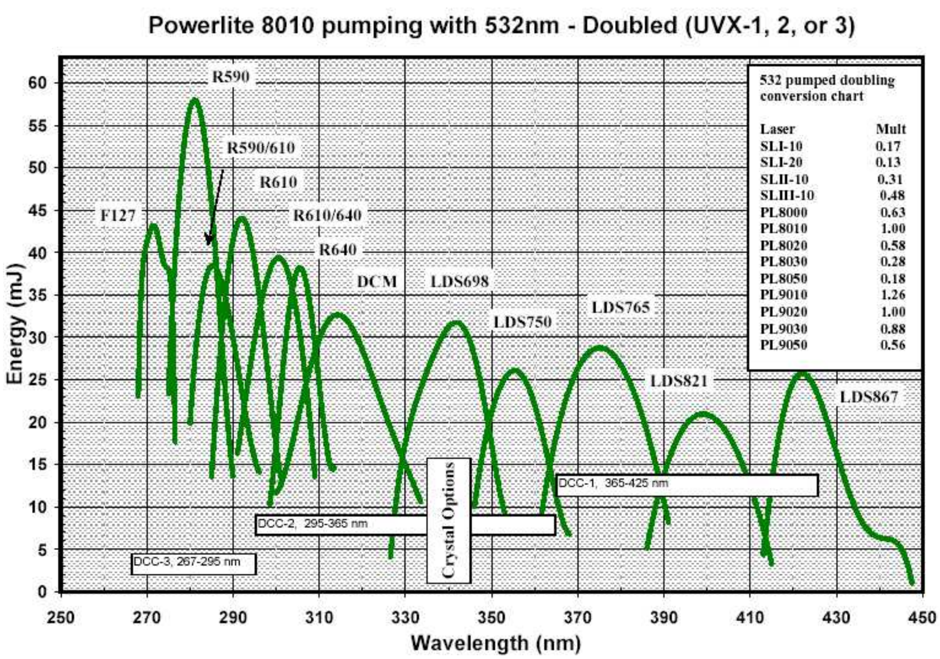
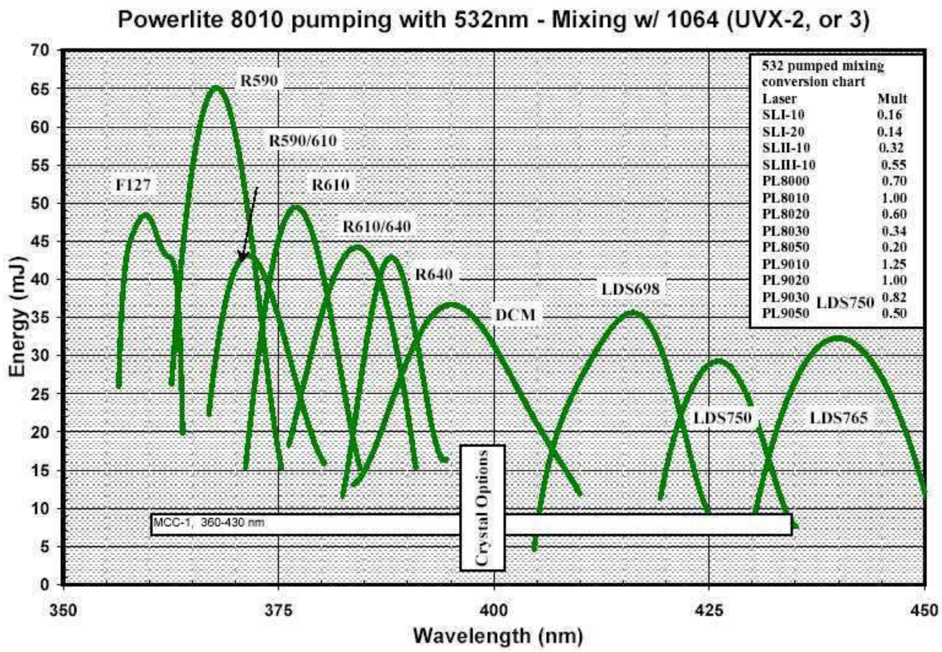


Figure 4.4c
ND6000 Performance Specifications Diagram
(in the UV range)



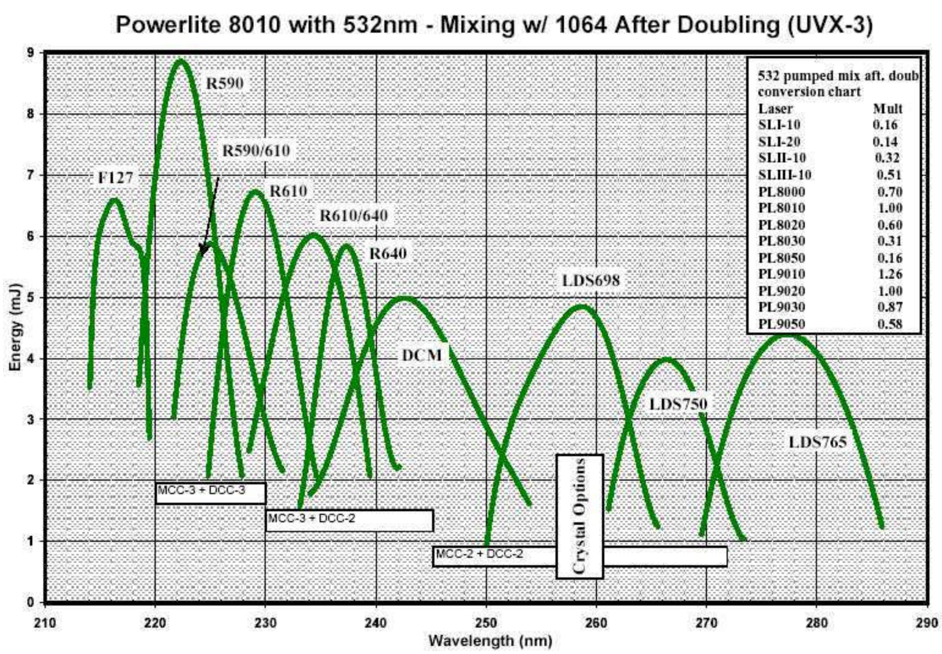
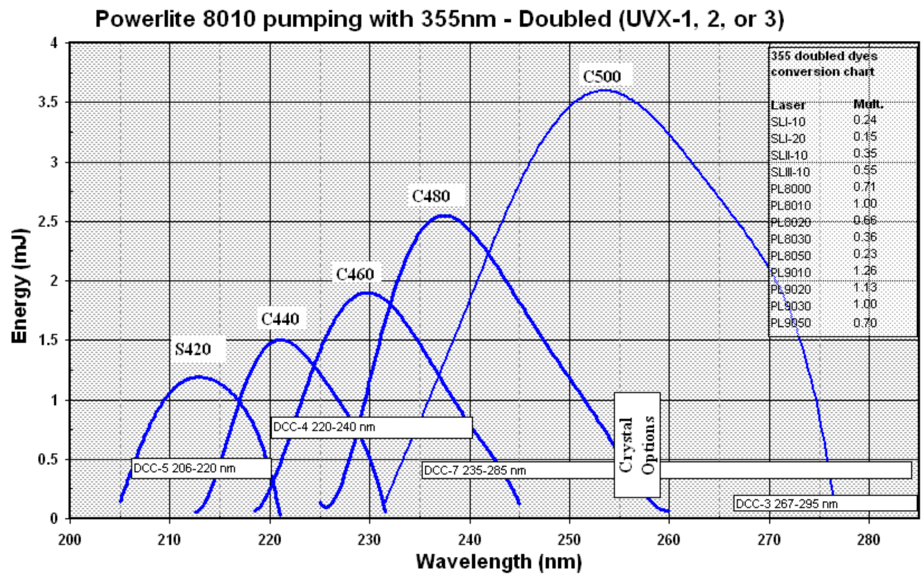


Figure 4.4d
ND6000 Performance Specifications Diagram
(in the UV range)



Data System

The laser can be scanned and controlled by its own and/or external data system and/or external event triggers through standard serial ports. Continuum software provides flexible wavelength adjustment and scanning modes.

Dye Circulator

The newly designed DCP6100 dye circulator makes dye and filter changes more convenient. Its closed loop dye flow path reduces the danger of contamination and spills. Drain valves remove dye solutions easily for renewing or changing dyes. Easy access to the dye reservoir simplifies dye concentration optimization. A safety interlock prevents laser operation when dye solution is not flowing.

New Features

The ND6000 optical path contains oversize optics in precise, adjustable, quick-release mounts, to simplify alignment and pump laser conversion.

D. Optics

General Description

Optical Paths

The ND6000 optical path contains one oscillator and two amplifier cells (see Figure 4.8). The moya Oscillator (9) and first amplifier (15) dye cells are rectangular, and the last amplifier (17) is of capillary design. All dye cells are transversely pumped.

Optical Paths

The ND6000 contains 2 optical paths: pump beam and dye beam. Systems with optional wavelength extensions may also contain a third beam path for the pump beam IR fundamental.

Dye Beam

Total internal reflection prisms (18) fold the dye beam path to make the laser more compact. A diverging lens (14) expands the beam before it enters the first amplifier, and an adjustable converging lens (16) collimates the exiting beam at the proper diameter.

Pump Beam

After entering the dye laser, dichroic mirrors (3) fold the pump beam twice, and a lens (4) and dichroic mirror (3a) direct it onto the final amplifier cell. An uncoated beam splitter (2a) splits 5% of its energy into the oscillator and another splitter (2b) diverts 10% of the pump beam energy into the first amplifier. The remainder pumps the final amplifier. The pump beam input must be vertically polarized; when it is not, a $\lambda/2$ plate (1) rotates it vertically.

Three pairs of lenses, a spherical diverger (6) and cylindrical converger (7 and 8) shape and focus the pump beam onto the three dye cells.

Optional Optics

Different optical elements are required for both UV and high pump energy options.

Moya Oscillator

Oscillator

Figure 4.1 and the above section also describe the Moya Oscillator. Vertically polarized pump energy reaches the rectangular dye cell after being focused to a thick line by a longitudinally adjustable cylindrical lens (8). This line coincides with the lasing oscillation path. The lasing path is bounded by two totally reflecting mirrors (10 & 12), and the path also reflects from an internal cell window surface.

Linewidths

A diffraction grating in this oscillation path (13) narrows the lasing linewidth by reflecting all but a small wavelength range out of the lasing path. The first diffraction order is employed. A beam expander (11) spreads the lasing beam over the entire grating surface, increasing its wavelength selectivity. Optional dual gratings create even narrower linewidths (the second grating replaces mirror 12). Figure 4.3 gives grating specifications.

Tuning

After diffraction by the grating, the light is directed toward a flat, rectangular silvered mirror (12), which is the rear mirror of the ND6000 oscillator cavity. This mirror rotates around an axis centered on the grating to select different wavelengths. Details of rotation are discussed in **Tuning Mirror Drive and Wavelength Control** in this chapter.

Output Coupling

Energy is coupled out of the lasing path by diffraction around an edge of the dye cell window (see Figure 4.1). Neither the laser oscillation path nor the main direction of fluorescence emission (parallel to the cell's long axis) coincide with the direction of the output beam.

Thermal Control

The entire oscillator assembly rests on a platform thermally isolated from the optical bench. Optional heater strips maintain the oscillator at a constant temperature (35°C) to increase the frequency stability of the output wavelength. A green LED next to the ND6000 power switch indicates that the oscillator is at thermal equilibrium.

Amplifiers

The ND6000 dye circulator passes dye solution through both amplifiers' dye cells. The dye concentration is typically less than in the oscillator cell. In each amplifier cell, the pump laser beam enters transversely and focuses to a thick line overlapping the entire dye laser beam in the cell. Unlike a lasing cavity, the amplifier cavities magnify beam power while the beam passes through once; reflection is kept to a minimum.

First Amplifier

The first amplifier is a rectangular dye cell, tilted in a vertical plane at Brewster angle to maintain the vertical polarity of the dye beam and to minimize reflection back towards the oscillator. The vertically polarized pump beam is focused onto a segment of the dye beam by a cylindrical lens (8) which can be rotated and longitudinally translated to make the it coincide with the dye beam. A diverging lens (6) elongates the pump beam before it goes into the cell for maximum overlap with the dye beam.

Last Amplifier

The second amplifier is a capillary (cylindrical) dye cell (17), with an internal diameter of 5mm and a length of 50mm along the dye beam axis. Broadband anti-reflection coatings on both end windows reduce reflection backwards along the beam path. The pump beam is expanded by a diverging lens (6c) and focused onto the entire cell by an adjustable cylindrical lens (7).

Beam Output

A converging lens (16) moves longitudinally to collimate the dye output beam after lens (14) expands the dye beam to completely fill the capillary cell.

E. Tuning Mirror Drive and Wavelength Control

The angular position of the tuning mirror (12) selects the wavelength. The ND6000 Control Computer Module (CCM) controls this mirror: a computer driven stepper motor turns a lead screw, causing in turn a horizontal movement of the translation stage. The translation stage pushes a pivoted actuator which changes the angle of the turning mirror using the sine drive principle. The sine drive converts a movement of the translation stage into a linearly proportional wavelength change. Thus each stepper motor step causes the same change in wavelength. Refer to Figures 4.5 and 4.6.

Computer Control

Software translates CCM mouse-driven commands to move or scan wavelength into velocity and position information which it sends to the stepper motor driver in the CCM. This driver generates power pulses which move the stepper motor.

Translation Stage

The stepper motor turns a lead screw using a belt and pulleys. The stepper motor makes 25,000 steps per turn. The belt drive has a 4:1 ratio so that each turn of the lead screw requires 100,000 motor steps.

The lead screw moves the translation stage along the plane of the lead screw. The translation stage pushes on a pivoted actuator bar which changes the angle of the tuning mirror using the sine drive principle.

Limit Switches

A limit switch at each end of the translation stage normal range prevents the stepper motor from damaging the translation stage by moving it too far and the CCM reads these switches' status.

Zero Reset

A photodiode and detector assembly on the lead screw and pulley provide a known position for the translation stage, which corresponds to a known wavelength. Calibration finds this position and relates it to the known wavelength. In this procedure, the stepper motor moves the translation stage towards the motor (low wavelength). When an interrupter on the stage passes the reset limit photodiode, the translation stage stops. The motor reverses and slowly turns the lead screw pulley about 3/4 of a turn until the zero reset photodiode detects a slot in the pulley. This position is the **zero reset** point.

If the translation stage trips a limit switch, the **zero reset** is lost and must be restored with a new self-calibration (see below).

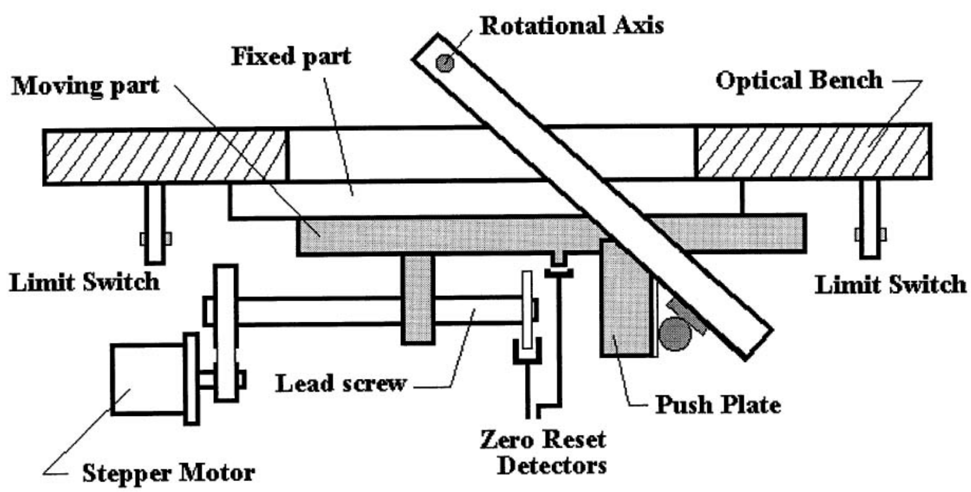


Figure 4.5
Tuning Mirror, Translation Stage & Sine Drive Arm

F. Sine Drive

The sine drive mechanism translates the linear change of the translation stage into a linear change in wavelength. That is,

$$\lambda = \text{constant} * (\text{Translation stage position}) + \text{constant}$$

Drive Principle

The translation stage rotates an actuator arm around an axis centered on the diffraction grating, translating the stage's linear motion into an angular change of the tuning mirror (see Figure 4.5). At any specific angle, the tuning mirror reflects a single wavelength back to the position it left the grating.

At a specific angle **B** between grating and mirror, the tuning mirror reflects light with wavelength **λ** striking the grating at angle **A** back onto the grating. These angles are related by the grating equation, where **d** is the groove spacing and **m** is the diffraction order (in this case λ)

Sine B + sine A = dm λ (grating equation)
From the definition of sine, **sine B' = x/L**, where x is the amount of translation stage movement, and **L** is the length of the actuator arm. Since the ND6000 is factory aligned so that angles **B** and **B'** are equal, and since **sine A** is a constant (**CONST**), substituting **x/L** for **sine B** in the grating equation and solving for **λ** gives:

$$\lambda = (1/dmL) * x + CONST \quad \text{(sine drive equation)}$$

Since **1/dmL** is constant, the sine drive indeed converts linear translation stage movement (i.e. turns of the lead screw) into a linear wavelength change.

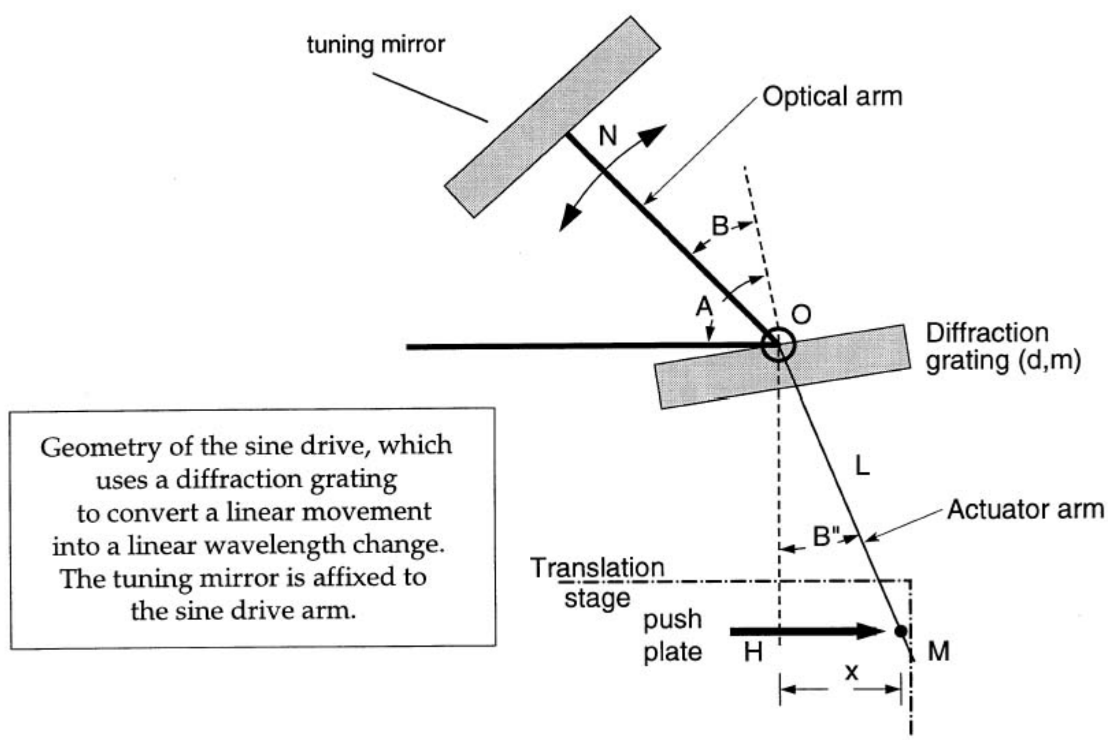


Figure 4.6
Tuning Mirror Control and Drive

G. Wavelength Calibration

ND6000 wavelength calibration (self-calibration) enables CCM software to use the sine drive equation (above) to move the translation stage to the position which corresponds to a desired wavelength.

Calibration

The sine drive equation contains two constants, a slope and y-intercept. To determine the zero point, self-calibration first returns the translation stage to a precisely known lead screw position. (See the ***Zero Reset*** section for details). This **zero reset** position is retained as the y-intercept constant; it is typically just to the blue of the current dye's absorption maximum.

The slope of the sine drive equation, **1/dmL**, is kept by the CCM as the **Å/turn** parameter. It is nominally 6.25 Ang/turn but its exact value, determined during factory calibration, differs for each ND6000, and never changes.

Both the **zero reset** and **Å/turn** parameters for this laser can be viewed in the Grating Calibration window. See Chapter III for more details. Knowing both constants in the sine drive equation, the CCM can now steer the ND6000 to any desired wavelength within its range. After this self-calibration, software returns the ND6000 to the last wavelength selected.

Caution:
Changing Å/turn or the zero reset affect wavelength calibration.

Backlash

Some backlash in the movement of the lead screw is unavoidable. Always consider this backlash, particularly when making manual adjustments or using the Displacement mode. To minimize backlash, always approach the scan start or target wavelength from the same direction. The mechanics of the lead drive screw have less backlash when the desired frequency is approached from the lower wavelength direction. For example, if you are scanning from 700 nm to 710 nm, GOTO a value less than 700 nm, bring the wavelength up to 700 nm, then start the scan.

H. Electronics

ND6000 electronics control the translation stage's stepper motor and the oscillator's optional thermal stabilizer. A IBM PC, or compatible clone (the **CCM**), provides the user interface for the stepper motor. The **stepper motor**

driver under the optical bench also contains the oscillator heater control and dc power supply for the stepper motor. The **DCP6100** contains a dc power supply, electric pumps, and other control logic. A **safety interlock** is the only additional electrical circuit on the ND6000.

CCM

The **C**omputer **C**ontrol **M**odule (CCM) is CD ROM drive (or compatible clone) computer running Windows, a floppy drive and monitor. It is supplied with ND6000 control software and Windows

NOTE:
Because computer models and manufacturers' have different specifications and placement of modules, Figure 4.7 is a representation. You may have to refer to the manual that comes with your specific computer to ensure your connections are in the correct place.

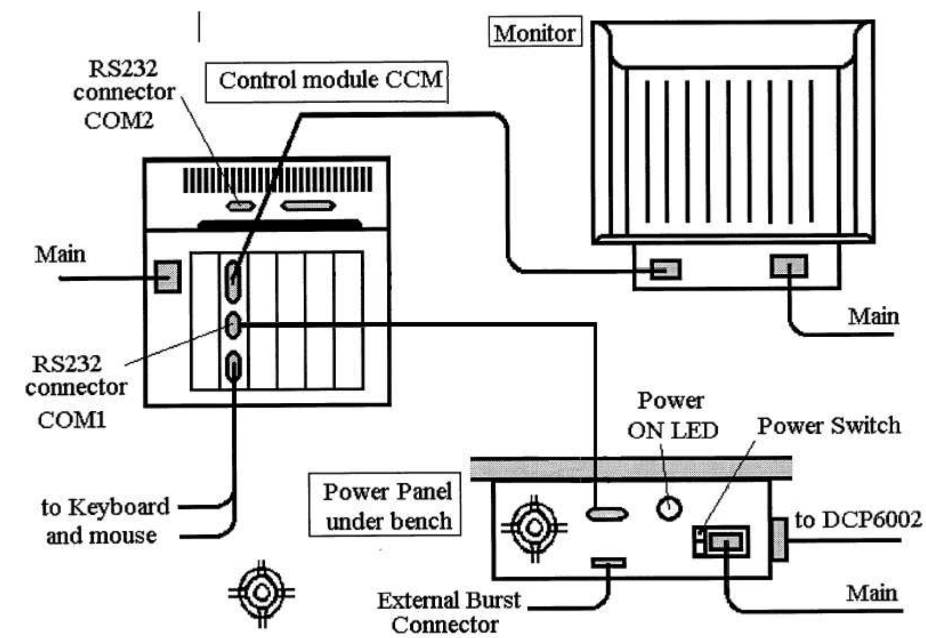


Figure 4.7
Rear View of ND6000 and CCM

Stepper Controller

When the controller receives wavelengths, scan ranges and speeds and the type of positioning or scanning, it converts this input into acceleration, velocity and position information which it then sends to the stepper motor driver as control pulses (see Figure 4.7).

Stepper Driver

The stepper driver induces a precise motion of the stepper motor, based on the signals generated by the controller. Additional logic monitors both limit switches, the zero reset reference point and the motor's direction; this information reaches the CCM through the same cable.

Power Supplies

Power supplies which drive the stepper motor and its electronics are located in the stepper motor driver box, mounted below the ND6000 optical bench. (The optional thermal control requires an additional power supply.) The DCP6100 dye circulator has its own power supply.

Power Switch

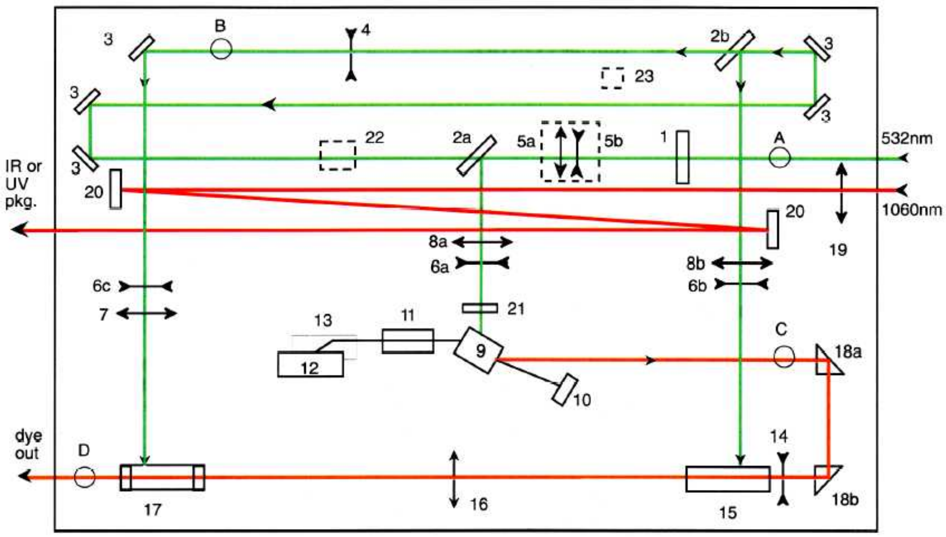
The ND6000 ac power switch and amber lamp (on when ac power is on) are also located on this electronics box (see Figure 4.7).

Dye Circulator

A newly designed DCP6100 dye circulator makes dye and filter changes more convenient. It contains two dye flow paths, one for the oscillator and first amplifier, another for the last amplifier. These closed loops reduce the danger of contamination and spills. Drain paths are provided to remove dye solutions easily. Easy access to the dye reservoir simplifies dye concentration optimization. A safety interlock prevents laser operation when dye solution is not flowing.

Frequency Stabilization Option (temperature control)

The FSO (Frequency Stabilization Option) heats the thermally isolated oscillator enclosure to a constant temperature (35° C) to increase ND6000 wavelength stability. When installed, a green LED near the ac power switch (Figure 4.7) lights when the oscillator reaches thermal equilibrium. The red power LED blinks whenever this option is installed but the heaters are not functioning.



1	Half wave plate	108-0002	12	Sine drive mirror	105-0027
2a	Beam splitter	105-0157	13	Grating, 2400 lines	199-0012
2b	Beam splitter	105-0158	14	Lens, -70 mm	102-0027
3	Mirror, dichroic	105-0022-/0023	15	Dye cell, preamp	199-0084
4	Lens, spherical, -1000 mm	102-0055	16	Lens, +300 mm, spherical	101-0040
5a	Lens, cylindrical, +200 mm, AR 355/532	101-0080	17	Dye cell, amp, windows 5 mm capillary for above	199-0013
5b	Lens, spherical, -150 mm, AR 355/532	102-0046	18	Prism, 90	109-0008
6	Lens, spherical, -70 mm	102-0031	19	Lens for 1064 nm beam	Varies
7	Lens, cylindrical, + 70 mm	101-0095	20	Mirror, 0	105-0001
8	Lens, cylindrical, +50 mm	101-0041	21	Filter, neutral density	Varies
9	Dye cell, oscillator	199-0080	22	Beam dump	618-3900
10	Moya mirror, oscillator	105-0026	23	Safety interlock defeat	
11	Beam expander	618-0810	Note: Telescope 5a & 5b is used with Surelite II		

Figure 4.8
ND6000 Layout with Options, Optics & Part Numbers

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Chapter V Routine Maintenance

Warning!
Some routine maintenance requires removing laser covers and defeating the safety interlock. Since the output beam can be very dangerous to the eyes, take exceptional care when operating the laser in this way. Wear laser protective eyewear.

The ND6000 has been designed for minimal and easy maintenance. However, certain routine operations are recommended to maintain the system in good operating order. Refer to Figure 5.1 below for the recommended maintenance schedule.

Type of Maintenance	Each Week	Each Month	On Inspection
Inspect and dust optics		Every month	
Clean and replace optics			As indicated on inspection
Replace dye solutions	2-4 days for Coumarins	Every month for Rhodamines	
Clean dye filters		Every month or when replacing dye solutions	
Routine alignment		Every 3 months	
Clean lab of dust	Once per week or more often in a dusty environment		

Figure 5.1
Maintenance Schedule

Perform these operations and others described in this chapter whenever indicated in troubleshooting (Chapter VI).

A. Maintaining Optics

Periodically inspect the coated surfaces of the ND6000 optical components for dust, discoloration and damage. This section shows how to inspect all components in the beam path, and to clean them when necessary. Procedures to replace damaged optics are also given here. Remember that an optical alignment is necessary after replacing any optical element.

Tools and Supplies Required

Assemble these tool and supplies for examining, cleaning and replacing ND6000 optics:

- Finger cots or surgical or fine cotton gloves
- High-intensity flashlight
- Inspection mirror
- Reagent grade (or better) methanol
- Eyedropper
- Lens tissues
- Cotton swabs
- Flat-blade screwdriver
- Metric Allen wrenches
- Hemostat (surgical pliers)
- Silicone rubber adhesive, GE RTV 108
- Mechanical pencil
- Razor blade.
-

Preparing for Optical Maintenance

To prepare the ND6000 for optical maintenance:

Step 1 Turn OFF the pump laser, ND6000, CCM and DCP6100.

Step 2 Raise the hinged top and remove the smoked plastic cover by first removing its mounting screws, all located on its top.

Step 3 Remove the metal oscillator cover, attached by 4 side screws.

Step 4 Assemble above tools and supplies for examining, cleaning and replacing ND6000 optics.

Inspecting and Dusting Optical Components

Dust on an optical surfaces absorbs laser light and the hot spot will burn the optical surface. Regular inspection and cleaning can prevent damage. Follow these steps to dust the optics and determine whether an optical surface needs cleaning or a component requires replacement.

Step 1 Turn off the ND6000 laser and raise lid.

Step 2 Systematically examine the surfaces of each prism, lens, mirror, grating and half wave plate in the optical path for dust, fingerprints, discoloration and burn marks in the surface coating. Use a bright flashlight to light the surfaces and illuminate reflections. Use an inspection mirror where needed.

Step 3 Use clean compressed air to clear dust and loose debris present on the face of any optical component.

Step 4 Note those components that need cleaning and those components that need replacing. Cleaning and replacement procedures in this chapter give further instructions.

Cleaning Easy to Reach or Unmounted Optics

Caution:
Do not clean or replace any component unless cleaning with compressed air shows that action is necessary.

Step 1 Wash your hands and put on gloves or finger cots.

Step 2 Place one sheet of lens tissue over optic to be cleaned (use the hemostat if necessary). Using an eyedropper, place a few drops of good quality methanol on top of the tissue.

Step 3 Drag the lens tissue across the optic only once. If a visible solvent residue remains on the optic, repeat using less solvent and a new tissue until no residue remains.

Cleaning Hard to Reach Optics

Step 1 Wash your hands and put on gloves or finger cots.

Step 2 Wrap lens tissue on a cotton tipped applicator. Apply a few drops of solvent directly to the tissue; shake off any excess.

Step 3 Swab optic gently with the applicator. Repeat these steps with a drier swab to remove remaining residue.

Cleaning Dye Cell Exteriors

Step 1 Wash your hands and put on gloves or finger cots.

Step 2 Fold lens tissue into a pad about 1 square inch and hold with a hemostat. Add a few drops of methanol to the pad.

Step 3 Drag the pad **once** across the surface without using **any** pressure. Repeat if needed.

Cleaning Dye Cell Interiors

Oscillator and dye cells are sometimes damaged by having dye burned onto their inside surfaces. Before removing the cell to clean it, first replace the dye solution with methanol and flush the cell overnight. This may remove the dye deposits.

Step 1 If flushing does not remove the dye spot, remove the cell for cleaning (refer to **Replacing or Rotating Dye Cells** in this chapter).

Note:
Moving a dye cell requires realigning the optics. If not familiar with alignment, do not remove any optic.

Step 2 Place the cell in a beaker of methanol and sonicate the cell for at least 30 minutes.

Step 3 Wash your hands and put on gloves or finger cots.

Step 4 Re-inspect. If a spot is still visible, rub the inner surfaces with a methanol-soaked cotton swab.

Step 5 If there is no remaining damage visible on the original face, reinstall the cell in its same configuration, and clean the exterior. Otherwise, rotate the cell before reinstallation (refer to **Replacing or Rotating Dye Cells**).

Step 6 Realign the cell as described in the **Detailed Alignment** section of this chapter. Only perform the alignment steps which concern the moved cell.

Cleaning Gratings

Never touch a grating with tissue or a solvent. Blow dust off with a stream of clean air, and avoid touching them with anything else.

Caution:
NEVER touch or try to clean a grating. Solvents will permanently damage it and replacement requires Continuum factory service.

Replacing a Prism

Note:
Replacing a prism requires realigning the optics. If not familiar with alignment, do not remove any optic.

To replace a prism:
Step 1 Using the mechanical pencil to outline its position.

Step 2 Pull the prism from the silicone adhesive that is securing it to its mount.
Step 3 Scrape off the old adhesive from the mounting surface with a razor blade until the surface is flat and smooth.

Step 4 Put a small amount of adhesive in the center of the prism outline.

Step 5 Using gloves, place the new prism in the location. Press down on the prism and turn it to spread the adhesive into a thin even layer.

Caution:
The prism must be absolutely flat.

Step 6 Make sure that the new prism lines up with the marks from the old prism. Allow 30 minutes for the adhesive to harden.
Step 7 Realign the prism as described in the Routine Alignment section of this chapter.

Replacing a Round Optical Component

Round optical components have a three-point mount, and are secured with a 1.5 or 2.0 mm set screw. To replace a round optical component:

Note:
Replacing an optical component requires realigning it. If not familiar with alignment, do not remove any optic.

Step 1 Note the position of the component in the mount and loosen its set screw, located at the top of the mount. Push the component out of the mount.

Step 2 Wearing gloves, place the new component into the mount and push it into the previous position. Tighten the set screw.

Caution:
Over-tightening the set screw may damage the optical component.

Step 3 Realign the optic as described in the **Routine Alignment** section of this chapter.

Replacing a Lens

Lenses are glued to a mounting ring, which is held in a lens mount by a 1.5 or 2.0 mm set screw. Follow these steps to replace a lens:

Note:
Replacing optical components requires realigning them. If not familiar with realignment, do not remove any optic.

Step 1 Note the position of the lens mounting ring in the mount.

Step 2 Loosen the ring's set screw (at the top of the mount) and push the ring out of the mount.

Step 3 Note the orientation of the lens and ring. Pull the lens from the silicone adhesive holding it to the ring.

Step 4 Remove the old adhesive from the mounting ring, and use new adhesive to attach the new lens to the ring. Use the adhesive sparingly; apply a small amount at three or four points around the perimeter of the ring.

Step 5 Press the lens and ring together to spread the adhesive evenly. Allow the adhesive about 30 minutes to dry.

Step 6 Place the new assembly into the mount and push it into the position of the original assembly. Tighten the set screw.

Step 7 Realign the lens as described in the **Routine Alignment** section of this chapter.

Replacing or Rotating a Dye Cell

Note:
Replacing optical components requires realigning them. If not familiar with alignment, do not remove any optic.

If flushing fails to remove dye burns, remove the cell and clean its interior. If the face is still damaged, remount the cell with an undamaged face toward the pump laser beam using this method. Rotate the oscillator 180° or first amplifier cell 90°

about its vertical axis, or the last amplifier capillary 90-120° about its cylindrical axis to orient a clean face towards the pump beam. Only when no undamaged face remains must a cell be replaced.
When rotating or replacing a cell, examine its associated “O”rings and replace any that are hard or inflexible. O-ring part numbers (compatible with methanol and dioxane) are given in Figure 5.4.

Rectangular Cuvettes

1) Turn off the pump laser, ND6000 and DCP6100 and remove the hose from the top of the cuvette cap (loosen its knurled retaining ring and pull the hose off).

2) While holding the cuvette in place with lens tissue or finger cots to keep it from falling out, remove the two Allen retaining bolts from the top of the cuvette cap.

3) Remove the cuvette and examine the “O”rings which seal it to its top and bottom plate. Replace them if they are hard or no longer flexible.

4) Pick up the cuvette, rotate it around a vertical axis and place it back in the mount. If replacing the cell, place the new cell in position. Be sure that the cuvette seats properly against the “O”rings. These, in turn, seal the cell against the top and bottom plates.

Note:
While the rectangular oscillator cell must be rotated 180° to move a fresh surface (with its thinner wall) toward the pump beam, all 4 faces of the square first amplifier may face the pump beam (a 90° rotation is allowed).

5) Press the cuvette into the channel of the back mounting plate, and replace the top stainless steel mounting bracket. Take care not to overtighten its two mounting bolts.

6) Reconnect the teflon hose, turn on the dye circulator and test for leaks. Once the cuvette and hoses are filled, turn off the DCP6100 and look for air leaking into the cuvette.

7) If the oscillator cuvette was rotated and if the energy per pulse of the laser is low, adjust the horizontal axis of the oscillator front mirror (10). Refer to **Detailed Alignment**.

Final Amplifier Capillary

1) Turn off the pump laser and DCP6100. Remove the teflon hoses from the final amplifier after loosening their locking nuts.

2) Refer to Figure 5.2. Using a pencil, make a line on the union plate (1) at its junction with the adjustable plate (4) and then remove the two screws, which connect the union plate (1) to the adjustable plate (4). Wear gloves or finger cots to avoid handling the capillary assembly and protect your hands from any remaining dye solution.

3) Remove the screw that holds the light shield (3) in place. This will also release the nylon block, which is mounted behind it.

4) To rotate the capillary to an undamaged area of the cell, simply grasp it with lens tissue or finger cots and rotate it 90-120° to present an undamaged face to the incoming pump beam. It may be possible to rotate the capillary 3-4 times. If it is possible to rotate, proceed to step 11.

5) If rotation is not possible, remove one of the stainless steel endpieces (2) by loosening its mounting screws while supporting it with your hand. Gently pull off the endpiece.

6) Remove the damaged capillary from the mount and remove its "O"rings. Replace them if they have become inflexible.

7) Place two "O"rings over each end of the new capillary and position them approximately 5 mm from each end.

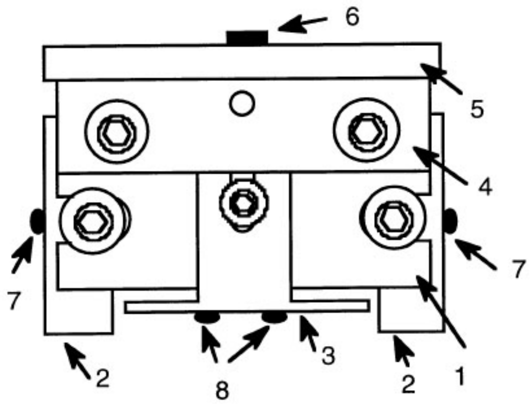
8) Using the nylon block removed in step 3 as a spacer, remount the stainless steel endpiece (2) tightly to the union plate(1) with the capillary in place. The capillary will rattle around loosely between the two endpieces at this point.

9) Using the rounded portion of a paper clip, push one o-ring at a time into the slots of the stainless steel endpieces (2). Continue pressing the "O"rings into place until they are recessed enough to be missed by the pump beam. Clean the capillary at this point, if necessary.

10) Remount the nylon block removed in step 3 between the endpieces (2) and the light shield (3) on top of the union plate using the same screw.

11) Reattach the union plate (1) to the adjustable plate (4) using the pencil mark made in step 2 as a reference.

12) Realign the capillary as described in the final amplifier alignment section of detailed alignment in this chapter. It should not be necessary to make pump beam adjustments.



1. Union plate
2. Stainless steel
   endblocks
3. Light shield
4. Adjustable plate
5. Mounting bracket
6. Pivot screw
7. Mounting bolts
8. Locking bolts

Figure 5.2
Final Amplifier Mount

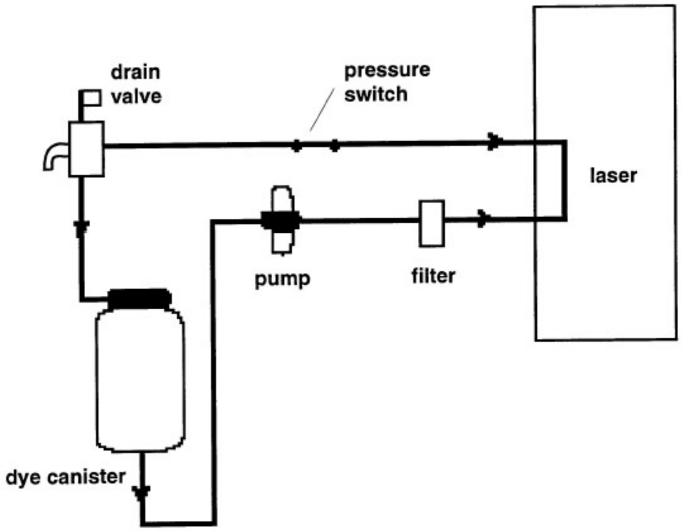
Completing Optical Maintenance

If no optical components were replaced as a result of these inspections, replace all covers and close the lid. The ND6000 is ready for operation.

If you replaced a prism, lens, or splitter, you **must** realign the component you replaced (refer to the routine alignment section of this chapter).

B. Dyes and the DCP6100 Dye Circulator

Warning!
Some dyes are potentially mutagenic and/or carcinogenic. Wear gloves and observe all safety rules. Material Safety Data Sheets (in Chapter VII) explain the dangers of each dye.



The DCP6002 contains 2 closed dye circulation paths, one for the oscillator, another for the two amplifier cells.

This figure shows one of the two DCP6002 closed flow paths. With the valve open, the solution from the dye canister flows into a waste container.

Figure 5.3
DCP6100 Dye Flow

It is important to use the highest quality solvents and to maximize dye lifetimes and beam energy.

CAUTION:
Activating the dye circulating system 20 minutes before the YAG pump laser beam is admitted can prevent possible damage (burning) to the dye cell windows.

When the dye laser has not been used for a month or more, dye deposits can form. After such a period of disuse, Continuum recommends that the entire circulating system be flushed with methanol and fresh dye used.
Optical damage (burning) can occur on the windows of the dye cells from dye deposits, contamination or degradation. Even if the laser is run only occasionally, change the dye after three or four months. Using fresh, good quality dyes can also also help avoid burning.

Storing Dye Stocks Dye Lifetimes

Dye lifetimes vary significantly; from just hours to six months depending on the dye, conditions of use and factors such as temperature and oxygenation. Typically, opened bottles of dye will last for at least 6 months. UV dyes, especially Coumarins, may have only a 3 month shelf life.

Purchase dyes in small quantities for freshness. A dry dye needs replacement when a new solution does not improve beam power, or improves beam power for less than a day.

Dry Storage

Always store bottles of dye tightly closed in a refrigerator. Do not store in a freezer. Mark them with the date opened, and open them only when making new solutions.

Cleaning or Replacing DCP6100 Filters

When to Clean

DCP6100 filters (P/N 313-0088) are permanent; they are made of sintered stainless steel and should be cleaned monthly with regular use. Failure to clean the filters will cause them to clog and slow dye flow.

Always clean filters when switching to a new batch of the same dye, or to a new type of dye, especially to a Coumarin dye from any other dye. If switching between Coumarins and other dyes frequently, use two pairs of filters, reserving one pair for Coumarins. To clean or replace DCP6100 filters:

Step 1 Turn OFF the pump laser.

Step 2 Open both DRAIN valves and evacuate both dye loops to prevent spillage when the filters are removed. The solution may be reused, but it is better to replace it.

Step 3 The filter housings are swagelock fittings on the top rear of the DCP6100. Unscrew each 1.125” nut, exposing the filter, while holding a second wrench on the filter body to minimize strain.

Step 4 Tap each filter element with a nonmetallic object to break it free from its tapered seat. Remove each element with tweezers and place both in a beaker of methanol. Place it in a sonic bath for 15 minutes.

Step 5 Replace the solution with fresh methanol and put it in a sonic bath for one hour. If the filters are clogged, soak them overnight as well.

Step 6 Replace both filters, tapping to reseat them. Inspect the mating surfaces and gasket; clean if dirty. Then tighten the housing nuts, again using 2 wrenches. Tighten only finger tight plus 1/8 turn.

Step 7 Replace solutions, turn on the DCP6100 to check for leaks and retighten filter housing nuts if necessary.

Replacing Dye Solutions

When to Replace

Most dye solutions last for several weeks in normal use; heavy usage reduces the lifetime of all dyes. Coumarin dyes degrade after just 2 - 3 days. The first indication of an old dye solution is loss of output power.

Coumarins are **VERY** sensitive to degradation by other dyes and contaminants. When changing a Coumarin, clean the filters and flush the system at least two times more than normal.

Solution Storage

Store dye solutions in Teflon or glass bottles ONLY. Refer to the Material Safety Data Sheet for each dye (in the **Appendix** of this manual) for more information on dye and solvent handling and storage.

Solvents and “O”rings

The ND6000 uses silicone “O”rings, which are best for use with methanol. “O”rings of different materials are needed when non-polar or acidic solvents are used. The following table gives part numbers for silicone and ethylene/propylene (EPR) “O”rings. Please check with Continuum if you plan to use other solvents.

Dye cell	Part Number	Material
Oscillator	306-0142	EPR
	306-0118	Silicone
First amp	306-0141	EPR
	306-0023	Silicone
Final amp	306-0143	EPR
	306-0024	Silicone

Figure 5.4
"O" rings & Solvent Compatibility

Flushing the DCP6100

Always flush both dye pathways when changing or replacing dyes, or when evidence of dye burning first becomes visible. Dye may be drained from the ball valves on the DCP 6002 dye circulator from either one reservoir or both reservoirs simultaneously.

Warning!
Methanol is flammable. Use extreme caution. Wear gloves and be sure to have paper towels ready in case of spillage.

Step 1 Place the dye circulator on a stand, approximately one foot tall. If you are to save the dye from the laser for future use, drain the old dye into suitable containers. Use 1 liter (minimum) Teflon or glass bottles with lid. Mark the bottles with the type of dye and concentration.

Step 2 Place the ends of the hoses from the ball valves into the empty bottles. Repeatedly flush the system with clean methanol to properly clean the old dye out of the circulator.

Step 3 Open the ball valves. Turn on the power switch. Drain the reservoirs until they are dry and then refill them with fresh methanol. Repeat this procedure until the dye coming out of the dye circulator is clear.

Caution:
Do not run the pumps dry for longer then 10 seconds as it will damage them.

Step 4 While flushing with fresh methanol, momentarily close the ball valves just enough to force some of the clean methanol back through the short return lines between the ball valves and the dye reservoirs. These internal lines do not receive fresh methanol when the ball valves are open.

Step 5 Repeat the flushing procedure a few times until the methanol is clear. After flushing the system, drain the clear methanol from the system until the reservoir is dry.

Step 6 Remove the hex covers from the filter assemblies. Then, remove the filter elements and wash them in a beaker of acetone or replace them. It is a good idea to wash the new filter elements as well. Reassemble the filter units.

Installing Fresh Dye

Step 1 Mix new dye in a separate glass or Teflon container ONLY.

Step 2 Pour the fresh dye from Step 1 into the reservoirs of the dye circulator. Turn on the power switch. Let the dye circulate in the dye laser for a minute until the bubbles have disappeared from the lines. Do not fire the dye laser with the Nd:YAG laser until the bubbles have disappeared, before opening the Nd:YAG laser's shutter to pump the dye laser.

Step 3 Optimize the dye concentration for the optimum dye laser output power. Record the dye concentrations.

Step 3 Add about 200cc of clean methanol to each dye reservoir, rinsing down the reservoir walls in doing so. Circulate for 15 minutes, then drain.

Step 4 Remove, clean and reinstall both filters. Refer to **Cleaning or Replacing DCP6100 Filters** for details. Repeat step 3.

Step 5 If adding a Coumarin dye, repeat step 3 again.

Step 6 Replace methanol in both reservoirs and add new dye.

This is an approximate guide of optimum ND6000 operation with 300-450 mJ/pulse for 532 nm or 200 mJ/pulse for 355 nm				
DYE	*Oscillator mg/1*	*Amplifier mg/1*	*Peak Wavelength*	*Tuning Range (10% max)*
Stilbene 420	*298*	*51.4*	*425*	*420-459*
Coumarin 440	*240*	*99*	*443*	*427-464*
Coumarin 460	*374*	*129.4*	*461*	*442-490*
Coumarin 480	*1086*	*470*	*474.5*	*459-508*
Coumarin 500	*1280*	*514*	*507*	*483-559*
Rh560			*563*	*541-583*
Rhodamine 590	*120.6*	*51*	*563*	*552-584*
Rhodamine 590 + 610	*69/30.6*	*34/12.4*	*579*	*567-599*
Rhodamine 610	*107*	*37.4*	*591*	*581-607*
Rhodamine 610 + 640	*21.3/37.8*	*10.6/18.7*	*605*	*594-629*
Rhodamine 640	*214*	*110*	*613*	*605-630*
DCM	*100*	*33.3*	*635.5*	*607-676*
DCM + LD700			*675*	*659-700*
LDS698	*75.6*	*18.9*	*693*	*661-740*
DCM + LD700			*685*	*673-705*
LD 700			*708*	*692-742*
LD 730	*38.7*	*14.5*	*713.5*	*693-757*
LDS 750	*38.7*	*24.2*	*719*	*693-757*
LDS 765	*100*	*13.3*	*766*	*730-812*
LDS 821	*97.9*	*12.9*	*812*	*780-844*
LDS 867	*85*	*20*	*861*	*830-880*

Figure 5.5
Concentration

Optimizing Dye Concentration Levels

Dye concentration affects many aspects of ND6000 performance. There is no concentration, which is best for all applications. For most applications, the correct dye concentration approaches optimized power output while avoiding effects of over-concentration. See Figure 5.5.

Power Output

Optimal dye concentration varies inversely with the amount of pump energy. As pumping energy increases, less dye produces the same output. There is an optimal concentration for any given pump beam energy. More dilute dye solutions will not cause enough fluorescence to produce complete lasing and amplification. Conversely, too much dye will limit lasing to a fraction of the cell volume. Both these effects reduce laser efficiency.

Over Concentration

Too much dye concentrates lasing in just the first part of the solution struck by the dye beam. The dye/pump beam interaction should occupy the entire volume of the final amplifier capillary, and the entire beam path of the other two cells. Thus over concentration reduces output power and distorts peak shape. Too much dye increases unwanted fluorescence, increasing ASE and broadening line widths and red-shifting them.

Finally, too much dye increases the likelihood of dye burns inside cells.

Under Concentration

Too little dye (or old dye) reduces lasing and amplification efficiency, thus reducing output power.

Dye Optimization

Tools Needed:

- Safety glasses
- White paper
- Burn paper
- Metric Allen wrenches
- Methanol
- 10 ml pipette
- 500 ml beaker
- Power meter

This procedure is designed for an aligned dye laser pumped by 300mJ of green light and rhodamine 590 dye. It is also adaptable to other dyes found in Figure 5.5. Simply start with low concentrations of dye (~30% of recommended) in both reservoirs (but enough for lasing to occur) and increase the oscillator reservoir concentration about 10% per addition. Later, treat the amplifier reservoir concentration similarly.

Check laser alignment by performing a routine alignment (details are in this chapter). Perform a detailed alignment if needed.

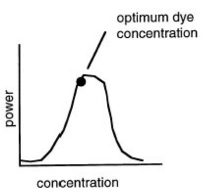


Figure 5.6

Relationship between dye concentration and power output

1) Make a dye concentrate of .35g of rhodamine 590 in 250ml methanol. (This step can be modified for other dyes: For example, the amount of rhodamine 640 to use is .35g*214/120.6^{3}.6g, where 214 and 120.6 are the optimum oscillator concentrations of rhodamine 640 and rhodamine 590, respectively, from Figure 5.5).

2) Drain and flush both dye reservoirs. Add about 750ml of solvent and 60ml of concentrate to the oscillator dye reservoir and the same amount of solvent plus 20ml of concentrate to the amplifier reservoir.

3) Tune the ND6000 to the peak of the dye absorption curve. Place a power meter at output and fully pump the oscillator, preamplifier and final amplifier with the pump beam optimized.

4) While monitoring power, add about 8ml of dye concentrate to the oscillator reservoir. Allow 2 minutes for mixing, and note the difference in power.

5) Repeat this step until power does not increase 10% or more after a new addition of concentrate. This is the oscillator cell's optimum concentration. See Figure 5.5.

6) Remove the power meter. While lasing at full pump power in multi-shot mode, take burns at the laser beam exit port. Left and right sides of the burn should have equal intensity.

7) If the right side of the burn is weaker than the left, add about 4ml of concentrate to the amplifier reservoir, wait 2 minutes and retest. Repeat until the burns are symmetrical.

8) If the left side of the burn is weaker, add 80ml of methanol to the amplifier reservoir wait 2 minutes and retest. Repeat until the burns are symmetrical. If necessary, discard an equal volume of amplifier dye solution before making an addition.

C. Alignment

Here are several techniques available to view the pump and dye beams while performing the alignments in this chapter. These techniques check beam quality and position.

Tools Needed:

- Safety glasses
- Red fluorescent paper
- Burn paper
- Metric Allen wrenches
- High intensity lamp
- Inspection mirror
- Power meter
- Modular beam dump
- Alignment jigs

Viewing the 532 nm Pump Beam

Use red fluorescent paper to view the green pump beam when using laser goggles that absorb green light. The paper has a red coating that fluoresces white when struck by the pump beam. This red paper enables you to see the pump beam at low intensity.

Caution:
Always turn the pump laser down to a low level before using this paper.

Viewing the Dye Beam

Red fluorescent paper also allows you to see the dye beam (>730 nm) at low oscillator output levels. You can use the back of a white business card (or equivalent) to see the dye beam (<730 nm) during alignment procedures.

Caution:
Always turn the ND6000 laser down to a low level (<30mJ) before using the red or business cards.

Taking Burn Profiles

Warning!
Keep the burn paper directly in front of and at 90° to the beam and your eyes to avoid dangerous reflections from the plastic bag.

Always make burn profiles of the pump beam at high energy levels when it is not possible to view the beam with the eye or use red fluorescent paper or a white card.

Use burn paper to make burn profiles of the pump or dye beam. This paper is pink when taken from the box. Before taking burn samples, expose the burn paper to room light for about 30 minutes or until it turns light brown.

To take a burn profile, put the burn paper in a plastic bag to prevent spreading debris from the burn paper onto the beam components. Normally, profiles are made on the emulsion (brown) side of the paper, but for high power measurements, expose the non-emulsion (white) side of the paper, so the thickness of the paper attenuates the beam energy and shows the beam details more clearly.

Routine Alignment

Perform routine alignment whenever ND6000 startup tests reveal low beam power or distorted shape (see **Chapter III** for more details).

Use red paper or burn paper, depending on beam intensity, to locate and analyze beams throughout this alignment. When using burn paper, enclose it in a plastic bag. Numbers in this procedure refer to Figure 5.7.

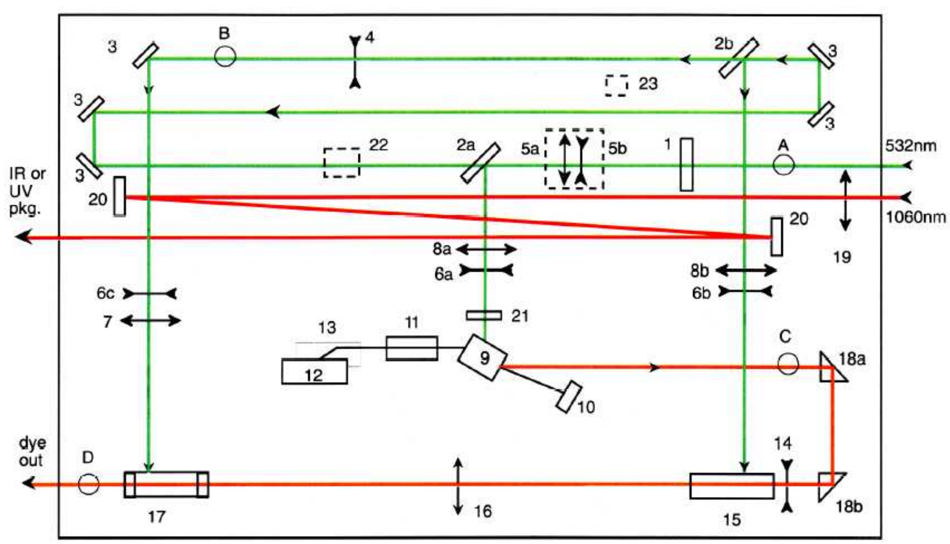


Figure 5.7
ND6000 Optics

KEY: Numbers refer to optical elements, letters to alignment jig stations

Initially set the pump laser to single shot when making burn profiles. For later tests, use the pump laser's continuous mode, rapidly moving the paper through the beam. The continuous setting gives a performance profile to compare with the burns from this laser, found on the System Data Sheet in the front of this manual.

Warning!
WEAR GOGGLES. Observe all safety precautions. Avoid reflections from the plastic bag when taking burns.

Preparation

Before beginning alignment, be sure that all optical surfaces are clean, then turn on the dye beam.

1) Open the laser's hinged cover, remove the smoked plastic cover and engage the interlock defeat bar (23). Remove the oscillator's sheet metal cover.

Standard ND6000 Optics	
1. Half wave plate	108-0002
2a. Beam splitter	105-0157
2b. Beam splitter	105-0157
3. Mirror, dichroic	105-0022/0023
4. Lens, spherical, -1000 mm	102-0055
5a. Lens, cylindrical, +200 mm, AR355/532	101-0080
5b. Lens, spherical, -150 mm, AR 355/532	102-0046
6. Lens, spherical, -70 mm	102-0031
7. Lens, cylindrical, +70 mm	101-0095
8. Lens, cylindrical, +50 mm	101-0041
9. Dye cell, oscillator	199-0080
10. Moya mirror, oscillator	105-0026
11. Beam expander, NPB-3	618-0810
12. Sine drive mirror	105-0027
13. Grating, 2400 lines	199-0012
14. Lens, -70 mm	102-0027
15. Dye cell, preamp	199-0084
16. Lens, +300 mm, spherical	101-0040
17. Dye cell, amp, windows	110-0010
5 mm capillary for above	199-0013
18. Prism, 90 degrees	109-0008
22. Beam dump	618-3900
Beam dump filter	107-0061
23. Safety interlock defeat	
A-D. Alignment test points	

High energy pump beam options	
5. Dichroic mirror	105-0160
5. Dichroic mirror	105-0160
Optics for UVX option	
19. Lens for 1064 nm beam	varies
20. Mirror, 0 degree	105-0001
21. Filter, neutral density	varies
Pump beam diameter options	
7 mm pump beam telescope	618-3100
17. Amp dye cell window for 3 to 5 mm capillaries	110-0010
3 mm capillary for above	199-0074
4 mm capillary for above	199-0073
5 mm capillary for above	199-0013
6 mm capillary for above	618-3200
355 mm pump beam options	
1. Half wave plate	108-0002
2a. Beam splitter	105-0156
2b. Beam splitter	105-0159
Grating options (2 if dual option)	
13. Grating, 1800 lines	199-0046
13. Grating, 3000 lines	199-0078
13. Grating, 2400 lines	199-0012
Dual wavelength options	
12. Sine drive mirror	105-0073
9. Osc. Cell windows	110-0037

2) Verify that beam splitters (2a, 2b), dichroic mirrors (3) and aiming prism (3a) match the pump wavelength used. Be sure the $\lambda/2$ plate is in the beam path only for 355 nm pumping.

3) Add fresh, correctly concentrated dye solution if needed (see **Optimizing Dye Concentrations** in this chapter).

4) Inspect all optics for damage and cleanliness with an inspection mirror and high intensity lamp. Clean dirty optics (see **Maintaining Optics** in this chapter).

5) Replace the oscillator's sheet metal cover.

6) Turn on the pump and dye lasers, dye circulator and computer. Detune the pump beam to approximately 25 mJ/pulse at 532 nm.

Pump Beam

The pump beam must strike the center of beam splitters (2a and 2b) and the final turning mirror (3). To align the pump beam over its entire path:

1) Use the pump laser optics to center the pump beam on the 43mm hole in alignment jigs placed in positions A and B.

2) Adjust the dove dichroic mirrors (3) to center the pump beam on the final turning mirror (3) and on the dove prisms without clipping. Horizontally center the beam in beam splitters (2a, 2b). If necessary, repeat step 7.

3) Engage the amplifier beam dump (22) and maximize pump beam energy. Only the oscillator is now pumped.

Cell Pump Beams

The pump beam must strike all three dye cells correctly for maximum output power. First, align the pump beam over its entire path (above), then align the beam to correctly strike each cell in turn.

Oscillator

1) Adjust the vertical control of the oscillator beam splitter (2a) so that the dye oscillator beam exits the oscillator housing 43 mm above the optical bench. Check with an alignment jig set in hole **C**.

2) Adjust turning prism (18a) to center the most intense portion of the dye beam through the final amplifier (17).

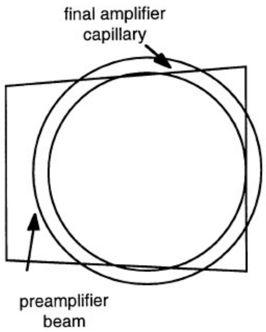


Figure 5.8
Proper alignment of dye beam on entrance window of final amplifier

First Amplifier

1) Place the modular beam dump between beam splitter (2b) and turning mirror (3). Raise the amplifier beam dump (22). Now the Adjust the horizontal control of beam splitter (2b) to center the stronger of its two reflections on the first amplifier cuvette (15).

2) Adjust the vertical control of beam splitter (2b) to align the dye beam to pass parallel and as close as possible to the cuvette wall which admits the pump beam. Use burns taken before and after the final amplifier to aid this adjustment; both burns should be similar. Repeat this and the previous step.

Final Amplifier

1) Lower the amplifier beam dump . Place the modular beam dump after the first amplifier's cylindrical lens (8b). Raise the amplifier beam dump to pump the oscillator and final amplifier.

2) Adjust the vertical control of mirror (3) to center the pump beam vertically on the final amplifier (17). The pump beam is centered when burns taken at beam output are symmetrical from left to right.

3) Center the pump beam on the final amplifier using the horizontal control of mirror (3); centering maximizes the output energy. Don't allow the pump beam to strike the metal endpieces of the final amplifier. Repeat this and the previous step.

4) With the pump laser off, lower the amplifier beam dump, remove the modular beam dump, raise the amplifier beam dump and reinstall the plastic dye laser cover.

Pump Beam Focus

1) Monitor pulse power with a power meter while the pump laser fires continuously at full power. Adjust the three *focus* knobs (these labels are on the plastic cover). Turn each of them in turn no more than 1/4 turn in each direction while maximizing output beam energy.

2) Examine output beam burn shapes and compare to burns in the front of this manual. The ND6000 is now aligned.

Detailed Alignment

Perform detailed alignment when restarting the ND6000 upon reinstallation or when Routine alignment does not attain the laser specifications. Attempt this procedure only if familiar with the ND6000, and read other Alignment sections of this chapter first.

WARNING!
WEAR GOGGLES. Observe all safety precautions. Avoid reflections from the plastic bag when taking burns.

Numbers in this procedure refer to **Figure 5.7.** Use red paper or burn paper, depending on beam intensity, to locate and analyze beams. When using burn paper, enclose it in a plastic bag.

Preparation

1) Perform routine alignment steps 1 through 20, above.

2) Bolt the YAG and dye lasers together and connect the safety interlock between them (refer to **Connecting the Safety Interlock** in **Chapter VI**). If the lasers cannot be bolted together, take extra care in aligning the pump laser to the ND6000.

3) Turn on the pump and dye lasers, dye circulator and computer. Reduce the pump beam to approximately 30 mJ/pulse. Be sure software contains the calibration parameters for this laser and grating.

Pump Beam Aligning

1) Use the pump laser optics to center the pump beam on the 43 mm hole in alignment jigs placed in positions A and B.

2) Adjust the dichroic mirrors (3) to center the pump beam on the final turning mirror (3) and on the dichroic mirrors. If necessary, repeat step 4.

3) Adjust beam splitters (2a & 2b) so the beam is centered on them and strikes the dye cells (9, 15) without being clipped. Check that the beam still strikes the center of the final turning mirror (3). Be sure to use the stronger reflection from each beam splitter (from their front faces). Then repeat steps 4 to 6 if necessary.

4) Similarly adjust the final turning mirror (3) to center the pump beam on the last amplifier (21).

5) Adjust the horizontal positions of beam shaping lenses (6, 7, 8) so that the beam is centered on them and is not clipped. Recheck steps 6 and

> Warning!
> Use extreme caution to avoid stray laser beams from the oscillator, especially when taking burns.

6) Close the amplifier beam dump and maximize the pump beam energy. Tune to the dye peak.

Oscillator Alignment

> Note:
> Perform step 1 only if the pump beam energy has changed. Call Continuum customer service if the cell energy remains outside the desired range.

Oscillator Energy

The oscillator cell requires 10 - 15 mJ pump energy at 532nm (and at 355nm) for maximum gain while retaining narrow linewidths. Remount the oscillator beam splitter (2a) in the second position of its kinematic mount to direct the split beam away from the dye cell. Measure the beam's strong reflection with a power meter. (Place any neutral beam filter (21) present in front of the meter first.) Replace splitter (2a) in its normal position.

> Warning!
> Never remove or install optics, mounts or covers when the pump beam is on.

Pump Beam Shape

1) Remove cylindrical lens (8a) and spherical lens (6a) without disturbing the height indexing stops on their mounts. Center the stronger split beam on the oscillator housing input hole. The round, unfocused pump beam should also appear centered on the dye cuvette. Reinstall the spherical lens at the center of the beam and reset its height stop. Similarly reinstall the cylindrical lens.
2) Check that the dye fluorescence striking the grating (13) overlaps equally (on its long axis). Adjust the vertical control of shaping lens (8a) to center this fluorescence.

Warning!
Never remove or install optics, mounts or covers when the pump beam is on.

Cavity Tuning

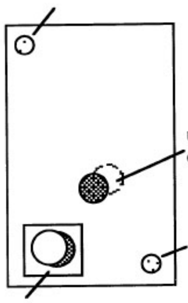


Figure 5.9 Horizontal and vertical adjustments of the lasing cavity front mirror. Loosen the central knob before making horizontal adjustments. Never touch the vertical (top) adjustment.

1) Place red paper between the grating (13) and expansion prisms (11), and rotate the cylindrical lens (8a) to maximize beam intensity. Check both lens heights to center the beam through the expansion prisms and make the same amount of beam fluorescence overlap each end of the grating.

2) Adjust the front mirror (10) to optimize lasing (horizontal adjustment only; see Figure 5.9); monitor at the cell exit. To adjust, loosen the lock screw in the center of the mirror mount and turn the lower set screw.

3) Reinstall the dye oscillator cover.

Dye Beam Output

Adjust the first turning prism (18a) to steer the oscillator beam through the center of the final amplifier (17). The oscillator beam will overfill the final amplifier, so move the prism (18a) to aim the most intense portion of the oscillator beam through the final amplifier. Use red paper after the final amplifier to evaluate this adjustment.

First Amplifier Alignment

Cell Position

For maximum amplification, the dye beam must intersect the pump beam as close to the cuvette window which admits the pump beam as possible. However, since the dye beam diverges slightly, the dye beam will be clipped by this window. Proper alignment means compromising between beam losses due to clipping and losses from intersecting the pump beam away from the entrance window, after it has been attenuated. Positioning requires both a rotation and displacement:

Loosen both 5mm Allen bolts securing the cuvette assembly (15) to the bench. Place red paper after the first amplifier cell and rotate it around a vertical axis while pumping the oscillator only. Rotate the cell until dye beam reflections from the window are minimized and the oval main dye beam almost completely absorbs the sharper vertical beam image from the wall of the cuvette. See Figure 5.10.

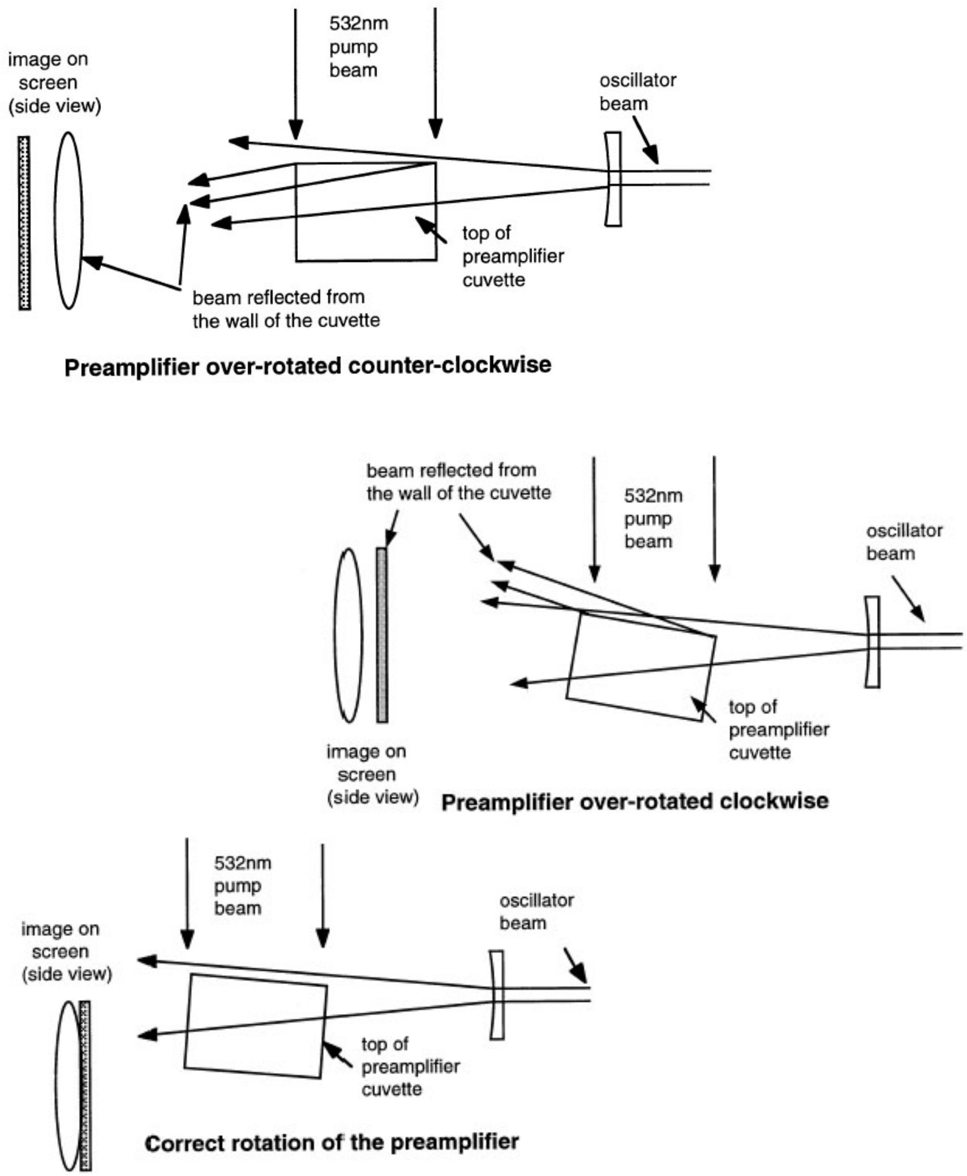


Figure 5.10
First Amplifier Rotation

When properly aligned, the dye beam will be parallel to the pump beam window. The two exit images (a round main beam & a vertical slit caused by the dye beam passing through the edge of the window) will almost overlap.

Now move the cell along the pump beam axis to maximize the strength of the main beam while letting it overlap the cell wall image as much as possible. Repeat steps 1 and 2.

Dye Beam Aligning

1) Remove diverging lens (14) and converging lens (16) without disturbing their height stops. Install alignment jigs at positions C and D. Adjust prism (18a) to center the beam on the 43mm high pinholes on the jigs.

Note:
When pumping with 355nm UV light, adjust this dye beam to pass close to the cuvette wall admitting the pump beam to maximize the amplification. Beam shape will not be ideal. To improve beam shape without loss of power, Continuum recommends using a Bethune cell as the final amplifier in place of the 5mm capillary cuvette.

2) Reinstall and center the diverging lens (14) and repeat step 3. Repeat after reinstalling the converging lens (16).

Pump Beam Aligning

1) Place the modular beam dump in front of turning mirror (3) and open the amplifier beam dump. Detune the pump beam to obtain approximately 25 mJ/pulse. The oscillator and first amplifier are now being pumped.

2) Aim the pump beam with beam splitter (2b) so that the brighter of the two beams completely overlaps the first amplifier cuvette. Also maximize horizontal beam symmetry by taking burns after the final amplifier.

3) Horizontally adjust shaping lenses (6b and 8b) until they do not clip this beam. If focusing the lens (8b) causes the pump beam to move vertically, repeat steps 6 and 7.

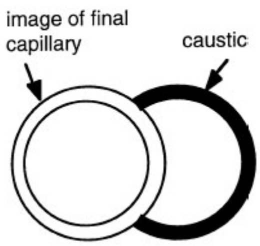
4) Re-optimize the energy of the pump beam.

5) Adjust the height of the first amplifier pump beam with beam splitter (2b) to overlap the center of the dye beam.

6) Using burn paper before and after the final amplifier, focus lens (8b) so the amplified section of the oscillator beam is as thick as the diameter of the final capillary. See Figure 5.8.

7) Rotate the cylindrical lens (8b) to maximize output energy as measured by a power meter.

8) Repeat steps 9 to 11 if the beam no longer fills the 5mm inner diameter of the final amplifier entrance face.

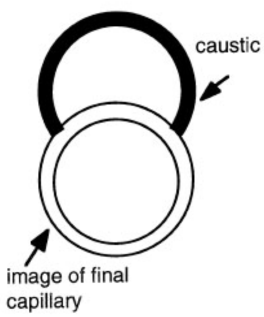


Final Amplifier Alignment Caustics

With only the final amplifier pump beam blocked, place red paper several meters past the laser exit and look for caustics in the beam. Caustics are loops of light, which diverge rapidly from the main beam (see Figure 5.11). Caustics should not appear if the output beam is aligned using steps 3 and 4 of the first amplifier alignment section.

Horizontal Caustics

If horizontal caustics persist, rotate the final amplifier in the horizontal plane after loosening the mounting bolts (Figure 5.2) which attach it to the bench.



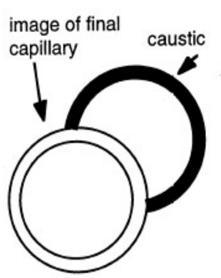
Vertical Caustics

To eliminate vertical caustics, loosen both amplifier mount locking bolts (Figure 5.2) and then rotating the cell around the axis of the pivot screw. Rotate the cell about the pivot opposite these loosened bolts.

Combined Caustics

A combination of horizontal and vertical adjustments may be necessary. Re-tighten all bolts after caustics disappear.

Figure 5.11 Typical Shapes of Caustics



Pump Beam Aligning

1) Lower the amplifier beam dump. Place the modular beam dump on the first amplifier's cylindrical lens (8b) translation stage so that the pump beam strikes its white plastic block. Raise the amplifier beam dump. This pumps the oscillator and final amplifier.

2) Detune the pump beam to approximately 25 mJ/pulse.

3) Center the pump beam horizontally and vertically on the amplifier capillary with final turning mirror (3). Adjust shaping lenses (6c, 7) horizontally if they clip this beam.

4) Optimize the pump beam for maximum energy.

5) Optimize the vertical adjustment of the final amplifier pump beam with mirror (3) so that the exit beam burn is symmetrical top and bottom.

6) Focus the cylindrical lens (7) so the pump beam just fills the final amplifier from top to bottom. Use burn paper to analyze adjustments. If focusing this lens causes the pump beam to move vertically, re-align lenses (6c) and (7).

7) Rotate the cylindrical lens (7) for maximum energy.

8) Adjust the horizontal control of the mirror (3) for maximum energy. Do not allow the pump beam to strike the amplifier's stainless steel endpieces.

9) Lower the amplifier beam dump, remove the modular beam dump and raise the amplifier beam dump.

Pump Beam Focus

1) Monitor pulse power with a power meter while the pump laser fires continuously at full power. Adjust the three *focus* knobs (these labels are on the plastic cover). Turn each of them in turn no more than 1/4 turn in each direction while maximizing output beam energy.

Final Steps

2) Adjust the amplifier dye concentration to optimize the beam quality across the beam (see optimizing dye concentrations in this chapter).

3) Measure the average power of the system to show that the laser is operating correctly. Disengage the interlock defeat bar and reinstall the plastic cover. The ND6000 is now ready to run.

D. Switch Grating Procedure

The ND6000 allows you to switch gratings for additional options. Optional lower gratings allow the ND6000 to cover extended ranges and optional upper gratings narrow the bandwidth of the output. Identify the wavelength range you want to use, select a grating and follow the corresponding procedure that follows:

Warning!
Always close the YAG output shutter before switching a grating. Use extreme caution to avoid stray beams. Failure to close the output shutter may also damage the laser. DO NOT TOUCH optical surfaces of the gratings. They cannot be cleaned.

Single 1800 Grating (506nm - 986.667nm)

1) Close the YAG output shutter.

2) Using the mouse, select the Configuration Window> Grating Option>1800 mm.

3) Remove the current grating and replace it with the 1800 mm grating. Be sure to choose the correct grating. Verify that the tuning mirror is a mirror and not a dual grating placed in the system at Normal Incidence by mistake.

4) Be sure to use the correct dye in the system. Refer to Figures 4.3 and 5.5 in this manual.

5) If the **GOTO** window has not been opened, click the **GOTO button**. Using the Numeric Keypad, input the destination wavelength and click the **Start b**utton to begin movement.

6) When movement has ended, open the YAG output shutter. The ND6000 should be set up for the correct wavelength range.

Dual 1800 Grating (675.673nm - 957.961nm)

1) Close the YAG output shutter.

2) Using the mouse, select the Configuration Window> Grating Option> Dual 1800 g/mm.

3) Remove silvered mirror and replace it with the 1800 mm grating in the Littrow position. Verify that the bottom grating is 1800 mm. Refer to Figure 5.11.

4) Be sure to use the correct dye in the system. Refer to Figures 6.3 and 5.5 in this manual.

5) If the **GOTO** window has not been opened, click the **GOTO button**. Using the Numeric Keypad, input the destination wavelength and click the **Start** button to begin movement.

6) When movement has ended, open the YAG output shutter. The ND6000 should be set up for the correct wavelength range.

Dual 2400 Grating (506.755nm - 718.470nm)

1) Close the YAG output shutter.

2) Using the mouse, select the Configuration Window> Grating Option>Dual 2400 mm.

3) Remove silvered mirror and replace it with the 2400 mm grating in the Littrow position. Verify that the lower grating is 2400 mm. Refer to Figure 5.11.

4) Be sure to use the correct dye in the system. Refer to Figures 4.3 and 5.5 in this manual.

5) If the **GOTO** window has not been opened, click the **GOTO button**. Using the Numeric Keypad, input the destination wavelength and click the **Start** button to begin movement.

6) When movement has ended, open the YAG output shutter. The ND6000 should be set up for the correct wavelength range.

Single 3000 Grating (304nm - 592nm)

1) Close the YAG output shutter.

2) Using the mouse, select the Configuration Window> Grating Option>3000 mm.

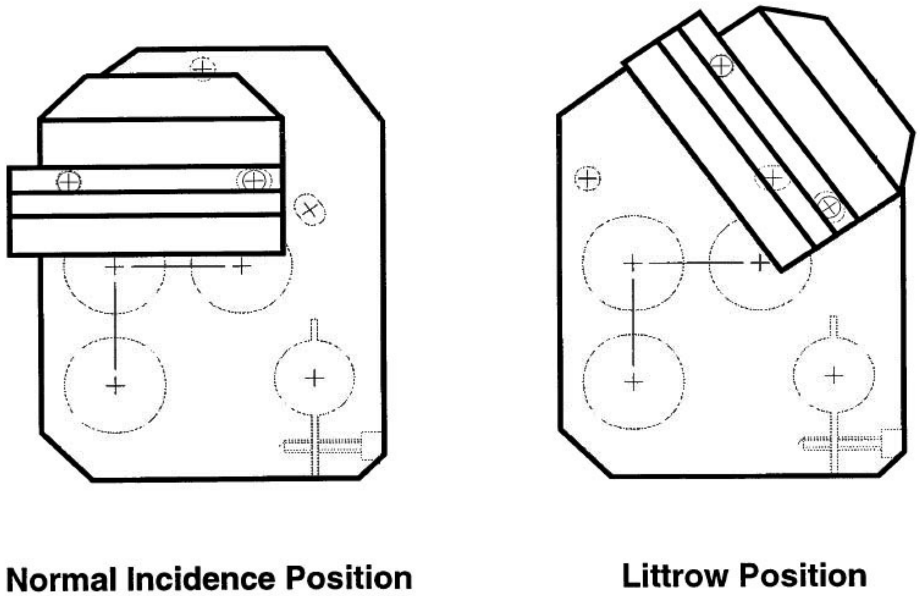
3) Remove the current grating and replace it with the 3000 mm grating. Verify that the upper portion of the mount is a mirror and not of a grating mounted at Normal incidence position by mistake. Refer to Figure 5.11.

4) Be sure to use the correct dye in the system. Refer to Figures 4.3 and 5.5 in this manual.

5) If the **GOTO** window has not been opened, click the **GOTO button**. Using the Numeric Keypad input the destination wavelength and click the **Start b**utton to begin movement.

6) When movement has ended, open the YAG output shutter. The ND6000 should be set up for the correct wavelength range.

Figure 5.12
ND6000 Normal Incidence and Littrow Positions



Dual 3000 Grating (405.404nm - 574.776nm)

1) Close the YAG output shutter.

2) Using the mouse, select the Configuration Window> Grating Option>Dual 3000 mm.

3) Remove silvered mirror and replace it with the 3000 mm grating in the Littrow position. Refer to Item 12, Figure 5.7.

4) Be sure to use the correct dye in the system. Refer to Figures 4.3 and 5.5 in this manual.

5) If the **GOTO** window has not been opened, click the **GOTO button**. Using the Numeric Keypad, input the wavelength you want and click the **Start button** to begin movement.

6) When movement has ended, open the YAG output shutter. The ND6000 should be set up for the correct wavelength range.

Chapter VI Troubleshooting

This chapter describes problems with ND6000 performance and its electronics, and suggests repairs. There are electronics troubleshooting sections for the ND6000, the CCM and DCP6100. Sections of this chapter contain two parts:

1) **Troubleshooting Instructions and Information:** Tables to quickly determine the source of most common problems in the optics, electronics, CCM and DCP6100. These tables list the most common problems that may occur while operating the ND6000 and suggest corrective action. Figure 6.1 covers problems associated with the optical path, Figure 6.2 deals with problems occurring with the software or the CCM, Figure 6.3 concerns ND6000 electronics problems, and Figure 6.7 covers the DCP6100.

2) **Tests:** Procedures to identify problems in the ND6000 and DCP6100, with faultfinding down to the replaceable component level. This section also contains routine and detailed laser alignment procedures.

Caution!
Read and follow the safety instructions in Chapter 1 and in this chapter before performing any test procedure with the pump laser ON.

Laser Radiation!
Some of these procedures are performed with the safety covers OFF and the Class IV pump laser operating. Laser goggles must be worn at all times the pump laser is ON.

Laser Radiation!
These procedures must be performed ONLY by personnel qualified to operate Class IV laser equipment who have received training by a Continuum service engineer.

Laser Radiation!
These procedures should be performed with the pump laser turned down unless otherwise instructed.

A. Optical System and Overall Performance Problems

Figure 6.1 suggests solutions for many common ND6000 problems for which the symptoms include poor laser performance. These problems are usually caused by damaged optics, misalignment, or incorrect dye solutions.

Symptom	Possible Cause	Check
Low beam energy	Low pump laser beam energy Incorrect or old dye solution Laser not tuned to top of dye curve Dirty or damaged optics and cells	Adjust pump laser performance Replace dye Tune to dye peak or select a dye with a proper absorption range Inspect, clean, rotate or replace
High ASE	Tuning mirror drive is not operating	Dilute or replace dye solution Perform routine alignment, then detailed alignment of oscillator Remove reflections along optical path due to external optical elements Contact Continuum Service Dept.
Poor beam shape	Laser is misaligned Improper dye concentration Dirty or damaged optics and cells	Perform routine alignment Replace or correct concentration of dye solution Inspect, clean, rotate or replace
Poor linewidth	Dye is too concentrated Oscillator is misaligned Optics or cells are dirty or damaged	Dilute or replace dye solution Perform routine alignment, then detailed alignment of oscillator Inspect, clean, rotate or replace
Burn dye cell(s)	Dye concentration is too high Old dye solution Contaminated solvent Pump beam focused on cell(s) too high	Change solution; clean or rotate cell(s) Change solution; clean or rotate cell(s) Use new solvent and replace dye solution; clean or rotate cell(s) Perform routine alignment; clean or rotate cell(s)
Poor shot-to-shot stability	Pump laser instability	Correct pump laser performance

Figure 6.1
Common Problems Relating to ND6000 Performance

B. Control Module (CCM) and Software Problems

Figure 6.2 *Common problems relating to the CCM and Wavelength Control of the ND6000* suggests solutions for many common CCM and software problems. If these solutions and associated procedures do not restore the CCM to operating status, call Continuum customer service.

CCM Troubleshooting Guide

Symptom	Possible Cause	Check
CCM does not turn on	No power to CCM	Check that the CCM monitor power is ON, all cables are connected, the CCM fuse is OK and that the ac power source is ON.
Laser wavelength does not change when scanning.	Tuning mirror drive is not operating.	Be sure tuning drive has power (check ac power, power switch, amber lamp is ON, and fuse is OK), and check all cables (including safety interlock) between CCM and laser, then refer to Electronic Troubleshooting below.
CCM-selected wavelength is incorrect.	Calibration incorrect, perhaps the laser was turned off before the CCM.	Use Menu and Calibration/ Zero Reset.
Zero Reset fails	Zero reset photosensors fails	Refer to Electronic Troubleshooting below.

Figure 6.2
Common problems relating to the CCM and Wavelength Control of the ND6000

Test Procedures for the CCM and Self-Calibration

CCM Test

Follow this procedure when the CCM does not respond to keyboard instructions after power **ON**.

Step 1 Check that all cables are connected and properly seated; refer to Figure 4.7.

Step 2 Check that the power switch on the ND6000 is **ON**.

C. Stepper Motor Electronics

ND6000 electronics consists of control electronics for the stepper motor and optional oscillator thermal controller. The CCM hold the stepper controller. Both stepper motor driver and its power supply are located in the electronics module underneath the ND6000 optics bench.

The CCM commands the stepper controller to supply TTL pulses to the stepper motor driver via connector J4. The stepper controller also reads the lead screw limit switches and coarse and fine zero position sensors through connector J6. The stepper motor driver in turn sends pulses to move the sine drive motor via connector J5, using an associated power supply.

Stepper Motor Troubleshooting Guide

The following table suggests solutions for many common problems in the stepper motor and its control electronics. If these solutions do not restore the CCM to operating status, call Continuum customer service.

Figure 6.3
Troubleshooting Guide to Stepper Motor Electronics

Symptom	Possible Cause	Remedy
Stepper motor does not respond	No Power	Check ND6000 fuse, power connections , power switch
	CCM shut off while a limit switch is tripped.	Refer to restart after tripping limit switch, below
	Defective 24 Vdc power supply for stepper controller in CCM	Look for 24 Vdc across pins 1 and 4 of stepper controller.
	Defective stepper controller in CCM	Refer to testing the stepper controller, below
	Defective stepper motor driver	Refer to testing the stepper motor driver, below.
	Defective stepper motor	If the above tests of the stepper motor driver and stepper controller (above) are negative, this motor is defective.
Self- calibration fails	Failed photosensor voltage regulator	Refer to testing the zero reset photosensor system, below
	Defective coarse zero position photosensor	Refer to testing the zero reset photosensor system, below
	Defective fine zero position photosensor	Refer to testing the zero reset photosensor system, below

Test Procedures for Stepper Motor Electronics

With the pump laser off, detach the control box from the ND6000 just until access to its electronics is possible; it is attached by 3 bolts to the optical bench. Also remove the covers of connectors J4 and J6 (25 pin and 15 pins respectively). High and low refer to 5 Vdc and 0 Vdc. Use an oscilloscope or voltmeter for these tests.

Please refer to the table of parts (Figure 6.4), description of connectors (Figure 6.5) and schematic diagram (Figure 6.6) which follow.

Figure 6.4
Replaceable Stepper Motor Parts

P/N	Description	Location
615-7110	Control module assembly	Under optical bench
994-0069	Stepper controller	CCM
436-0215	Stepper motor driver	ND6000 electronics module
425-0003	24 Vdc power supply	ND6000 electronics module
427-0014	5 V voltage regulator	ND6000 electronics module
422-0018	Stepper motor	Translation stage
416-0164	Coarse zero position	Translation stage

	photosensor	
416-0165	Fine zero position photosensor	Translation stage

Figure 6.5
Connectors on the ND6000 Electronics Module

Name	PINS	M/F	Type	Purpose
J1	7	Female	Amphenol	DCP6000 power and interlock
J2				120 Vac
J3	2	Female	Molex	Security interlock
J4	9	Female	D	Input from CCM controller
J5	9	Female	3X3 molex	Output to stepper motor
J6	15	Male	D	Output to CCM controller
J7	2	Male	Molex	Security interlock
J8	9	Male	3X3 molex	Input to CCM from translation stage, limit switches, zero reset sensors
J9	3	Female	Molex	External burst control

Reset After Losing CCM Control With a Limit Switch On

If the CCM loses power while a limit switch has been activated (usually by attempting to scan manually past the allowed range and then turning off the CCM), the CCM will lose control over the stepper motor. When the CCM is restarted, the stepper motor will not respond. Use this procedure to restart the CCM:

Caution:
Be sure to scan in the right direction when a limit switch is jumpered (and thus not operating). Scanning to the end of the lead screw will cause serious damage to the translation stage.

If the blue limit switch has been tripped, the tuning mirror in the oscillator cavity (mirror (12) in Figure 4.8) will be horizontal and J6 pin 1 will be high. Jumper pins 1 and 2 together, then restart the CCM and use the manual scan mode to move at least 50 Å to the red. Remove the jumper.

If the red limit switch has been tripped, the tuning mirror will be almost vertical and pin 11 will be high. Jumper pins 10 and 11 together, then restart the CCM and use the manual scan mode to move at least 50 Å back into the blue. Remove the jumper.

Testing the Stepper Controller

The stepper controller produces four output signals. Pins 1, 14, 2 and 15 of J4 must respond correctly to software commands, or the stepper controller is defective. The tests are:

1) J4 pin 1 (red stepper pulse) should show a 1 μsec pulse (high) with duty cycle inversely proportional to scan rate while scanning in the red direction (e.g. 1 Ång/sec = 400 μsec/pulse, 2 Ång/sec = 200 μsec/pulse). Pin 1 is normally low.

2) J4 pin 14 (blue stepper pulse) should behave the same as pin 1 when the motor moves toward the blue, except that pin 14 is normally high and the pulses dip low.

3) J4 pin 2 (red direction indicator) should be high when motor moves in red direction, otherwise low.

4) J4 pin 15 (blue direction indicator) should be high when motor moves in blue direction, otherwise low.

Testing the Stepper Motor Driver

Please read the general instructions above. Look for a square wave signal (0 to 24 V) on connectors A, A+, B and B+ located on the stepper motor driver. The square waves will have a frequency inversely related to motor speed (e.g. 1 Ång/sec = 400 μsec/cycle, 2 Ång/sec = 200 μsec/cycle), and should be present only when the motor is on.

Testing the Zero Reset Photosensor System

For self-calibration to succeed, the CCM must be able to locate the zero reset position of the stepper motor. During self-calibration, the ND6000 first scans towards blue until reaching the coarse zero photosensor, then scans slowly back toward red until reaching the fine zero photosensor.

This is the zero reset point.

Step 1 Test the photosensor voltage regulator: Pin 5 of J6 (15 pins) should read +5 Vdc.

Step 2 Test the coarse zero position photosensor: Pin 6 of J6 (15 pins) should be high while system moves toward the blue during self-calibration, and low otherwise.

Step 3 Test the fine zero position photosensor: Pin 7 of J6 (15 pins) should be high while system moves toward the blue and returns to the red during self-calibration, becoming low only when reaching the exact zero point.

D. Frequency Stabilization Option

The FSO consists of two heater PCB's and a thermistor which are flush mounted on the oscillator assembly and a thermal controller inside the ND6000 control box. The heaters are powered by a larger version of the normal ND6000 24 Vdc power supply.

Figure 6.6

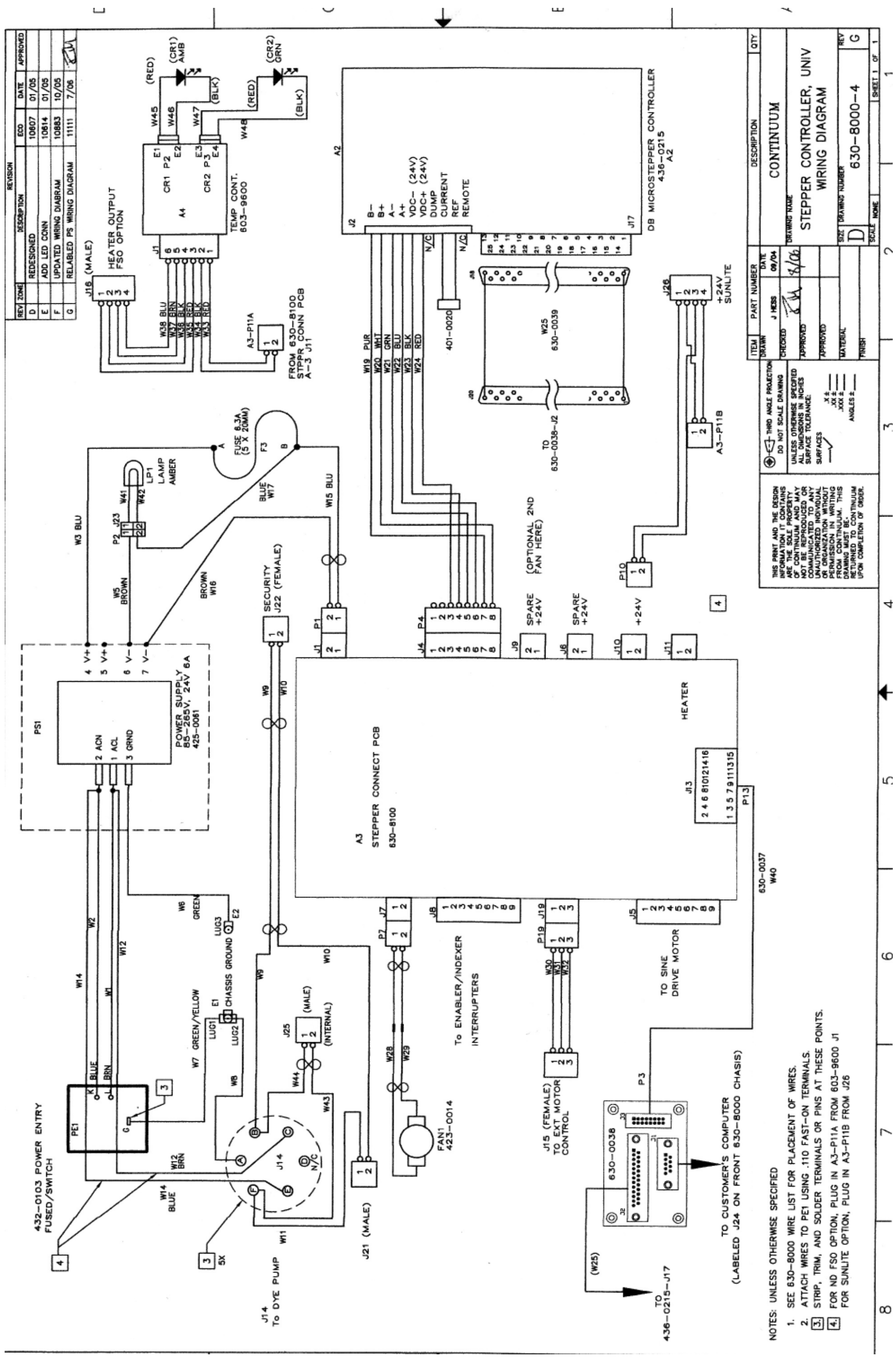

CONTINUUM
STEPPER CONTROLLER, UNIV WIRING DIAGRAM
630-8000-4
POWER SUPPLY 85-265V, 24V 6A 425-0061
STEPPER CONNECT PCB 630-8100
DB MICROSTEPPER CONTROLLER 436-0215 A2
TEMP CONT. 603-9600
HEATER
TO SINE DRIVE MOTOR
TO ENABLER/INDEXER INTERRUPTERS
J14 To DYE PUMP
FAN1 423-0014
432-0103 POWER ENTRY FUSED/SWITCH
TO CUSTOMER'S COMPUTER (LABELED J24 ON FRONT 630-8000 CHASIS)
NOTES: UNLESS OTHERWISE SPECIFIED
1. SEE 630-8000 WIRE LIST FOR PLACEMENT OF WIRES.
2. ATTACH WIRES TO PE1 USING .110 FAST-ON TERMINALS.
3 STRIP, TRIM, AND SOLDER TERMINALS OR PINS AT THESE POINTS.
4 FOR ND FSO OPTION, PLUG IN A3-P11A FROM 603-9600 J1
FOR SUNLITE OPTION, PLUG IN A3-P11B FROM J26

Figure 6.7
DCP6100 Troubleshooting Guide

Symptom	Possible Cause	Remedy
	No AC power	Check DCP6100 fuse, ON switch and power connector to ND6000
Main LED is on, but nothing functions	24 Vdc Power Supply	Look for 110 VAC at TVI pins 2-3; look for 24 Vdc at TB2, pins 4-5
One of two dye loops does not operate.	Obstructions	Check fluid levels, kinks or obstructions in tubing, and clean the DCP6100 filters (see ChapterV).
	Pump motor.	The presence of 24 Vdc on J2, pins 1-2 (oscillator motor) or pins 34 (amplifier motor) indicates the motor is defective.
	DCP6100 PCB	Refer to testing the DCP6000 PCB, below.

Figure 6.8
Replaceable DCP6100 Parts

Part Number	*Description*
618-8400	DCP6100
425-0093	Power supply
618-0040	DCP6100 PCB
424-0021	Pump motor
313-0088	Filter
312-0702	Bottle

E. DCP6100 Electronics

The DCP6100 receives its power from the ND6000. It is separately fused and contains its own 24 Vdc power supply. Its two dye fluid loops each consist of a pump, pressure switch, reservoir bottles and gravity drain valve.

This section refers to connectors J2 and J4 on the control PCB and connectors TB1 and TB2 on the power supply. Remove the DCP6100 top cover to obtain access to all internal parts. Also refer to **Figures 6.7** and **6.8:** *DCP6100 Troubleshooting Guide* and *Replaceable DCP6100 Parts* respectively.

Test Procedures for DCP6100 Electronics

Testing the DCP6100 Flow

Step 1 Drain dye solution in the failed loop to be measured.

Step 2 Place the other end of the drain tube in a 500 ml graduated beaker and fill the DCP6100 reservoir with methanol.

Step 3 Measure the flow rate. Ideal flow (using methanol without filters) is 1500 ml/min. A flow rate below 750 ml/min. is inadequate. If the flow rate is below this level, clean the filters and look for obstructions in the tubing.

Step 4 If the flow rate remains below this level, call Continuum Service.

Testing the DCP6100 PCB

When one or both of the dye loops are not functioning and other causes (see above) have been eliminated, use a voltmeter on these test points. Lack of 24 Vdc across any of them indicates a defective PCB.

J2, pins 1-2	oscillator pump motor power
J2, pins 3-4	amplifier pump motor power

Figure 6.9

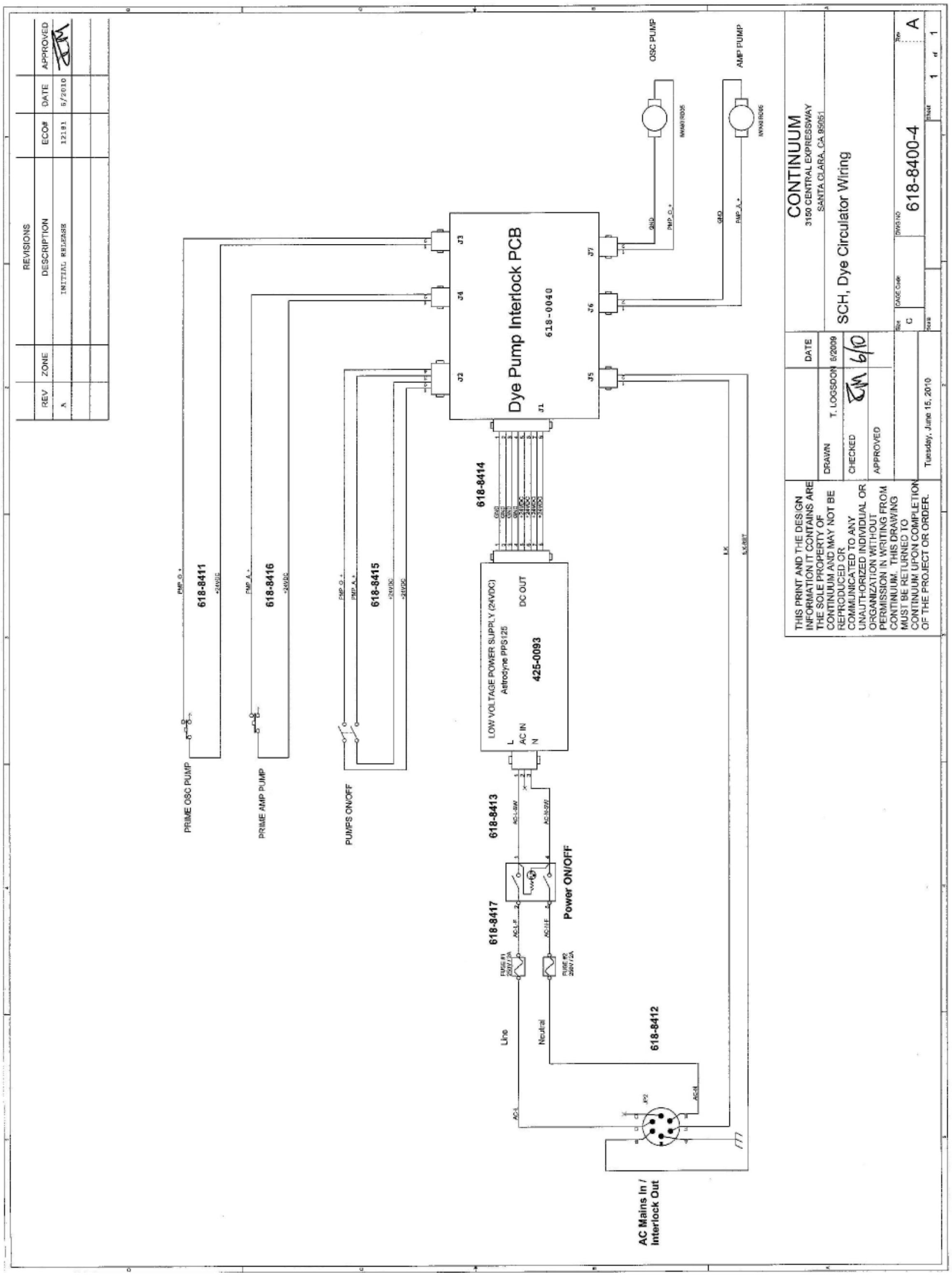

REVISIONS
REV
ZONE
DESCRIPTION
ECO#
DATE
APPROVED
INITIAL RELEASE
12181
5/2010
Dye Pump Interlock PCB
618-0040
OSC PUMP
AMP PUMP
618-8411
618-8416
618-8415
618-8414
618-8413
618-8417
618-8412
PRIME OSC PUMP
PRIME AMP PUMP
PUMPS ON/OFF
LOW VOLTAGE POWER SUPPLY (24VDC)
Astrodyne PPS125
425-0093
AC IN
DC OUT
Power ON/OFF
Line
Neutral
AC Mains In / Interlock Out
CONTINUUM
3150 CENTRAL EXPRESSWAY
SANTA CLARA, CA 95051
SCH, Dye Circulator Wiring
618-8400-4
A
DRAWN
CHECKED
APPROVED
DATE
T. LOGSDON
6/2009
Tuesday, June 15, 2010
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Figure 6.10
DCP6100 Front & Rear Panels

Rear View

Front View

Figure 6.11

Wiring Diagram

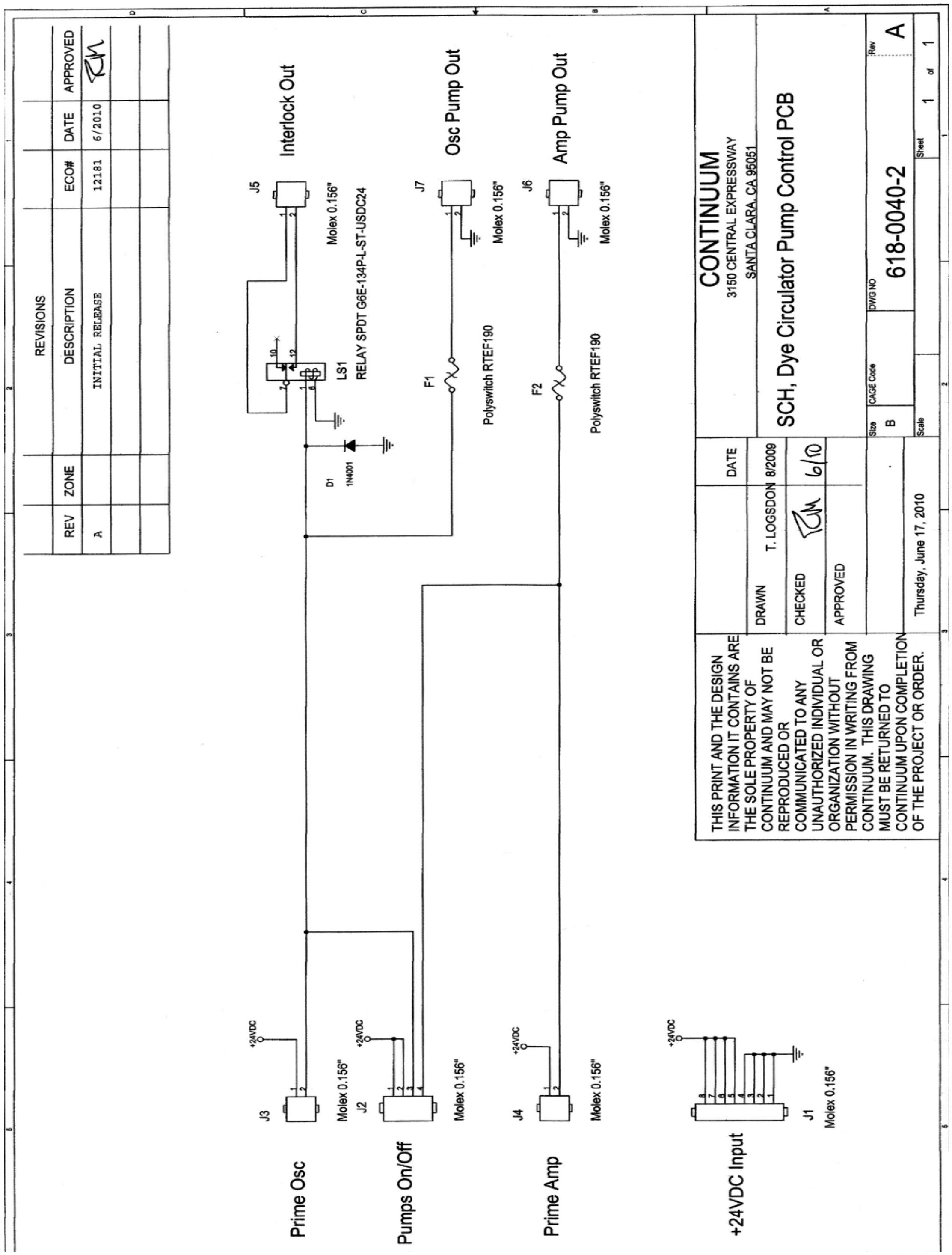


Figure 6.12a

Figure 6.12a

FSO replacement parts	
416-0093	voltage regulator
425-0025	24 Vdc, 5A power supply
426-0019	thermistor
434-0123	bottom heater PCB
434-0211	top heater PCB
603-9600	temperature controller

Continuum
Block Dia. ND6000
Control FSO
615-7210-3

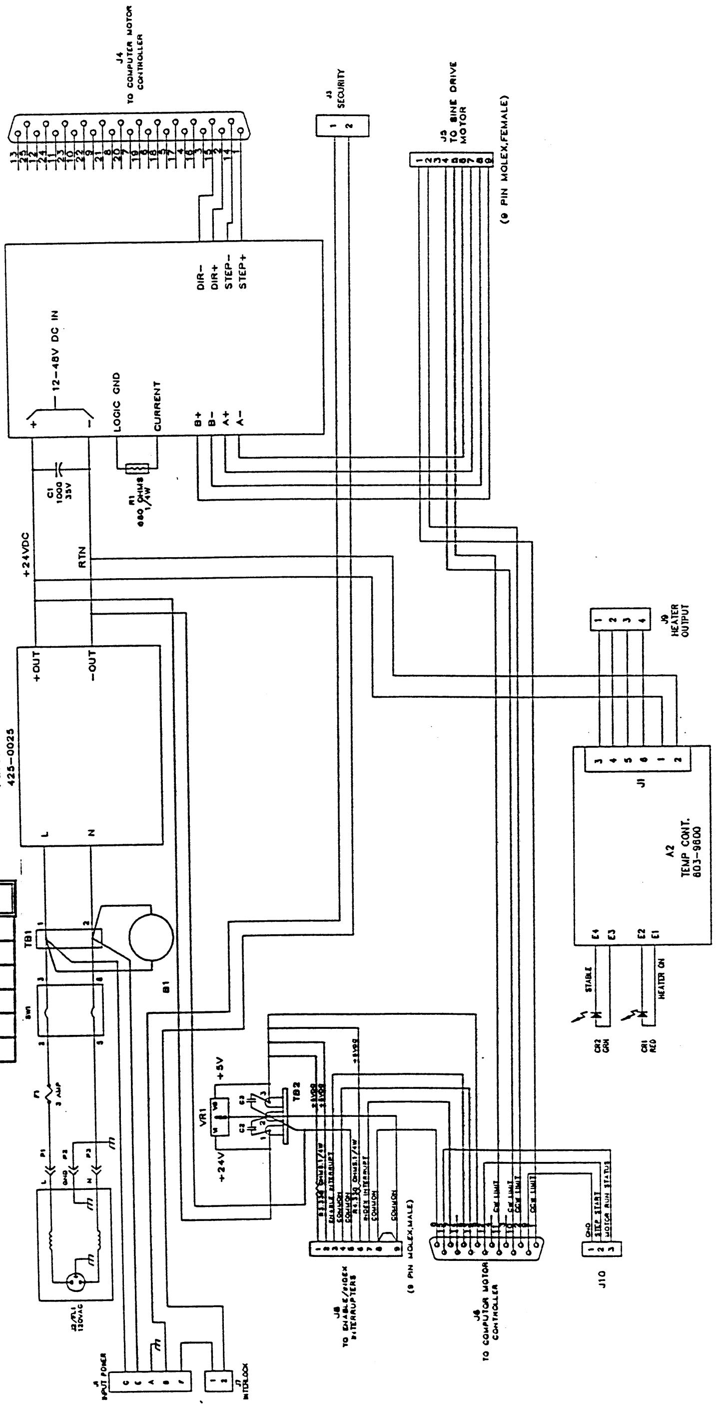
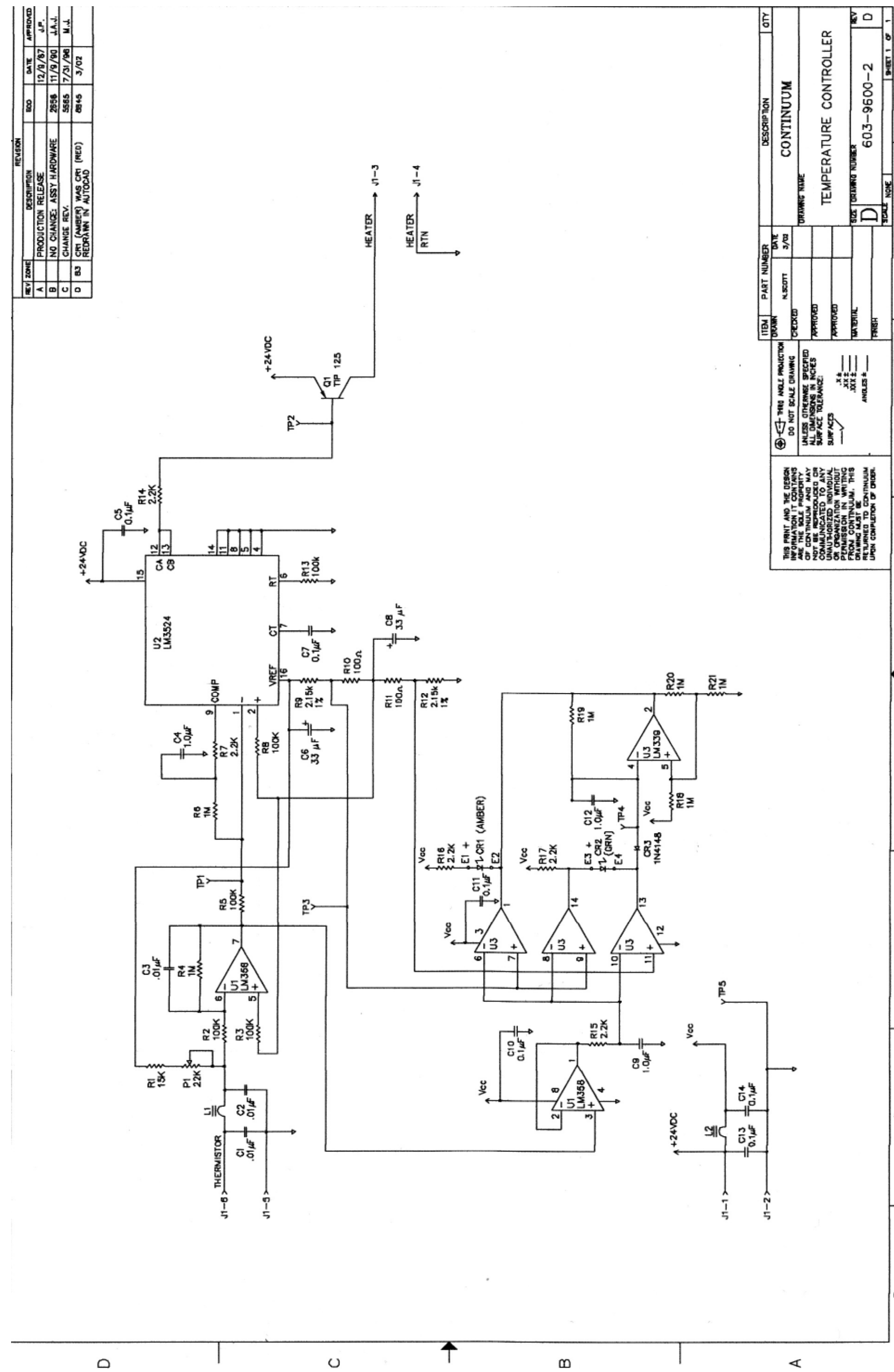


Figure 6.12b


CONTINUUM
TEMPERATURE CONTROLLER
603-9600-2
LM3524
LM358
LM339
HEATER
THERMISTOR
+24VDC

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Chapter VII Appendix

A. Express Warranty

Unless otherwise specified, all mechanical, electronic and electro-optical assemblies manufactured by Continuum are warranted to be free from defects in workmanship and materials for a period of one (1) year following delivery of the equipment to the FOB point.

Exclusions are optics and crystals, which are warranted for 90 days.

B. Limitation of Remedy

The remedy available under this warranty shall be the repair of the defective material so long as the following are observed:

1) This warranty does not apply to equipment or components which inspection by Continuum shall disclose to have become defective or unworkable due to abuse, mishandling, misuse, accidental alteration, negligence, improper operation or other causes beyond Continuum's control;

2) This warranty shall not apply in the event that the original device identification markings have been removed, defaced or altered or if any parts have been substituted or modified without the express consent of Continuum

3) The customer's general account at Continuum is current and not delinquent in whole or in part.

C. Disclaimer of Implied Warranty

The foregoing is in lieu of all other warranties Express or Implied, and there are no warranties of Merchantability or fitness or any other remedies available other than as expressed herein.

D. Returns, Adjustments & Servicing

If warranty or general repair or service to a Continuum product is requested by the customer involving the product's return to Continuum, the terms of the return shall include the following:

1) The customer shall obtain a return authorization number from the Continuum Service Department

2) The product must be properly packed in the original Continuum shipping container. Additional shipping containers may be purchased from Continuum if needed. All water must be removed from the water-cooled products prior to packing

3) Freight and insurance (for the full value of the shipped goods) charges must be prepaid by the Buyer and all risk of loss, damage or delay in shipment shall be borne solely by the Buyer

4) After receipt of product, Continuum reserves the right to inspect the product and to determine the cause of failure and warranty status. Continuum shall have no duty to perform a warranty repair where the product has suffered damage in shipment that prevents a determination by Continuum of the cause or existence of the asserted defect

5) If the product is found to be under warranty it will be repaired or replaced free of charge in accordance with the terms of the Continuum warranty. The warranty period on a repaired or replacement product shall be the balance of the warranty period remaining on the original product, i.e. no new warranty is created by such a repair

6) If the product is determined to be of a non-warranty status the customer will be advised and a written purchase order for the repair or service work will be required before the work begins. The cost and terms of non-warranty service shall be according to Continuum's then prevailing policies, which are subject to change.

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continuum@exceltech-japan.com

E. Appendix 1: Using the CCM Serial Interface

The ND6000 Computer Control Module (CCM) can be controlled via a PC remote computer by sending ASCII characters through its RS232C port. The remote computer may be used to:

- Send commands to the CCM and receive feedback data from it.
- Interpret data from the CCM to interactively control the CCM.

Responsibility for creating hardware connections and computer programs lies with the user. Creating an interactive program should pose no problem for an experienced programmer.

The CCM stepper motor controller may also be programmed directly, but Continuum does not recommend this approach. Any such program must contain drivers which consider specific characteristics of the sine drive, such as backlash compensation and limit switches. Continuum does not provide assistance for writing such programs.

The examples in this chapter are designed to illustrate the approach used to communicate with the ND6000 CCM.

The basic steps required are:

- Prepare the proper cable
- Choose serial communication parameters
- Establish communication between the remote computer and CCM
- Write software using embedded CCM commands to control the CCM or receive CCM data and interactively control the CCM

The section following treat these 4 steps in more detail.

CCM to Macintosh

Establish the hardware link using the Mac modem port (the printer port may be used if necessary). Set the Macintosh modem port communication parameters (baud rate, data bits, etc.) using any modem terminal program or communication program (e.g. Z-term, Microphone, or Red Ryder).

Programming the modem port on the Macintosh is more complex than programming a PC. The only RS232C driver examples available for the ND6000 are written in LabVIEW2, a high-level programming language from National Instruments of Austin, Texas.

The following figures outline RS232C communication using LabVIEW. First set the Macintosh modem port communication parameters.

Next, write a command to the ND6000 as shown in frame 0 using the “Serial port write” vi (virtual instruments).

Determine the number of return bytes as shown in frame 1 using the “Bytes at serial port” vi. If there are many return bytes, check the number of return bytes more than once to ensure that all of the bytes have arrived.

Pass the number of return bytes to the “Serial port read” vi. The characters returned by this vi should match the original command string.

F. Preparing Cables for Remote Computer Control

Serial Data Format and Protocol

To use the communication line, you must make sure the asynchronous communication parameters (baud rate, parity, data bits and stop bits) of the sending and receiving devices are properly set.

Serial Data Format

9600 Baud rate	no parity bit
1 stop bit	no automatic character echo
8 data bits	common ground
type RS232C	asynchronous
two active lines	(Transmit data & Receive data)

Serial Interface Pin Assignments

The pinouts for the ND6000 serial port are given in Figure 7.1. There are two different possible connectors depending on the controller used, either a male 25 pin connector or a male 9 pin connector. The serial port signals available and the pinouts are listed here and on the next page for these two different connectors.

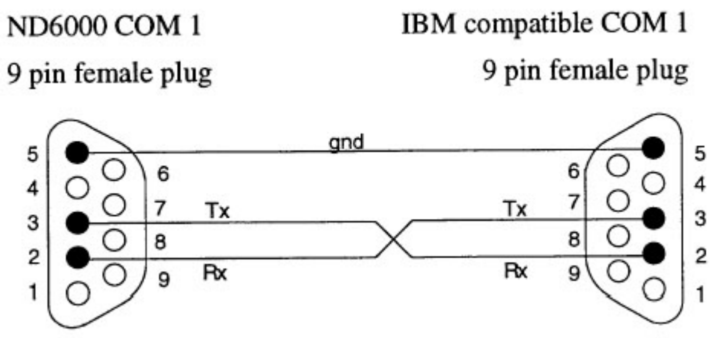
Signal definitions

- Frame (chassis) ground: safety ground.

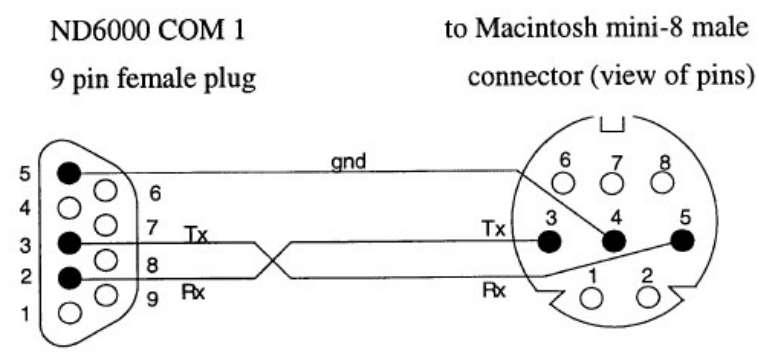
- Signal ground: common signal ground.

- Transmit data: serial bits are sent to the PC remote over this time.

Figure 7.1
Remote Control Interface Cables



RS-232 interface cables: ND6000 to IBM PC



RS-232 interface cables: ND6000 to Mac

Receive data: serial bits are received from the PC remote over this line.

Request to send: high level is sent to the PC remote when CCM initialization is complete. Request to send stays high until power is shut off.

First set the Macintosh modem port communication parameters.

Next, write a command to the ND6000 as shown in frame 0 using the “Serial port write” vi (virtual instruments).
Determine the number of return bytes as shown in frame 1 using the “Bytes at serial port” vi. If there are many return bytes, check the number of return bytes more than once to ensure that all of the bytes have arrived.

Pass the number of return bytes to the “Serial port read” vi. The characters returned by this vi should match the original command string.

G. Writing Programs

External CCM Commands

This section describes the commands that are used to control operation of the ND6000 CCM.

The ND6000 CCM commands are sequences of ASCII characters using the character "@" as delimiter. Any command or string of commands received by the ND6000 CCM is BUFFERED. After receiving the delimiter character, the command is echoed to the remote computer and sub-commands are analyzed and executed in their input order. Commands which have missing characters or have improper parameters values are ignored. The ND6000 CCM will send an error message (Z0@) through the serial port and resume the proceeding sub-commands.

Delimiter

All individual commands end with a delimiter that signifies that the command is complete. The character "@" is used as delimiter in all messages sent to the ND6000 CCM. Spaces are not recognized.

Functional External Commands

Software supports external control of the ND6000 through a serial port on the ND6000 computer. ASCII control commands may be sent to the ND6000 over an RS232C serial line, and the ND6000 echoes these commands and provides scan statu information.
When you want to start an *External Burst* scan without the (up to 100 msec) delay of the RS232C signal protocol, you can use the Direct TTL port on the ND6000 laser. Refer to Chapter V, Fast Triggering of Burst Modes for more details. This provides a much faster response. Fast External Burst can use only Direct TTL and has the least delay time of the three burst modes.

Sending commands initiates the same control-software response as entering the command directly with the mouse. The remote operator may:

- Send commands to the ND6000 and receive its status
- Interpret the ND6000 status to interactively control the ND6000
- Send multiple commands at once (macros).

Programming the serial interface is the user's responsibility. The following section describes the protocols and commands used for remote control of the ND6000.

Remote Command Syntax

All remote commands begin with one or two letters (not case sensitive) and terminate with the "@" or with another command in the macro. No other delimiter is recognized. Spaces are not allowed inside a command and are ignored before or after one. In the following tables, xxxx.xxx refers to a wavelength in nm, x.xxxx refers to a scan speed in nm/sec, x.xxx refers to the *Burst Delay* in seconds [n] or [,n] refers to the scan number. The symbol [ ] meaning that inside is optional.

The optional argument 'n' ($0 \leq n \leq 6$) refers to the one of six numbered (1 to 6) Scan window buttons and to its set of saved parameters. When n is specified and non-zero, only the value stored in scan button n, and not the current value, is changed (or used). This is used to prepare saved scans for later use. A comma must precede 'n' when it is sent directly after a number or the comma is optional.

Command Buffer

Remote Commands can be two types: 1) those that execute immediately, and 2) those that wait for prior commands to be completed. The command buffer stores up to 50 waiting commands. Commands may be sent

Figure 7.2
ND6000 Remote Commands

Commands that cause an operation

H@	**H**alt any current motion and erase command buffer
R@	**R**eset (Same as H@)
C@	**C**ontinue (restart) halted operation if capable to resume
A@	When in motion, **A**bort the motion (same as H@; when not in motion, return status)
Gxxx.xxxx@	**G**OTO wavelength
D[-]xxx.xxxx@	**D**isplace wavelength by [-]x nm ([ ] is optional)
P[,n]@	Start **P**reset scan with current values [use button n]
X@	Step to next when in TE[,n] (*External Burst*) scan mode

Commands that set parameters

Bxxx.xxxx[,n]@	**B**eginning scan wavelength is x [set scan button n value]
Exxx.xxxx[,n]@	**E**nd scan wavelength is x [set scan button n value]
VPx.xxxx[,n]@	**V**elocity of Preset scan is x [set scan button n value]
VGx.xxxx[,n]@	**V**elocity of **G**OTO is x (nm/sec) (GOTO speed = Scan Return speed and Burst Step speed)
V*@	**R**eturn all Velocities (current VP and VG)
Sxxx.xxxx[,n]@	**S**tep width for *Burst* san is x [set scan button n value]
Lxxx.x[,n]@	**L**ength of Burst pause in seconds [set scan button n value]
Nxx[,n]@	**N**umber of scans to repeat [set scan button n value]; only usable *Normal* (TN[n]@) and Internal (TI@) scan modes
TN[n]@	Type of scan is ***N**ormal* [set scan button n value]
TI[n]@	Type of scan is ***I**nternal Burst* [set scan button n value]
TE[n]@	Type of scan is ***E**xternal Burst* [set scan button n value]
TF[n]@	Type of scan is ***F**ast Burst* [set scan button n value]
F0@	Do not report the Fundamental λ position during a scan
F1@	Report the Fundamental λ position during a scan

Commands echoes during motion

Nxx@	Current scan Number (sent before and after all scans)
Xxxx.xxxx@	Beginning 1 (sent before any motion starts)
Yxxx.xxxx@	End of motion or scan λ (after motion ends)
Ixxx.xxxx@	If F1@ is on, give current λ while moving, up to 10 times/sec (the vertical line symbol | is usually below the backspace key)

The only commands that execute immediately (and so are not stored in the command buffer) are H@, A@, R@, C@, X@, and V*@.

- H@, A@, and R@ also erase the command buffer when executed
- C@, V*@, and X@ do not erase the command buffer.

Echoes and Status Reports

All received commands are echoed when executed, as the following examples illustrate.
Fill zeroes and commas are always added.

Scan Mode Report

The P@ command echoes the type of scan as well as starting it:

Command <u>to</u> ND6000	**Echo and report <u>from</u> ND6000**	**Meaning**
P@		Start scan of current mode
	Pn@	Report scan mode: : N (Normal), I (Internal), E (External), F (Fast)

Report While Moving

The additional echoes N@, X@, and Y@ appear during each scan, while X@ and Y@ echoes confirm the start and stop points of all other moves. This example assumes the current scan has been set to *Normal*, between 700 and 702 nm and repeating 2 times.

Command <u>to</u> ND6000	**Echo and report <u>from</u> ND6000**	**Meaning**
P@	Pn@	Start current scan (mode n)
	N1@	Scan 1
	X600.000@	At 600 nm
	Y600.000@	Scan has ended at 602 nm
	N1@	Scan 1 has completed
	N2@	Scan 2 (final scan) is starting
	X600.000@	At 600 nm
	Y600.000@	Scan has ended at 602 nm
	N2@	Scan 2 has completed

Intermediate I Reports

Intermediate wavelength echoes (lxxx.xxx@) appear during motion if F1@ was issued. This example is otherwise the same as the one above:

Command <u>to</u> ND6000	**Echo and report <u>from</u> ND6000**	**Meaning**
F1@	F1@	Issue intermediate λ reports
P@	Pn@	Start current scan (mode n)
	N1@	Scan 1
	X600.000@	At 600 nm

	|600.512	Intermediate λ report
	|601.023	Intermediate λ report
	|601.678	Intermediate λ report
	Y600.000@	Scan has ended at 602 nm
	N1@	Scan 1 has ended
	N2	Scan 2 is starting
	X600.000@	At 600 nm
	|600.589	Intermediate λ report (not made at same moment as scan N1)
	|601.111…	…etc.

Speed Status Report

The V@ command returns 2 speed values; its echo is:

Command to ND6000	**Echo and report from ND6000**	**Meaning**
V*@		Issue report of scan speeds
	VPx.xxxx@	Current scan speed
	VGx.xxxx@	Current GOTO scan speed (same as Step, Return scan speeds)

Displacement Reports

The Dxxx.xxxx@ command echoes itself and gives the start and end of its motion. This example assumes a current GOTO ending at 600 nm:

Command to ND6000	**Echo and report from ND6000**	**Meaning**
D10@		Wait for end of any current motion, then start a (*Displacement*)
	Y600.000@	Report of end of last GOTO move
	D10@	Start new (*Displacement*) move using a relative offset in nm
	X600.000@	Report λ at (*Displacement*) start
	Y610.000@	Report absolute nm at motion end (Reverse scan occurs without a report)

Scan Report

The A@ command echoes and returns 8 more status echoes if no scan is in progress. The format of its status return is:

Command to	**Echo and report from**	**Meaning**

ND6000	**ND6000**	
A@	A@	Abort the current motion
A@	A@	No motion, so give scan status
	Mxxx.xxxx@	Main (right) display λ (Fundamental only)
	Fn@	Format label of Auxiliary (left) display (n=harmonic output for ND 6000) “Fundamental” = n “Doubling” = n “Tripling” = n “UV Mixing” = n “IR Mixing” = n “Mix After Doubl” = n
	Axxx.xxxx@	Auxiliary (left) display λ
	Pn@	Last scan mode: n = E (*External*) n = N (*Normal*) n = I (*Internal*) n = F (*Fast*)
	Bxxx.xxxx@	Start of last λ motion
	Exxx.xxxx@	End of last λ motion
	VPx.xxxx@	Current scan speed (or VGx.xxxx@ if last motion was GOTO)
	Nxx@	Number of scans (echoed or *Normal* & *Internal Burst* only)

Examples of Control Command Sequence

This simple example shows the remote control of an *External Burst* mode, sent one command at a time:

Command <u>to</u> ND6000	**Echo and report <u>from</u> ND6000**	**Meaning**
TE@	TE@	Select *External Burst* mode
B510.1@	B510.100@	Begin *Burst* scan at 510.1 nm
E512.6@	E512.600@	End *Burst* scan at 512.6 nm
VG.5@	VG0.500@	Step speed set o 0.5 nm/sec
S.1@	S.100@	Move 0.1 nm each Burst step
P@	PE@	Start scan (echoes scan mode)
X@	X510.100@Y510.200@	Step to 510.2 nm and pause (echoes λ before and after move)
X@	X510.200@Y510.300@	Step to 510.3 nm and pause
X@	X510.300@Y510.400@	Step to 510.4 nm and pause
…	…	(Repeated X commands sent)
X@	X512.500@Y512.600@	Step to 512.6 nm and pause
X@	X512.600@Y512.700@	Step past end, pause and return
X@	PE@	Start next scan
X@	X510.100@Y510.100@	Step to 510.1 nm and pause
X@	…	…etc.

This example shows how to store values in a scan button, and how the effect of a macro (F0B510.1, 5TN5E512.6, 5VP.25, 5P5@) is integrated. If F1 replaces F0, the report will include additional wavelength positions, sent as lxxx.xxxx between each X amd Y (see example above):

Command to ND6000	Echo and report from ND6000	Meaning
F0	TE@	Do not report intermediate | λ's
B510.1, 5	B510.100@	Set scan button 5 start λ value
TN5	E512.600@	Set scan button 5 mode = Normal
E512.6, 5	VG0.500@	Set scan button 5 end λ value
VP2.5	S.100@	Set scan button 5 scan rate
P5@	PE@	Wait for end of any current motion, then start scan with button 5 (and already chosen *Scan reverse*)
	N1@	Beginning of first scan
	X510.100@	Starting λ (scan time now elapses)
	X512.600@	Ending wavelength report
	N1@	End of scan report
	N2@	Beginning of second scan
	X510.100@	Starting λ (scan time now elapses)
	X512.600@	Ending wavelength report
	N2@	End of scan and macros report, assuming scan button 5 already has number of scans set to 2

The *Report OFF* choice causes the ND6000 to echo only commands and wavelength positions at the beginning and end of all scans. *Report ON* means that the port sends intermediate wavelength positions in format |xxx.xxx while scanning as well, at up to 10 times per second at 9600 baud. The F1/F0 remote software commands are the same as *Report ON/OFF*.

The ND6000 uses only the transmit, receive and ground pins of a standard 9-pin or 25-pin serial port. Serial signals should be conditioned so that high =+12 Vdc max and low = -12 Vdc max. Figure 5.1 gives the definition of the ND6000 serial port and the way to build a cable to it from a remote Macintosh or PC.

Fast Triggering of Burst Modes

To trigger a Burst step directly without using the RS232C interface, use the 3-pin Direct TTL connector, located on the ND6000 power module near its ON/OFF switch (Figure 5.3). Pin 2 of the Direct TTL connector triggers a step only in Fast Burst and External Burst scans (scan types TF@ and TE@). Pin 3 goes high during motion after using the Blue, Red, <, >, buttons, the GOTO start command, and when measurements are taken in all scan modes (scanning in normal scan, waiting for trigger in Burst scans).

H. Material Safety Datasheets

Figure 7.2
List of attached Material Safety Datasheets

AMMONYX LO	LDS 765
BDN	LDS 798
Coumarin 440	LDS 821
Coumarin 460	LDS 925
Coumarin 480	PYROMETHENE 597
Coumarin 500	PYROMETHENE 650
Coumarin 540	Q-Switch 1
DaQTeC	Q-Switch 2
DASPI	Q-Switch 5
DCM	Rhodamine 560 Chloride
DDI (DDCI)	Rhodamine 590 Chloride
Ethylene Glycon	Rhodamine 560 Chloride
Fluorescein 548	Rhodamine 590 Tetrafluoroborate
IR 140	Rhodamine 610 Chloride
LD 466	Rhodamine 610 Perchlorate
LDS 698	Rhodamine 640 Perchlorate
LDS 720	Sulforhodamine 640
LDS 750	Stilbene 420
LDS 751	