SNO N_2/Dye Laser System Manual (Model A, S/N 9708)

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Contents

1 Introduction

The SNO N_2/Dye Laser System is a remote computer controlled laser system delivering pulsed 337.1 nm radiation and up to four other dye laser wavelengths in the range 360 – 600 nm. The pulse time duration is 0.5 nanosecond (nsec), with a repetition rate up to 45 Hz. The beam is delivered to a fibre optic ST coupler on the front panel through a quartz fibre profiler. The beam energy attenuation is remotely adjusted with two neutral density filter wheels, providing a large intensity range.

The N_2/Dye Laser System was designed to be connected to a fibre optic cable which is connected to a light diffusing ball for the optical calibration of the Sudbury Neutrino Observatory (SNO) (see figure 1). The fibre optic cable is 100 feet and consists of a bundle of 22 silica 100 micron step index fibres. The fibres are loosely jacketed in PVC shrink tubing and then potted with RTV silicone (GE RTV615) into a 1/2" silicone 'umbilical'. The diffuser ball (called the laserball) is moved within the SNO detector with the rope manipulator system. The umbilical cable is stored and deployed in a linear (non-rotating) pulley array. The laserball is a 500ml quartz glass boiling flask filled with diffusing glass bubbles set into potting silicone.

This manual provides the system description, safety procedures, operating procedures, alignment, maintenance and repair for the SNO N_2/Dye Laser System. The calibration, manipulator and umbilical systems are described elsewhere.

The N_2/Dye Laser system consists of the following components:

- Commercial N_2 TEA thyratron triggered UV pump laser (Laser Photonics Inc. LN203C).
- Four dye laser units which are selected by moving a pump beam steering mirror. The steering mirror is mounted on a lead screw carriage powered by a computer controlled stepper motor.
- Optical table where the dye lasers and beam optics are mounted. The beam optics are setup so that the beams from the four dye lasers converge on a single axis. The optical table also includes beam profiling and focusing optics.
- Two attenuator wheels with 8 neutral density filters each. The wheels rotate with stepper motors which are computer controlled.

- Fibre-optic beam profiler which removes pulse-to-pulse beam pattern instabilities. This enables high bandwidth fibres to be used in SNO as a beam delivery system without loss of beam energy stability. The fibre has a lens coupling device and an x-y translational mount. The front panel fibre-optic coupler is an ST type connector.
- Remote and local system power control and trigger control of pump laser and trigger lockout. Full remote control of dye laser selector and attenuator wheels.
- Pump beam and dye beam laser energy monitors, amplifiers, and a fast beam activated event trigger.

Throughout this manual there are procedures that require the top cover of the laser to be removed to access various controls or components. It always has to be understood that the laser covers can never be removed while the laserball is in the SNO detector and the detector is collecting data. The light leakage down the fibre optic and/or the RF pickup in the electronics can add significantly to the detector noise/trigger rates. Also, when the laser is operated with the cover(s) removed for repair or alignment, you must record running times/dates in the log book so that any SNO detector pickup can be reconciled.

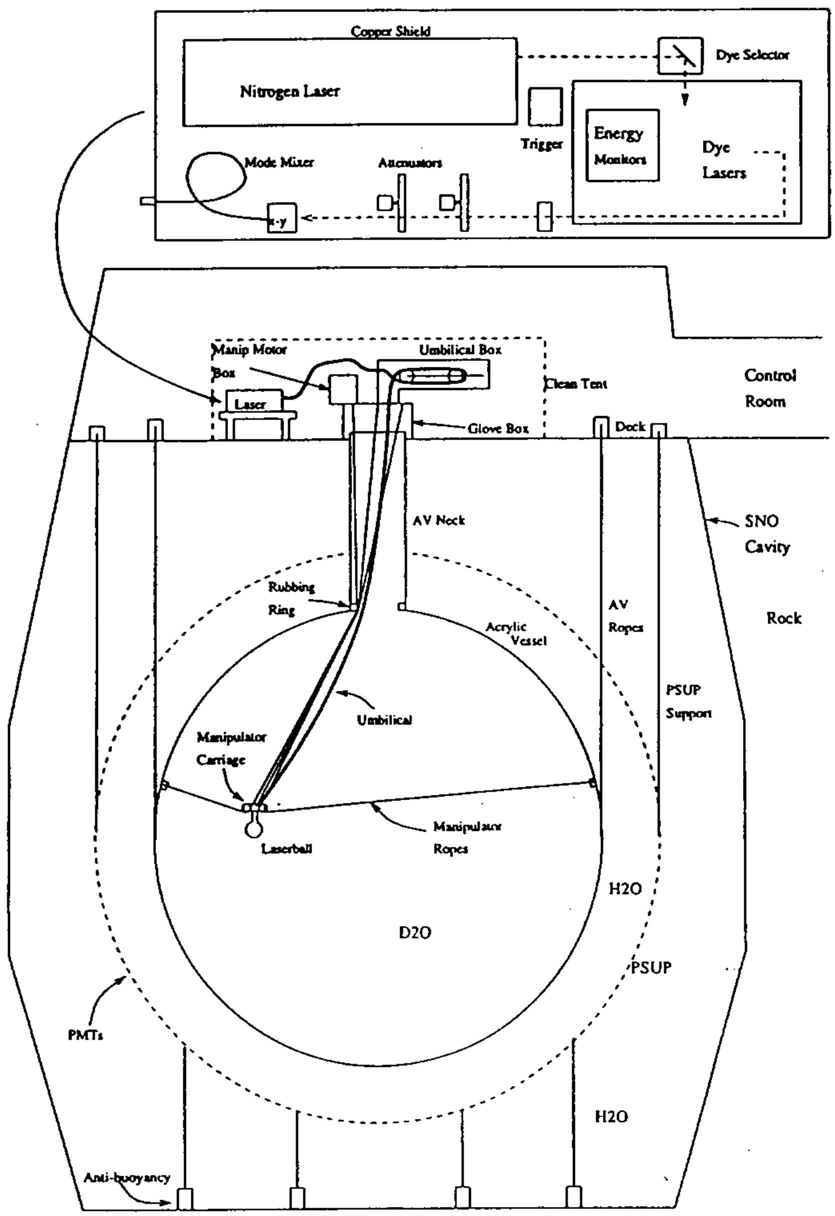

Figure 1: Schematic of the N_2 laser calibration system.

2 Safety

The SNO N_2/Dye Laser System is classified as a class 3b laser system by virtue of the commercial class 3b N_2 laser which forms part of the system. However, the overall system is considerably safer, since the N_2 laser is fully enclosed and at most only a fraction of the laser power can be delivered to the output aperture.

For this reason most of the laser safety procedures and restrictions apply only when the laser is under repair or alignment, when the external covers are removed.

The vender supplied manual for the commercial N_2 laser is reproduced in appendix A. The safety section of that manual should be considered part of this section and reviewed accordingly.

Working safely with the SNO N_2/Dye Laser System will be ensured by a combination of administrative procedures and the proper use of safety engineering controls as laid out in the following subsections. There are 4 modes of laser operation which will have different safety considerations: remote operation, local operation, repair/alignment with N_2 laser RF shield in place, and repair/alignment with N_2 laser RF shield removed.

2.1 Remote Laser Operation

The laser power, triggering, beam steerer and attenuators can be operated fully remotely by the SNO Data Acquisition Computer or other computer sites with a connection to the SNO calibration computer.

A remote operator of the laser does not require qualification beyond that to run the controlling software, and reading the safety and operator sections of this manual. Instead, permission must be obtained from the the SNO underground shift supervisor before the laser system is powered and triggered. The shift supervisor will check with a qualified operator of the laser as to whether the laser is safely configured for that mode of operation.

Note that the laser power and trigger will not operate remotely unless the local panel switch controls are set for remote operation. Only a qualified operator can set these switches. The switches will not be set to 'remote' unless the alignment is correct, the laser is covered and the external port aperture is either covered or connected to an optical cable. The laser does not emit any light externally under these circumstances and is safe for remote control.

2.2 Local Laser Operation

The laser can be triggered at the local panel only by a qualified operator. An operator is qualified after he/she has read and understood this manual in its entirety, and has demonstrated competence in operation of the laser.

When all the system cover panels are in place the laser can be operated without access restrictions or safety equipment.

Do not look directly into the beam aperture or at light reflected off smooth mirrors etc. Diffuse scattered radiation is safe.

2.3 Repair/Alignment with N_2 Laser RF Shield On

This mode of operation provides for alignment of the dye laser beams and repair of any of the optics or electronics. This work can be done with any of the external (aluminum) covers removed but with the internal copper N_2 Laser RF Shield in place.

This work can only be performed by persons qualified to operate the laser and are familiar with the internal components. Persons must be competent to work on the dye laser system. Remote triggering must be disabled by setting the front panel switches.

Operation in this manner makes the room a 'laser control area'. This means that a qualified operator must be in the room at all times, that access is by permission of the operator only, and that proper laser warning signs are posted.

Laser safety glasses should be worn when the laser is running for an extended period of time. Laser safety glasses are not required for short (several minutes) of operation if non-reflective beam stops are inserted into the beam path.

Do not look directly into the beam or at light reflected off smooth mirrors etc. Diffuse scattered radiation is safe for short term eye exposures.

All covers must be replaced and secured before the laser can be left for an extended period of time (more than 1/2 half hour). The laser can be left for short time periods (eg. for lunch) with the 'trigger lockout' switch on.

2.4 Repair/Alignment with N_2 Laser RF Shield Off

This mode of operation provides for repair and alignment of the N_2 Laser head. Here the external covers and the internal copper N_2 Laser RF Shield are removed which provides access to the laser head and high voltage components.

This work can only be performed by qualified service technicians who are qualified to operate the laser, are familiar with the internal components and are familiar with the N_2 laser head and high voltage components. Persons must be competent to work on these components. Remote triggering must be disabled by setting the front panel switches.

The N_2 laser has a high voltage safety interlock on the laserhead cover. This interlock can be defeated and the laser re-triggered during servicing. In addition the cabinet feet have to be unbolted and the laser moved forward (or lifted out) before the laserhead cover can be removed.

Operation in this manner makes the room a 'laser control area'. This means that a qualified operator must be in the room at all times, that access is by permission of the operator only and that proper laser warning signs are posted.

Laser safety glasses should be worn when the laser is running for an extended period of time. Laser safety glasses are not required for short (several minutes) of operation if non-reflective beam stops are inserted into the beam path.

Do not look directly into the beam or at light reflected off smooth mirrors etc. Diffuse scattered radiation is safe for short term eye exposures.

Due to the high voltage the laser cannot be left unattended for any period of time without either: the N_2 laser key switch turned off and the key removed, or the N_2 Laser RF Shield fully replaced.

2.5 Handling of Laser Dyes

The laser dye solutions are a low hazard under normal use. However, good laboratory practices must be competently observed, and the MSDS sheets (appendix C) should be reviewed. Use latex gloves when handling laser dye powder and solutions. All dye powder, solution, solvent and waste containers should be labeled and dated. Make sure any spills are immediately cleaned up, and liquid waste is disposed of according to laboratory procedures.

3 System Description

3.1 N_2 Laser

The N_2 laser is a commercial research laser manufactured by Laser Photonics Inc. of Orlando, Florida. The unit delivers 337.1 nm radiation in a 600 psec pulse width with a maximum power of 150 kW and 45 Hz repetition rate. The vendor supplied manual and specifications are reproduced as appendix A. Note that a replacement laser optical cavity was designed and manufactured at Queen's University, so that the beam characteristics may differ from that given in appendix A.

The nitrogen laser has an unusual three level laser system with high optical gain and a very short-lived upper level state (figure 2). The high gain and rapid de-excitation make the laser beam 'super-radiant'. The laser does not have the coherence of a normal laser since there is no real optical resonator.

The laser operates by applying a rapid voltage discharge across the gas cell which creates a high temperature electron gas. The population inversion proceeds via collisional excitation. It turns out that the $C^3\Pi_u$ level is populated preferentially to any of the intermediate levels. This has to do with the idea that electronic transitions are more rapid than inter-nuclear motions, thus a transition to any of the intermediate levels would result in an additional vibrational excitation for which the phase space is smaller. This is known as the Frank-Condon principle [6].

Once a population inversion has been attained lasing is rapid to the $B^3\Pi_g$ lowest state. The $B^3\Pi_g$ band is quite long lived (10μsec) due to the Frank-Condon principle, but it will radiatively decay into the $A^3\Sigma_g$ band emitting a 0.8-1.2μm photon. The $A^3\Sigma_g$ band is meta-stable due to the $\Delta S = 0$ selection rule; with a lifetime of several seconds this ultimately limits the pulse rate possible.

Due to relative stability of the $B^3\Pi_g$ lower state high gain is possible only for about a nanosecond before the $B^3\Pi_g$ lower state become significantly populated. Thus the critical part in the design of the nitrogen laser is the development of a high voltage rapid discharge circuit.

The resonant capacitor transfer method is used for the high voltage discharge circuit. A capacitor, in series with the laserhead capacitor, is charged at high voltage. On triggering, a thyratron switch shorts the first capacitor

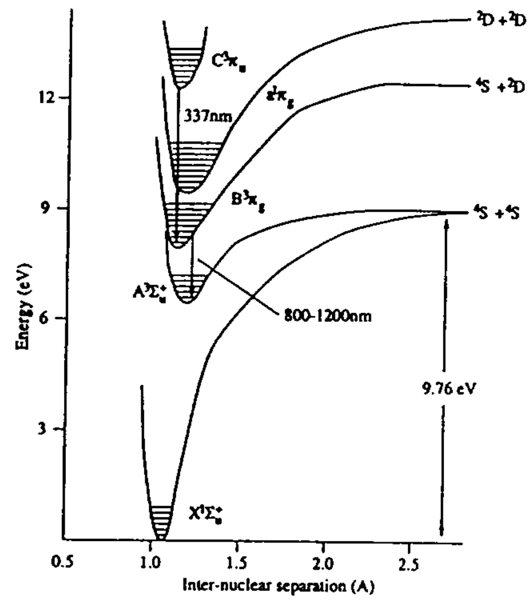

Figure 2: The nitrogen laser level scheme.

which transfers charge to the laser head capacitor. In the resulting oscillation the laserhead gets to over-voltage and begins to break down just as the laserhead capacitor is fully charged. The thyratron is crucial as it provides very fast low inductive switching.

The N_2 laser is mounted separately within the system and completely enclosed with a copper RF shield. The RF shield attenuates the high level of RF radiation that is emitted by the laserhead. This is critical since the RF noise is synchronous with the laser light and would create a lot of noise in the SNO pmts. The RF shield has an aperture for the laser beam and other holes just large enough for the nitrogen gas, the power cable and the control cable.

Since the N_2 Laser controls are hidden under the RF shield, they cannot be adjusted. Thus the nitrogen gas flow control, the power keyswitch and the repetition rate have to be setup before first use of the laser. They can be adjusted as part of regular maintenance. The laser trigger, lockout, and status indicators are provided through the remote control cable. This cable

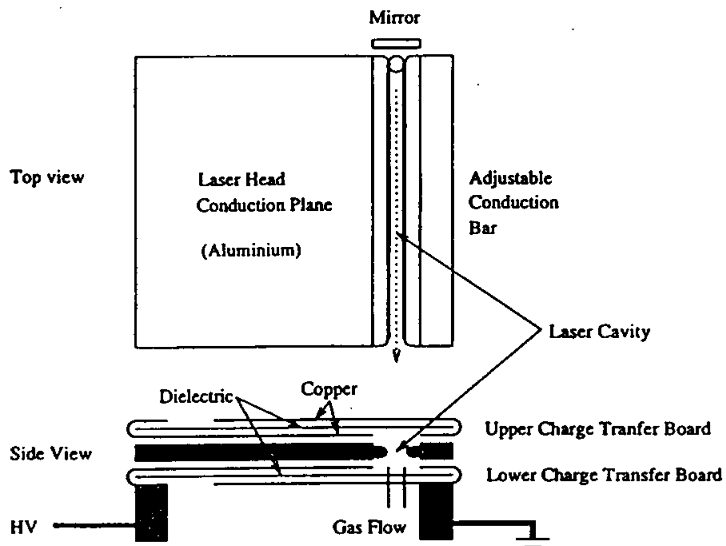

Figure 3: The LN203C laser head configuration.

goes to the trigger control board with is mounted inside the control box on the front panel. The laser can be started with the switches on the front panel, or there is a cable which connects to the computer interface board to enable computerized remote power and trigger control.

3.2 Dye Lasers

The N_2 laser beam, which is UV light at 337.1 nm, can be delivered directly to the beam profiling pipe, or it can be used to pump a dye laser. The dye laser provides laser light at other (longer) wavelengths from 360 nm up to 700 nm, dependent on the dye type selected. The light is broad band (about 20 nm), but the system can be modified by adding a grating feedback to provide narrow band radiation.

There are 4 dye laser units mounted on the raised optical table at the back half of the system. The units are identical with the intention that different dye solutions be used in each so that 4 different wavelengths can be selected on-the-fly. The dye laser is pumped with the N_2 laser beam, which is

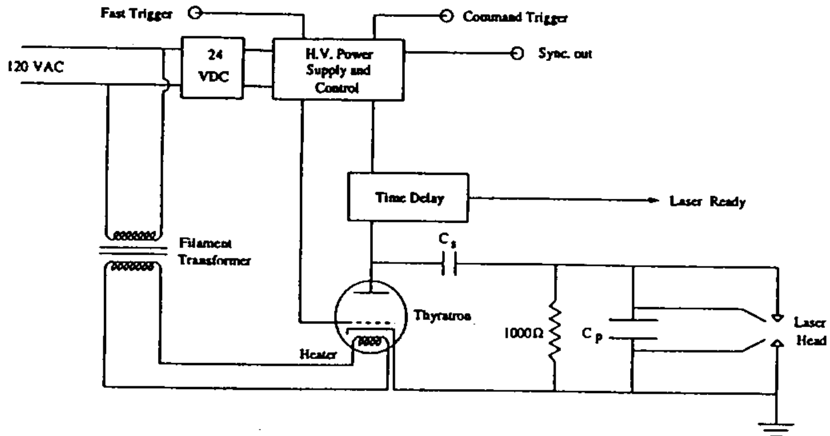

Figure 4: The laserhead HV circuit.

directed by the high-reflectance mirror mounted on the lead screw carriage. Moving the carriage up and down permits selection of the dye lasers or the fundamental 337.1 nm beam.

The dyes are usually large organic molecules, with energy levels consisting of wide rotational and vibrational bands. This causes the broad band output and large oscillator strengths The 337.1 nm radiation is absorbed to provide excitation in the S_1 band, but de-excitation can occur between any combination of states between the S_1 and S_0 bands (figure 5). Non-radiative transitions to the bottom of the S_1 band are extremely rapid (picoseconds), so that the dye acts as a wavelength shifter and does not absorb its own radiation. The oscillator strengths are large and so the emission is rapid, hence the resonator cavity with the plain mirror amplifies a large range of modes. The output is super-radiant and lacks the coherence of a cavity mode laser. The dye laser can be mode locked by using a diffraction grating in place of the mirror to reduce the output bandwidth. The dye laser pulse rate is limited by intersystem crossing to the triplet levels.

The N_2 laser beam is focused through a cylindrical lens to a line just inside the dye cell cuvette wall (figure 6). The mirror and optical coupler provide feedback so that the emission has a well defined beam along the focused edge of the fundamental beam. The dye cell cuvette is mounted at

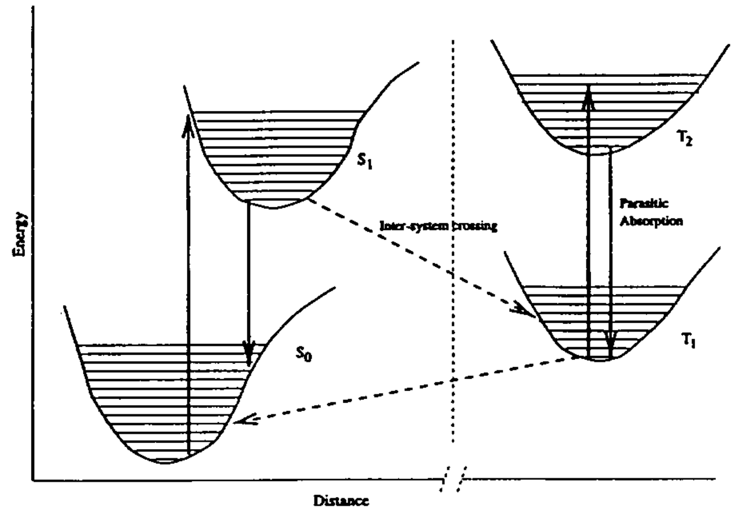

Figure 5: The dye laser level scheme.

an angle so that feedback from internal reflections are un-amplified.

The cuvette mount incorporates a motor that magnetically drives a stirring agitator placed in the bottom of the cuvette. The dye molecules will disassociate over time; the dye stirrer helps maintain a more even dye solution. Also the dye circulation help prevent beam instabilities from the local buildup of parasitic meta-stable triplet states. The dye motors should be on for repetition rates over 20 Hz. The stirrer is powered from a divider off the 40V supply and is controlled by a switch mounted next to the cuvette.

3.3 Beam Optics

The beam optics consists of the dye laser lenses, the beam profilers, steering mirrors, recombination beam splitters, the reducing lens, the attenuator wheels, the large diameter mixing fibre and the coupling lens (fig 6).

Each dye laser (described in the preceding section) consists of a dye solution cuvette, a feedback mirror and a cavity output coupler. The beam then goes through the beam profiler which is a hole 2.5mm in diameter that cuts out any beam halos. The beam next goes through a lens which approx-

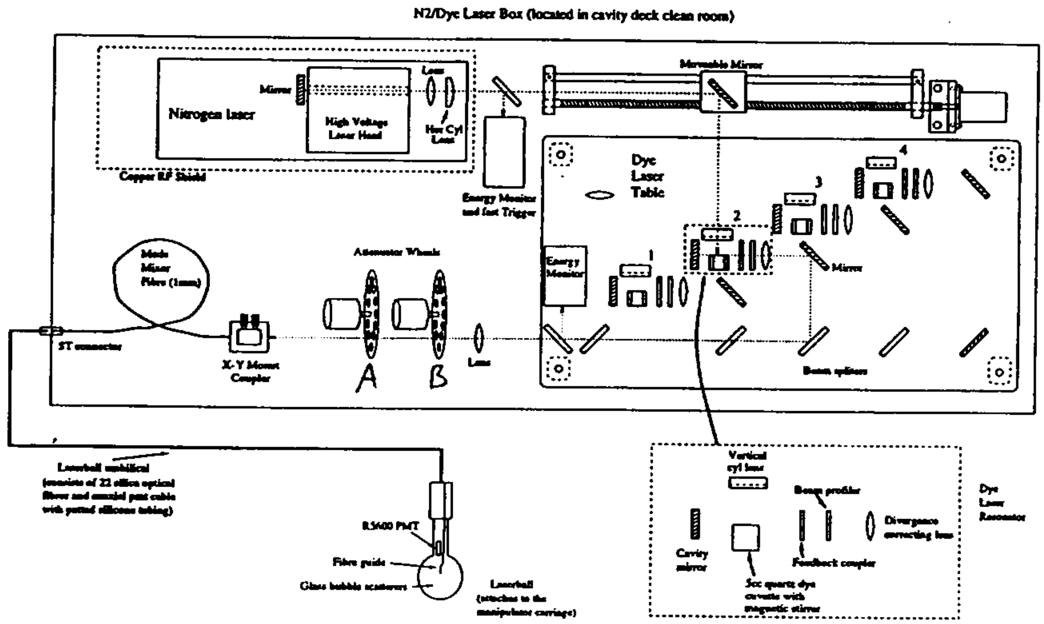

Figure 6: Schematic of the N_2 laser calibration system.

imately cancels the average beam divergence. The beam is then steered to the main beam channel by an adjustable mirror.

The main beam channel consists of four 50% neutral density filters. Each of these filters steers 50% of the beam from one of the dye lasers down the beam channel. The dye lasers further up the channel will be attenuated by 50% at each steering filter. In this way all four dye lasers and the N_2 laser can be adjusted to follow the same beam line. The filter and mirror orientations can be finely adjusted within the o-ring compression housings to facilitate this alignment.

We see that the 4th dye laser would be attenuated a factor of two more than dye cell 3, which is a factor of two less than dye cell 2, etc. If the dye solutions are arranged so that cell 4 has the longest wavelength, and so on, then the steering filters will compensate for the higher attenuation of shorter wavelengths in the optical fibres. In fact, the 50% filters can be changed to another value that would more closely compensate for this differential attenuation.

The next component is a reducing lens mounted at the front of the first attenuation filter wheel. This lens focuses the beam to reduce the beam size at the mixer fibre coupler. The two attenuator wheels provide for a large variation in beam attenuation by the combination of the two filter wheel positions. The wheels also have beam stop positions and open positions.

The final component is the mixer fibre. The whole beam is focused down into the 1 mm diameter quartz fibre via the coupling lens. The coupler is mounted in an x-y translator to allow fine adjustment of the position. The fibre is looped around to cause greater power mode dispersion within the fibre. This way the power becomes evenly distributed between the many optical modes of the fibre. This power profiling provides a stable mode distribution for coupling to high bandwidth fibres at the output aperture. Without the mixer fibre, the pulse-to-pulse beam profile instability of the N_2/dye laser would translate into unstable coupling efficiencies into the small diameter transmission fibres.

3.4 Light Trigger and Energy Monitors

The N_2/dye laser system has two beam energy monitors and a fast output trigger. The output trigger and one of the energy monitors are housed together and located with a beam splitter from the 337.1 nm beam. The second energy monitor is located with a beam splitter on the optical table to monitor the dye laser beam channel.

The output trigger provides a pulse for external triggering of detectors which are highly synchronized to the laser light pulse (figure 7). This allows, for example, measurement of the transit time distribution for the photomultipliers in SNO. Note that this level of timing precision could not be obtained from the N_2 laser logic command trigger pulse, since the nature of the high voltage circuit causes several nanoseconds of command jitter with respect to that trigger signal.

The beam energy monitor consists of a large area diode which is mounted beside an optical cuvette which diffuses the 337.1 nm laser beam. The purpose of the diffuser is to eliminate any beam profile instabilities which would manifest as detector efficiency instability if the beam was coupled directly to the diode. The diode is connected directly to a charge preamplifier (figure 8). The charge preamplifier is designed for high common mode noise rejection and a long integration in order that RF interference is minimized. The diodes, diffuser and amplifiers are housed together a small metal shielding with an optical window at the front.

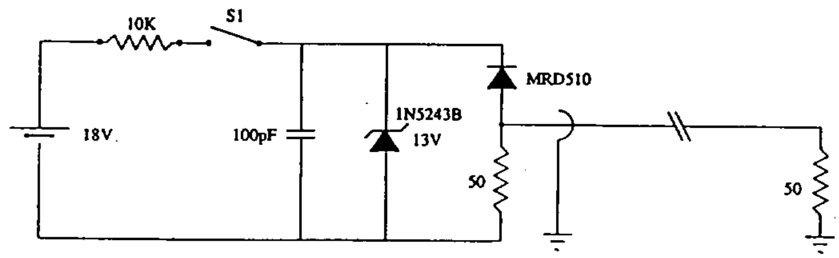

Figure 7: Light event trigger circuit.

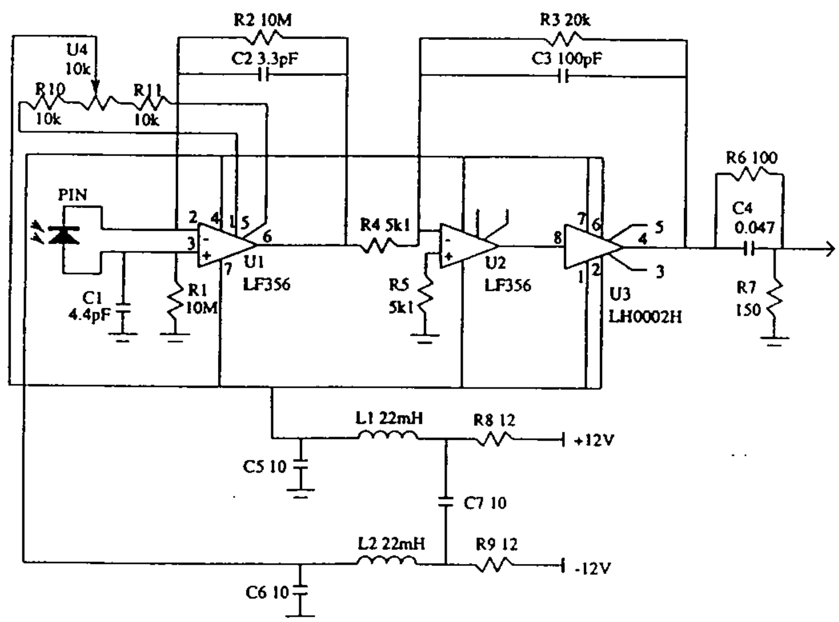

Figure 8: Beam energy monitor diode and amplifier.

The second energy monitor also has a large area diode with a light diffusing cell. Both diodes are contained in metal housings to enhance RF shielding. The trigger and energy monitors are powered by +12V/-12V (24VDC) from the internal power supply. The outputs are connected to 50Ω RG174U cables which run to lemo terminal connectors on the front panel (figure 15).

3.5 Stepper Motor Controllers

The stepper motors for the two attenuator wheels and the dye laser selector mirror are powered from current drivers mounted on the back panel (figure 9). The drivers require 40V power, 5V logic power, a 5V direction line, a 5V all-winding-off line, and a TTL pulse signal for stepping the motors. The 40V and 5V logic power are provided from internal supplies, while the direction, all-winding-off and TTL signals are cabled to the front panel bulkhead connectors for external computer control.

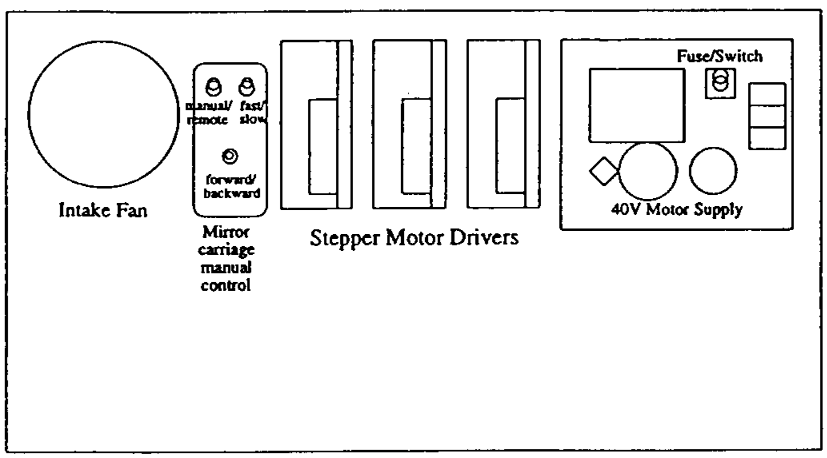

Figure 9: Inside rear panel layout.

The motors are run from a computer with a National Instruments TIO-10 timing board with custom current drivers. There is a switchbox mounted on the back panel which contains a TTL oscillator to allow the dye laser mirror carriage to be moved conveniently without the computer control. Note that external software will have to recalibrate the mirror carriage position if the mirror is moved either by hand or with the internal switchbox.

3.6 Computer Interface

Computer interface hardware provides remote control of the laser power and trigger, the attenuator wheels and dye selector mirror, and status monitoring of the laser and gas supply system. Remote control of the laser is preferable since the software can monitor the laser output and gas pressures and stop the laser if there are any problems. Also, the dye selector mirror and the attenuator wheels can only be positioned effectively using a computer to run the stepper motors. When the laserball is in the detector the selector mirror and the attenuator wheels must be computer controlled since the laser cover cannot be removed. The position of the mirror carriage and the and attenuator wheels can be precisely determined with the optical shaft encoders which are read through the computer interface.

The optical encoders and pressure transducers are controlled by the encoder counter boards; these are the same counter boards as are used in the SNO manipulator motor system. The laser power/trigger and other status monitoring is controlled by a modified version of the counter board. These boards are selectable by address and daisy chained onto one analogue and one digital cable. These cables connect to the 25 pin and the 40 pin connectors respectively on the front panel. Figure 10 shows the computer interface logical connections for the N_2/dye laser system.

The counter boards communicate with a SNO calibration data-concentrator board. Several of these boards in an interface crate are then connected to the calibration computer via a custom PC bus interface.

3.7 Optical Encoder/Transducer Counter Boards

The Optical Encoder/Transducer Counter Boards (counter boards) are SNO custom designed boards to read optical shaft encoders and transducers. The digital side of the boards consists of 4 sequential counters to provide 16 bit range for the optical encoders. The analogue side of the board provides a bridge voltage and variable gain instrument amplifiers for reading loadcells or transducers.

There are four counter boards mounted in boxes underneath the dye laser optical table. The counters boards are accessed with addresses E0, E4, E8, and EC. Board E4 reads the dye selector mirror encoder; it has no analogue connection. Board E0 reads the attenuator wheel 1 encoder, and the N_2

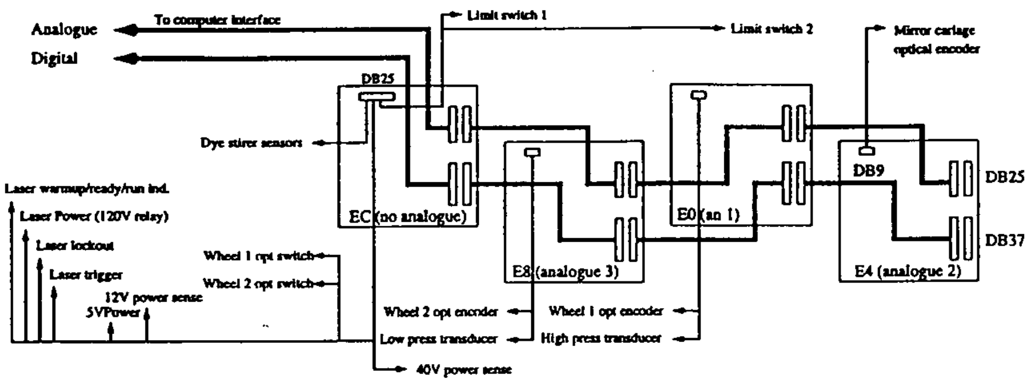

Figure 10: Schematic of the N_2 laser computer control.

pressure transducer on the high pressure side of the flow meter. Board E8 reads the attenuator wheel 2 encoder, and the N_2 pressure transducer on the low pressure side of the flow meter.

Board EC is a highly modified version of the counter board used for power and trigger control of the laser and for status readouts. On the regular counter boards the two least significant bits of the address are not used. On the modified version of the board these two bits provide the power enable, the trigger enable, and laser shutdown commands (see figure 12). The 16 bit data bus, normally buffered to the counters, instead is used as a monitor for system status conditions. Assignments for the data bits are given in table 1, and summarized below.

- Bits 0-1 are the zero point optical switches on the attenuator wheels.
- Bits 2-3 are the limit switches on the dye laser selector carriage.
- Bits 4-5 are 12V/40V power supply status.
- Bits 6-11 are the N_2 laser status bits.
- Bits 12-15 are the dye stirrer on/off status bits.

The external wiring connections through the top 25-pin connector for the modified board EC are given in table 2. The general method is that

Data Bus	Counterboard	Bit define	Comments
D0	U1 A0	Optical switch A	Zero position filter wheel A
D1	U1 A1	Optical switch B	Zero position filter wheel B
D2	U1 A2	Limit switch 1	Dye mirror end limit switch
D3	U1 A3	Limit switch 2	Dye mirror near limit switch
D4	U1 A4	div 12V power	12V power status
D5	U1 A5	div 40V power	40V power status
D6	U1 A6	U11-5 (Q1)	Trigger lockout status
D7	U1 A7	U15-5 (Q1)	Trigger status
D8	U2 A0	IRF730 front pan	Laser warmup indicator
D9	U2 A1	B1 Clt front pan	Laser ready indicator
D10	U2 A2	B4 Clt front pan	Laser running indicator
D11	U2 A3	U15-9 (Q2)	120V power control status
D12	U2 A4	div on motor pwr	Dye stir 1 status
D13	U2 A5	div on motor pwr	Dye stir 2 status
D14	U2 A6	div on motor pwr	Dye stir 3 status
D15	U2 A7	div on motor pwr	Dye stir 4 status

Table 1: Computer data bus bit assignments for the modified counterboard EC.

the data bits for the EC board are tied high with a 10K resistor to 5V, then the external connection (eg. a limit switch) will pull the data bit to ground potential. In other instances (eg. power supply monitors) the external connections provide voltage divider at about 5V for the data bit. Three of the external connections provide a 5V current, through a 2N2222 transistor to drive the laser trigger and 120V relays. Finally the remaining connections provide 5V power to the attenuator wheel optical switches and a connection to ground and 5V power.

3.8 Laser Power/Trigger Control

The power/trigger circuit board (figure 13) is located on the front panel inside the switch box. The circuit is designed as an interface between the counterboard 5V logic and the floating 24V logic of the N_2 laser remote

Data Bus	Counterboard	Bit define	Comments
D0	U1 A0	Optical switch A	Zero position filter wheel A
D1	U1 A1	Optical switch B	Zero position filter wheel B
D2	U1 A2	Limit switch 1	Dye mirror end limit switch
D3	U1 A3	Limit switch 2	Dye mirror near limit switch
D4	U1 A4	div 12V power	12V power status
D5	U1 A5	div 40V power	40V power status
D6	U1 A6	U11-5 (Q1)	Trigger lockout status
D7	U1 A7	U15-5 (Q1)	Trigger status
D8	U2 A0	IRF730 front pan	Laser warmup indicator
D9	U2 A1	B1 Clt front pan	Laser ready indicator
D10	U2 A2	B4 Clt front pan	Laser running indicator
D11	U2 A3	U15-9 (Q2)	120V power control status
D12	U2 A4	div on motor pwr	Dye stir 1 status
D13	U2 A5	div on motor pwr	Dye stir 2 status
D14	U2 A6	div on motor pwr	Dye stir 3 status
D15	U2 A7	div on motor pwr	Dye stir 4 status

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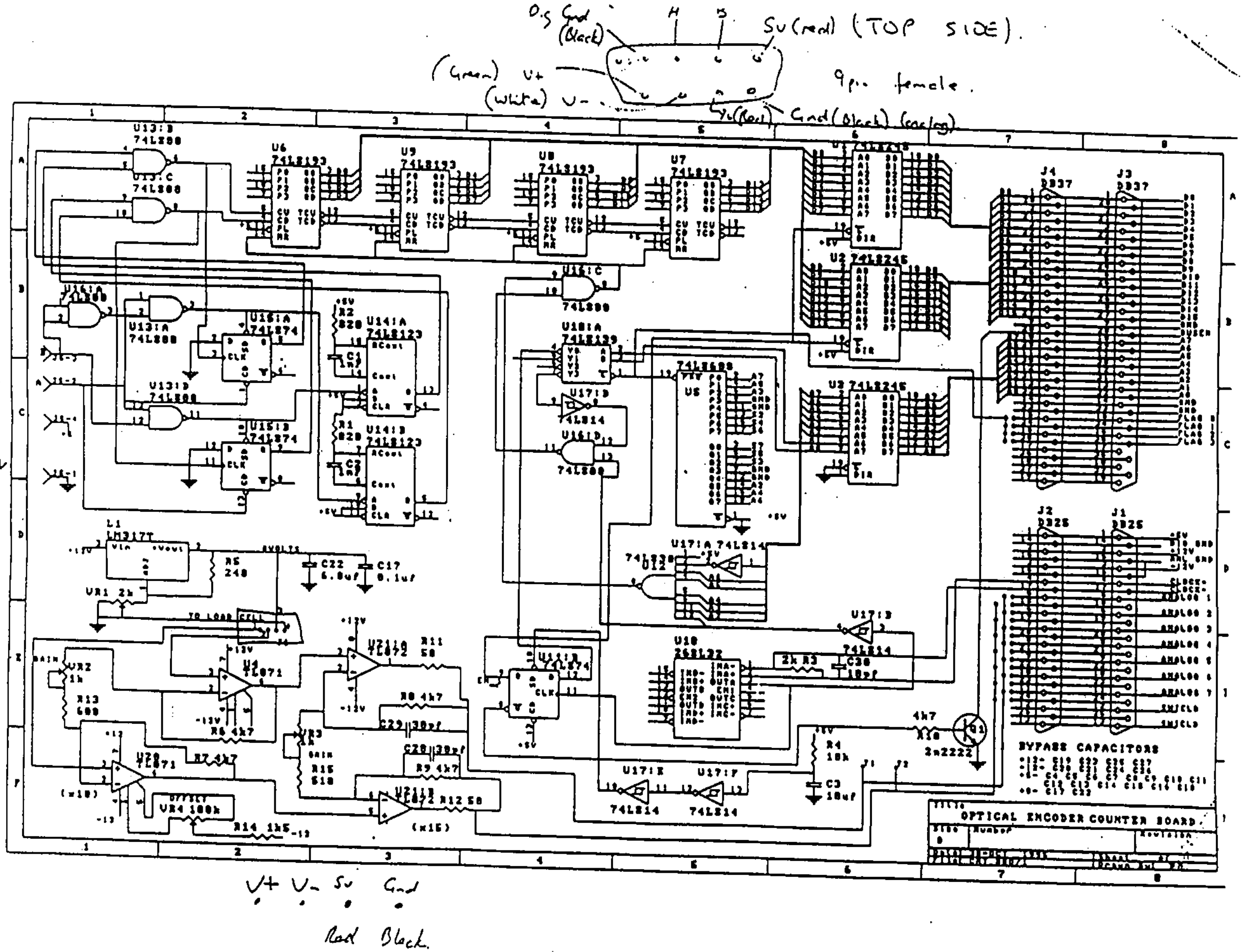


Figure 11: The calibration counterboard (CB) circuit.

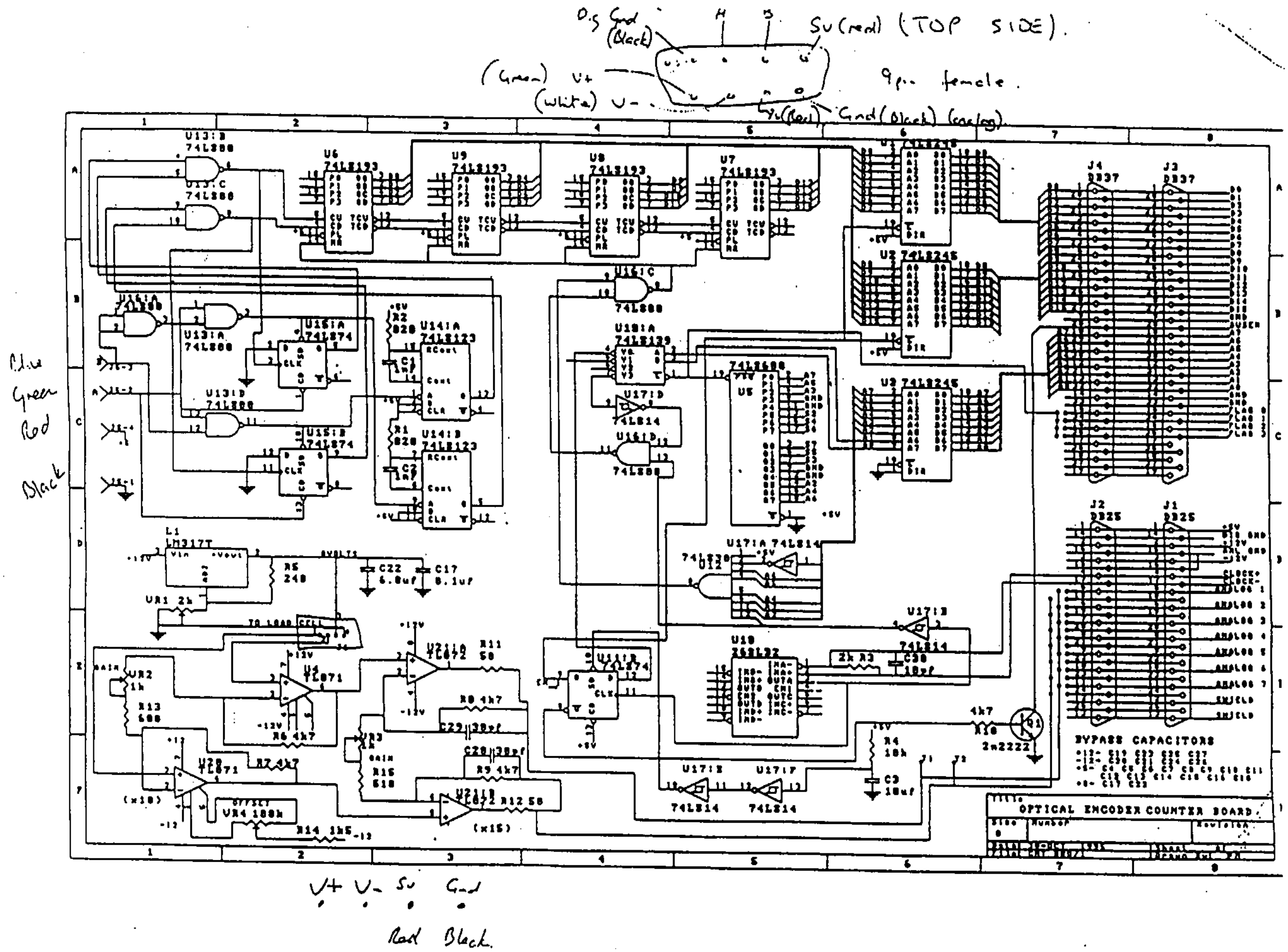


Figure 11: The calibration counterboard (CB) circuit.

Connector	Counterboard	External	Comments
1	U1 A0	10K hi, opt sw to gnd	Detector side of
14	U1 A1	10K hi, opt sw to gnd	Honeywell switch
2	U1 A2	10K hi, limit sw to gnd	Mirror motor limit
15	U1 A3	10K hi, limit sw to gnd	switch to ground
3	470Ω to 5V (Q1)	opt switch LED	LED side of
16	470Ω to 5V	opt switch LED	Honeywell switch
4	E 2N2222 (U11 Q2)	Lockout Bosfet B2 Inp	1=unlock,0=lock
17	U1 A5	10K gnd, 10K out	div for 12V sensor
5	U2 A0	10K hi, FET to gnd	Laser warmup (=0)
18	U2 A1	10K hi, B1 bosfet to gnd	Laser ready (=0)
6	U2 A2	10K hi, B4 bosfet to gnd	Laser running (=0)
19	U1 A4	10K gnd, 50K out	div for 40V sensor
7	U2 A4	10K gnd, 5V zener	dye stirrer 1 powered
20	U2 A5	10K gnd, 5V zener	dye stirrer 2 powered
8	U2 A6	10K gnd, 5V zener	dye stirrer 3 powered
21	U2 A7	10K gnd, 5V zener	dye stirrer 4 powered
9	Gnd	Common gnd	gnd out
22	Gnd	Common gnd	gnd out
10	Gnd	Common gnd	gnd out
23	Gnd	Common gnd	gnd out
11	0.7Ω to 5V	To 5V supply	5V power boost
24	U15 $\overline{Q1}$	not connected	
12	E 2N2222 (U15 Q1) ✓	Trigger bosfet B3 Inp	Trigger laser
25	U15 $\overline{Q2}$	not connected	
13	E 2N2222 (U15 Q2) ✓	120V relay	Power swt remote 120V
Internal connections (U1-8)	U1 A6	U11-5 (Q1)	1=unlocked, 0=locked
	U1 A7	U15-5 (Q1) U15-9 (Q2)	1=trig, 0=no trig
	U2 A3	U15-9 (Q2) U15-5 (Q1)	1=power on, 0=off

Table 2: Wiring assignments for the 25-pin connector for the modified counterboard EC.

U1-9 (A7) → U15-9 (Q2) trigger.
U2-5 (A3) → U15-5 (Q1) Power

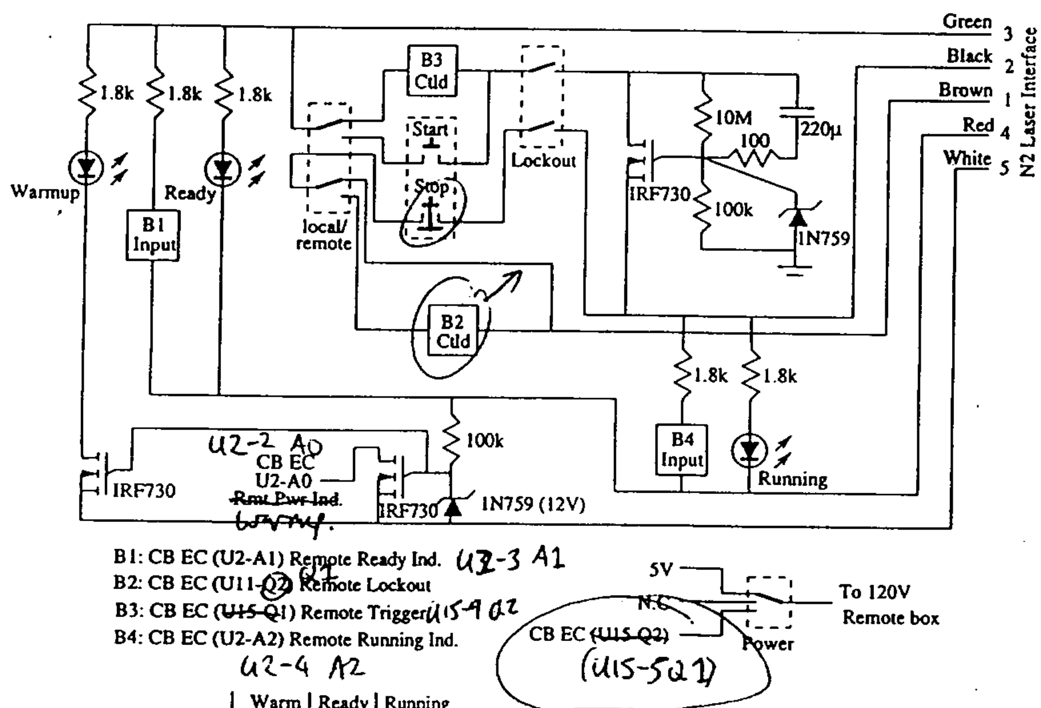
~~A6/A7~~ A0/A1	action
00	readout counterboard data
10	set U15-9 Q2 (120V power)
01	~~set~~ U15-5 Q1 (trigger)
11	clear U15 Q1 and Q2

U15-5 (Q1)
toggle U15-9(Q2)

Table 3: 2 bit address logic for the modified counterboard EC.

(Power off)

N2/Dye Laser Front Panel Power/Trigger Control



	Warm	Ready	Running
Green	24.0V	24.0V	24.0V
Black	22.4V	0V	23.2V
Brown	0.1V	0V	23.2V
Red	22.4V	0V	0.2V
White	0V	0V	0V

B* are BOSFETs (Bi-directional FET switch). 'Input' is the control (a diode), 'Ctld' is the switched output (bi-direction).

Figure 13: Schematic of the N_2 laser trigger circuit.

4 Operating Instructions: Local

4.1 Plugging in the 120V Power

The SNO N_2/dye laser system runs off 120V power which is supplied by a 15A cable and plug from the local front panel. See figure 14 for a schematic of the 120VAC power distribution. First you should ensure that the laser power switch on the front panel is in the off (centre) position (see figure 15 for the front panel layout).

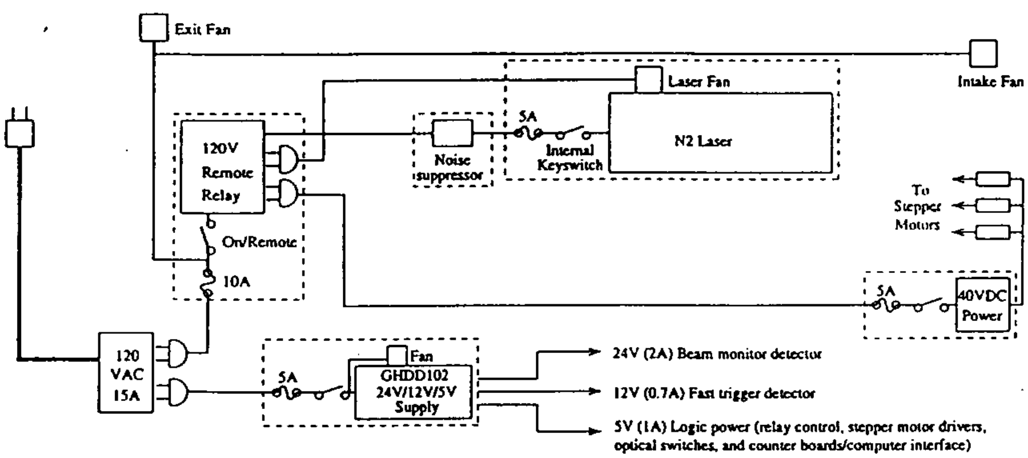


Figure 14: Distribution of 120VAC power and low voltage power.

Now plug in the main power cable. This will immediately start the two fans at the cabinet ends which flow air in the rear end and out of the front end of the cabinet. Also an internal power supply is immediately energized to supply 5V logic power and +12V/-12V power for the monitor diode amplifiers.

When the laser is in daily use is normal to leave it plugged in, with the laser power off. The 5/+12/-12 supply can be switched off internally but it is normal to leave it on as the 5V logic power is needed for remote or front panel trigger control. Also the monitor diode amplifiers are more stable if left on.

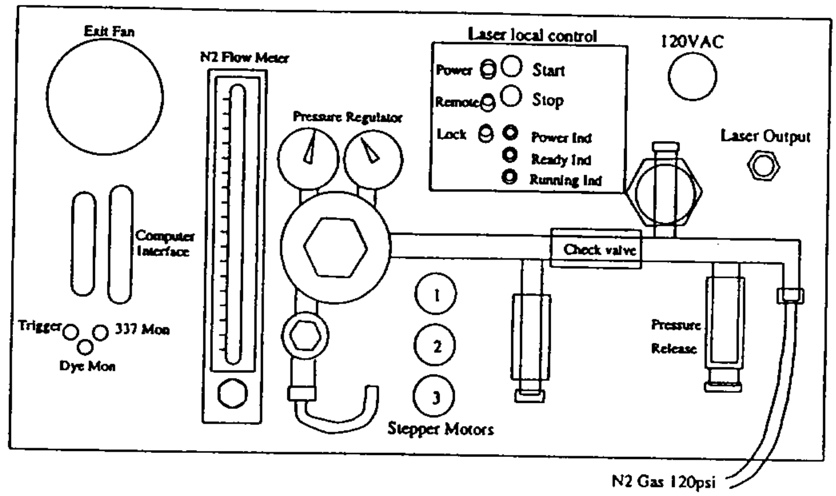


Figure 15: N2/Dye laser front panel layout.

4.2 Nitrogen Gas Supply

Before the laser can be powered you must ensure that the proper nitrogen gas pressure and flow are set. It is assumed here that a supply of either bottled pre-purified or liquid nitrogen boil-off is plumbed in to the laser gas supply and has a pressure between 100 psi and 140 psi. A pressure less than 90 psi is insufficient to run the laser without damage. A pressure over 150 psi will release the pressure safety valve, which again will result in insufficient pressure at the laser.

The gas flow is turned on by the flow knob on the front rotometer. Open it a good two turns since the flow rate should already be set internally. Now check that the regulator pressure is set at about 90 psi and adjust if necessary. Check now the rotometer flow is between 25 and 35 on the scale, if the gas flow is not within range it must be adjusted internally by a technician qualified to work on the laser.

4.3 Laser Power Control

After the gas flow is set the main laser and motors power can be switched on. Move the laser power switch from the centre position up to the on position.

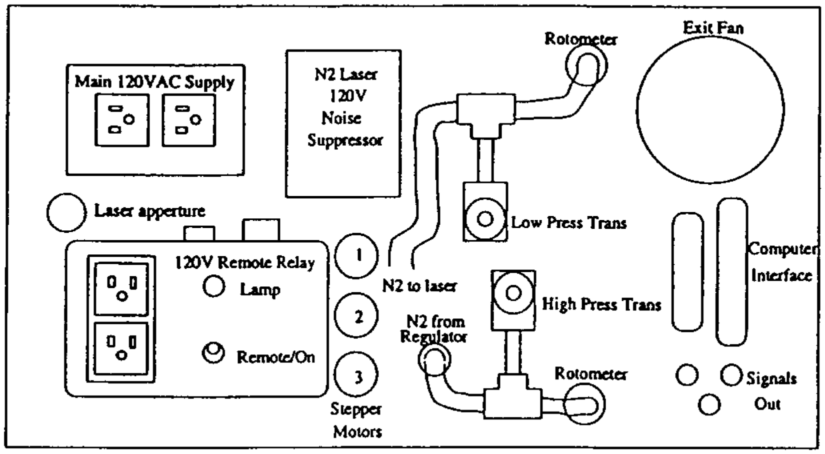


Figure 16: N2/Dye laser inside front panel layout.

This supplies 5V logic power to the 120V relay box, so that anything connected to or plugged into this box is now powered. The N_2 laser is normally connected to the 120V relay through a noise suppressor module.

In the standard cable configuration the N_2 laser has the keyswitch turned to the on position before the copper N_2 laser RF shield is installed. Thus the N_2 laser is immediately powered when the 120V relay box is energized. The cooling fan mounted on the N_2 laser RF shield is also connected to the 120V relay box and is powered at this time. Similarly the 40V power supply switch is normally in the on position and plugged into the 120V relay box so that it is powered at this time.

When the laser gets 120V power it first begins a thyratron warmup period. At this time you will hear the cooling fans begin to run and the red warmup indicator lamp on the front panel should glow. After about three minutes the red warmup lamp will go out and the green ready lamp will glow. If the warmup lamp did not come on then then it is likely that the 5V power or the 120V relay box is off. Reconfiguring these switches will require the top cover to be removed by a qualified operator.

Before triggering the laser you will first have to determine what the position the dye laser selector mirror is in, and what the attenuator wheel settings are. This can be determined using the computer commands, or by removing the top cover to check.

4.4 Dye Laser Selector Mirror

Even though the laser is being controlled at the local panel it is still better to use the calibration computer control for setting the dye laser steering mirror and the attenuation wheels. This is because the computer can position the motors more precisely, and because computer control does not require removal of the top cover, which requires adherence to the safety procedures described in section 2. Also, moving the mirror manually will require a zero position re-calibration as the software will have lost track of where the mirror is. When the laserball is in the SNO detector you especially should not open the top cover since the light leak down the fibre optic and the RF pickup can add significantly to the detector noise rate.

If the mirror position is questionable, or if the laser produces no output then a software zero position re-calibration should done (see appendix B for the calibration computer software commands). The zero position re-calibration procedure will run the mirror carriage into the front limit switch and then zero the optical encoder and the stepper motor counter. You can then advance the mirror to the desired laser cell which should be aligned properly now.

If you do need to move the dye laser mirror carriage manually, then there is a TTL oscillator switch located inside the laser box on the back panel to make the job easier (fig 9). First you should check that the 40V power is on, then switch the motor 'remote/local' switch to 'local'. The 'forward/backward' switch will now step the motor as expected. The 'fast/slow' switch sets the oscillator rate to allow fine motor control when aligning the pump beam with the dye cell.

4.5 Attenuator Filter Wheels

The positions of the neutral density filter wheels can be determined and adjusted either by software control or by hand in the same way as for the steerer mirror. In a similar way the wheels can be zero positioned via a software routine that locates a tab at the optical switch mounted on the wheels (see appendix B for the calibration computer software commands).

Manual positioning of the wheels can done by hand. The software will require a zero position recalibration for the wheel if it is moved by hand. The wheels must be set by computer control if the laserball is in the SNO detector since you should not open the cover.

4.6 Laser Trigger Control

The local trigger control is on the front panel. There is a 'start', 'stop', 'remote/local' and a trigger 'lockout' switch. First the 'remote/local' switch must be switched to local to get local trigger control. Then, if it is safe and if the nitrogen gas pressure and flow are correct, the 'lockout' switch can be switched to unlock. The laser trigger has a time delay safety feature so that you must wait 90 seconds before triggering or retriggering the laser. After the green ready light has been on for 90 seconds the laser can be started by pressing the start button for a second.

The laser can be stopped either with the stop button, setting the trigger lockout switch or by switching off the power. If the stop button is used the thyratron heater will remain on, but there is still a 90 second delay before retriggering is possible.

5 Operating Instructions: Remote

The remote operation of the SNO N_2/dye laser system depends on the software designed for that task. The reader is directed to that software documentation for information on the commands available and functionality of the software. Appendix B describes the commands available for the SNO calibration computer software for operation of the N_2/dye laser. In this section the actions resulting from the software commands are described. The commands listed in appendix B apply to the manipulator control software that runs on the calibration computer. The laser can also be operated from a remote site using the calibration computer server. The commands can be issued directly (eg. using a telnet client) or other client software (eg. the graphical DAQ manipulator controller) can be used. The online documentation for the specific software should be consulted, but the command actions are simple enough that they can easily be followed from the discussion below.

Before the laser can be operated remotely, the laser system must be plugged in to 120V and the internal power supplies must be plugged in and switched on. See the section for local operation first. On the front panel the power switch and the trigger control switch should be the remote position. Also the trigger lockout switch should be in the unlock position.

5.1 Power and Trigger Control

The 120V laser power and the 40V motors power can be switched on remotely if the local panel 'power' switch is in the 'remote' position.

The laser power is switched on with the N2LASER POWERON command. This command will select the EC counter board through the PIA interface card. The actual address on the bus will have 10 as the last two bits (ie. EE, see table 3) which will toggle the ~~U15B Q2~~ flip-flop. This output U15A Q1 is buffered through a 2N2222 transistor and routed to the front panel trigger board. If the power switch is set to 'remote' then the output will drive the 120V relay box. Thus anything plugged into the relay box will be turned on; this should be the N_2 laser, the 40V motor supply and the laser shield fan. After a few seconds the N2LASER MONITOR command should display the laser status as 'warmup'.

After about three minutes the laser status should change to 'ready'. The laser can now be triggered with the N2LASER START command. This

U15B Q2

command is similar to the POWERON command except that the address line now carries 01 which toggles the ~~U15A QI~~ flip-flop. This output is also buffered through a 2N2222 transistor and routed to the front panel trigger board where it activates a bosfet opto-isolator. The bosfet triggers a capacitor circuit which connects the 24V laser trigger. The capacitor circuit needs about 90 seconds before it is retriggerable, so the N2LASER START command actually waits 90 seconds before the command is executed. During this time the laser status will be 'waiting', after triggering the status will be 'running'.

The N2LASER START can be issued before the laser thyratron is warmed up; the command will automatically get executed after the warmup. The laser can be stopped with the N2LASER STOP or the N2LASER POWEROFF commands. The laser will not start and it will shut down automatically if the N_2 gas flow or pressure falls out of range. In this case the laser status will be 'problem'.

The N2LASER MONITOR command will show the laser status as well as the N_2 gas flow and pressure and the status of the dye stir motors and the power supplies. This is the best diagnostic in case of problems.

stop leave thyratron on.

5.2 Dye Laser Selector Mirror

The dye laser selector mirror is controlled with the DYELASER commands. The software runs the motors by programming a TIO10 timing card (which uses the AM9513 chip) output squarewave function to the stepper motor drivers. The number of steps is counted and controlled, but the actual motor position is determined from an optical shaft encoder. The shaft encoder output is read out from the counterboards. The counterboard for the mirror carriage is E4.

The DYELASER FORWARD command moves the mirror carriage forward (in cm), while the DYELASER BACKWARD command moves it backward. The positions of the dye laser resonator cell positions are stored in a database; this way the DYELASER CELL command can move the mirror directly to a given cell number. The DYELASER WAVELENGTH command will move to the cell closest to the requested wavelength (in nanometers). Entering or updating these cell positions is a configuration/maintenance job which will require the DYELASER CALCELL command. The carriage leadscrew has limit switches at the ends which are read out by the EC counter board and used in the software to stop the carriage motor. The DYELASER FINDZERO starts a procedure to seek out the near limit switch so that the motor position can be calibrated to a known location. This command is used after an abnormal power outage or whenever the motor position is questionable.

5.3 Attenuator Filter Wheels

The attenuator filter wheels are controlled by the FILTERWHEELA (the front wheel) or FILTERWHEELB commands. The motors are stepper motors with shaft encoders and are controlled just the same way the mirror carriage motor is. The commands FILTERWHEELA CWD and CCWD move clockwise and counter-clockwise in degrees, while the FILTERWHEELA CWS and CCWS move a number of filter positions. Again the ND filter values and positions are stored in a database, so that the FILTERWHEELA POSITION command will go directly to a certain filter while the FILTERWHEELA ND command will select the ND filter closest to the value requested.

The FILTERWHEELA FINDTAB will calibrate the wheel position by seeking the optical switch tab stop (similar to the DYELASER FINDZERO command).

6 Maintenance

With the stable temperatures expected in the lab at SNO the laser system should operate for many hundreds of hours with very little maintenance. The most common maintenance will be checking and changing the dye solutions and slightly adjusting the beam optical alignments. The dye solutions need to be inspected regularly as the solvents will evaporate over time. The beam alignments can be expected to change a little as the o-rings in the compression mounts can be expected to relax and migrate.

An important part of the maintenance is to record the beam energy, as measured from the monitor with an multi-channel analyser, and a running time or estimated shot count. This is especially important after any major repairs or re-alignments.

This section describes procedures for disasembly of the laser, rebuilding and setting up the N_2 laser, configuring the dye lasers and aligning the beams. A recommended maintainence schedule is given with a description of the procedures.

6.1 Some Disassembly Procedures

Many of the maintenance and repair tasks will requires removal of the cover and shields etc. These tasks are described here in detail for greater brevity of the maintenance task descriptions.

6.1.1 External Covers

The N_2/Dye laser system is enclosed in an aluminum box which is constructed with a heavy $\frac{1}{2}$" 2'×6' base, an angle frame and sheet aluminum covers. This box provides mechanical stability for the optical components, a dust shield, a laser light shield and an RF emission shield. For easy operation and maintenance there is hardware mounted only on the end covers, and the external switches and controls are all on the front cover. Thus the top and side covers can be readily removed to provide easy access to all of the internal components.

The covers are removed by carefully unscrewing the hexhead bolts and supporting the cover until it is free. Note that the side covers provide support for the frame so that the top cover should be removed before the side covers.

The covers should be replaced by using all of the retention bolts. Failure to use all of the bolts may result in reduced RF shielding and interference problems in SNO pmts and electronics. Use $\frac{3}{8}$" or longer 6-32 hexhead bolts as replacements.

6.1.2 Dye Laser Table

The dye lasers, beam optics and the dye laser energy monitor are mounted on a $\frac{1}{4}$" aluminum table. This table can be removed for adjustment/modification or to provide access to the counterboards located beneath the table.

Remove the top cover (sec 6.1.1). Unplug the electrical connectors for the energy monitor and the dye stirring motors. Then unbolt the four corner leg hexhead bolts. The table can then be lifted out. The dye laser table has aluminum standoffs at the edges so that it can set set down on any flat bench top. Installation is the reverse of removal. While this procedure is straight forward, it requires a large amount of care and attention since there is very little clearance for the counterboard cables and the dye stirring motors. The table must be placed in position, it cannot be slid around to align the holes. Take care in reconnecting the cables correctly.

6.1.3 N_2 Laser RF Shield

This copper shield provides a great reduction in the RF radiation from the N_2 laser high voltage switching. To function properly this shield must have a minimum number of appertures/holes and be tightly secured. The shield must not be modified by enlarging any of the cable holes or drilling any new holes. The shield is secured by a set of rails which tightly seal the shield perimeter while providing a convenient method of removal. There are sliding rails on three sides of the shield; the forth side is sealed by locating the shield edge into a slot in the left-bottom cover frame member.

First remove the top and left side external covers (sec 6.1.1). Unplug the shield cooling fan from the 120V relay box. Next loosen the bolts so that the three RF shield rails can be slid away from the bottom edges of the shield. Then carefully work extra slack in the power and control cables and the nitrogen gas tubing. This is done by pulling on the cables to retrieve some of the cable slack that is inside the shield. When you have sufficient loose cable the shield can be lifted out and placed on top of the aluminum frame. When lifting out the shield you will first have to slide it away from the edge so that the forth edge of the shield is removed from the frame slot. As you lift out the shield you may need to rework the cables through the holes to get sufficient cable length.

Note that the shield cannot be completely removed without disconnecting the 120V power line from the noise suppressor and disassembling the control cable connector. However, complete removal of the shield will never be necessary since the N_2 laser can be serviced and/or removed with the RF shield removed as described above.

Installation is the reverse of removal. Special care must be taken to put the left shield edge into the slot under the bottom left frame member. If you have problems it might help to slide a straight edge (or other rod) under the shield and laser to push the shield edge into the slot from the inside. Slide the 3 rails over the shield edges and tighten down. Lastly work the slack in the cables into the holes. Finally make an inspection of the soldered edges to ensure there is no corrosion or damage. Check that the cooling fan is plugged into the 120V relay box and that the fan works.

6.1.4 N_2 Laser

Most of the N_2 laser maintenance can be done with just the RF cover removed: adjust pulse rate, adjust gas flow, check/adjust thyratron voltage and adjust the horizontal divergence lens. However, to gain access to the laser head, high voltage or triggering components will require that the laser be removed since the laser cabinet cover can not be removed with the laser in place.

First remove the RF shield (sec 6.1.3). The laser stands on four cushion feet which are retained with three hexhead bolts each. The ball type allen keys are useful for removing the bolts since the bolt heads are just under the laser. To access the laser head the laser does not have to be completely removed. With the cushion feet unbolted the laser can be moved forward enough so that the sliding cabinet cover can slide back far enough to access the head. The sliding cabinet cover is released by removing the two thumbnuts. Note that moving the sliding cover will release the laser interlock switch, so that the laser will not get power until the sliding cover is closed or the interlock switch is defeated. The interlock switch can be temporarily defeated by pulling out the centre pin an extra half inch. The interlock switch is at the control end of the N_2 laser under the lip of the sliding cover.

The N_2 Laser can be completely removed and placed on a bench by first disconnecting the power and control cables and the gas line. The laser can be operated on the bench top without the control cable, ie. just with the gas line and power cable. However, the laser will not operate unless the 1 and 2 pin of the remote connector are joined to complete the trigger safety interlock circuit. There is a 9-pin connector terminator available that just connects the 1 and 2 pins for this purpose. The laser can then be operated as described in the vender manual (appendix A).

6.2 Laser Dye Solution Preparation

The laser dyes are purchased in powder form and must be dissolved with the correct solvent (eg. ethanol[1]) to make a solution of the correct concentration. The correct solvent for each dye and the quantities to be mixed are shown in table 4. The dye solutions should be mixed in quantities of 50 cc or more so that the dye weight can be measured more precisely and so that solvent evaporation will not cause a large discrepency. The solutions should be mixed and stored in tightly stoppered bottles with correct labels including the date. Note that you must review the MSDS sheets (appendix C) before mixing the dye solutions. Do not come into skin contact with the powdered dyes or the dye solutions. Close the dye containers as soon as possible and wash hands thoroughly after handling the dyes. It is a good idea to use latex gloves for mixing and transfering the laser dye solutions.

The solutions are made by weighing out a pre-determined quantity of the powered dye using disposable foil trays (or similar). Use a Metler or other precision balance; do not forget to subtract the tray weight. Transfer the dye powder to the solution bottle that is large enough for the required quantity of solvent. Use a measuring cylinder to add the solvent, then stopper the bottle and shake to mix thoroughly. Some dyes are difficult to dissolve and may have to be left for a while.

Here are a few extra pointers. Weigh out an arbitrary, but precisely weighed, quantity of the dye powder that is close to your pre-determined weight. Then make the concentration precise by adjusting the volume of

[1]Preferably ethanol should be laboratory grade pure. However, methanol de-natured upto 15% is acceptable.

Dye	Wavelength (nm) Peak	Range	Molecular Wght (gm)	Solvent	Conc. ($M \times 10^{-3}$)	Conc. (mg/cc)
BPBD	365	357-395	354	Toluene	4.0	1.42
PBD	366	360-386	298	Toluene (50) Ethanol (50)	5.0	1.49
BBQ	386	373-399	675	Toluene (50) Ethanol (50)	2.5	1.69
DPS	406	396-416	332	P-Dioxane (or Ethanol)	1.2	0.398
M-MSB	418	408-432	310	P-Dioxane (or Ethanol)	1.2	0.372
C-500	500	473-547	257	Ethanol	10.0	2.57

Table 4: Laser dye solution information table.

solvent that is added. This method is easier since the powdered dyes tend to be 'clumpy' and difficult to dispense. Ordinary good laboratory practice regarding cleaning of glassware etc. will of course apply.

The dye solution can be transfered to the laser dye cuvettes using an eye dropper. The cuvette should be rinsed thoroughly, including the stopper, using the primary solvent of the dye solution (usually ethanol). The eye dropper should also be thoroughly rinsed before and after the transfer. The cuvettes should be handled only by the top, bottom and top edges. After filling, clean the outside of the cuvette with solvent and wipe dry with lint free wipes to remove any oil or dye residues. For the underground SNO lab it is suggested that the dye solutions be mixed above ground. Then the solution bottles, eye droppers, lint free wipes and quantities of the solvent can be stored underground.

6.3 Beam Alignment

Throughout the beam alignment procedures use a piece of paper or cardboard to observe the laser beam. Note that for wavelengths below 400 nm you are actually observing fluoresced, not scattered, radiation. Photocopier or other bleached papers work best as they appear to fluoresce better. Never place any shiny or reflective parts near the dye laser table that could cause a laser beam to strike a person's eye. See section 2 for further information on safety.

The following procedures describe the setup and alignment of the dye lasers and output optics. It is assumed the N_2 laser beam is configured, goto section 6.4 if this is not the case.

6.3.1 Dye Laser Beam Alignment

Remove the top cover and start the laser. Move the steering mirror carriage to the dye laser cell to be aligned.

Loosen the screws for the horizontal cylindrical lens mount. Fold a piece of paper and replace the dye cuvette with the paper such that the paper has a flat surface at the front of the cuvette holder. Now adjust the lens position until a sharp image line is focused on the paper. This ensures that the pump beam is focused at the edge of the dye cuvette.

Next replace the dye cuvette back in the holder (tighten the thumb screw until it just prevents the cell from moving – overtightening will damage the cell) Observe the output at the out of the front of the cell (with paper!). You should see two beams (possibly diffuse) that are displaced vertically. Check the mirror carriage to ensure that the pump beam is centred on the cuvette. Then loosen the set screw on top of the cylindrical lens and rotate the lens until the two vertically displaced beams converge.

Next the beam can be tuned up by adjusting the resonator feedback mirror. Loosen the locking nuts on the three hexhead bolts and loosen the bolts. Now tune the laser beam by tightening the hex bolts which press against a nylon ring around the mirror edge. Tighten the lock nuts when done.

You may have to repeat the above procedures to get an intense well defined beam. The dye laser beam alignment takes some practice to achieve the best results.

Lastly, if you have had to reposition the pump beam mirror carriage then you should update the position database on the calibration computer (use the DYELASER CALCELL command).

6.3.2 Multi-Beam Alignment

We assume that all the dye laser resonators are configured, and that now we wish to align the beams so that each beam, when selected, will be aligned into the mixer fibre and hence at the output aperture.

All the beam steering mirrors and beamsplitter filters are in custom mounts which incorporate an o-ring compression adjustment. The mounts also have slotted stands so that the alignment can be coarsely set before fine adjustment is made.

Start with the N_2 laser beam, then work back with dye laser one, then two, and so on. First, roughly set all the beams so that they all travel 1-1/4" off the table and they all travel through the beam splitters. Also be sure that the beams enter the dye laser monitor input after the beam splitter. For each dye laser start your adjustments at the first mirror since this will have the most angular leverage.

When all the beams make it off the table, next position the mixer fibre to about the mean position using the x-y positioning screws. Note that you will need to move the attenuator filter wheels to the blank positions. Now go through each beam and adjust it so that it precisely hits the centre of the mixer fibre coupler.

Again this procedure may take a long time and some practice if you are starting from completely unaligned beams.

6.4 Servicing the HV N_2 Laserhead

The HV N_2 laserhead is the optical cavity where the laser beam forms as the high voltage discharge creates an electron plasma. The laserhead can be serviced with the laser unit removed to the lab bench, or with the unit in place. See section 6.1.4 to remove the RF shield and get access to the laserhead.

The laserhead operates at 15 kV high voltage, and is a class 3b UV laser device. Only competent and trained persons should work on the laserhead. See section 2 for information on safety. The following are procedures to disassemble and rebuild the laserhead, and set the electrode gap to produce a stable laser beam. For beam adjustment only go directly to section 6.4.3.

6.4.1 N_2 Laserhead Disasembly

The laser should be stopped and the power turned off at the laser cabinet keyswitch. Also turn off the nitrogen gas supply. Remove the six hexhead 'electrode bolts' as shown in figure 17. Retain the 1000Ω resistor and the lock washers. The head can now be lifted straight out. Disconnect the nitrogen gas line from the underside of the head.

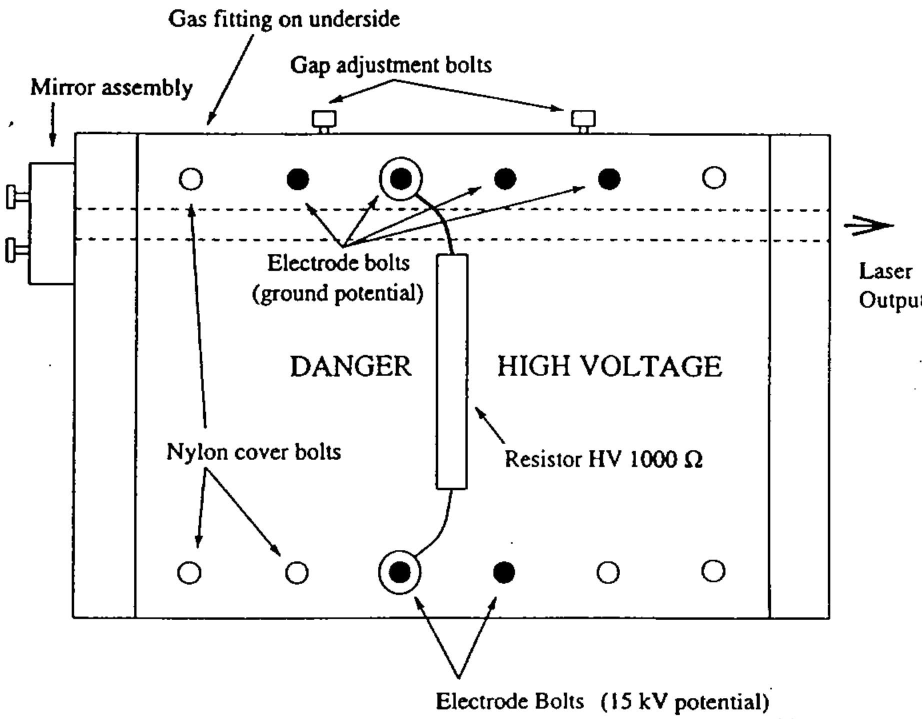


Figure 17: Diagram of the top view of the N_2 laserhead.

The head can now be disassembled by removing the remaining nylon bolts on the top and the sides that are retaining the top cover plate. The components inside the head are shown in figure 3; they consist of an upper and a lower charge transfer board[2], an aluminium conduction plane and a

[2]Note that the charge transfer boards (also called transmission boards) are the capacitor C_p in figure 4. The boards are about 0.02" think and have a capacitance of about 2 nF.

smaller conduction bar. Remove the top charge transfer board by handling the board at the edges only – do not touch the copper. The large conduction plane can now be removed, lookout for any tabs at the back of the plane that are used as spacers. You should include these spacers when re-assembling the head, else you may not be able properly adjust the electrode gap.

The conduction bar can now be removed by removing the 'gap adjustment bolts' – watch out for the two springs. The lower charge transfer board can now be removed, again do not touch the copper planes. It is not necessary to remove the mirror assembly. Inspect both of the charge transfer boards. You are looking for signs of corrosion, arcing around the edges of the boards (blackened channels) or crazing of the fibre glass down the channels. Check the channels on *both* sides of the boards for crazing. Crazing is an indication of impending failure due to high voltage stress. The channel on the outside side of the board should be covered in kapton tape; remove this for your inspection, then replace with new tape (if the board is reuseable). Upon any signs of board failure you should use new charge transfer boards. If you are servicing the laserhead because of laser breakdown, then you will likely see a 'punched through' arc pinhole.

Now inspect the delrin[3] plastic housing and cover plate. If the laserhead housing shows evidence of serious corrosion and/or arcing (blackened areas) then you will need to fabricate a new housing – see section 6.5 and the drawings in appendix D.

6.4.2 N_2 Laserhead Assembly

Clean the housing by wiping with a clean lint free cloth with mild detergent solution, wipe with lint free damp cloth to remove all detergent residues. Clean the conduction plates with metal cleaner and alcohol, then handle as little as possible. Clean the charge transfer boards by wiping with mild detergent to remove any oxides, wipe dry. Run a single line of kapton tape over the discharge channel that is opposite to the laser discharge channel, ie. the unused channel.

Assembly is the reverse of disassembly with the following extra points (see figures 3 and 17). Replace the conduction bar with bolts only one turn

[3]Delrin is a trade name for a tough heat resistent thermoplastic with a high electrical breakdown strength. Similar plastics of other tradenames (eg. metacetal and polysulfone) are acceptable.

in, this will result in a narrow electrode gap which will be adjusted later. Replace the aluminium conduction plane along with any spacers that were removed so that the plane stands away from the back edge of the housing. Carefully replace the top charge transfer board and the housing cover so that the aluminium conduction plane does not shift from its position. Tighten the side bolts and the nylon cover bolts on the opposite side to the conduction bar (*but do not over tighten the bolts*). Replace, but not do tighten, the nylon bolts over the conduction bar; this allows the bar to move during adjustment.

Now replace the laserhead back into the laser by reconnecting the gas line and placing the head over the high voltage contacts. Replace the steel hexhead electrode bolts and the resistor; but again do not tighten the bolts on the conduction bar side of the head. You are now ready to start the laser and set the electrode gap.

While you have the laser cabinet open, check that the cooling fan is working.

6.4.3 N_2 Beam Setup and Adjustment

To adjust the electrode gap to get a good powerfull laser beam will require you to continously observe the beam using a UV viewing card. As discussed in section 6.3 this is easily achieved with bleached white paper that fluoresces. Setup such a piece of paper about 5 cm to 15 cm away from the laserhead exit apperture. Also place a more substancial cardboard beam stop behind the paper to ensure laser light cannot get scattered during the procedure.

This adjustment procedure requires the laser to be running while the 'gap adjustment bolts' are adjusted (see figure 17). Great care must be taken to ensure your hands or any tools do not come close to the 15 kV 'electrode bolts' during this procedure, especially since this procedure is best performed in dim lighting. *Warning: the bolts and the resistor on the HV side of the laserhead cover are at high voltage when the laser is triggered.* See the safety section 2.

Turn on the nitrogen gas flow and power the laser, but do not trigger it yet. It is easier here to use the enable/disable toggle switch on the laser cabinet to trigger the laser, as you will need to start and stop the laser many times. You should also turn down the trigger rate knob so that the laser only fires at 1 or 2 Hz during this procedure.

Loosen the four electrode bolts on the conduction bar side (ground potential) of the laser head; this allows the conduction bar to move. The bolts should not be very loose, just enough to let the bar move. The conduction bar is adjusted by turning the 'gap adjustment bolts' which move the bar in and out. You will find that the bar only moves smoothly when you are moving the bar out (clockwise). Often you will need to back off the bolt, then push on it to move the bar in. Hence the strategy is to start with the electrode gap too small, and then make the adjustments by moving the bar out. Now back off the bolts and push in the bar to begin the adjustment.

Now trigger the laser. You will (likely) find that the laser fired with a loud bang and did not produce any laser light. Also you will have seen that there was a bright flash of blue-white light from one of the ends of the laser cavity – this is the high voltage arcing across the laser channel. Quickly disable the laser trigger, it is not good to run the laser for many flashes this way, because it will carbon-track the cavity.

Now adjust the bar at the end that the light flash came from (quarter to half turn) to widen the gap. Now trigger the laser again, and stop when you have seen which end was arcing. Repeat this process, and you will find the arcing intensity decreases, and the bangs get quieter, as laser light starts to appear. You will need to dim the lights to be able to see where the arcing is occuring as it becomes less intense. Now it is a matter of making fine adjustments. You should be able to eliminate the arcing (the laser should be much quieter) and produce an intense laser beam. Often you will need to push the bar back in, then wind it out again.

The laser beam should be rectangular, about 3 mm by 5 mm. If the beam is more square shaped, then the electrode gap is still too small. If the laser appears to be running well (no arcing) but the beam is not very intense and looks distorted or diffuse, then you can adjust the cavity mirror with the three bolts at the end.

When the beam looks good, disable the laser and tighten the electrode top cover bolts. Do not over tighten, and work from the middle out. Trigger the laser and check the beam adjustment. If the beam is good then close the cabinet sliding cover and reinstall the laser. Now check the *horizontal* divergence of the laser and adjust the position of the cylindrical horizontal lens at the front of the N_2 laser. Finally, reset the pulse rate.

6.5 Maintenance Schedule

Table 5 gives a general guide for the recommended maintenance schedule. The procedure descriptions follow. The maintenance schedule is given with dependencies on a time period or on a running time. Where both are given the interpretation is whichever occurs first. There will be a log book for the laser system, all use and maintainence activities should be reported in the log book.

#	Task	Period	Hours
1	Pulse energy check (N_2 and dyes)	Daily and after other procedures	3
2	Dye solvent level check, and check magnetic stirrers	Weekly	25
3	Replace ST coupler optical grease	Weekly (or when disconnected)	25
4	Check RF shield and in/out Fans	Monthly	100
5	Dye laser beams alignment and check/clean optical components	Monthly	100
6	Check N2 beam alignments into dyes	Monthly	100
7	Check N2 gas leaks and check/recalibrate transducers	2 Months	
8	Check thyratron res. voltage	Monthly	100
9	Check/adjust N2 beam quality		200
10	Check HV transfer boards, clean/rebuild laser head		500
11	Check HV supply and replace thyratron. Check resistor/capacitor	2 years	1000
12	Fabricate and install new laserhead housing and new transfer boards		1000 - 2000

Table 5: SNO N_2 multi-dye laser maintenance schedule.

1. **Pulse energy check.** Record the pulse energy of the N_2 laser and the dye lasers using the centroid value from an MCA (either a local MCA

or the SNO data stream output for the beam monitor channels). If available use a laser energy monitor with a fibre optic plugged into the ST output connector.

2. **Dye Solvent Check.** Inspect the level of the dye solutions in each of the dye cuvettes. If the dye solution is between 3/4 and full is should be topped-up with the correct dye solution. Transfer the dye solution with an eye dropper as described in section 6.2. If the cuvette is less than 3/4 full, or if the dye has run for more than 25 hours then the dye solution should be changed. Thoroughly rinse out the cuvette before refilling with new dye. Clean the outside of the cuvette as described in section 6.2.

   If the dye is topped-up too many times or if the level gets low then the dye concentration will be wrong. Also used dye solutions contain dissociation products which will be inefficient, and may even absorb laser light.

   Check that the magnetic stir rotor is upright within the cuvette and that it spins when the motor is on.

3. **Replace ST coupler grease.** Apply a small amount of optical coupling gell to the male end of the fibre connector and reconnect. Occasionally, when the top cover is removed, disconnect both sides of the fibre connector and try to clean out the old gell. Then reconnect applying new gell.

4. **Check all fans.** Check that the 3 cooling fans are working: the fan on top of the RF shield and the input/output fans. The laser fan on the RF shield is particularly important.

5. **Check optical components.** Check beam quality for all dye laser beams and alignment through all optical components. Inspect optical components and clean as required. The pressurized air cans are useful for removing dust. Follow procedures in section 6.3 to tune the dye laser beams.

6. **Check N_2 beam alignment at dye laser.** For each dye laser check that the control computer positions the beam steering mirror at the

correct position. The focused beam line should be centred on the quartz cuvette.

To make adjustments use the DYELASER FORWARD (or BACKWARD) command (argument in cm) to move the mirror carriage. When finished use the DYELASER CALCELL command to update the position database. Finally move the mirror to a different position and then back again to check the position accuracy.

7. **Check for N_2 gas leaks and recalibrate transducers.** With the power off (so you can hear) turn on the nitrogen gas and inspect all the gas connections and fittings for leaks. Now remove the laser RF shield (section 6.1.3) and close the needle value so that no gas flows. Now the transducers will be at the same pressure (equal to the regulator gauge pressure) since there is no gas flowing. Check the computer readout of the pressure transducers at several different pressures (use the needle valve to bleed off the gas at the laser). The zero-offset and the amplifier gain can be adjusted for the transducers by removing the dye laser table (section 6.1.2) and and adjusting the pot(s) on the analogue part of the E0 and E8 counterboards. Also the scale and zero-offset can be changed in the software by editing the file LOADCELL.DAT.

8. **Check thyratron voltage.** Remove the RF shield (section 6.1.3). With the laser power on and ready (but not triggered) check thyratron test voltage at the test point on the end of the laser cabinet with a volt meter. The voltage should be -6.8V, if out by more than 0.1V then adjust with the pot.

9. **Check/adjust N_2 beam quality.** Using a UV viewing card (photocopy paper works well) inspect the shape and divergence of the N_2 laser beam. To make adjustments remove the RF shield (section 6.1.3), open the laser cabinet cover (section 6.1.4), and adjust the beam following the procedure in section 6.4.3.

10. **Check HV boards, clean laserhead.** After several hundred running hours the N_2 laser may begin to have an irregular beam pulse and not be as intense. Likely the HV transfer boards need cleaning or replacing. Remove the RF shield (section 6.1.3) and open the laser cabinet cover (section 6.1.4). Follow the procedure for removal, disassembly and

inspection of the laserhead (section 6.4.1). Then reassemble and install the head (section 6.4.2) and tune the laser beam (section 6.4.3).

11. **Check HV supply and thyratron.** After 1000 hours or so you might be unable to tune the N_2 laserhead to produce a stable beam. This is because the thyratron is worn out and can no longer switch fast enough.

    To check the high voltage module remove the RF shield (section 6.1.3) and remove the nitrogen laser to an area where it can be run on the bench (section 6.1.4). Remove the black platform in the front of the laser cabinet (the old dye laser platform). You now have room to insert a high voltage probe to the contact under the laserhead between the thyratron and the capacitor (C_s in figure 4). Cover the output apperture of the laser with thick black tape so that no laser light will escape (for safety). Now connect the laser to gas and power and trigger the laser. View the HV probe on an oscilloscope. On each pulse the voltage between the the capacitor and the thyratron should ramp to 15 kV over about 10 ms and hold 15 kV for about 5 ms before the sudden discharge. If the HV holds at 15 kV then the HV module and the capacitor are functioning properly.

    To replace the thyratron, remove the laserhead (section 6.4.1), disconnect the thyratron heater and trigger wires and then remove the cathode bolt. Replace with a hydrogen thyratron model 7782-JAN (Richardson Electronics Ltd.) or equivalent. Replace the laserhead and tune the beam (section 6.4.3).

12. **Install new laserhead and HV boards.** Anytime after 1000 hours the laser may begin irregular firing due to arcing or current leakage through the laser cavity housing. Also the housing maybe fatigued due to high voltage stress and may not be maintaining the charge transfer boards flat against the electrodes. If replacing the charge transfer boards does not improve the laser, and if the thyratron still has less than 500-1000 hours, then it is time to consider replacing the laserhead housing.

    A new housing can be machined according to the drawings in appendix D. Use a hard heat resistent plastic with high electrical breakdown strength (eg. delrin). Start with 1" sheet for the housing and

$\frac{1}{4}$" sheet for the cover. When milling out the housing be aware that plastics tend to warp after a large amount of bulk material has been removed. It is suggested that you mill out the housing to a depth $\frac{1}{16}$" short. Then after other machining, remove the work and allow it to relax for a day before making the final cut. Note that it is critical that the inside surfaces of the housing are flat so that the charge transfer boards make uniform contact with the electrodes.

Reassemble the head (section 6.4.2) and tune the beam (section 6.4.3).

7 Troubleshooting

7.1 Remote Control

When operating the laser from a remote location it is useful to use the N2LASER MONITOR command if you suspect there is a problem. The software client you are using (eg. the DAQMac) may automatically display the information from the monitor command. The monitor command has information about the laser status (eg. off, warmup, ready, running, waiting, problem), power supply status, the nitrogen gas pressure and flow rate, the dye laser selector motor, the attenuator filter wheels position and the dye stiring motors.

Usually if the laser does not appear to be functioning properly in remote mode, then you will need somebody underground to check or run the laser at the local panel. In this subsection there is no mention of a malfunction, as this can be determined only by operation at the local panel. If the laser runs properly from the local panel, and then the power and remote switches are set to remote operation. If then the laser still does not run properly in remote mode then there is likely a problem with the computer interface. This will likely be a problem with the external calibration computer interface cards. However, it could be a fault with the special counterboard EC. If so there is a spare version of the special EC board; use the circuit diagram in this manual (fig 12) to then repair the old board.

Here are some conditions and possible causes and solutions.

- *Laser does not change to warmup status after POWERON command.*
  - The local panel switches have not been set to remote mode.
  - With monitor command check the 12V/40V power, if you do not have 12V/40V power then likely the laser system is not plugged in, or the internal power supply or the 120V relay box is switched off
- *Laser status is running, but there is no evidence of laser light.*
  - With monitor check status of the dye laser mirror carriage and the attenuator wheels. If the dye selector is not at a dye position,

or if the filter wheels are not at a stop position then that is why there is no laser output.

  - The dye selector motor and/or the filter wheel may be 'lost' (ie. they are not where the computer thinks they are). You will have to re-initialize them, use the DYELASER FINDZERO command for the dye selector and the FILTERWHEELA FINDTAB for each of the filter wheels (A and B). Then select a dye laser and the filterwheel positions again. Check if there is output from the laser energy monitor channels to help diagnose the problem.
  - The laser may not have triggered for some reason. Stop the laser and wait two minutes before re-triggering.

- *The laser reports a problem status.*
  - With the monitor command check the gas pressure and flow. If either is low then the software will not allow the laser to run in remote mode. This could be a real situation where the pressure is too low, or it could be that the transducers are reporting bad readings due to gain drift or noise.

- *The dye selector motor and/or filterwheels seem not to be moving.*
  - With the monitor command check the 40V status, it could be switched off or unplugged.
  - The dye selector motor could have been left in local mode.

7.2 Local Control

Remember, if a problem occurs while the laserball is in the SNO detector then you must remove the laserball before opening the laser cover. If the laser is operated with the cover off then this must be noted in the log book.

See the maintenance section for descriptions on how to replace components, and tune-up and align the laser cavities.

- *Laser power will not switch on.* Open the top cover.
  - Check that the internal 5/12/24V supply is switched on.

- Switch 120V relay control to 'override'. If the laser gets power now then the problem is with the 120V relay box or with the 5V logic wire to it. If the laser does not get power then there is a break in 120V cable inside the RF shield or the noise suppressor has shorted.

- *Laser has power, and the ready light comes on, but it will not trigger.*
  - Check if the trigger lockout switch is in the unlock position and the remote/local switch is in the local position.
  - Wait 2 minutes, then retry the trigger. Hold in the start button for 1 second.
  - There might be a problem with the trigger controller. Remove the RF shield. Unplug the remote control connector and insert the connector that connects pins 1 and 2 to allow standalone operation. Use the trigger switch on the laser cabinet. If the laser starts then the trigger board on the front panel is faulty. If the laser does not start then the fault is in the internal trigger circuit - likely the 556 timing chip.

- *The laser triggers but seems very loud and does not produce laser light.*
  - STOP THE LASER NOW. There is no nitrogen flow, check the supply. If the laser was triggering for a while without nitrogen gas then you will likely need to clean and rebuild the laserhead. (Another good reason to run in remote mode!).
  - Laserhead is arcing. Failed charge transfer board or housing (replace).

- *The laser is running but there doesn't seem to be any output.*
  - At the computer check the positions of the dye selector mirror motor and the filter wheel motors. Move them if required.
  - The selector mirror motor and/or the filter wheels could be 'lost' (ie. not where the computer thinks they are). Use the DYELASER FINDZERO and the FILTERWHEELA/B FINDTAB commands, then move to new positions. Check if there is output from the laser energy monitor channels to help diagnose the problem.

- Laserhead is arcing. Failed charge transfer board or housing (replace).
- Dye level is too low.

- *The dye selector motor and/or the filterwheels don't run.*
  - Check the 40V supply.
  - Check the 5V supply to the stepper motor drivers.
  - Try the low level motor commands, if they work then the problem is reading the optical encoder(s). This could be a problem on the counterboards or with the external data concentrator card or the computer interface card.
  - Try running the dye selector motor with the internal switch, if this works then the problem is external – likely with the computer AM9513 timing card or the calibration watchdog timer.

- *The laser is running but there is no output from the event trigger or the energy monitor outputs.*
  - Check the 12/24V power connections to the amplifier boxes.
  - Check beam alignment to the detectors.

- *Pulse weak and energy unstable/irregular.*
  - Laserhead needs tuneup.
  - Arcing or current leakage in charge transfer boards or laserhead housing.
  - Need realignment of laser dye cell.
  - Failed Thyratron (replace).

A LN203C Manual

Laser Photonics, Inc.

LN203C
SEALED NITROGEN/DYE LASER

Operator's Manual

P/N 7011-0034 Rev. X8

November 1991

Fax # 407-380-3479

Laser Photonics, Inc. • 12351 Research Parkway • Orlando, Florida 32826 • (407) 281-4103

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LASER PHOTONICS, INC.
Scientific Product Warranty

LASER PHOTONICS, INC. (LPI), hereinafter, the "Company", warrants to the original purchaser, that the instrument sold hereunder is free from defects in material and workmanship under normal usage for a period of one (1) year from the date of shipment (*see the following page for warranty of consumables*). The Company will replace, at is own expense, all broken or defective parts during the period for which such part is warranted (excluding consumables). Equipment returned to the Company for warranty repair requires prior authorization from Laser Photonics Customer Service. The Company will pay freight charges (ground services only) for all warranty repairs.

Defects or breakage due to negligence, tampering, abuse of the instruments, or intrusion of the instrument by other than Company personnel or their authorized representative shall not be warranted. The Company shall not be liable for consequential or incidental damage caused by normal wear and tear or exposure to contaminated environments. Contamination includes: dust, graphite (from pencils), soot, lint, dew (city water below dew point), tobacco smoke, oils (including fingerprints), condensible vapors, e.g., resin, smoke, outgassing from products generated when the beam strikes partial absorbers such as optic mounts, o-rings, rubber pads ("footprint" surfaces). Please note that "blow off" dust generated at the aperture in an under-coupled or misaligned oscillator can move to contaminate the optics on both sides of the aperture.

The Company strongly recommends that the laser chassis be kept closed. When the top covers must be removed, the laser chassis should be inside a polyethylene clean tent or laminar flow bench. Before opening the beam line, wipe down the laser and table using a lint-free wiper moistened with alcohol. Do no set open containers of liquid (e.g., coffee cups or dye cuvettes) on or in the laser chassis. Where warranty labels/seals exist, authorization from Laser Photonics Customer Service must be obtained prior to breaking the seals. Failure to do so voids the warranty.

The buyer expressly agrees that the instrument has been selected BY THE BUYER as a proper design, size, fitness, and capacity; and the buyer is satisfied that the instrument is suitable and fit for the buyer's purposes.

Consumables

All consumables are warranted for ninety (90) days, except as noted below.

Flashlamps	Thyratrons
Arc Lamps	D.I. Cartridges/Filters
Tubes	

Pulsed YAG Lasers

Flashlamps are warranted free of defects in material or workmanship for 5,000,000 shots or 90 days, whichever comes first. Warranty replacement of flashlamps will be charged on a pro-rated basis based on the number of shots actually fired.

Continuous Wave Solid-State Lasers

Arc lamps are warranted free of defects in material or workmanship for 200 hours or 90 days, whichever comes first.

Sealed Gas Lasers

- Model LN300 Sealed Tube - warranted to be at least 50% of rated power after 100,000,000 shots or one (1) year, whichever comes first.
- CO_2 Sealed Tubes - warranted to be at least 80% of rated power after 2,000 hours or one (1) year, whichever comes first.
- Thyratron (Model LN300) - warranted for ninety (90) days.
- Thyratron (UV Series) - warranted for ninety (90) days.

Deionizer Cartridges/Filters

Deionizer Cartridges are warranted free of defects in materials and workmanship for a period of ninety (90) days.

THIS WARRANTY IS EXPRESSED IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, AND THE COMPANY DISCLAIMS ANY WARRANTY OR MERCHANTABILITY OR OF FITNESS FOR A PARTICULAR ,PURPOSE. NO OTHER OBLIGATIONS OR LIABILITIES ARE ASSUMED BY THE COMPANY.

Prior to the return of a unit, or any portion thereof, the Laser Photonics Service Department must be consulted to avoid unnecessary shipping. If return of the equipment is deemed necessary, a Return Material Authorization (RMA) number will be assigned. This number must be recorded on the outside of the shipping container and on the packing list.

Laser Photonics, Inc.
Customer Service Department
12351 Research Parkway
Orlando, Florida 32826

Telephone:	(407) 281-4103
	(800) 624-3628
Facsimile:	(407) 281-4114 or 380-3479

INTRODUCTION

The LN203C is an ultraviolet wavelength (337.1 nm) nitrogen laser which combines thyratron triggering with high pressure, sub-nanosecond "strip line" operation.

Thyratron triggering delivers pulses of uniform energy at precisely timed intervals. This feature provides accurate synchronization with events occurring on a nanosecond time scale.

The atmospheric pressure (TEA) design greatly simplifies operation and provides high power compared to sub atmospheric units.

The higher power derives from the generation of shorter pulses - subnanosecond vs. nanosecond.

The simplified operation is due, in part, to the absence of any vacuum system components such as pumps, pump exhaust systems, gas manifolds, linkages and connections. The strip line channel design is of the fast charge/fast discharge type. This is essential as its stored energy must be deposited in the channel within a fraction of a nanosecond to produce high power laser pulses.

Command charging provides "on demand" high voltage just before each pulse. This extends component lifetime by reducing average voltage levels. There is also a provision for convenient remote status checks and remote function control.

Each accessory dye laser module is suited to particular requirements:

- The LD1S module provides broad band tuning across the range of visible wavelengths by interchange of dye solutions.
- The LD2S provides narrow band (0,5 - 1.0 mm), continuously lined output from 357-710 nm.

Section I.
SAFETY

OVERVIEW

All persons operating the Laser Photonics, Inc. LN203C Sealed Nitrogen/Dye Laser, and all persons in the vicinity of the laser must be aware of the hazards of laser beams. All personnel should carefully review the safety precautions listed in this chapter before operating the laser.

When recommended safety measures are consistently adopted and practiced, potential-hazards are minimized. Most laser-related accidents and injuries are operator-caused due to inexperience or carelessness.

This section will review some safety considerations, precautions, and warnings related to the use of the Laser Photonics, Inc. LN203C Sealed Nitrogen/Dye Laser system.

SAFETY CONSIDERATION SUMMARY

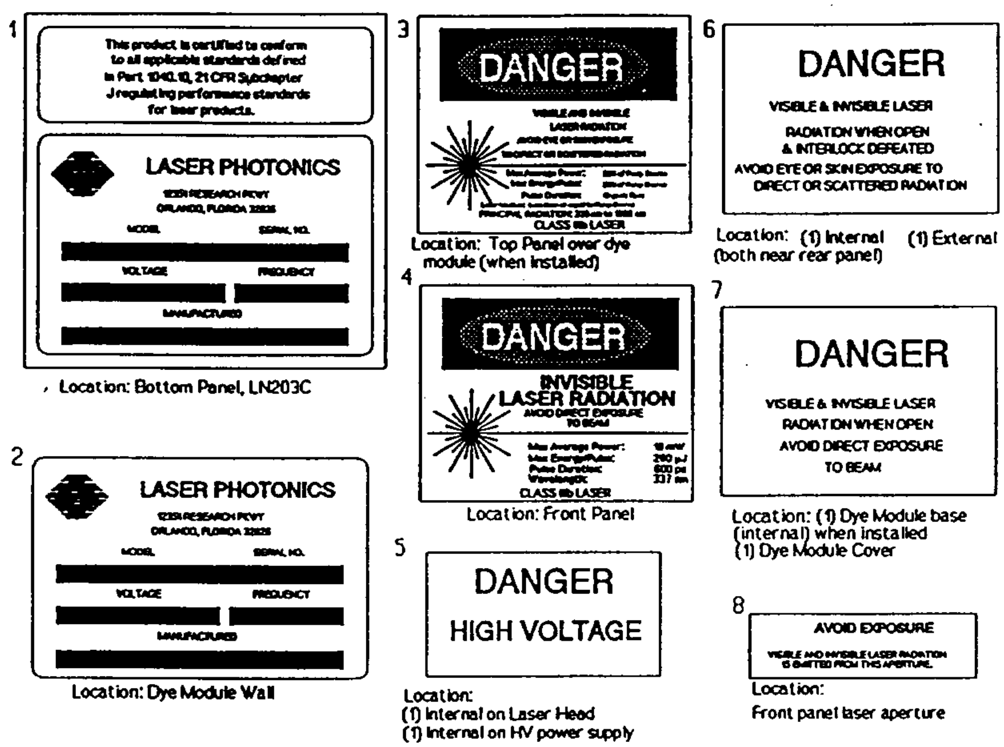
- Only qualified personnel should operate the laser system.
- Equip the work area with a UL approved fire extinguisher in case of equipment or material fire.
- Wear safety glasses or goggles when operating the laser for extended periods of time.*
- Do not look directly into the laser beam.
- Do not expose skin to laser beam for extended periods of time; skin burns could result. Extended exposure may also cause photochemical injury to skin.
- A high voltage safety (cover) interlock is located on the rear panel of the laser. Removal of the top access panel is required only for servicing and will automatically break the interlock. Lethal high voltages and currents exist inside the laser while it is operating. Only qualified service technicians should defeat the safety interlock. Any interlock interruption will required ~~the high~~ the high voltage enable switch to be re-engaged.
- A remote safety interlock connector is located on the rear panel, and requires continuity for the laser to operate. Laser Photonics recommends the use of this interlock in all cases when the possibility of accidental exposure to the beam exists. Ideally, remote continuity is provided to the connector only when all access doors to the laser containment room are closed.
- Read this document, in its entirety, before operating the laser system.

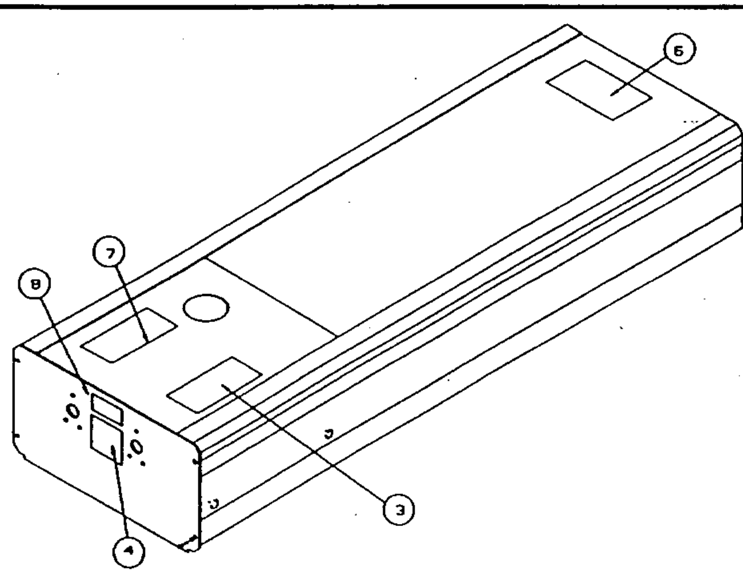
*Consult the *Handbook of Laser Science and Technology (Vol. I.), Section G: Laser Safety* for more information.

LABELS AND SAFETY FEATURES

In compliance with the U.S. Code of Federal Regulations Title 21:21 CFR Subchapter J, Part 1040.10, this laser produce has incoproated the required safety features: keyswitch, mechanical beam shutter, panel lights, remote interlock and cover interlock. In addition, in compliance with the above the following labels have been affixed to this product.

Figure 1-1. Warning Labels/Locations





Section II.
SYSTEM DESCRIPTION

OVERVIEW

The LN203C Nitrogen Laser and Optional Dye laser system specifications are described below. Brief descriptions of nitrogen laser characteristics, dye lasers, overall optical, and system layout are discussed in this section.

SYSTEM SPECIFICATIONS

Item	*Description*		
	LN203C	**LD2S**	**LD1S**
• Spectral Output (nm)	337.1	357-710	357-950
• Spectral Bandwidth (nm)	0.1	1-3	10-30
• Pulsewidth (ps FWHM)	600	300-500	300-500
• Energy/Pulse (μJ)	100	Dye dependent	dye dependent
• Conversion Efficiency (%)	N/A	15 @ 500 nm	20 @ 500 nm
• Energy/Stability (%) @ 10 hz	3	3	3
• Peak Power (kW)	167		
• Repetition Rate (maximum) (Hz)	50	50	50
• Maximum Average Power (mW)	5	dye dependent	dye dependent
• Beam Dimensions (hor. x ver.) (mm)	5.5 x 3.1	2.5 mm at exit	2.5. mm at exit
• Beam Divergence hor x ver. (mrad) (half-angle)	6.2 x 2.5	2**	2**
• Flow Rate (L/min) @ 10 hz	1.51		
• Trigger In	TTL		
• Trigger Out	TTL		
• Command Jitter (nm)	± 2		
• Input voltage	110 V; 60 Hz		
• Dimensions (in.) L X W X H)	28.5 x 8.5 x 5.25		
• Dimensions (cm) (L X W X H)	71.3 x 21.3 x 13.3		
• Weight (lbs)	20		
• Weight (kg)	9		

** < 1 with CL20.

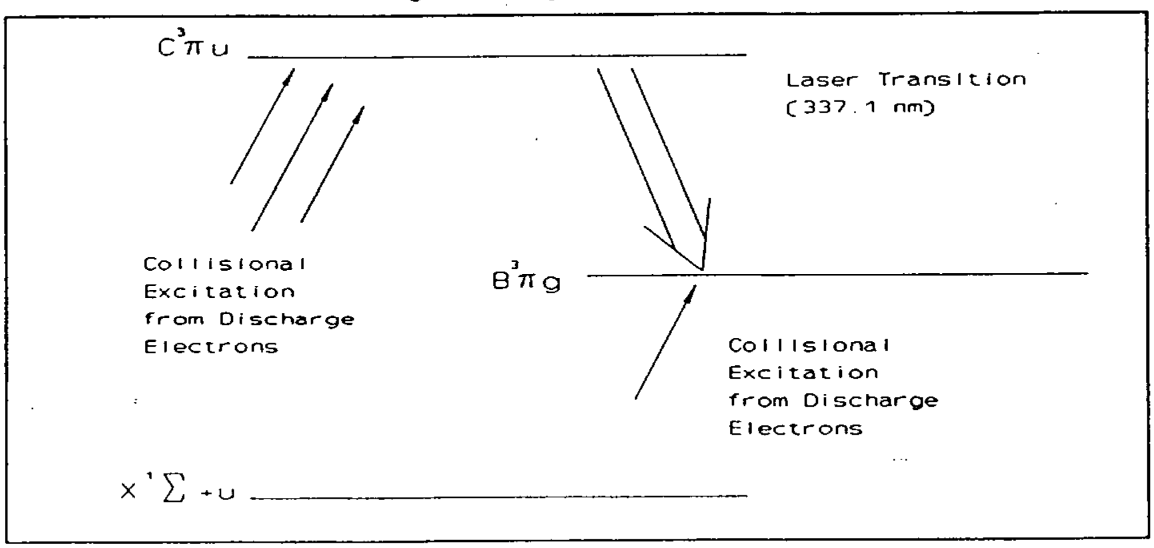
NITROGEN LASERS

Nitrogen lasers are unique, high peak power devices, producing ultraviolet light at 337.1 nm. Although the terminal state of the laser transition is metastable, and the upper level is extremely short-lived, this three-level laser (the third level is the ground state) can exhibit extremely high gain. In fact, the laser is capable of "super radiant" performance, requiring no mirrors. Most nitrogen lasers, however, have mirrors to enhance and direct the super radiant output (*See Figure 2-1. "N_2 Laser Mechanism".*)

The mechanism, which allows the high gain population inversion between the two upper levels ($C^3\pi u$ and $B^3\pi g$) of the N_2 molecule, is the enhanced free electron collisional rate for the $C^3\pi u$ state excitation is comparison to the lower $B^3\pi g$ state excitation. Although the $B^3\pi g$ state is metastable, there can still be gain very early in time, before the lower state is greatly populated. This property of the N_2 molecule is the reason the laser pulses are extremely short (<10ns).

As a result of the short inversion time for the N_2 laser, special high speed electrical circuits are required. The two basic types are the capacitor transfer method and the "Blumlein" method (*see Figure 2-2. "Excitation Circuits for the N_2 Laser"*).

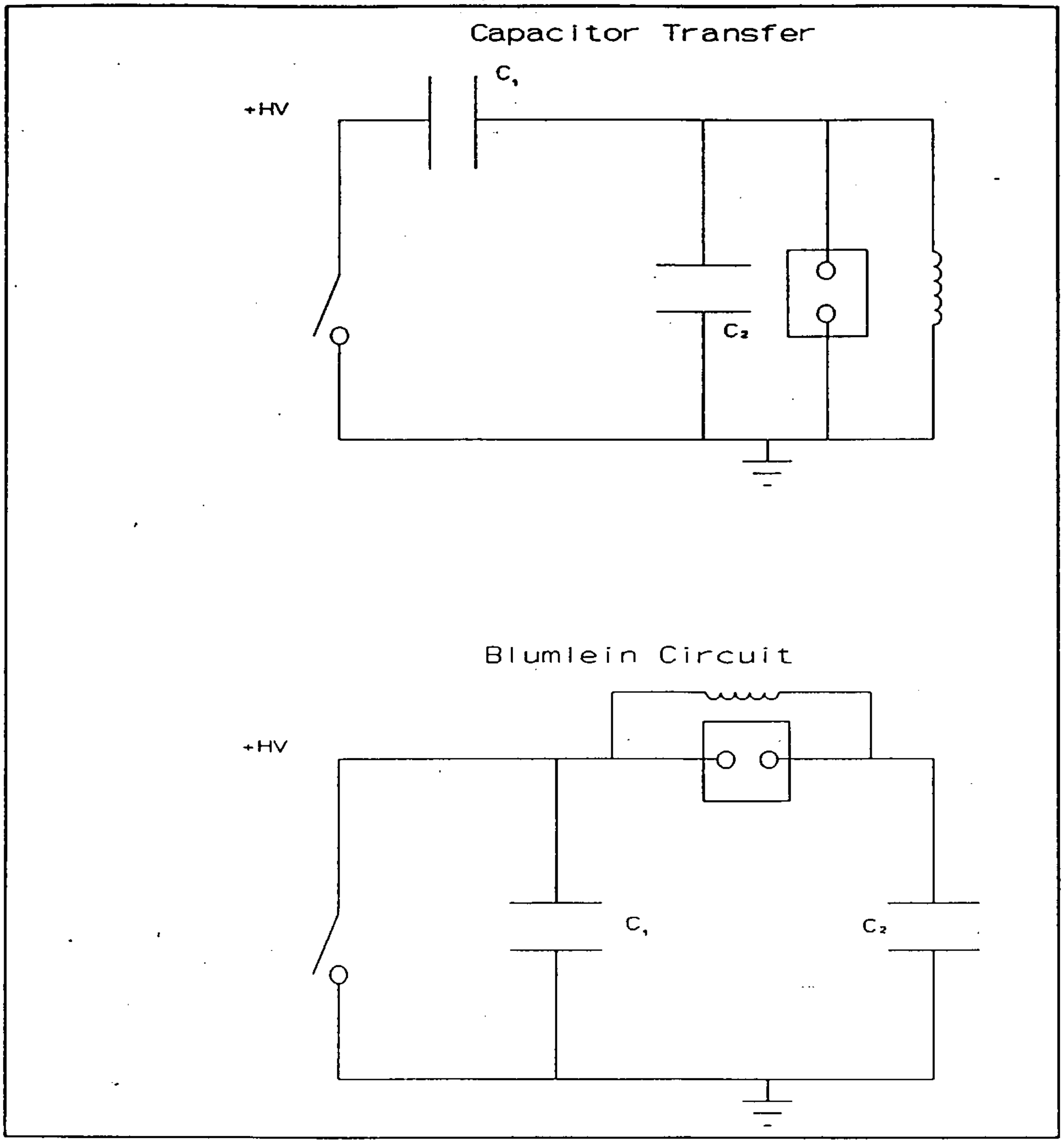
Figure 2-1. N_2 Laser Mechanism



Transfer Method

In the transfer method,the high voltage source charges the main storage capacitor, while the switching element isolates the secondary capacitor and laser channel from the high voltage. When the switch is closed, the charge on C_1 is transferred to C_2. The faster C_2 is charged, the higher the overvoltage reached, before the gas has sufficient time to break down. Both loops must have sufficiently low inductance to transfer the charge quickly. This constraint is especially important for the secondary loop since C_2 is the main contributor of energy to the laser channel. Typically, this type of circuit can product pulse durations of 5-10 ns. shorter pulses are possible only with careful design.

Figure 2-2. Excitation Circuits for the N_2 Laser



Blumlein Method

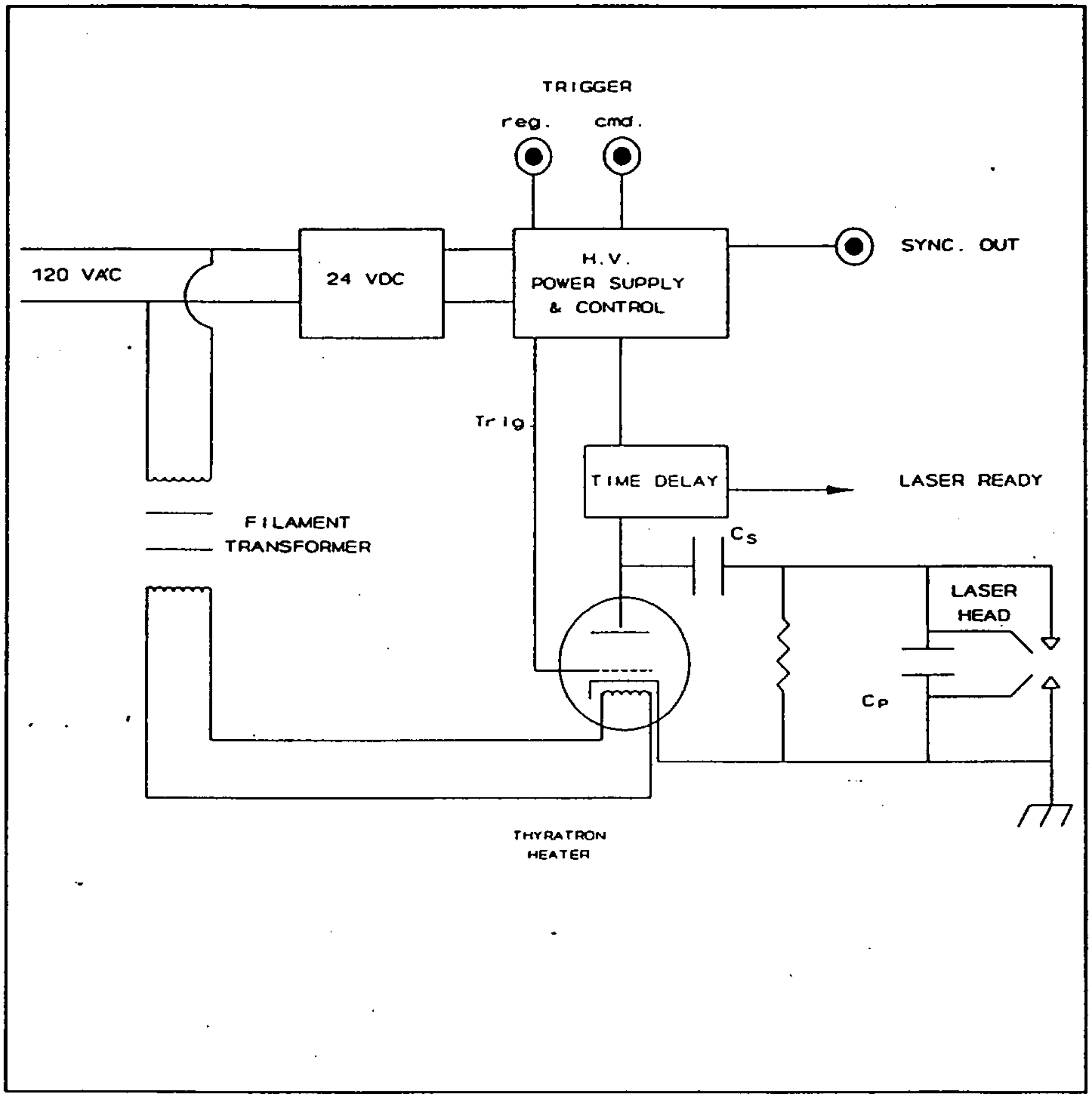
In the Blumlein method, both capacitors C_1 and C_2 are initially charged in parallel to the applied high voltage potential, while the laser channel electrodes are effectively shorted by an inductive lead. When the switch is triggered, the capacitor C_1 is rapidly shorted through the switch. Because of the inherent inductance in the loop, damped oscillation occurs such that voltage reversal occurs on C_1 and C_2. This equivalent potential can be nearly twice the applied potential. The Blumlein method can produce pulses typically from 1-5 ns.

In general, the Blumlein method is well-suited to Transverse Electric Atmospheric (TEA) N_2 lasers, since the gain for these lasers can be only sustained for about 1 ns. In comparison, the capacitor transfer method is sufficiently fast for sub-atmospheric N_2 laser, for which gain can typically be sustained for up to 10 ns. With special (strip-line) design considerations, the transfer method can also be applied to TEA N_2 lasers, such as the LN203C. The transfer technique has the further advantage of increased reliability since the laser channel and secondary capacitors do not have to be maintained statically at a increased high voltage potential.

Major Components

A system layout for the LN203C is shown below (*see Figure 2-3. "LN203C System Layout"*). The major components of the laser are the DC power supply - which powers most of the laser, the high voltage module, and control circuitry board, and the laser head which includes tube and capacitors. A filament supply powers the thyratron heater directly from the AC line. The thyratron is the switching element for this capacitor transfer circuit and is triggered by a high voltage signal from the control board.

Figure 2-3. LN203C System Layout



DYE LASERS

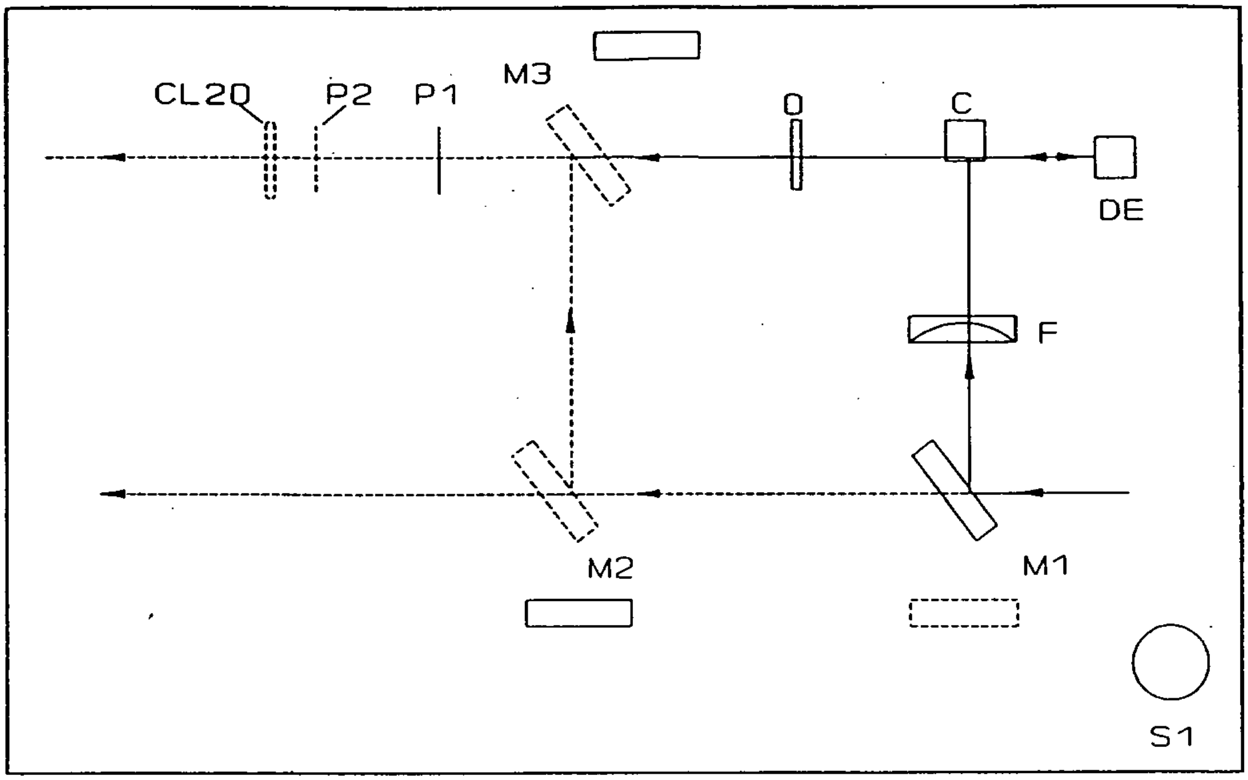
The LN203C consists of a UV nitrogen laser and optional dye laser module combination. The 337.1 nn nitrogen laser is operable, and its beam accessible, with or without a dye module installed. The modules use the nitrogen laser beam as the pump source, and can be installed, removed, or replaced when required.

The nitrogen laser wavelength is fixed, but the modules offer variable wavelengths. The mechanism for this tunability feature is based on the unique emission properties of certain organic liquid dyes when irradiated with an intense UV source such as the LN203C laser. The dye laser emits broadband radiation within the overall gain curve of the dye (LD1S), or radiation spectrally narrowed within the gain curve (LD2S).

Dye Module Components

Component	Description	Function
M1	High Reflectivity Turning Mirror	Turns nitrogen laser beam 90° to pump dye module. Mount is rotatable to allow nitrogen beam throughput.
M2, M3	Beam Steering Mirrors	Steers nitrogen laser beam through dye beam aperture. Allows option for collinear beams.
F	Plano-Cylindrical Lens	Focuses 337.1 nm nitrogen beam into dye cell.
C	Quartz 1 cm Square Dye Cell Cuvette and Agitator.	Contains the laser dye. Tilted to minimize internal feedback. The magnetic stirrer agitates the dye.
DE	Cavity Dispersive Element	Provides spectrally dispersed feedback to the gain medium. LD1S option uses mirror (zero dispersion). LD2S option uses Littrow type grating and sine bar.
O	Cavity Output Coupler	Provides feedback to the gain medium; optically aligned with DE.
P1	Spatial Beam Filter	Improves dye beam quality. Filters out amplified spontaneous emission.
P2 (Optional)	Spatial Beam Filter	As above. Included with CL20 option.
CL (Optional)	Plano Convex ½ diameter collimating lens	Collimates dye beam. Threads into collar located on front panel.
S1	Dye Stirrer Toggle Switch	Powers the magnetic stirrer in the dye cuvette.

Figure 2-4. Dye Module Optical Layout



Section III.
INSTALLATION

OVERVIEW

Instructions given of the following pages of this manual provide safe, step-by-step procedures to be followed in setting up and operating the laser.

PRE-INSTALLATION PROCEDURES

First, remove the laser from the packing case and visually inspect for shipping damage. If no damage is apparent, proceed. Otherwise, contact a Laser Photonics, Inc. representative immediately so that the proper claims may be filed with the shipping agent. Save the packing crates - lasers returned for servicing should be repackaged in these boxes. Shipping damage resulting from improper packaging by the customer will be repaired at the customer's expense.

DYE MODULES INSTALLATION/REMOVAL

The following procedure should be used when installing or removing a module from a Laser Photonics LN203C nitrogen laser/dye laser.

1. Ensure the power line cord is disconnected. Remove the sliding lid and module lid. If a module has not already been installed, the removal of the module lid requires the removal of the top access screw and the stand-off beneath it.

2. The front panel has the two beam apertures. Remove the four screws holding it in place, and set the panel aside.

3. Grasp the aluminum bottom panel and slide out through the exposed front of the laser.

4. Carefully turn the laser on one side so that the bottom of the laser is now exposed. Remove the two screws holding the module to the back side of the laser. Now carefully turn the laser on this front side, and remove the remaining two screws holding the module to the front panel.

5. Reposition the laser (carefully) with the top up.

6. To remove a module, first disconnect the power connector, then grasp the front of the module chassis and slide it out the front.

7. To install a module, insert the module into the side panel grooves (see *Figure 3-1. "Module Installation and Removal"*). Slide the module until the mounting holes match and insert the four screws to secure using the procedure listed in step 4, above. Plug the module power connector into the receptacle provided beneath the LN203C chassis.

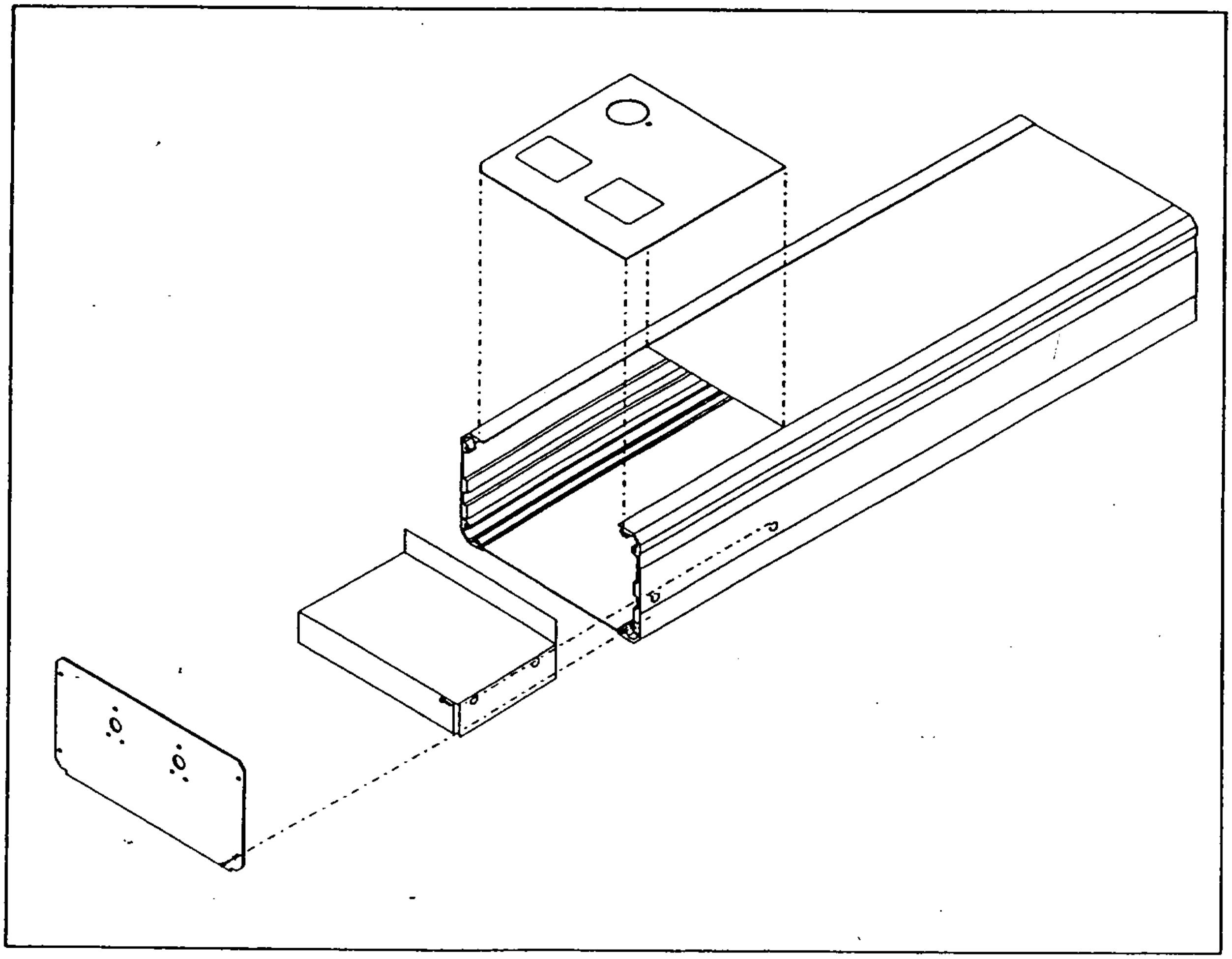
8. Replace the aluminum bottom panel.

9. Replace the front panel and secure with the four screws.

10. If a module has not already been installed.

    a. Turn the dye stirring motor *ON*.
    b. Ensure the main turning mirror, M1, is rotated to the steering position; mirror should self locate automatically when correctly positioned.
    c. Install the new small lid which accompanies the module.
    d. Replace the sliding lid over the nitrogen laser. If friction is severe, loosen the front panel, slide the lid in, and resecure the front panel.

Figure 3-1. Module Installation and Removal



Section IV.
SYSTEM OPERATION

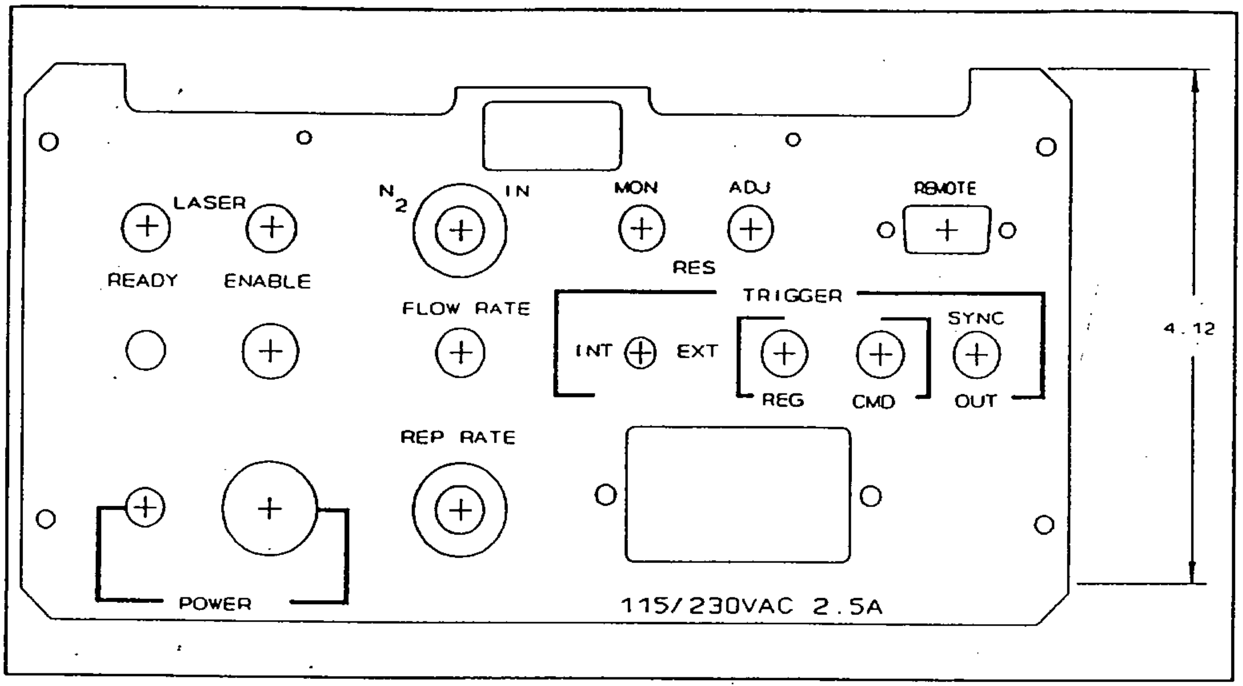
OVERVIEW

It is important that this section is read thoroughly. A clear understanding of the laser operating controls will minimize any initial difficulties when attempting to power the unit. In addition, the operating instructions should be read carefully before turning on the unit for the first time.

CONTROLS FOR OPERATION

All of the controls to operate the laser are conveniently located on the rear panel of the laser (*see Figure 4-1. "Control Panel"*).

Figure 4-1. Control Panel



Control	*Description*
POWER (switch)	This keyswitch provides AC power to the system (but does not energize the laser), activates a five minute delay circuit for the high voltage, and supplies current to the thyratron heater. The key cannot be removed with *POWER ON*.
POWER (LED)	Illuminates when the *POWER* keyswitch is activated to indicate AC power to the system.
VAC RECEPTACLE	Standard IEC "mains" connector. it contains a replaceable fuse and a small voltage selection board that allows 120/240 VAC selection.
LASER READY	Illuminates (green) after the five minute warm-up time, indicating that the laser is ready to be fired.
LASER ENABLE (switch)	To activate firing, the *ENABLE* switch must be raised toward the enable position, and released. This switch will prevent automatic restart due to remote interlock, cover-interlock or main electrical power interruption. The enable switch must be reactivated after any interruption. To terminate lasing, the operator may either depress the *ENABLE* switch or de-energize the entire system via the keyswitch. In the latter case, the delay circuit will be activated upon reenergizing. <u>Always deactivate the switch before making any cable connections to the rear panel.</u> When a dye module is installed, this switch also controls power to the dye stirring motor.
LASER ENABLE (LED)	Illuminates (red) when the laser is enabled. This light indicates laser operation and the presence of high voltage.
TRIGGER IN/EXT	This toggle switch can be set for internal trigger source (generated from the laser circuit) or external trigger source coupling. A special locking device prevents inadvertent switching. The switch lever must be pulled in order to alter its position.

<u>Caution.</u> *Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.*

REP RATE	This potentiometer controls the repetition rate of the laser The internal trigger mode will allow a range of approximately 1-50 Hz, depending on the setting. In *EXTERNAL TRIGGER* mode, this control is disabled.

TRIGGER REG/CMD

When the trigger source is in the ***EXTERNAL*** position, the BNC trigger input (co-axial cable connector) can be either regular (***REG***) mode or command (***CMD***) mode.

REG

In regular mode, a positive TTL type input signal (5V) will fire the laser on the rising edge of the input pulse. In this mode, the laser high voltage is continuously applied to the laser head components, allowing the laser to fire immediately upon triggering (a 750 ns delay). This mode is most useful for synchronization.

CMD

In this mode, the laser high voltage is not activated until a "rising edge" 5 volts signal appears at the connector. The laser is configured to fire on the "falling edge" of the signal. (A 30 ms wide pulse is required for achieving fully charge.) This mode should be used when synchronization with another device is not required but external triggering is required, (i.e., very low repetition rates). In contrast to regular mode, command mode minimizes the time that static high voltage is held on the laser head, thus improving long term reliability of the head components (thyratron, capacitors, etc).

TRIGGER SYNC OUT

Outputs a TTL type signal approximately 250 ns before the laser optical pulse is emitted.

REMOTE

This multi-pin connector input allows remote interlock control, as well as remote status check and remote high voltage enable. If the connection between pins 1 and 2 is interrupted, the high voltage will be automatically disabled, and re-enabling is required to re-activate the laser. This is the normal interlock feature. In addition, pins 3 and 5 can be monitored and controlled with a remote auxiliary circuit. Referring to *Figure 4-2. "Remote Operation Schematic"*, only a few components are required to remotely monitor or enable the laser.

RES MON

This jack is intended as a convenience for maintenance. The monitor voltage corresponds to the thyratron reservoir voltage and can be measured with a standard DVM.

☞ WARNING! DO NOT MEASURE THE RESERVOIR VOLTAGE WHEN THE LASER IS OPERATING OR METER DAMAGE MAY OCCUR.

The reservoir voltage setting at the time of factory testing is documented on the test sheet.

RES ADJ

This control permits adjustment of the reservoir voltage for the thyratron and is mainly intended as a convenience for maintenance. A locking device is normally used on the control to ensure the reservoir voltage is not altered inadvertently.

N_2 IN

This is the inlet port for connecting the nitrogen gas. Laser Photonics recommends a purity of 99.995%. Always ensure the hose fitting is tight.

FLOW RATE

Located below the N_2 in gas port, this needle (metering) valve allows fine adjustment of the gas flow rate to the laser head. Each repetition rate requires an adjustment in the flow rate for optimum performance. Flow rate can be best optimized if the laser energy is monitored at the same time.

Table 4-1.

FLOW CHART		
Repetition Rate	Approximate Flow Rate SCFH (LPM)	LPM
1	1	0.47
5	2	0.94
10	2.5	1.18
20	4	1.88
30	5	2.35
40	6	2.82
50	7.5	3.53

COVER INTERLOCK

A cover interlock switch is located between the top panel and the rear control panel. In the event the top panel is removed for servicing, the cover interlock will be disrupted, thus disabling the laser.

BEAM SHUTTER

A push-pull aperture shutter is located on the beam exit aperture panel, i.e., the panel located at the opposite end of the cabinet from the control panel. Both the dye laser and nitrogen laser apertures are closed by the shutter.

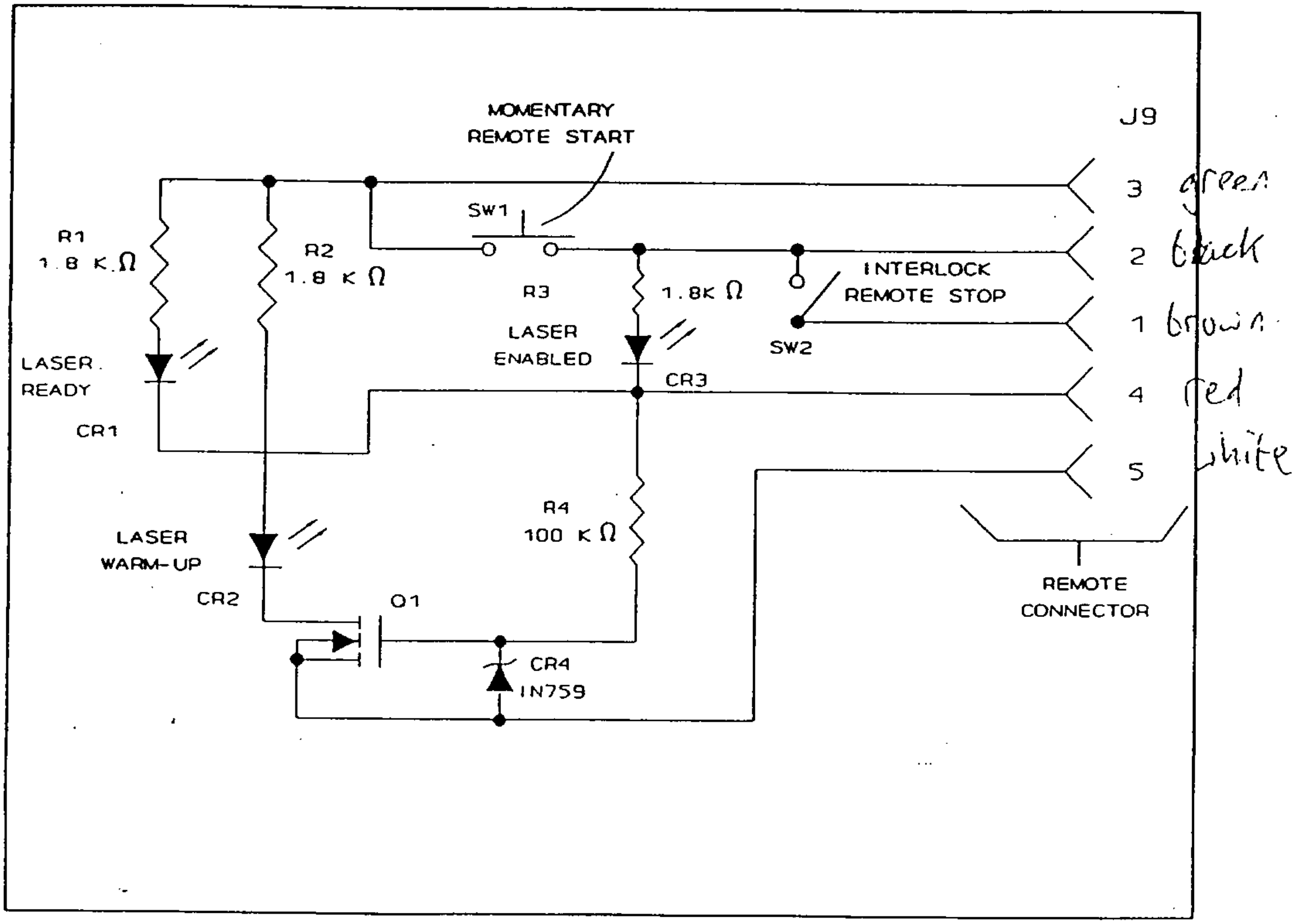
CUVETTE ACCESS PORT

Located near the exit aperture and permits cuvettes to be inserted into, or removed from, the dye laser. During operation, the access port is covered by a movable port cover.

DYE AGITATOR POWER ON

A small toggle switch is located on the base of the dye laser module near the beam input aperture. When in the ***ON*** position, the dye stirrer motor is activated. If only the nitrogen laser beam is required, it is advisable to switch the motor ***OFF***.

Figure 4-2. Remote Operation Schematic



OPERATING INSTRUCTIONS

General

- Position the laser on a stable platform. Position the output aperture in the desired direction and use safeguards to ensure that the laser beam cannot directly contact any personnel. Ensure that the beam aperture is closed.
- Connect the AC line cord between the laser and the wall plug.
- Connect a regulated gas line to the ***N_2 IN*** port at the back of the laser. Set the pressure to 80-90 psi (550 KPA), or if a flow meter is available, consult the flow chart in "*Controls for Operation*" on page 4-1. A lower inlet pressure can normally be used if the laser is to be operated at the repetition rates lower than 50 Hz. Keep the gas tank valve closed until the laser is to be operated.
- Insert the key into the keyswitch.
- Plug the remote interlock connector into the remove receptacle, and ensure continuity.
- Turn the key switch to the right and energize the laser. The power light will illuminate.
- Wait approximately five minutes until the green ***READY*** light is illuminated and check that the turning mirrors of the dye module do not intercept the nitrogen beam. This would prevent beam exit from the cabinet.
- Open the gas tank valve and adjust the gas flow needle valve according to the flow chart.
- Turn the ***TRIGGER TOGGLE*** switch to the ***INTERNAL*** position.
- Adjust the ***REP RATE*** control to the desired position. (Repetition rate may be monitored from the ***SYNC OUT BNC*** connector.)
- Raise the ***ENABLE*** toggle switch toward the ***LASER ENABLE*** label. The laser will begin firing.
- Open the beam aperture when ready and view the effect on a fluorescent card placed a few centimeters from the aperture.

☞ WARNING! DO NOT LOOK INTO THE FRONT APERTURE OF THE LASER HEAD UNDER ANY CIRCUMSTANCES!

Dye Laser Module Operating Instructions

To initiate lasing activity within the dye laser, please follow these dye laser module operating instructions:

1. Prepare the appropriate dye mix according to the chart on page A-1. Dyes supplied by the factory will normally be pre-measured in 50 cc bottles. Simply add 50 cc of the appropriate solvent into the bottle. Secure the bottle cap and shake vigorously until no solid or crystalline particulates are visible at the bottom of the bottle.

2. Place a clean magnetic stir agitator inside a 1 cm x 1 cm square quartz cuvette. Using an eye dropper, carefully fill the cuvette (dye cell) to just below the top. Secure the plastic cap tightly. If required, shake the cell until the agitator is positioned with the flat side on the bottom.

3. Ensure all sides of the dye cell are clean, preferably polished with lens tissue.

4. After checking the nitrogen laser is operating satisfactorily, disable the high voltage.

5. Slide the dye cuvette access port cover open.

6. Insert the dye cuvette into the port, and push down until it is secured. Slide the dye cuvette access port to the closed position.

7. Set the repetition rate for 10 Hz or less.

8. Open the beam shutter and place a white card or screen in front of the laser beam path. Exercise due caution (*see Section I. "Safety"*).

9. Enable the high voltage.

10. Adjust the repetition rate appropriately.

Note: Periodically, the dye module top panel may need to be removed (e.g., for cleaning, etc.). Laser Photonics, Inc. strongly recommends the laser be de-activated (high voltage disabled) before removing the top panel. Since there is a risk of exposure to scattered radiation from the pump beam inside the module, <u>only qualified service personnel should operate the laser with the top panel removed</u>.

Tuning

LD1S Module

Output wavelength is tuned by changing dye types. Each type will provide a broadband output centered about the labelled dye wavelength number. Refer to the tuning curves of the LD2S as a guide for wavelength emission characteristics.

LD2S Module

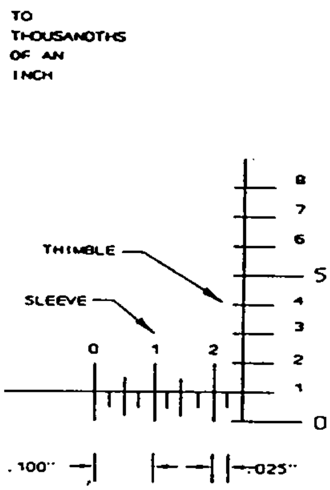
Output wavelength is indicated by the inch micrometer setting. The wavelength in nanometers corresponds to the number of thousandths of an inch displayed on the micrometer. Please consult the following, "*How to Read Inch Micrometers*". The tuning characteristics are shown on the specification sheets.

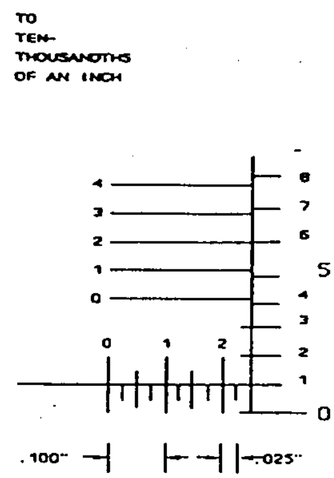
Precautions

Always ensure dye cell surfaces are clean. Never touch the sides of the cell. If necessary, isopropyl alcohol or an equivalent solvent should be used for cleaning.

☞ WARNING! ADJUSTMENTS TO DYE MODULES AS DETAILED IN SECTION V. MAY INVOLVE EXPOSURE TO IIIb RADIATION. THESE SERVICE ADJUSTMENTS, IF NECESSARY, ARE TO BE PERFORMED BY QUALIFIED PERSONNEL ONLY!

*HOW TO READ INCH MICROMETERS***





SLEEVE: The micrometer sleeve is divided into forty equal parts. Each part or division is indicated by a vertical line. Each vertical line represents one-fortieth of an inch or .025", and, each fourth line is marked by a longer line and a number which designates one hundred-thousandths.

More simple, the line marked "1" represents .100", the line marked "2" represents .200" and so forth.

THIMBLE: The thimble is divided into twenty-five equal parts, and, one complete rotation of the thimble coincides with the smallest division on the sleeve. Thus, the division on the thimble is one-twenty-fifth of .025" or .001".

READING EXAMPLE:

1. *Note that the thimble has stopped at a point beyond "2" on the sleeve indicating .200" (see illustration above.)*
2. *Note that one additional line visible between the graduation numbered "2" and the edge of the thimble, indicating .025".*
3. *Line numbered "1" on the thimble coincides with the center line of the sleeve. It means additional one-thousandth of an inch.*

(1)	Reading on the Sleeve	.200"
(2)	No. of lines between "2" and the edge of the thimble	.025"
(3)	Thimble line corresponding to the centerline of the sleeve	.001"
	TOTAL READING	.226"

To read to one ten-thousandth requires an additional scale called the "Vernier" scale, named after the inventor, Pierre Vernier.

In the case of a regular micrometer, the vernier consists of ten divisions, marked on the sleeve, which are spaced within nine divisions of the thimble scale.

Each division on the vernier, therefore, is one tenth shorter than that of the thimble's, thus representing .0001".

READING EXAMPLE:

1. *Read to the thousandth of an inch in the same manner as shown on the left.*
2. *The vernier on the sleeve reads to one tenth of a thousandth of an inch, or .0001".*
3. *To read the vernier, find which line on the vernier scale coincides with a line on the thimble and read the number off the vernier scale. It is important to note that when finding the vernier (ten-thousandth) reading, the correct figure is ALWAYS taken from the number at the vernier scale and NEVER from the thimble.*
4. *Note that the vernier line numbered "2" coincides exactly with a thimble lin8e indicating .0002".*

(1)	Reading on the Sleeve	.200"
(2)	No. of lines between "2" and the edge of the thimble	.025"
(3)	Thimble has passed .001" line on the Sleeve	.001"
(4)	Vernier line coinciding exactly with a Thimble Line	.0002"
	TOTAL READING	..2262"

***Excerpt from Mitutoyo Measuring Instruments Catalog No. 6000, p. 26.*

Section V.
MAINTENANCE

OVERVIEW

The LN203C nitrogen laser and companion dye laser modules are designed for minimal maintenance. To ensure optimum system performance, only a few simple procedures are recommended.

LN203C

Check pulse energy and thyratron reservoir voltage periodically. Record the readings in a lab book, together with the estimated shot count. A copy of this record should be included with the unit in case it is returned to Laser Photonics for service. The thyratron voltage should not exceed 6.8 volts. The laser channel is aligned at the factory. However, severe temperature changes can slightly alter the alignment. If adjustment is ever required, use the three plastic alignment screws at the rear of the laser channel to re-optimize beam quality and pulse energy. Follow all labeled precautions and warnings when accessing the laser head. Only qualified personnel should access the head. Normally, the unit should be returned to the factory if re-alignment is required.

LD1S, LD2S

Replace the dye solutions frequently for optimum energy and beam quality. Each dye has its own characteristic photochemical properties. Thus, some dye solutions will require more periodic replacement than others. In addition, solvents evaporation will alter the dye concentration. Periodically, check that the dye cuvettes are filled to the top.

Clean the cuvettes frequently. Fingerprint oils are highly absorptive at UV wavelengths, yet cannot be seen easily in visible light.

For the LD2S, check wavelength calibration frequently. Any adjustment of the dye module output coupler can change calibration.

For both modules, visually inspect the condition and orientation of the dye laser; stir agitator periodically. Re-orient the agitator as necessary. The flat side should be on the bottom.

Section VI.
TROUBLESHOOTING

OVERVIEW

This section covers basic troubleshooting of the LN203C. The questions listed below are common problems that can be solved by the operator. This section also includes instructions on how to return parts for both warranty and nonwarranty service.

TROUBLESHOOTING

Problem: ***Power light does not illuminate.***

Action:

- Check that the AC power cord is connected to an active AC socket.
- Ensure that the keyswitch is in the *ON* position.
- Check the fuse.

Problem: ***Laser Enable light does not illuminate***

Action:

- Check that the remote interlock connector is providing continuity.
- If the top cover is removed, ensure that the cover interlock is providing continuity. *Only qualified service personnel should remove access panels.*
- Check that the green *READY* light is illuminated. A five minute time delay from "power on" is required before green light will illuminate.

Problem: ***No laser output.***

Action:

- Check that, in the case of external trigger source selection, a trigger source is provided. Otherwise, maintain internal trigger selection.
- Ensure that the beam aperture is open.
- Check the N_2 gas pressure and flow rate.

SERVICE RETURN INSTRUCTIONS

Warranty

Please obtain prior authorization before returning a product for warranty repair or service. Please call (407) 281-4103 or fax (407) 281-4114 to obtain a return authorization number (RMA).

- A product subject to warranty repair should be returned freight prepaid to:

LASER PHOTONICS, INC. *12351 RESEARCH PARKWAY* *ORLANDO, FL 32826* *RMA # _________*

Note: Please Show RMA number on shipping label and packing list.

- Repack the product carefully using the original shipping carton. Insert a description of the malfunction inside the packing case.

- Please submit a malfunction report with the following information:
  - Buyer's name; company affiliation; date
  - RMA number
  - Return shipping address
  - Telephone number where contact can be made
  - Original purchase date and purchase order number (if known)
  - Laser model and serial number
  - Describe briefly how the laser was used, including the operating environment
  - Describe malfunction

Non Warranty

Follow the instructions listed above for products covered under the warranty.

APPENDICES

- Appendix A - Dye Checklist
- Appendix B - N_2 & Dye Laser Literature References
- Appendix C - 220 V Operation

APPENDIX A. DYE LIST

MODEL #	ORDER #	DYE	MOLECULAR WEIGHT (gm)	CONCENTRATION (M)	SOLVENT	WEIGHT (mg) PER 50 CC	WAVELENGTH (NM) PEAK	RANGE
7A365	P0076-9018	BPBD	354	4.0x10-3	TOLUENE	70.9	365	357-395
7A366	P0076-9026	PBD	298	5.0x10-3	TOULUENE/ETHANOL (50/50)	74.6	366	360-386
7A386	P0076-9034	BBQ	675	2.5x10-3	TOULUENE/ETHANOL (50/50)	84.4	386	373-399
7A400	P0076-9042	PBBO	347	5.0x10-3	TOLUENE/ETHANOL (70/30)	8,7	400	391-411
7A406	P0076-9059	DPS	332	1.2x10-3	P-DIOXANE	19.9	406	396-416
7A421	P0076-9067	BIS-MS13	310	1.2x10-3	P-DIOXANE	18.3	421	411-430
7A425	P0076-9075	S-420	562	1.8x10-3	METHANOL	50.6	425	408-453
7A437	P0076-9083	C-440	175	5.0x10-3	ETHANOL	43.8	437	427-457
7A447	P0076-9091	C-450	217	1.0x10-2	ETHANOL	108.6	446	428-465
7A457	P0076-9109	C-460	231	1.0x10-2	ETHANOL	115.7	457	440-478
7A470	P0076-9117	C-480	255	1.0x10-2	ETHANOL	127.7	470	2453-495
7A481	P0076-9125	C-481	285	2.0x10-2	P-DIOXANE	285.6	481	460-518
7A500	P0076-9133	C-500	257	1.0X10-2	ETHANOL	128.6	500	473-547
7A520	P0076-9141	C-485	257	1.0x10-2	ETHANOL	128.6	520	490-560
7A536	P0076-9158	C-540A	309	1.0x10-2	ETHANOL	154.7	536	515-583
7A579	P0076-9166	R-590	479	5.0x10-3	ETHANOL	119.8	579	568-603
7A609	P0076-9174	R-610	479	5.0x10-3	ETHANOL	119.8	609	594-643
7A644	P0076-9182	R-640	591	5.7x10-3	ETHANOL	168.5	644	620-673
7A660	P0076-9190	CV670/R590	362/479	2.5x10-3/3.3x10-3	ETHANOL	45.3/30.0	660	641-687
7A665	P0076-9299	DCM	303	5.0x10-3	DMSO	75.8	665	655-700
7A696	P0076-9208	NB690/R610	418/479	3.8x10-3/8.0x10-4	ETHANOL	79.4/46.0	696	683-710
7A735	P0076-9257	HIDC	510	5.0x10-3	DMSO	127.5	735	710-775
7A750	P0076-9215	OX725	424	5.0x10-3	DMSO	106.0	750	720-770
7A775	P0076-9224	OX750	470	5.0x10-3	DMSO	117.5	775	760-800
7A800	P0076-9232	DOTC	512	5.0x10-3	DMSO	128.5	800	785-825
7A850	P0076-9240	DTTC	544	5.0x10-3	DMSO	136.0	850	830-870
7A870	P0076-9265	HITC	536	5.0x10-3	DMSO	134.0	870	825-890
7A925	P0076-9273	IR-125	774	5.0x10-3	DMSO	193.5	925	890-945
7A960	P0076-9281	IR-140	779	5.0x10-3	DMSOI	194.8	960	940-990

Appendix B. - N_2 & DYE LASER LITERATURE

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8. "Lasers: Physics, Systems, and Techniques". Ed: W.J. Firther and R.G. Harrison, Published by Scottish Universities Summer School in Physics, 1983 (TA 1673.S38). (Text).

9. "Lasers and Light". Readings from Scientific American, San Francisco, W.H. Freeman (1969) (QC 351.L35).

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Appendix C. 220 V OPERATION

1. Remove the power cord from the laser plug receptacle.

2. Slide the clear plastic fuse cover to the left to expose the fuse.

3. Remove the fuse by using the fuse puller.

4. Remove the printed circuit board located beneath the fuse holder. To do this, firmly grip the printed circuit board at one end with a pair of needle nose pliers and pull. By alternately pulling at either end, the board will eventually become dislodged.

5. Re-insert the board such that the desired voltage level is legible (120 V or 240 V are the only allowable choices. The laser will not function if any other voltage is chosen).

6. Install the fuse and replace the fuse cover.

GLOSSARY:
Terms Used with Laser Systems

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Terms Used with Laser Systems

Term	Description
Ablation	Volume removal of material by vaporization.
Absorption	Uptake of light energy by tissue, converting into heat.
Absorption coefficient	Factor describing light's ability to be absorbed. Optical properties of different material alters the absorption coefficient.
Acetic Acid	CH_3COOH; a clean colorless liquid with a pungent odor miscible with water or alcohol; a component of vinegar.
Acetone	CH_3COOH_3; a colorless, volatile, extremely flammable liquid, miscible with water; used as a solvent and reagent.
Activate	To start activity or motion in a device or material.
Active Medium	(laser Medium) The material used to emit the laser light.
Aiming Beam	A HeNe (or other visible light source) used as a guide light. Used coaxially with infrared or other invisible light.
Align	To adjust the components of a system for proper interrelationship.
Alternating current	AC; electric current that flows in one direction and then in the opposite direction.
Amplifiers	A device which acts upon an incoming signal (input) to increase or amplify it.
Amplitude	The maximum height of a wave. Implies power.
Angstrom (Å)	A unit of length equal to one hundred millionth (10^{-8}) of a centimeter.
Anode	The primary source of positive charges in a laser.
Argon	A gas used as a laser medium. It emits blue/green light at 488 and 515 nm.
Articulated	A configuration in which relative motion is allowed to occur between parts, usually by means of a hinged or sliding joint or joints.
Atom	The basic unit of any chemical element. It is composed of a dense, positively charged nucleus orbited by negatively charged electrons.
Attenuation	The decrease in energy as a beam passes through an absorbing or scattering medium.
Bandpass	A specification which defines the wavelengths which a device will transmit.
Bandwidth	Defines the wavelength range over which a signal exists.
BBO	Beta Barium Borate. A (frequency doubling) crystal which converts an incident range of visible wavelengths to an ultraviolet range at one half the incident wavelengths.
Beam	A concentrated, nearly unidirectional flow of photons, or a like propagation of electromagnetic or acoustic waves.
Beam Diameter	The distance between diametrically opposed points in the cross section of a beam.
Beveled	The angle between one line or surface and another line or surface; a sloping surface or line.

Term	Description
Binoculars	Any optical instrument designed for use with both eyes to provide depth of field focus.
Biostimulation	The use of a low-power (usually milliwatts) laser, to stimulate metabolic activity on a subcellar level; experimentally used for pain relief and wound healing.
Calibrate	To determine the settings of the control devices so that a system will operate or perform within certain limits.
Carbon	C; a nonmetallic chemical element that occurs in many inorganic and in all organic compounds.
Carbon Dioxide	CO_2; A colorless, odorless, tasteless gas about 1.5 times as dense as air.
Cathode	The primary source of negative charges in a laser.
Cautery	Achieving hemostasis of bleeding vessels, usually by heat from laser, or electro-surgical units. Contrasts with laser-induced protein coagulation.
Centimeter	cm; a unit of length equal to 0.01 meter or 0.3937 inch. (1 inch = 2.54 cm).
Chromophore	Optically active (colored) material in tissue which acts as the target for the laser light.
Circuit	A path or group of interconnected paths capable of carrying electric currents.
Circuit Breaker	An electromagnetic device that opens a circuit automatically when the current exceeds a predetermined value.
Coagulation	Destruction of tissue by heat without physically removing it.
Coating (Optical)	A surface additive of an optical component to achieve a desired effect; e.g., an anti-reflective coating to reduce surface reflection.
Coherence	Orderliness of wave patterns by being in phase in time and space.
Coherent Radiation	Radiant electromagnetic energy of the same wavelength and with definite phase relationships between different points in the field.
Collimation	Waves or rays traveling in a nearly parallel direction, with negligible divergence.
Combiner Mirror	The mirror in a laser which combines two or more laser beams of different wavelengths into a coaxial beam, i.e., CO_2 and HeNe beams.
Contact Probe	Synthetic ceramic material, like sapphire, used with laser fibers to allow touch of tissue with the probe, intensifying its effects and allowing cutting, vaporizing, or coagulation if tissue at relatively low powers and high degree of control.
Continuous Wave	Laser beams with a continuous flow of photons.
Cornea	The transparent anterior portion of the outer coat of the eye covering the iris and pupil.
CW	Continuous Wave
Debris	Fragments arising from disintegration.
DHE	Dihematoporphyrin Ether. A photosensitizing agent used in photodynamic therapy (PDT). DHE is a more refined form of HpD.
Dichroic Filter	Filter that allows selective transmission of colors

Term	Description
Diffraction	The bending of a light beam as it passes near an object.
Diffuse	To transmit and scatter light particles through a translucent material.
Diopter	An optical instrument that allows field of view adjustment.
Direct Current	DC; electric current which flows in one direction only.
Distal	Located away from the point of origin or attachment.
Distortion	To change from the original or usually shape or character of signals or objects.
Divergence	The amount of spread of a laser beam with distance travelled, usually measured in milliradians.
Dosimetry	Measuring the amount (joules) of light energy delivered to tissue.
Doubling Crystal	An optical crystal which generates radiation at a wavelength of one-half of that of the incident radiation.
Dovetail	A horizontal and/or vertical mounting bracket on a microscope to accommodate accessories.
Electricity	Physical phenomenon involving electric charges and their effects when at rest and when in motion.
Electromagnetic Radiation	The flow of energy consisting of orthagonally vibrating electric and magnetic fields lying transverse to the direction of propagations.
Electromagnetic Spectrum	The span of frequencies (wavelengths) considered to be light from radio & t.v. waves to gamma and cosmic rays.
Electron	Negatively charged particle of an atom.
Emission enable	Any radiation of energy by means of electromagnetic waves. To allow an activity which would otherwise be suppressed.
Endoscope	An instrument inserted into the body through an orifice (either therapeutic or surgical) that allows viewing and manipulation of tissue. May be rigid or flexible.
Energy	Potential forces, capacity for vigorous action expressed in Joules (watts/second).
ENT Surgery (ears, nose and throat)	Surgery performed in the ears, nose and throat area including laryngeal papillomatosis, polyps, nodules, polyposis, hemangioma, hyperkeratosis, cordal lesions, cordectomy, repair of stenosis and webs, excision of benign lesions, excision of malignant lesions of oral cavity, and dermatological, intranasal and major head and neck surgery.
Excimer	"Excited Dimer." A gas mixture used as the basis of lasers emitting ultraviolet light.
Excitation	The state of increased internal energy of an atom or molecule gained when an electron assumes a large orbit after the absorption of light energy.
Excited State	The state of an atom or molecule after the absorption of energy.
Excited State Lifetime	The length of time during which an excited state exists.
Extinction Length	The thickness of a substance in which 98% of the incident energy is absorbed.
Femtosecond	10^{-15} second. Shorter than a picosecond or a nanosecond.

Term	Description
Fiberoptics	A system of flexible quartz or glass fibers with internal reflective surfaces that pass light through thousands of glancing reflections. Many hundred or thousands of individual fibers are needed to transmit an image, but only single fibers are used to transmit laser light during treatment.
Field of View	The area which can be viewed through an optical instrument.
Filter	That which passes as output a portion of the input; as of an optical or electrical signal; a discriminator.
Fine Focus	The most precise ability to move an optical lens toward or away from an object to obtain the sharpest possible image of the object.
Fixed	Firmly in position; unmovable.
Fluorescence	The process by which an atom or molecule on decaying from an excited state emits light energy. Also known as spontaneous emission.
Focal Length	The distance from the focal point of a lens or curved mirror to the lens or mirror surface.
Focal Point	The point to which rays that are initially parallel to the axis of a lens, mirror, or other optical system are converged or appear to diverge.
Focus	The point or small region at which rays converge or appear to diverge; to move an optical lens toward or away from an object to obtain the sharpest possible image of the object.
Frequency	The rate of occurrence of an event; the symbol, f; units per second or Hertz (*see "Wave Equation"*).
Frequency Doubling	The action of doubling the frequency of a signal (halving the wavelength).
Fuse	An expandable device for opening an electric circuit when the current therein becomes excessive.
Gated Pulse	A discontinuous burst of laser light, made by timing (gating) a continuous wave output - usually in fractions of a second.
Gaussian Curve	Normal Statiscal curve showing a peak with even distribution on both sides. May either be a sharp peak with steep sides, or a blunt peak with shallower sides. Used to show power distribution in a beam. The concept is important in controlling the geometry of the laser impact.
Grating	An optical device consisting of a number of closely space grooves or lines which has the ability to break up or resolve in incident light beam into its constituent
Gross Focus	The first of two focusing systems that moves an optical lens toward or away from an object to obtain the sharpest possible image of the object.
Ground	A conducting path between an electric circuit or equipment and the earth, or some conducting body serving in place of the earth.
Ground State	The energy state to which an atom or molecule returns an excited state and in which it is most often found.
Harmonic Generation	The production of signals at frequencies which are multiples of the frequency of an original signal (*see "Frequency Doubling"*).

Term	Description
Helium	He; a colorless, odorless, tasteless, inert gaseous element used in laser media.
Hemostasis	The arrest of a flow of blood; the stopping or slowing of circulation.
HeNe	Helium Neon. A laser-producing, low-power (milliwatts). Used as a guide light for infrared lasers, or experimentally for biostimulation.
Hertz	Hz; unit of frequency; also know as cycles per second.
Hologram	A three-dimensional picture made by interference patterns created by the coherence of laser light. Created as transmission, reflection or integral holograms.
Horizontal	Being in a plane perpendicular to the gravitational field, that is, perpendicular to a plumb line, at a given point on the earth's surface.
HpD	Hematoporphyrin Derivative. A photosensitizing drug used with photodynamic therapy as a treatment for cancer.
Illumination	The density of lighting on a surface.
Impact Size	The size crater or width of incision left by a laser impact. Related to spot size of the beam, except impact size varies depending on how the energy is applied.
Infrared	*See "Spectrum".*
Infrared Radiation	Electromagnetic radiation with a wavelength that lies in the range of 0.7 microns to 1 micrometer.
Intensity	The strength of amount of a quantity; the power transmitted by a light wave across a unit area perpendicular to the wave.
Intermittent	Stopping and starting at intervals.
Ionizing Radiation	Radiation commonly associated with X-Ray, that is of a high energy enough to cause DNA damage with no direct, immediate thermal effect. Contrasts with non-ionizing radiation of surgical lasers.
IR	Infrared (*see "Spectrum"*).
Irradiance	See Power Density.
Jitter	The uncertainty of a specification during operation of timing signals.
Joule	A unit of energy. Laser powers are sometimes described in joules per second. A power of one (1) per second is known as one (1) watt as is the rate of energy delivery.
Joystick	A device for moving the CO_2 and Helium Neon laser beams with a microscopic beam delivery attachment.
KTP	Potassium Titanyl Phosphate. A crystal used to change the wavelength of a Nd:YAG laser from 1060 nm (infrared) to 532 nm (green).
Laser	A light source which produces narrow, directional, intense and monochromatic ("pure color") beams. Light amplification by the stimulated emission of radiation.
Laser Energy Source	The mechanism - either heat, chemical, electrical or laser radiation— which initiates and supports lasing action.

Term	Description
Laser Head	**The laser medium, together with mechanical supports, optical components and electrical connections from which laser radiation is emitted.**
Laser Medium	**(Active Medium) material used to emit the laser light and for which the laser is named.**
Laser Plume	**Smoke, vapor, and airborne particles that are the by-products of CO_2 laser vaporization.**
Laser Pump	**See laser energy source.**
Lens	**A curved piece of ground and polished or molded material, usually glass, used for the refraction of light.**
Light	**Electromagnetic radiation with wavelengths capable of causing the sensation of vision.**
Loupes (magnifying)	**Small magnifying glasses set in eye pieces.**
Magnification	**A measure of the effectiveness of an optical system in enlarging or reducing an image.**
Metal Vapor Lasers	**A class of lasers using vaporized metal as the laser medium, such as the copper vapor emitting yellow light at 578 nm and gold vapor emitting red light at 630 nm. These are usually high frequency pulsed systems.**
Metastable state	The state of an atom, just below a higher excited state, which an electron occupies momentarily before destabilizing and emitting light.
Meter	The fundamental unit of length (equivalent to 39.37 inches) in the metric system; a device designed to measure, indicate, record, or regulate power, etc.
Methanol	CH_3OH; a colorless, toxic, flammable liquid miscible with water either, and alcohol.
Micromanipulator	Device attached to a microscope that controls delivery of the laser beam into the microscopic field of view. In non-ophthalmic surgery are most commonly used with CO_2 lasers, then with Argon & KTP, and least with Nd:YAG lasers.
Micrometer	(μm) Limit of
Microprocessor	A digital chip (computer) that operates and monitors some lasers.
Microscope	An instrument through which minute objects are enlarged by means of a lens or lens system.
Millimeter	(mm); a unit of length equal to one-thousandth of a meter or 0.00394 inch.
Milliradian	A unit of angular measure used to describe beam divergence, one thousandth of a radian.
Minimal Thermal Effect	When CO_2 is absorbed in water and minimizes conductivity of heat.
Mirror	A surface which specularly reflects a large fraction of incident light.
Mode	A term used to describe how the power of a laser beam is distributed within the geometry of the beam. Also used to describe the operating mode of a laser such as continuous or pulsed.

Term	Description
Mode-Locking	A process similar to Q-switching except that the pulses produced are even shorter (about 10^{-12} seconds) and energy in short trains of pulses instead of singularly. It is usually achieved with a dye cell.
Molecule	A group of atoms held together by chemical forces; the smallest unit of matter which can exist by itself and retain all its chemical properties.
Monochromatic	Consisting of electromagnetic radiation having an extremely small range of wavelength; having only one color.
Monochromaticity	The state in which laser waves are the exact same length.
Nanometer	Abbreviated nm–measure of length. One nm equal 10^{-9} meters, and is the usual measure of light wavelength. Visible light ranges from about 400nm in the purple to about 760 nm in the deep red.
Nanosecond	10^{-9} (one billionth) of a second. Longer than a picosecond or a femtosecond, but shorter than a microsecond. Associated with Q-switched ophthalmic Nd:YAG lasers.
National Center for Devices and Radiological Health	Section of U.S. Government Department of Health and Human Services that regulates the laser industry.
Nd:YAG	Neodymium:Yttrium Aluminum Garnet. The crystal used as a laser medium to produce 1064 nm light.
Necrosis	The pathologic death of living tissue.
Neodymium	The rare earth element that is the active element in a Nd:YAG laser.
Neon	Ne; a rare, inert gaseous element occurring in the atmosphere. It is colorless, but glows reddish-orange in an electric discharge.
Nitrogen	N_2; a gaseous, colorless odorless element.
Nonlinear Effect	Not a normal, linear temperature rise induced by laser. Refers to the plasma "spark" and snap created by the Q-switched Nd:YAG laser.
Nuclear	The positively charged core of an item.
Objective	The first lens or lens system through which light passes in an optical system.
Optical Breakdown	Plasma formation by stripping electrons off atoms/molecules. Caused by high laser energy densities and used to create a "spark." Used in ophthalmology with Q-switched or mode-locked Nd:YAG lasers to cut membranes.
Optical Cavity	(Resonator) Space in between the laser mirrors where lasing action occurs.
Optics	Components of an optical instrument designed to assist sight.
Output Coupler	The partially transmissive mirror that allows laser output from the optical cavity.
PDT	Photodynamic Therapy. The use of photosensitizing drugs, activated by certain pure colors of light produced by the laser, to achieve selective tissue destruction. Its current major use is investigational as a selective treatment for cancer.
Phase	Waves are in phase with each other when all the troughs and peaks coincide and are "locked" together. The result is a reinforced wave in increased amplitude (brightness).

Term	Description
Photocoagulation	Tissue coagulation caused by light (laser).
Photodisruption	Creating an acoustical shock wave, through Q-switching or mode-locking, to gently "snap" apart membranes. This is a "cold cutting" technique with laser. Ophthalmologists use the Q-switched Nd:YAG to photodisrupt an opacified posterior capsule secondary to cataract surgery.
Photon	The quantum of electromagnetic energy, generally regarded as a discrete particle having zero rest mass or no electric charge.
Picosecond	10^{-12} seconds. Longer than a femtoseconds but shorter than a nanosecond. Associated with mode-locked ophthalmic Nd:YAG lasers.
Plane	A surface containing any straight line through any two of its points.
Plasm	The fourth state of matter in which electrons have been stripped off the atoms. The extremely high internal temperature expands rapidly, setting up an acoustical shock wave. Usually experienced as a lightning bolt (plasma) and resulting thunderclap (shock wave).
Plasma Shield	The ability of plasma to stop transmission of laser light.
Plastic Surgery and Dermatology	Excision of benign, malignant, and/or highly vascular tumors; operations in highly vascular areas such as scalp or tongue; operations involving infected or necrotic tissue, aesthetic plastic procedures, removal of tattoos, Moh's surgery, vaporization of basal cell carcinoma, condyloma acumulata, and removal of plantar warts.
Pockel's Cell	An electro-optical crystal used to achieve a Q-switch.
Population inversion	A state in which a substance has been energized, or excited, so that more atoms or molecules are in a higher given excited state than in a lower resting state. This is a necessary prerequisite for lasing action.
Power	The rate of energy delivery expressed in watts (joules per second).
Power Density	The strength of intensity of the laser beam; measured in watts/square centimeter; determined by the watts delivered at the tissue site and the spot size of the beam at the tissue surface.
Precise	Exact or sharply defined.
Proximal	Near the point of attachment or origin.
Pulse	A discontinuous burst of laser as opposed to a continuous beam. A true pulse achieves higher peak powers than that attainable in a continuous wave output - usually pulsed in microseconds or shorter. (See also gated pulse.)
Pulse Mode	Operation of a laser when the beam is intermittently on in fractions of a second.
Pulsed	A transient amplification or intensification of a wave characteristic of a system, followed by a return of equilibrium or steady state.
Pumped Medium	The energized laser medium.
Pumping	The process of supplying energy to the laser medium.
Q	Quality factor of resonator (energy storage); the ratio of total stored energy to the energy (removed) per cycle; the number of cycles to energy depletion.

Term	Description
Q-Switching	**Switching the "quality" of a resonator, producing very high peak powers (millions of watts) but for very short bursts (nanoseconds) - frequently achieved with a Pockel's cell. This creates a "sparking" and shock wave effect. (See photodisruptors, plasma, and mode-locking.)**
Quartz	**SiO_2; a colorless, transparent rock-forming mineral with vitreous luster; the most abundant and widespread of all minerals.**
Quartz Fiber	**Beam delivery material for the Nd:YAG laser.**
Radian	**A unit of angular measure which is the ratio of the divergence distance to the travel distance of a light beam.**
Radiation	**The energy transmitted by waves through space or some medium; also known as electromagnetic radiation or radiant energy.**
Radio Frequency	**Any frequency in the range within which radio waves are transmitted.**
Reagent Grade	**Any substance used in a chemical reaction to detect, measure, examine, or produce other substances; a very pure chemical.**
Reflect	**To throw or bend light from a surface.**
Refraction	**The bending of a light beam as it passes from one medium to a different one.**
Repetition Rate (Rep Rate)	The rate of occurrence of a particular event; pulses per second; Hertz.
Resonator	The chamber that allows oscillation of the light waves back and forth at the speed of light.
Rotate	To turn or spin on an axis.
Scientific Notation	A method of numerical comparison and manipulation based on multiples of 10, e.g., $10 \times 10 \times 10 = 1000 = 1 \times 10^3$; and $2500 = 2.5 \times 10^3$
Shutter	A mechanical device that cuts off a beam of light by opening and closing at different rates of speed.
Signal	A specific anticipated, detectable event, e.g., a laser pulse.
Spectral Line	A specific wavelength, usually with a defined line width.
Spectral Range	A defined continuum of wavelengths; e.g., G80 to 720 nm.
Spectral Region	A specific continuum of wavelengths; e.g., the visible 400-760 nm, V1S
Spectrum	The characteristic group of wavelengths radiated by a substance; spectral output; a group of wavelengths with a common basis, e.g., groups or ranges adjacent wavelengths; infrared wavelengths.
Spot Size	The mathematical measurement of a focused laser spot. In a TEMoo beam it is the area that contains 86% of the incident power. This is the "optical" spot size and does not necessarily indicate the size of the laser crater that will be made. The latter is the impact size.
Stability	The consistency over time of a given signal.
Sterilize	To render free from bacteria or other microorganisms.

Term	Description
Stimulated Emission	The process of excited state decay with photon emission induced by the interaction with another like photon.
Superpulse	An operating mode on the CO_2 laser describing a fast pulsing output (250-1000 times per second), with peak powers per pulse higher than the maximum attainable in the continuous wave mode. Average powers of superpulse (speed of tissue removal) are always lower than the maximum in continuous wave.
Switch	A device used to break or open an electrical circuit or to divert current from one conductor to another.
Target Site	Tissue that is aimed or fired at with the laser beam.
TEM	An acronym for T (transverse) E (electromagnetic) M (mode).
Thermal Effect	Impact of heat on tissue or cell matter.
Thermal Necrosis	Death of tissue or cell matter due to thermal impact.
Thermal Relaxation Time	The rate at which a structure can conduct heat. When pulse times of a laser are shorter than the time required for heat to spread out of a target, the heat damage will be confined to that target.
Tunable Dye Laser	A laser using a jet of liquid dye, pumped by another laser or flashlamps, to produce various colors of light. The color of light may be tuned by adjusting optical tuning elements and/or changing the dye used. Common medical applications are with the 630 nm continuous wave red, and the pulsed 577 nm yellow and 504 nm green.
Vertical	At right angles to the horizon; extending perpendicularly from a plane; upright.
Volt	V; the International System unit of the electric potential and electromotive force, equal to the difference of electric potential between two points on a conducting wire carrying a constant current of one ampere when the power dissipated between the points is one watt.
Watt	W; unit of power in the International System equal to one joule per second.
Wave Equation	The equation which relates the wavelength and frequency of wave motion to its speed of propagation. In the case of light waves, $c=f\lambda$; where c, the speed of light, has been measured as (approximately) $3x10^8$ m per second or $3x10^{17}$ nm per second. F, the frequency (number of wave per second); λ, the wavelength. A light source emitting 300 nm wavelength light would, therefore, do so at a frequency of $f \frac{c}{\lambda} = \frac{3x10^{17}}{300} = 1x10^{15}$ *cycles per second*
Wavelength	Distance between two points of corresponding phase in consecutive cycles.
X-Ray	A very short wavelength of light, producing ionization effects commonly associated with radiation hazards. Not a problem with surgical laser units.

B Software Commands

B.1 N_2 Laser Commands

These commands control the functioning of the nitrogen laser.

The N2 laser object is called N2LASER. N2LASER inherits other hardware objects for reading out the pressure transducers and reading the laser status. These objects can be commanded directly but this should never be necessary (see the software documentation).

Here are the N2LASER commands:

Commands for **N2LASER** object	
MONITOR	Status information
POWERON	Turns on the 120V power for the nitrogen laser and the motor power supply for the dye laser and filter wheels operation. On power-up the nitrogen laser begins the warmup cycle. You should check that the nitrogen pressure and flow are correct first using the MONITOR command. Note that this assumes the switch controls on the local panel are in the remote position and that the power connections are in the default configuration, see the N2/Dye laser manual for instructions.
POWEROFF	Switches off the nitrogen laser power and motor power if in remote mode (see above).
START	Commands the trigger controller to start the laser running. There is a 2 minute wait cycle before the laser will trigger, or re-trigger if it was stopped. The laser thyratron must be warmed up before the laser will trigger, although the start command can be entered at any time and it will get executed after the warmup.
STOP	Immediately stops the laser running without powering down the thyratron or high voltage. There is a 2 minute wait cycle before laser will retrigger.
HIPRESSURE	Show the N2 pressure at the local regulator (psi).
LOWPRESSURE	Show the N2 pressure at the laser inlet, after the flow meter. This should not be below 80psi (85-90 psi is normal). The laser will automatically stop if this pressure is below 70psi.
GASFLOW	Show the N2 gas flow calculated from the 2 pressure transducer reading. This has an arbitrary scale but should not get below 30.0 which corresponds to about 1.0 L/min. Laser will stop automatically below 20.0.

B.2 Dye Laser Commands

These commands control the output frequency (wavelength) of the laser by allowing you to select among various dye cells by controlling a mirror on a lead screw carriage.

The dyelaser object is called DYELASER and it inherits a motor and an encoder object which can be controlled directly, but this should never be necessary (see the software documentation).

Here are the DYELASER commands:

Commands for **DYELASER** object	
MONITOR	Status information
INIT <0.0>	Forces selector stepper motor to agree with the encoder readout. This should only be necessary during maintenance or an abnormal power outage. You should probably follow this command with the findzero command as the selector motor is likely lost at this point (unless you used the tostart command).
WAVELENGTH <wl>	Find the closest wavelength dye available and moves to select that dye cell. The wavelength is specified in nm. Use the monitor command to see which cell position and wavelength was selected.
CELL <num>	Moves the selector motor carriage to the position to use the cell number given.
FORWARD <dist>	Move selector motor forward this many centimeters.
BACKWARD <dist>	Move selector motor backward this many centimeters.
TOSTART	Go to the zero mark. If the zero-point limit switch is not encounted at the expected location then the motor will move the selector carriage slowly until it is found. You should use the monitor command to see if it did find the limit switch as expected.
TOEND	Go to end mark (see tostart).
TONEUTRAL	Goes to a location where the laser beam is hitting a black beam stop.
STOP	Stops the motor.
CALCELL <num>	Updates the carriage position database (dyelaser.dat) so that the present carriage position becomes the new position for the cell number given.
FINDZERO	The selector motor runs backwards until it locates the zero-point limit switch. It then initializes the optical encoder. This should only be necessary after an abnormal power outage.

B.3 Filter Wheel Commands

These commands control the output amplitude of the laser by allowing you to insert various density filters into the beam. There are two filter wheels, filterwheela and filterwhellb, each with eight stop (filter) positions. On each wheel one of the positions is a blank (straight through hole) and one of the positions is a beam stop. The other 6x6 positions are listed in the data file dyelaser.dat.

There are two filterwheel objects: FILTERWHEELA (the one nearest to the front) and FILTERWHEELB. They each inherit motor and encoder objects which can be controlled directly, but this should never be necessary (see the software documentation).

Here are the FILTERWHEELA/B commands:

Commands for **FILTERWHEELA/B** object	
MONITOR	Status information
CWD <degrees>	Advance wheel clockwise by degrees.
CCWD <degrees>	Move counter-clockwise by degrees.
CWS <stops>	Advance this number of stop positions.
CCWS <stops>	Counter-clockwise this many stops.
POSITION <num>	Goto this stop-position number.
TOTAB	Goto the zero mark tab stop.
CALTAB	Make the current position the zero-point position. Should not be necessary except during unusual maintenance.
ND <value>	Find and goto the stop-position with a ND filter closest to the value given. You might want to check with the monitor command to see what you got.
STOP	Stop the filter wheel movement.
CALPOSITION <num>	Update the stop-position database (filter.dat) to make the current wheel position the position for the given stop number.
FINDTAB	Find the zero mark tab stop and initialize the encoder. This should only be necessary after an abnormal power outage.
INIT	Initialize, force encoder readout to agree with stepper motor. This should only be necessary during maintenance or after an abnormal power outage. You probably want to use the findtab command next if the filter wheel is confused about it's position.

C Laser Dye MSDS Sheets

MATERIAL SAFETY DATA SHEET

EXCITON, INC.
P.O. Box 31126 Overlook Station
Dayton, Ohio 45437

IR125

Date of Preparation: 03-24-95
Person to contact: Larry Knaak
Telephone number for information: 513-252-2989

SECTION I. IDENTIFICATION

* Product Name: IR 125

* Synonym(s): 2-[7-[1,3-dihydro-1,1-dimethyl-3-(4-sulfobutyl)-2H-benz[e]indol-2-ylidene]-1,3,5-heptatrienyl]-1,1-dimethyl-3-(4-sulfobutyl)-1H-benz[e]indolium hydroxide, inner salt, sodium salt

* Cat No.: 09030

SECTION II. PRODUCT AND COMPONENT HAZARD DATA

COMPONENT(s):	Percent	TLV	CAS Reg. No.
IR 125	~100	N/D	3599-32-4

SECTION III. PHYSICAL DATA

* Appearance and odor: Dark green crystals, no odor
* Melting Point: 235°C decompose
* Vapor Pressure: Nil
* Evaporation Rate (n-butyl acetate=1): Not applicable
* Volatile fraction by Weight: Not applicable
* Specific Gravity (water=1): Not applicable
* Solubility in Water: Very slightly soluble

SECTION IV. FIRE AND EXPLOSION HAZARD DATA

* Flash Point: Not applicable.
* Extinguishing Media: Water spray; Dry chemical; Carbon dioxide.
* Special Fire Fighting Procedures: Wear self-contained breathing apparatus and protective clothing.
* Unusual Fire and Explosion Hazards: Fire or excessive heat may produce hazardous decomposition products.

SECTION V. REACTIVITY DATA

* Stability: Stable.
* Incompatibility: Strong oxidizers.
* Hazardous Decomposition Products: Combustion will produce carbon dioxide and probably carbon monoxide. Oxides of nitrogen and sulfur will also be present.
* Hazardous Polymerization: Will not occur.

SECTION VI. TOXICITY AND HEALTH HAZARD DATA

IR125

A. EXPOSURE LIMITS: Not established.
IARC: Not Listed
NTP: Not Listed

B. EXPOSURE EFFECTS:
Inhalation: Low hazard for usual industrial handling.
Skin: Low hazard for usual industrial handling.
Eye: No specific hazard known. Contact may cause transient irritation.
Ingestion: Expected to be a low ingestion hazard.

C. FIRST AID:
Inhalation: Remove to fresh air.
Skin: Wash after each contact.
Eye: Immediately flush eyes with plenty of water for at least 15 minutes and get medical attention if symptoms are present.
Ingestion: Drink 1-2 glasses of water. Seek medical attention.

SECTION VII. VENTILATION AND PERSONAL PROTECTION

* Ventilation: Good general room ventilation is recommended. Local exhaust may be needed.
* Respiratory Protection: A NIOSH approved dust respirator should be worn, if needed.
* Skin and Eye Protection: Protective gloves should be worn. Safety glasses should be worn.

SECTION VIII. SPECIAL STORAGE AND HANDLING PRECAUTIONS

* Keep from contact with oxidizing materials.

* Handling Precautions: In accordance with good industrial practice, handle with care and avoid unnecessary personal contact. Avoid contact with eyes and prolonged or repeated skin contact. Avoid continuous or repetitive breathing of dust. Use only with adequate ventilation. For laboratory use by technically qualified individual only.

* Shipping and Storing Precautions: Keep container tightly closed when not in use and during transport.

* Personal Hygiene: Wash thoroughly after handling.

SECTION IX. SPILL, LEAK, AND DISPOSAL PROCEDURES

Sweep up material and package for safe feed to an incinerator. Dispose by incineration or contract with licensed chemical waste disposal agency. Follow all federal, state and local laws.

SECTION X. REGULATORY INFORMATION

* Dot Proper Shipping Name: Not regulated as a hazardous material by the U.S. Dept. of Transportation (DOT) 49 CFR 172.101 Hazardous Materials Table.
* Dot Class: None.
* Dot Number: None.
* RCRA Status: Not a hazardous waste under RCRA (40 CFR 261).
* CERCLA Status: Not listed.
* SARA/Title III - Toxic Chemicals List: This product does not contain a toxic chemical for routine annual "Toxic Chemical Release Reporting" [illegible] 313 (40 CFR 372). [illegible] TSCA inventory

MATERIAL SAFETY DATA SHEET

EXCITON, INC.
P.O. Box 31126 Overlook Station
Dayton, Ohio 45431

BBO

Date of Preparation: 01-28-92
Person to contact: Larry Knaak
Telephone number for information: 513-252-2989

SECTION I. IDENTIFICATION

* Product Name: BBO

* Synonym(s): 2,5-bis([1,1'-biphenyl]-4-yl)-oxazole

* Cat No.: 04100

SECTION II. PRODUCT AND COMPONENT HAZARD DATA

COMPONENT(s):	Percent	TLV	CAS Reg. No.
BBO	~100	N/D	2083-09-2

SECTION III. PHYSICAL DATA

* Appearance and odor: White crystalline plates, no odor
* Melting Point: 238-240°C
* Vapor Pressure: Nil
* Evaporation Rate (n-butyl acetate=1): Not applicable
* Volatile fraction by Weight: Not applicable
* Specific Gravity (water=1): Not applicable
* Solubility in Water: Insoluble

SECTION IV. FIRE AND EXPLOSION HAZARD DATA

* Flash Point: Not applicable.
* Extinguishing Media: Water spray; Dry chemical; Carbon dioxide.
* Special Fire Fighting Procedures: Wear self-contained breathing apparatus and protective clothing.
* Unusual Fire and Explosion Hazards: Fire or excessive heat may produce hazardous decomposition products.

SECTION V. REACTIVITY DATA

* Stability: Stable.
* Incompatibility: Strong oxidizers.
* Hazardous Decomposition Products: Combustion will produce carbon dioxide and probably carbon monoxide. Oxides of nitrogen may also be present.
* Hazardous Polymerization: Will not occur.

SECTION VI. TOXICITY AND HEALTH HAZARD DATA

BBO

A. EXPOSURE LIMITS: Not established.
IARC: Not Listed
NTP: Not Listed

B. EXPOSURE EFFECTS:
Inhalation: Low hazard for usual industrial handling.
Skin: Low hazard for usual industrial handling.
Eye: No specific hazard known. Contact may cause transient irritation.
Ingestion: Expected to be a low ingestion hazard.

C. FIRST AID:
Inhalation: Remove to fresh air.
Skin: Wash after each contact.
Eye: Immediately flush eyes with plenty of water for at least 15 minutes and get medical attention if symptoms are present.
Ingestion: Drink 1-2 glasses of water. Seek medical attention.

SECTION VII. VENTILATION AND PERSONAL PROTECTION

* Ventilation: Good general room ventilation is recommended. Local exhaust may be needed.
* Respiratory Protection: A NIOSH approved dust respirator should be worn, if needed.
* Skin and Eye Protection: Protective gloves should be worn. Safety glasses should be worn.

SECTION VIII. SPECIAL STORAGE AND HANDLING PRECAUTIONS

* Keep from contact with oxidizing materials.

* Handling Precautions: In accordance with good industrial practice, handle with care and avoid unnecessary personal contact. Avoid contact with eyes and prolonged or repeated skin contact. Avoid continuous or repetitive breathing of dust. Use only with adequate ventilation. For **laboratory** use by technically qualified individual only.

* Shipping and Storing Precautions: Keep container tightly closed when not in use and during transport.

* Personal Hygiene: Wash thoroughly after handling.

SECTION IX. SPILL, LEAK, AND DISPOSAL PROCEDURES

Sweep up material and package for safe feed to an incinerator. Dispose by incineration or contract with licensed chemical waste disposal agency. Follow all federal, state and local laws.

SECTION X. REGULATORY INFORMATION

* Dot Proper Shipping Name: Not regulated as a hazardous material by the U.S. Dept. of Transportation (DOT) 49 CFR 172.101 Hazardous Materials Table.
* Dot Class: None.
* Dot Number: None.
* RCRA Status: Not a hazardous waste under RCRA (40 CFR 261).
* CERCLA Status: Not listed.
* SARA/Title III - Toxic Chemicals List: This product does not contain a toxic chemical for routine annual "Toxic Chemical Release Reporting" under SEC. 313 (40 CFR 372).
* TSCA Inventory Status: Chemical components not listed on TSCA inventory.

MATERIAL SAFETY DATA SHEET

EXCITON, INC.
P.O. Box 31126 Overlook Station
Dayton, Ohio 45437

BPBD-365

Date of Preparation: 03-24-95
Person to contact: Larry Knaak
Telephone number for information: 513-252-2989

SECTION I. IDENTIFICATION

* Product Name: BPBD-365
* Synonym(s): 2-[1,1'-biphenyl]-4-yl-5-[4-(1,1-dimethylethyl)phenyl]-1,3,4-oxadiazole
* Cat No.: 03650

SECTION II. PRODUCT AND COMPONENT HAZARD DATA

COMPONENT(s):	Percent	TLV	CAS Reg. No.
BPBD-365	~100	N/D	15082-28-7

SECTION III. PHYSICAL DATA

* Appearance and odor: White powder, no significant odor
* Melting Point: 137-138°C
* Vapor Pressure: Nil
* Evaporation Rate (n-butyl acetate=1). Not applicable.
* Volatile fraction by Weight: Not applicable.
* Specific Gravity (water=1): Not applicable.
* Solubility in Water: Insoluble

SECTION IV. FIRE AND EXPLOSION HAZARD DATA

* Flash Point: Not applicable.
* Extinguishing Media: Water spray; Dry chemical; Carbon dioxide.
* Special Fire Fighting Procedures: Wear self-contained breathing apparatus and protective clothing.
* Unusual Fire and Explosion Hazards: Fire or excessive heat may produce hazardous decomposition products.

SECTION V. REACTIVITY DATA

* Stability: Stable.
* Incompatibility: Strong oxidizers.
* Hazardous Decomposition Products: Combustion will produce carbon dioxide and probably carbon monoxide. Oxides of nitrogen may also be present.
* Hazardous Polymerization: Will not occur.

SECTION VI. TOXICITY AND HEALTH HAZARD DATA

BPBD-365

A. EXPOSURE LIMITS: Not established.
   IARC: Not Listed
   NTP: Not Listed

B. EXPOSURE EFFECTS:
   Inhalation: Low hazard for usual industrial handling.
   Skin: Low hazard for usual industrial handling.
   Eye: No specific hazard known. Contact may cause transient irritation.
   Ingestion: Expected to be a low ingestion hazard.

C. FIRST AID:
   Inhalation: Remove to fresh air.
   Skin: Wash after each contact.
   Eye: Immediately flush eyes with plenty of water for at least 15 minutes and get medical attention if symptoms are present.
   Ingestion: Drink 1-2 glasses of water. Seek medical attention.

SECTION VII. VENTILATION AND PERSONAL PROTECTION

* Ventilation: Good general room ventilation is recommended. Local exhaust may be needed.
* Respiratory Protection: A NIOSH approved dust respirator should be worn, if needed.
* Skin and Eye Protection: Protective gloves should be worn. Safety glasses should be worn.

SECTION VIII. SPECIAL STORAGE AND HANDLING PRECAUTIONS

* Keep from contact with oxidizing materials.

* Handling Precautions: In accordance with good industrial practice, handle with care and avoid unnecessary personal contact. Avoid contact with eyes and prolonged or repeated skin contact. Avoid continuous or repetitive breathing of dust. Use only with adequate ventilation. For laboratory use by technically qualified individual only.

* Shipping and Storing Precautions: Keep container tightly closed when not in use and during transport.

* Personal Hygiene: Wash thoroughly after handling.

SECTION IX. SPILL, LEAK, AND DISPOSAL PROCEDURES

Sweep up material and package for safe feed to an incinerator. Dispose by incineration or contract with licensed chemical waste disposal agency. Follow all federal, state and local laws.

SECTION X. REGULATORY INFORMATION

* Dot Proper Shipping Name: Not regulated as a hazardous material by the U.S. Dept. of Transportation (DOT) 49 CFR 172.101 Hazardous Materials Table.
* Dot Class: None.
* Dot Number: None.
* RCRA Status: Not a hazardous waste under RCRA (40 CFR 261).
* CERCLA Status: Not listed.
* SARA/Title III - Toxic Chemicals List: This product does not contain a toxic chemical for routine annual "Toxic Chemical Release Reporting" under SEC. 313 (40 CFR 372).
* TSCA Inventory Status: Chemical components listed on TSCA inventory.

MATERIAL SAFETY DATA SHEET

EXCITON, INC.
P.O. Box 31126 Overlook Station
Dayton, Ohio 45437

C450

Date of Preparation: 03-24-95
Person to contact: Larry Knaak
Telephone number for information: 513-252-2989

SECTION I. IDENTIFICATION

* Product Name: Coumarin 450

* Synonym(s): 7-(ethylamino)-4,6-dimethyl-2*H*,-1-benzopyran-2-one

* Cat No.: 04500

SECTION II. PRODUCT AND COMPONENT HAZARD DATA

COMPONENT(s):	Percent	TLV	CAS Reg. No.
Coumarin 450	~100	N/D	26078-25-1

SECTION III. PHYSICAL DATA

* Appearance and odor: Pale yellow crystalline powder: no significant odor.
* Melting Point: 168°C
* Vapor Pressure: Negligible
* Evaporation Rate (n-butyl acetate=1): Not applicable.
* Volatile fraction by Weight: Not applicable.
* Specific Gravity (water=1): Not applicable.
* Solubility in Water: Slight

SECTION IV. FIRE AND EXPLOSION HAZARD DATA

* Flash Point: Not applicable.
* Extinguishing Media: Water spray; Dry chemical; Carbon dioxide.
* Special Fire Fighting Procedures: Wear self-contained breathing apparatus and protective clothing.
* Unusual Fire and Explosion Hazards: Fire or excessive heat may produce hazardous decomposition products.

SECTION V. REACTIVITY DATA

* Stability: Stable.
* Incompatibility: Strong oxidizers.
* Hazardous Decomposition Products: Combustion will produce carbon dioxide and probably carbon monoxide. Oxides of nitrogen may also be present.
* Hazardous Polymerization: Will not occur.

SECTION VI. TOXICITY AND HEALTH HAZARD DATA

C450

A. EXPOSURE LIMITS: Non-mutagenic (Ames Test)
IARC: Not Listed
NTP: Not Listed

B. EXPOSURE EFFECTS:
Inhalation: Low hazard for usual industrial handling.
Skin: Low hazard for usual industrial handling.
Eye: No specific hazard known. Contact may cause transient irritation.
Ingestion: Expected to be a low ingestion hazard.

C. FIRST AID:
Inhalation: Remove to fresh air.
Skin: Wash after each contact.
Eye: Immediately flush eyes with plenty of water for at least 15 minutes and get medical attention if symptoms are present.
Ingestion: Drink 1-2 glasses of water. Seek medical attention.

SECTION VII. VENTILATION AND PERSONAL PROTECTION

* Ventilation: Good general room ventilation is recommended. Local exhaust may be needed.
* Respiratory Protection: A NIOSH approved dust respirator should be worn, if needed.
* Skin and Eye Protection: Protective gloves should be worn. Safety glasses should be worn.

SECTION VIII. SPECIAL STORAGE AND HANDLING PRECAUTIONS

* Keep from contact with oxidizing materials.

* Handling Precautions: In accordance with good industrial practice, handle with care and avoid unnecessary personal contact. Avoid contact with eyes and prolonged or repeated skin contact. Avoid continuous or repetitive breathing of dust. Use only with adequate ventilation. For **laboratory** use by technically qualified individual only.

* Shipping and Storing Precautions: Keep container tightly closed when not in use and during transport.

* Personal Hygiene: Wash thoroughly after handling.

SECTION IX. SPILL, LEAK, AND DISPOSAL PROCEDURES

Sweep up material and package for safe feed to an incinerator. Dispose by incineration or contract with licensed chemical waste disposal agency. Follow all federal, state and local laws.

SECTION X. REGULATORY INFORMATION

* Dot Proper Shipping Name: Not regulated as a hazardous material by the U.S. Dept. of Transportation (DOT) 49 CFR 172.101 Hazardous Materials Table.
* Dot Class: None.
* Dot Number: None.
* RCRA Status: Not a hazardous waste under RCRA (40 CFR 261).
* CERCLA Status: Not listed.
* SARA/Title III - Toxic Chemicals List: This product does not contain a toxic chemical for routine annual "Toxic Chemical Release Reporting" under SEC. 313 (40 CFR 372).
* TSCA Inventory Status: Chemical components listed on TSCA inventory.

MATERIAL SAFETY DATA SHEET

EXCITON, INC.
P.O. Box 31126 Overlook Station
Dayton, Ohio 45437

DPS

Date of Preparation: 03-24-95
Person to contact: Larry Knaak
Telephone number for information: 513-252-2989

SECTION I. IDENTIFICATION

* Product Name: DPS

* Synonym(s): 4,4''-(1,2-ethenediyl)bis-1,1'-biphenyl

* Cat No.: 04060

SECTION II. PRODUCT AND COMPONENT HAZARD DATA

COMPONENT(s):	Percent	TLV	CAS Reg. No.
DPS	~100	N/D	2039-68-1

SECTION III. PHYSICAL DATA

* Appearance and odor: White crystalline solid, no odor
* Melting Point: 300°C
* Vapor Pressure: Nil
* Evaporation Rate (n-butyl acetate=1): Not applicable
* Volatile fraction by Weight: Not applicable
* Specific Gravity (water=1): Not applicable
* Solubility in Water: Insoluble

SECTION IV. FIRE AND EXPLOSION HAZARD DATA

* Flash Point: Not applicable.
* Extinguishing Media: Water spray; Dry chemical; Carbon dioxide.
* Special Fire Fighting Procedures: Wear self-contained breathing apparatus and protective clothing.
* Unusual Fire and Explosion Hazards: Fire or excessive heat may produce hazardous decomposition products.

SECTION V. REACTIVITY DATA

* Stability: Stable.
* Incompatibility: Strong oxidizers.
* Hazardous Decomposition Products: Combustion will produce carbon dioxide and probably carbon monoxide.
* Hazardous Polymerization: Will not occur.

SECTION VI. TOXICITY AND HEALTH HAZARD DATA

A. EXPOSURE LIMITS: Not established.
IARC: Not Listed
NTP: Not Listed

DPS

B. EXPOSURE EFFECTS:
Inhalation: Low hazard for usual industrial handling.
Skin: Low hazard for usual industrial handling.
Eye: No specific hazard known. Contact may cause transient irritation.
Ingestion: Expected to be a low ingestion hazard.

C. FIRST AID:
Inhalation: Remove to fresh air.
Skin: Wash after each contact.
Eye: Immediately flush eyes with plenty of water for at least 15 minutes and get medical attention if symptoms are present.
Ingestion: Drink 1-2 glasses of water. Seek medical attention.

SECTION VII. VENTILATION AND PERSONAL PROTECTION

* Ventilation: Good general room ventilation is recommended. Local exhaust may be needed.
* Respiratory Protection: A NIOSH approved dust respirator should be worn, if needed.
* Skin and Eye Protection: Protective gloves should be worn. Safety glasses should be worn.

SECTION VIII. SPECIAL STORAGE AND HANDLING PRECAUTIONS

* Keep from contact with oxidizing materials.

* Handling Precautions: In accordance with good industrial practice, handle with care and avoid unnecessary personal contact. Avoid contact with eyes and prolonged or repeated skin contact. Avoid continuous or repetitive breathing of dust. Use only with adequate ventilation. For **laboratory** use by technically qualified individual only.

* Shipping and Storing Precautions: Keep container tightly closed when not in use and during transport.

* Personal Hygiene: Wash thoroughly after handling.

SECTION IX. SPILL, LEAK, AND DISPOSAL PROCEDURES

Sweep up material and package for safe feed to an incinerator. Dispose by incineration or contract with licensed chemical waste disposal agency. Follow all federal, state and local laws.

SECTION X. REGULATORY INFORMATION

* Dot Proper Shipping Name: Not regulated as a hazardous material by the U.S. Dept. of Transportation (DOT) 49 CFR 172.101 Hazardous Materials Table.
* Dot Class: None.
* Dot Number: None.
* RCRA Status: Not a hazardous waste under RCRA (40 CFR 261).
* CERCLA Status: Not listed.
* SARA/Title III - Toxic Chemicals List: This product does not contain a toxic chemical for routine annual "Toxic Chemical Release Reporting" under SEC. 313 (40 CFR 372).
* TSCA Inventory Status: Chemical components not listed on TSCA inventory.

MATERIAL SAFETY DATA SHEET

EXCITON, INC.
P.O. Box 31126 Overlook Station
Dayton, Ohio 45437

Bis-MSB

Date of Preparation: 03-24-95
Person to contact: Larry Knaak
Telephone number for information: 513-252-2989

SECTION I. IDENTIFICATION

* Product Name: Bis-MSB

* Synonym(s): 1,4-bis[2-(2-methylphenyl)ethenyl]-benzene

* Cat No.: 04210

SECTION II. PRODUCT AND COMPONENT HAZARD DATA

COMPONENT(s):	Percent	TLV	CAS Reg. No.
Bis-MSB	~100	N/D	13280-61-0

SECTION III. PHYSICAL DATA

* Appearance and odor: Greenish yellow solid with no odor
* Melting Point: 181-183°C
* Vapor Pressure: Nil
* Evaporation Rate (n-butyl acetate=1): Not applicable
* Volatile fraction by Weight: Not applicable
* Specific Gravity (water=1): Not applicable
* Solubility in Water: Insoluble

SECTION IV. FIRE AND EXPLOSION HAZARD DATA

* Flash Point: Not applicable.
* Extinguishing Media: Water spray; Dry chemical; Carbon dioxide.
* Special Fire Fighting Procedures: Wear self-contained breathing apparatus and protective clothing.
* Unusual Fire and Explosion Hazards: Fire or excessive heat may produce hazardous decomposition products.

SECTION V. REACTIVITY DATA

* Stability: Stable.
* Incompatibility: Strong oxidizers.
* Hazardous Decomposition Products: Combustion will produce carbon dioxide and probably carbon monoxide.
* Hazardous Polymerization: Will not occur.

SECTION VI. TOXICITY AND HEALTH HAZARD DATA

Bis-MSB

A. EXPOSURE LIMITS: Not established.
IARC: Not Listed
NTP: Not Listed

B. EXPOSURE EFFECTS:
Inhalation: Low hazard for usual industrial handling.
Skin: Low hazard for usual industrial handling.
Eye: No specific hazard known. Contact may cause transient irritation.
Ingestion: Expected to be a low ingestion hazard.

C. FIRST AID:
Inhalation: Remove to fresh air.
Skin: Wash after each contact.
Eye: Immediately flush eyes with plenty of water for at least 15 minutes and get medical attention if symptoms are present.
Ingestion: Drink 1-2 glasses of water. Seek medical attention.

SECTION VII. VENTILATION AND PERSONAL PROTECTION

* Ventilation: Good general room ventilation is recommended. Local exhaust may be needed.
* Respiratory Protection: A NIOSH approved dust respirator should be worn, if needed.
* Skin and Eye Protection: Protective gloves should be worn. Safety glasses should be worn.

SECTION VIII. SPECIAL STORAGE AND HANDLING PRECAUTIONS

* Keep from contact with oxidizing materials.

* Handling Precautions: In accordance with good industrial practice, handle with care and avoid unnecessary personal contact. Avoid contact with eyes and prolonged or repeated skin contact. Avoid continuous or repetitive breathing of dust. Use only with adequate ventilation. For laboratory use by technically qualified individual only.

* Shipping and Storing Precautions: Keep container tightly closed when not in use and during transport.

* Personal Hygiene: Wash thoroughly after handling.

SECTION IX. SPILL, LEAK, AND DISPOSAL PROCEDURES

Sweep up material and package for safe feed to an incinerator. Dispose by incineration or contract with licensed chemical waste disposal agency. Follow all federal, state and local laws.

SECTION X. REGULATORY INFORMATION

* Dot Proper Shipping Name: Not regulated as a hazardous material by the U.S. Dept. of Transportation (DOT) 49 CFR 172.101 Hazardous Materials Table.
* Dot Class: None.
* Dot Number: None.
* RCRA Status: Not a hazardous waste under RCRA (40 CFR 261).
* CERCLA Status: Not listed.
* SARA/Title III - Toxic Chemicals List: This product does not contain a toxic chemical for routine annual "Toxic Chemical Release Reporting" under SEC. 313 (40 CFR 372).

MATERIAL SAFETY DATA SHEET

EXCITON, INC.
P.O. Box 31126 Overlook Station
Dayton, Ohio 45437

KR620

Date of Preparation: 03-17-95
Person to contact: Larry Knaak
Telephone number for information: 513-252-2989

SECTION I. IDENTIFICATION

* Product Name: Kiton Red 620

* Synonym(s): N-[6-(diethylamino)-9-(2,4-disulfophenyl)-3H-xanthen-3-ylidene]-N-ethyl-ethanaminium hydroxide, inner salt, sodium salt

* Cat No.: 06200

SECTION II. PRODUCT AND COMPONENT HAZARD DATA

COMPONENT(s):	Percent	TLV	CAS Reg. No.
Kiton Red 620	~100	ND	3520-42-1

SECTION III. PHYSICAL DATA

* Appearance and odor: Dark red powder, no odor.
* Melting Point: Greater than 310^{o}C
* Vapor Pressure: Negligible
* Evaporation Rate (n-butyl acetate=1): Not applicable.
* Volatile fraction by Weight: Not applicable.
* Specific Gravity (water=1): Not applicable.
* Solubility in Water: Soluble

SECTION IV. FIRE AND EXPLOSION HAZARD DATA

* Flash Point: Not applicable.
* Extinguishing Media: Water spray; Dry chemical; Carbon dioxide.
* Special Fire Fighting Procedures: Wear self-contained breathing apparatus and protective clothing.
* Unusual Fire and Explosion Hazards: Fire or excessive heat may produce hazardous decomposition products.

SECTION V. REACTIVITY DATA

* Stability: Stable.
* Incompatibility: Strong oxidizers.
* Hazardous Decomposition Products: Combustion will produce carbon dioxide and probably carbon monoxide. Oxides of nitrogen and sulfur will also be preent.
* Hazardous Polymerization: Will not occur.

SECTION VI. TOXICITY AND HEALTH HAZARD DATA

KR620

A. EXPOSURE LIMITS: Non mutagenic: Ames Test
LD_{50} rat greater than 5,000mg/kg
IARC: Not Listed
NTP: Not Listed

B. EXPOSURE EFFECTS:
Inhalation: Low hazard for usual industrial handling.
Skin: Low hazard for usual industrial handling.
Eye: No specific hazard known. Contact may cause transient irritation.
Ingestion: Expected to be a low ingestion hazard.

C. FIRST AID:
Inhalation: Remove to fresh air.
Skin: Wash after each contact.
Eye: Immediately flush eyes with plenty of water for at least 15 minutes and get medical attention if symptoms are present.
Ingestion: Drink 1-2 glasses of water. Seek medical attention.

SECTION VII. VENTILATION AND PERSONAL PROTECTION

* Ventilation: Good general room ventilation is recommended. Local exhaust may be needed.
* Respiratory Protection: A NIOSH approved dust respirator should be worn, if needed.
* Skin and Eye Protection: Protective gloves should be worn. Safety glasses should be worn.

SECTION VIII. SPECIAL STORAGE AND HANDLING PRECAUTIONS

* Keep from contact with oxidizing materials.

* Handling Precautions: In accordance with good industrial practice, handle with care and avoid unnecessary personal contact. Avoid contact with eyes and prolonged or repeated skin contact. Avoid continuous or repetitive breathing of dust. Use only with adequate ventilation. For **laboratory** use by technically qualified individual only.

* Shipping and Storing Precautions: Keep container tightly closed when not in use and during transport.

* Personal Hygiene: Wash thoroughly after handling.

SECTION IX. SPILL, LEAK, AND DISPOSAL PROCEDURES

Sweep up material and package for safe feed to an incinerator. Dispose by incineration or contract with licensed chemical waste disposal agency. Follow all federal, state and local laws.

SECTION X. REGULATORY INFORMATION

* Dot Proper Shipping Name: Not regulated as a hazardous material by the U.S. Dept. of Transportation (DOT) 49 CFR 172.101 Hazardous Materials Table.
* Dot Class: None.
* Dot Number: None.
* RCRA Status: Not a hazardous waste under RCRA (40 CFR 261).
* CERCLA Status: Not listed.
* SARA/Title III - Toxic Chemicals List: This product does not contain a toxic chemical for routine annual "Toxic Chemical Release Reporting" under SEC. 313 (40 CFR 372).
* TSCA Inventory Status: Chemical components listed on TSCA inventory.

[redacted]

P0076-9034

BBQ

MATERIAL SAFETY DATA SHEET

EXCITON CHEMICAL COMPANY INC.
P.O. Box 31126. Overlook Station
Dayton, Ohio 45431

Date of Preparation: 10/03/86

Person to contact: Larry Knaak
Telephone number for information: 513-252-2989

SECTION I. IDENTIFICATION

* Product Name: BBQ
* Synonym(s): 4,4'''-bis[(2-butyloctyl)oxy]-1,1':4',1'':4'',1'''-quaterphenyl
* CAT No: 03800

SECTION II. PRODUCT AND COMPONENT HAZARD DATA

COMPONENT(S):	Percent	TLV	CAS Reg. No.
BBQ	~100	N/D	18434-08-7

SECTION III. PHYSICAL DATA

* Appearance and odor: White crystalline powder. No significant odor.
* Melting Point: 160°C
* Vapor Pressure: Negligible
* Evaporation Rate (n-butyl acetate = 1): Negligible
* Volatile Fraction by Weight: Negligible
* Specific Gravity (H_2O=1): Not Available
* Solubility in Water: Insoluble

SECTION IV. FIRE AND EXPLOSION HAZARD DATA

* Flash Point: Not Determined
* Extinguishing Media: Water spray; Dry chemical; CO_2
* Special Fire Fighting Procedures: Wear self-contained breathing apparatus and protective clothing.
* Unusual Fire and Explosion Hazards: Fire or excessive heat may produce hazardous decomposition products.

BBQ

SECTION V. REACTIVITY DATA

* Stability: Stable
* Incompatibility: Strong oxidizers
* Hazardous Decomposition Products: Combustion will produce CO_2 and probably CO.
* Hazardous Polymerization: Will not occur.

SECTION VI. TOXICITY AND HEALTH HAZARD DATA

A. EXPOSURE LIMITS: Nonmutagenic (Ames Test)

B. EXPOSURE EFFECTS: Not established

C. FIRST AID:
<u>Inhalation</u>: Remove to fresh air. Treat symptomatically. If symptoms are present get medical attention.
<u>Skin</u>: Immediately flush skin with plenty of water.
<u>Eye</u>: Immediately flush eyes with plenty of water for at least 15 minutes and get medical attention if symptoms are present.
<u>Ingestion</u>: Drink 1-2 glasses of water or milk. Call a physician.

SECTION VII. VENTILATION AND PERSONAL PROTECTION

A. VENTILATION:
Good general room ventilation should be used.
Local exhaust may be needed.

B. RESPIRATORY PROTECTION:
A NIOSH approved dust respirator should be worn, if needed.

C. SKIN AND EYE PROTECTION
Protective gloves should be worn. Safety glasses should be worn.

SECTION VIII. SPECIAL STORAGE AND HANDLING PRECAUTIONS

Keep from contact with oxidizing materials.

SECTION IX. SPILL, LEAK, AND DISPOSAL PROCEDURES

Sweep up material and package for safe feed to an incinerator. Disp[redacted]ion or contract with licensed chemical waste disposal agency. [redacted] treatment, or disposal may be subject to federal, sta or local laws.

D Laserhead Drawings

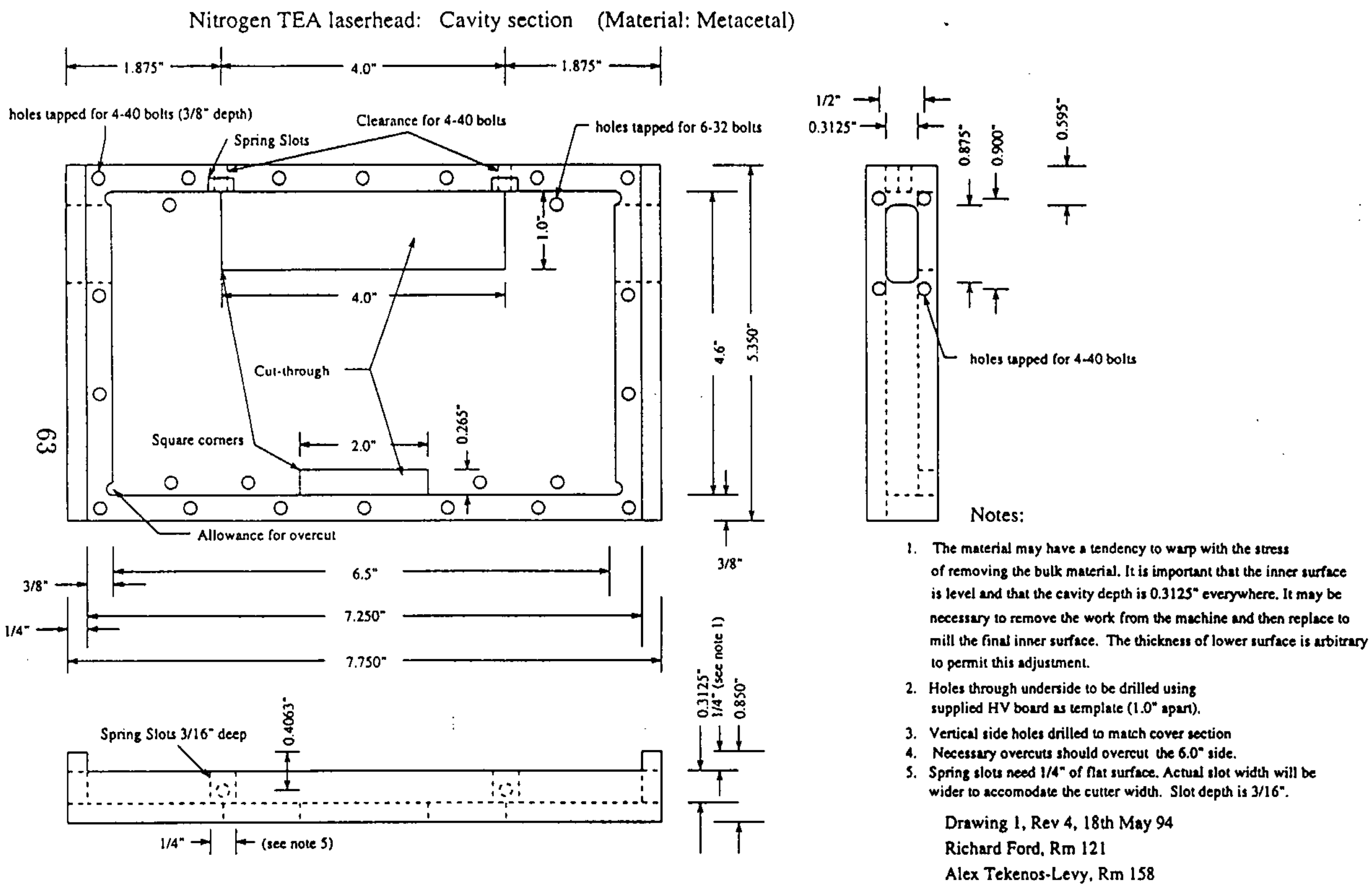
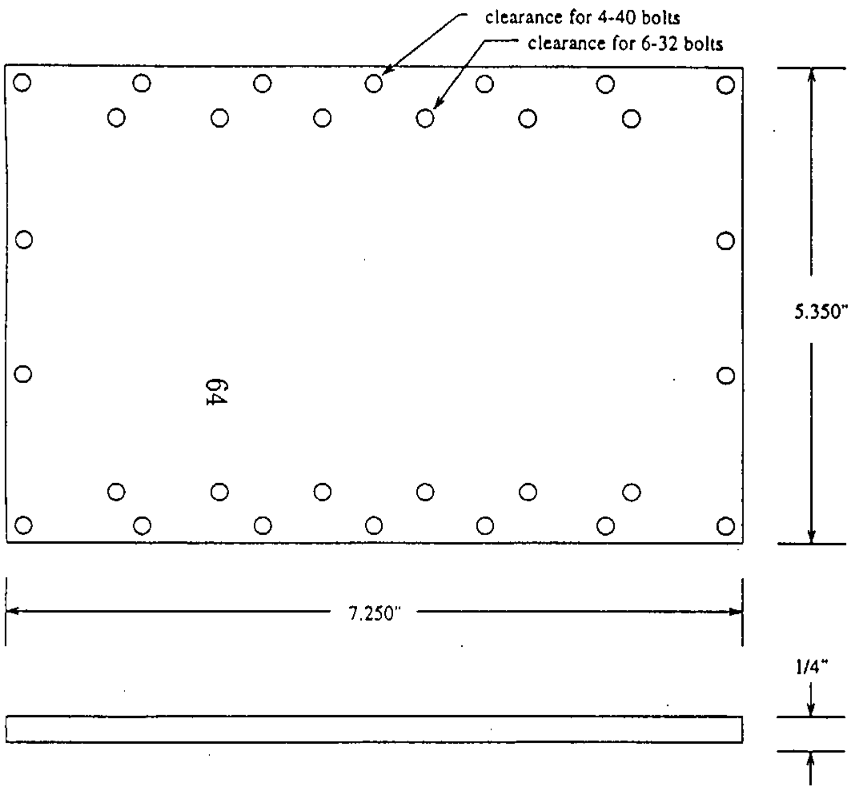


Figure 18: Drawing to fabricate new N_2 laser head cavity housing.

Nitrogen TEA laserhead: Cover section (Material: Metacetal)



Notes:

1. Inner holes drilled to match HV board template and cavity section holes (6-32, 1.0" apart). N.B. all 12 holes required.
2. Outer holes drilled to match side wall holes in cavity section (4-40).

Drawing 2, Rev 2, 9th May 94
Richard Ford, Rm 121
Alex Tekenos-Levy, Rm 158

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