COHERENT®

USER MANUAL

SDG II

SYNCHRONIZATION AND DELAY GENERATOR

Preface

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Disclaimer

This manual provides information regarding the operation and maintenance of the Coherent SDG.

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Coherent personnel will install the laser system. We do not guarantee laser performance unless the laser is installed by Coherent personnel or by an authorized representative of Coherent.

Support Needs

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Specifications

Inputs (trigger input and RF synchronization)

Trigger Input	TTL compatible, 0-50 kHz
RF Sync	10-100 MHz, > 100 mV peak to peak

Outputs: (one fixed and three variable delays)

Fixed delay	+200 ns (±ns)
Adjustable delays	0 – 1250 ns in 0.25 ns steps
Jitter	< 250 ps with respect to RF cycle
High Voltage	1 kV – 6kV DC for input to HSD (high speed driver)

Table of Contents

Warning Conventions

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

Warning Conventions

Danger!	Possible injury or hazard to personal safety
Warning!	Possible damage to equipment
Caution!	Warns against or prevents poor performance or error
Note	Exceptional circumstances or special reference
Danger! Laser Radiation	Laser radiation present
Eyewear Required	Safety eyewear required

1 Laser Safety

Caution!

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

This safety section should be thoroughly reviewed prior to operating the SDG II described in this manual. Safety precautions contained herein and throughout the manual must be carefully followed to ensure that all personnel who operate or maintain the laser are protected from accidental or unnecessary exposure to laser radiation.

The Coherent SDG II is not a laser and as such does not present a laser hazard. However the SDG II is designed to facilitate the amplification of short laser pulses. Use of the SDG II therefore presents a laser exposure hazard. It is imperative that the user familiarizes himself/herself with all aspects of laser safety. In particular, read the safety section of all the laser manuals provided with equipment you operate or are exposed to.

This safety chapter should not be construed as a substitute for the safety sections in the manuals provided with the lasers you operate. It is intended as an additional guide to laser safety.

1.1 Hazards

Hazards associated with lasers generally fall into the following categories:

- Exposure to laser radiation which may result in damage to the eyes or skin.
- Exposure to chemical hazards such as particulate matter or gaseous substances released as a result of laser material processing, or a by-product of the lasing process itself.
- Electrical hazards generated in the laser power supply or associated circuits.
- Secondary hazards such as:
    1. X-radiation from faulty power supplies
    2. Pressurized lamps, hoses, cylinders, etc.
    3. Pressurized liquids and gasses.

1.2 Optical Safety

The special nature of laser light poses safety hazards not associated with light from conventional sources. All users of lasers must make themselves familiar with the special hazards associated with their operation.

The safe use of the SDG II requires that all users are familiar with its operation. In particular, eye protection should be worn at all times.

The following safety precautions are to be read and observed by anyone working with the SDG II:

- Wear protective eyewear at all times; selection depends on the wavelength and intensity of the radiation, the conditions of use, and the visual function required. Protective eyewear vendors are listed in the *Laser Focus World, Lasers and Optronics,* and *Photonics Spectra* buyer's guides. Consult the ANSI, ACGIH, or OSHA standards listed at the end of this section for guidance.
- Avoid wearing jewelry or other objects that may reflect or scatter the beam while using the laser.
- Use an infrared detector to verify that the laser beam is on or off before working on the laser.
- Observe all safety precautions in the operator's manual.
- Never look directly into the laser beam.
- Set up controlled access areas for laser operation. Operate lasers only in well marked areas with controlled access. Be sure to post appropriate warning signs visible to all.
- The operation of lasers should be under the supervision of qualified personnel only. When not in use, lasers should be shut down completely and made off-limits to unauthorized personnel.
- Limit access to the laser system to persons required to be present.
- Terminate the laser beam.
- Work with the lowest energy consistent with the application.
- Eliminate unnecessary reflections and scattered laser radiation.
- Work in high ambient illumination.
- Maintain experimental setups at low level to prevent inadvertent eye encounter with beams.
- Follow the instructions in this manual.

1.3 Electrical Safety Precautions

- Disconnect main power lines before working on any electrical equipment when it is not necessary for the equipment to be operating.
- Do not short or ground the power supply output. Positive protection against possible hazards requires proper connection of the ground terminal on the power cable, and an adequate external ground. Check these connections at the time of installation, and periodically thereafter.
- Never work on electrical equipment unless there is another person nearby who is familiar with the operation and hazards of the equipment, and who is competent to administer first aid.
- When possible, keep one hand away from the equipment to reduce the danger of current flowing through the body if a live circuit is accidentally touched.
- Always use approved, insulated tools when working on equipment.
- Special measurement techniques are required for this system. Ground references must be selected by a technician who has a complete understanding of the system operation and associated electronics.

1.4 Protective Eye Wear

It is recommended that laser-safe eye wear is worn at all times. See the manual provided with your laser system for guidelines

1.5 Sources of Additional Information

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

1.5.1 Laser Safety Standards

SAFE USE OF LASERS (Z136.1)
AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)
1430 BROADWAY
NEW YORK, NY 10018
TEL: (212) 354-3300

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)
U.S. DEPARTMENT OF LABOR
200 CONSTITUTION AVENUE N.W.
WASHINGTON, DC 20210

A GUIDE FOR CONTROL OF LASER HAZARDS
AMERICAN CONFERENCE OF GOVER NMENTAL AND INDUSTRIAL HYGIENISTS (ACGIH)
6500 GLENWAY AVENUE, BLDG. D-7
CINCINNATI, OH 45211
TEL: (513) 661-7881

LASER SAFETY GUIDE
LASER INSTITUTE OF AMERICA
12424 RESEARCH PARKWAY, SUITE 130
ORLANDO, FL 32826
TEL: (407) 380-1553

1.5.2 Equipment and Training

LASER FOCUS BUYER'S GUIDE
LASER FOCUS WORLD
ONE TECHNOLOGY PARK DRIVE
P.O. BOX 989
WESTFORD, MA 01886-9938
TEL: (508) 692-0700

PHOTONICS SPECTRA BUYER'S GUIDE
PHOTONICS SPECTRA
BERKSHIRE COMMON
PITTSFIELD, MA 01202-4949
TEL: (413) 499-0514

LASERS AND OPTRONICS BUYER'S GUIDE
LASERS AND OPTRONICS
301 GIBRALTAR DR.
P.O. BOX 650
MORRIS PLAINS, NJ 07950-0650
TEL: (210) 292-5100

2 Product Overview

2.1 Background

Regenerative amplifiers, seeded by low energy laser pulses, are an extremely efficient means of obtaining high energy, high peak power pulses. The principle of regenerative amplification is to confine, by polarization, a single pulse (selected from a mode-locked train), amplify it to an appropriate energy level, then cavity dump the output. Typically an input pulse of energy only a few nanojoules can be amplified to over 1mJ in a single Ti:Sapphire laser rod, for example. This represents an overall amplification of greater than 10^6. The amplification takes place as the optical pulse passes through the laser rod, which has been optically excited. Normally the amplification of the laser rod is small, only about 3-4 in single pass, however the regenerative amplification technique enables the pulse to multipass the rod resulting in a much higher overall gain.

The amplification of short laser pulses is dependent upon proper timing between the seed-source pulse train operating at many MHz and the amplifier resonator typically pumped at 1-5 kHz. Proper timing can only be facilitated by precisely controlled fast electronics. The SDG II is designed to control the timing between a mode-locked seed source and an amplifier. In a typical configuration a SDG II enables synchronization between the output of a mode-locked laser and a Q-switch driver (HSD). This is accomplished by coupling the RF pulse of the laser mode-locker to the SDG II. Similarly the output of a fast photodiode can be coupled (detecting the pulse train of the mode-locked laser) to the SDG II. The input is synchronized precisely to the RF signal by high-speed electronics. Following synchronization, four delayed trigger signals are produced: one fixed and three user-adjustable in 250 ps steps. Typically, two of these are used to trigger Pockels cell drivers and the other(s) is/are used to trigger a pump-laser Q-switch or oscilloscope. An additional feature is an integrated countdown circuit that allows the experimenter to adjust the output repetition rate to values below the master input rate. The SDG II module is microprocessor controlled, and all delays are digitally displayed and accessible via front panel knobs and a rear panel RS-232 connection.

A prerequisite of regenerative amplifiers is the switching of the Pockels cells at the correct timing - an error of only two or three nanoseconds will result in multiple output pulses. Hence the timing associated with firing the Pockels cells is critical. In a regenerative amplification system alluded to above the first Pockels cell switches the pulse into the resonator. In order to ensure a single pulse is admitted to the resonator, the Pockels cells must be switched at the same time, with respect to the mode-locked pulse train (the seed pulses), every time. To achieve this, switching is synchronized to the RF signal generated by the mode-locker of the seed laser. Additionally, the phase of the switching (the time at which the Pockels cells switch with respect to the pulse train) must be adjustable. Following synchronization, there is a 0-200ns delay that allows phase adjustment. The synchronization electronics and phase adjustment are contained in SDG II module. The SDG II module is triggered by a TTL positive edge pulse that must be provided by the user. The SDG II then produces separate triggers, with adjustable delays, to the Pockels cells. The second Pockels cell switches the pulse out of the resonator. The pulse must be ejected after sufficient round trips and so a delay of approximately 200ns is required after the first Pockels cell switches. There are two adjustable delay adjustments on the timing electronics - the first provides a trigger to PC1, and the second provides a trigger to PC2.

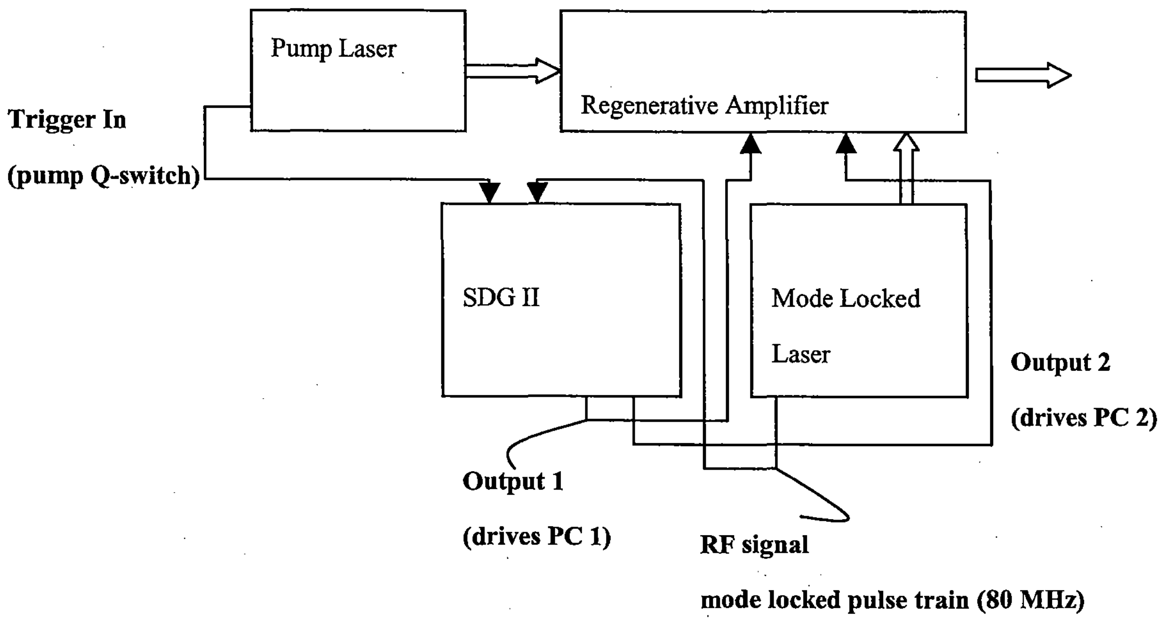
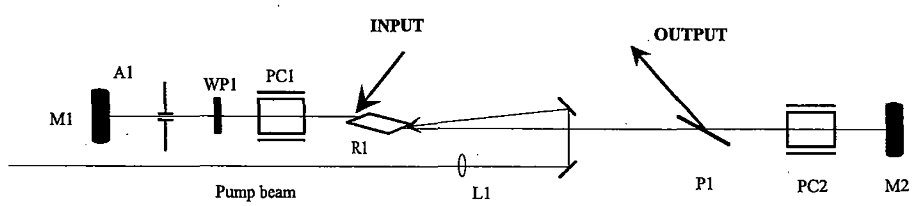


Figure 2.1 shows a typical amplification system. A pump laser provides energy to a cw mode-locked Ti:Sapphire oscillator, which produces approximately 500mW of ultrashort pulses. These pulses are directed to the regenerative amplifier to be stretched, amplified and then recompressed. The regenerative amplifier is pumped with a frequency doubled Nd:YAG or Nd:YLF laser.

A typical optical arrangement is illustrated below:



M1, M2	Resonator end mirror	A1	Aperture
PC1	Input Pockels cell.	P1	Output polarizer
WP1	Quarter-wave plate.	PC2	Output Pockels cell.
R1	Ti:Sapphire laser rod.	L1	Pump beam focusing lens

Figure 2.2: Optical components of a typical amplifier system

Operation is as follows:

1. The pulses from the pulse stretcher are directed into the regenerative amplifier laser cavity.
2. The mode-locked pulses are injected into the regenerative amplifier by reflection off the laser rod (R1).
3. While the input Pockels cell is deactivated, the pulses make a single round-trip through the Legend and exit again, receiving little or no amplification.
4. The pump laser Q-switch is activated providing a pump pulse to the Ti:Sapphire laser rod. This is the time when the Pockels cell, PC1, is activated to begin the amplification process.

We now consider the pulse that will be amplified:

5. The pulse enters the resonator by reflection off the laser rod.
6. The pulse passes through λ/4 plate and Pockels cell, which is off. It is reflected by mirror M1 and thus retraces its path. Because it has double passed the wave plate it has undergone a λ/2 rotation and is transmitted by the laser rod and the other resonator optics.
7. As soon as the pulse leaves Pockels cell PC1, quarter-wave voltage (3500V) is applied to it. The Pockels cell is now effectively a λ/4 plate and so negates the effect of the wave-plate. The pulse is trapped in the resonator.
8. After a number of round trips, usually about 20, a quarter-wave voltage is applied to the output Pockels cell, causing a half wave rotation to the pulse after it has double passed the Pockels cell. The pulse is thus ejected from the resonator by the polarizer. While trapped in the resonator the pulse has multipassed the rod and experienced a gain of over 10^6.

It is important to note that there are various schemes for switching pulse in and out of regenerative amplifier resonators. The primary difference is the number of Pockels cells used - either one or two. Both methods have their merits, at Coherentwe normally use two Pockels cells in our regenerative amplifiers, one to switch the pulse in, the other to switch it out, as described above. However each method requires two well-defined trigger signals, which the SDG II will provide (see figure 2.3).

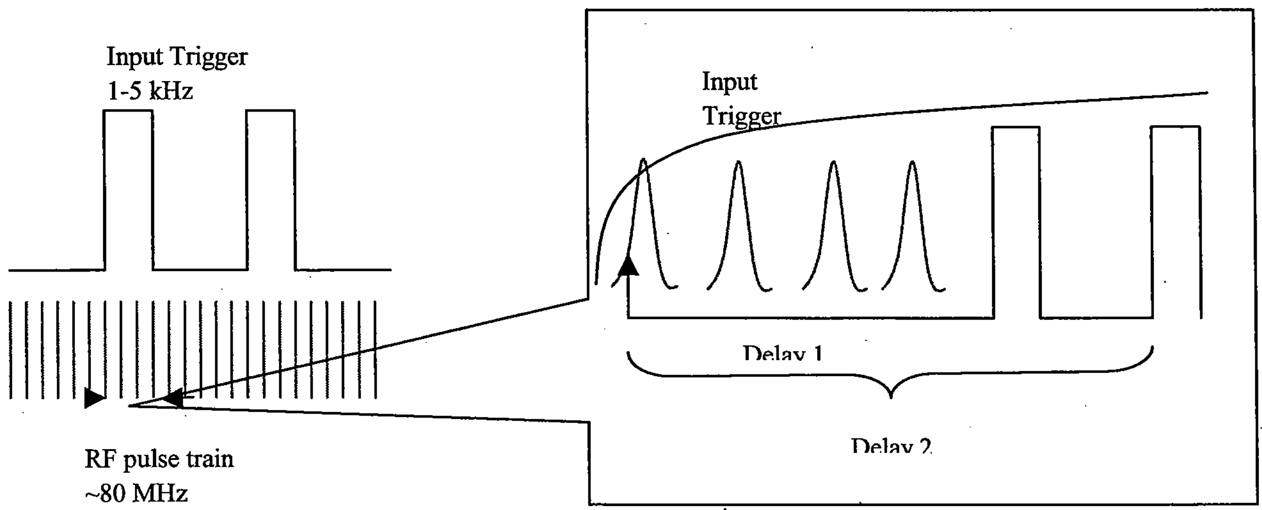


Figure 2.3: Schematic representing synchronization between the RF signal (red) originating form the mode-locked seeding laser and the outputs of the SDG II (delays 1 and 2). These outputs trigger Pockels cells 1 and 2 within the amplifier cavity respectively, switching in a single pulse (via delay 1), and following amplification, switching out a single pulse (via delay 2). Note: *Coordinate(s) not to scale.*

3 Set-up and Operation

Danger!
Laser Radiation

Laser radiation present

Eyewear Required

Safety eyewear required

3.1 SDG II Set-up and Connections

3.1.1 Voltage Selection

Normally the SDG II is shipped configured for use with 100 - 120 volt line. If the unit is shipped to a country where typical line voltage is 200 - 240 volts, then the SDG II will be set-up at Coherentto be compatible with this voltage. In this event the ac line port, on the rear of the SDG II, will be marked "200 - 220 Volt Operation". If it is not marked in this manner, you must ensure that your SDG II is set-up for operation at the correct input voltage.

To check the line voltage selection:

1. Disconnect the line voltage from the SDG II.
2. Remove the cover.
3. Close to the two transformers, at the rear right of the unit there are jumpers marked J25 through J28. The silk-screen on the printed circuit card indicates the position of the jumpers required depending on the input voltage.
4. Insure the jumpers are in the correct position to be compatible with the line voltage in your laboratory.
5. Replace the cover.

As already stated the SDG II provides 3 adjustable delay outputs and 1 fixed output that corresponds to the EXT TRIGGER in frequency. These outputs can also be synchronized with an RF signal from a mode locked laser or photodiode, also the output frequency can be divided by factors of 2,5,10 (see description below).

In order to connect the SDG II to your laser follow these instructions:

1. Connect a BNC cable from the output trigger of the pump laser to the input BNC on the SDG II labeled "Trigger In". When using a Coherent"Evolution X" laser to pump your regenerative amplifier then connect the BNC on the rear panel of the Evolution X laser power supply marked "Sync" to the input BNC on the SDG II labeled "Trigger In".

2. Connect a BNC cable from the mode-locker “Sync” or “RF out” to the SDG II "RF Sync" BNC socket.

The other connections on the SDG II rear panel are not necessary for normal operation. Their function is described below.

1. Connect a BNC cable between the "Output 1” on the SDG II and the BNC connector on the first Pockels cell driver in your regenerative amplifier.
2. Connect a BNC cable between the "Output 2" on the SDG II and the BNC connector on the second Pockels cell driver in your regenerative amplifier.
3. The SDG II is now connected for regenerative amplifier operation. Refer to the appropriate section of the manual for optimization of the adjustable outputs for regenerative amplification.

3.1.2 Set-up for Photodiode Synchronization

Normally it is possible to operate the SDG II by synchronizing to the RF output of the mode-locked laser. In some cases however, for example when used with a passively mode-locked laser, this signal is unavailable. In this case it is necessary to use a photodiode to as the source for the synchronization signal.

This path conditions the signal via a 50 Ohm termination. This termination can be switched on by removing the jumpers from the circuit board (labeled “50 Ohm Term. RF”) on the circuit board inside the SDG II near the “RF sync” BNC connector.

It is necessary to “pick off” some of the light from the mode-locked laser beam. Place a fast photodiode on this beam. The photodiode will produce an output that is a megahertz pulse train, similar to the mode-locked laser optical output of course. First, look at this signal on a fast oscilloscope, 300MHz or faster. Ensure that the signal level, *when viewed into a 50 ohm termination,* is 300mV or greater.

3.2 SDG II Detailed Description

3.2.1 SDG II Options

The SDG II has a "+ 5 VDC Enable" on the back which can be connected to an interlock, for example, so that when the interlock is tripped, the output of the regenerative amplifier is disabled by interrupting the triggers to the Pockels cells.

Another option available with the SDG II is to synchronize the Oscillator (or mode-locked laser you are using as a seed source) with a photodiode rather than the RF source provided by the Oscillator electronics. This is useful so that if the Oscillator stops mode locking, the synchronization is disabled since the photodiode will not provide the signal necessary to allow synchronization. If this option is used, then refer the section above.

3.2.2 Front Panel Controls and Connections

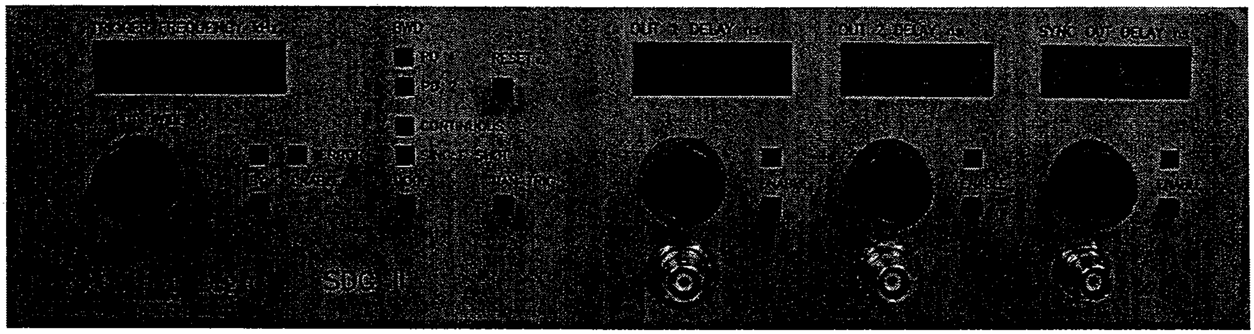


Figure 3.1: SDG II Front Panel

TRIGGER FREQUENCY READOUT: Displays the frequency of the SDG II's output indicators.

INPUT DIVIDE: This adjustment allows the operator to divide the output frequency of the SDG II by a factor of 2, 5, and 10.

SYNC ENABLE: This switch selects synchronized or un-synchronized mode of operation, if the LED is illuminated the synchronization is enabled. If the error light is illuminated, then the sync source has been eliminated or the modelocked locked laser has stopped modelocking. Pressing the sync enable button so that the LED turns off will correct the error condition but it will also disable the synchronization portion of the SDG II.

SYNC ERROR: This LED will illuminate when the SDG II is in the synchronized mode and the sync signal is absent.

BWD: This is the bandwidth detection part of the SDG II. The modelocked source beam must be aligned into the stretcher so that the LED's PD 1 and PD 2 can illuminate when the reset button is pressed. Any interruption of the beam alignment in the stretcher will cause either or both LED's to turn off, resulting in the trigger outputs being disabled. Pressing the reset button should return the LED's to their illuminated state. If they do not illuminate, the modelocked source characteristics or alignment have changed. The LED's will illuminate only after the reset button has been pressed; they will not illuminate as a result of a proper alignment of the beam onto the photodiodes without iteratively pressing the reset button. The BWD can be overridden (**not recommended**) by turning the BWD off. The on/off is controlled by a toggle switch on the back panel of the SDG II.

MODE: This allows the user to select between continuous repetition rate firing (based on input trigger) and single shot firing. The illuminated LED indicates the mode of operation.

MAN TRIG: This is the single shot control when the MODE selected in SINGLE SHOT. Pressing this button in this mode will cause the three output triggers to fire a single shot.

ENABLE: These three switches enable or disables the 3 adjustable outputs, it dose not effect the fixed TRIGGER OUT: on the rear panel. If the respective LED's are off, the outputs are disabled and if the LED's are on, the outputs are enabled.

OUT 1 DELAY ns: All adjustable outputs function identically so for simplicity, discussion will be on one output only.

DELAY READOUT: Displays the selected delay in nanoseconds for its corresponding output.

DELAY ADJUST: Adjusts the corresponding outputs delay in 1 ns steps, or 10 ns steps when the adjust knob is pushed in while adjusting. The adjustable range is 0 ns to 1275 ns..

3.2.3 Back Panel Controls and Connections

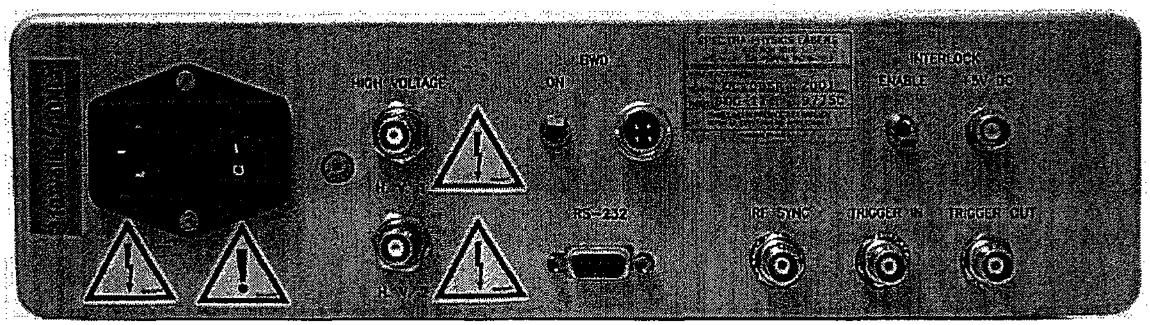


Figure 3.2: SDG II Rear Panel

INTERLOCK ENABLE: This switch enables or disables the +5VDC connector. In the up position the +5VDC connector is nonfunctional, in the down position the connector is functional.

+5VDC ENABLE: This connection allows the operator to connect an interlock switch to the SDG II that will disable all the adjustable outputs when the switch is open. Grounding the center pin of the BNC will enable operation.

TRIGGER OUT: is a fixed output. The input pulse trigger to the SDG II goes through a one-shot that results in this TRIGGER OUT before the signal is sent to the three adjustable outputs on the front of the SDG II.

EXT TRIGGER: Apply the trigger source to this connector. The trigger source should be 50Ω, TTL

RF SYNC: Apply the synchronization signal to this connector. The rf source should be >100mV, 0-100MHz into 50Ω. A jumper inside of the SDG II should be removed if the rf source is not 50Ω.

BWD ON: the BWD circuit is activated when the 4 pin 12mm connector is connected and the switch is in the up position. The switch in the down position disables the BWD (not recommended).

SERIAL PORT: Allows RS232 connection for control and programming of the SDG II via a computer using ASCII terminal software (see description below).

HIGH VOLTAGE: both HV1 and HV2 are 0-6kV DC outputs. These are connected and used to power both HSD's (High Speed Driver).

110/220 VAC: Fused primary power input for the SDG II, incorporated in this module is EMI protection, 1/2 Amp fuse and an on/off switch.

3.3 SDG II Computer Interface

Most functions of the SDG II can be controlled by any computer with a standard RS-232 serial port. The SDG II command syntax is designed to replicate the functions of the controls and read-outs on the front panel of the SDG II.

3.3.1 RS-232 Connector Wiring

The SDG II serial port accepts a standard 9-pin D-sub male/female extension cable for hookup. Only three pins on the are used for serial communications:

Pin Number	Function
2	SDG II transmit data, computer receive data
3	SDG II receive data, computer transmit data
5	Signal ground

3.3.2 RS-232 Communication Protocols

The SDG II uses the following communication protocols, which must be set accordingly in the communications program used to control the SDG II.

Setting	Value
Rate	9600 bps
Data bits	8
Parity	None
Stop Bits	1
Flow Control	None

3.3.3 Command/Query/Response Format

All SDG II RS-232 commands, queries, and responses are in ASCII format. Each command or query must be terminated with a carriage return <CR>. Commands that have a numerical argument be sent with all of the digits, preceded with zeros if necessary. Commands must be sent in all lowercase. All queries end with a question mark (?). Valid queries return data followed by a carriage return <CR>. Valid commands return the string “Ok”. Invalid commands or queries return the string “Bad”.

3.3.4 Command Quick Reference

Command	Parameter	Function
status?	none	Returns overall status of SDG II (see below)
set:cN #	0, 1	Enable (1) or disable (0) output on channel N (1-3)
read:cN?	none	Returns the output state of channel N (1-3)
set:del:cN ####.#	0000.0 to 9999.9	Set the delay for channel N (1-3) in ns
read:del:cN?	none	Returns the delay for channel N (1-3) in ns
set:rate ####	0001, 0002, etc.	Sets the trigger rate division factor
read:rate?	none	Returns the trigger rate division factor
read:bwd?	none	Returns the state of the BWD latching interlock
reset:bwd	none	Reset the BWD latching interlock
read:sta:bwd?	none	Read the state of the BWD photodiodes
set:rf #	0, 1	Enable (1) or disable (0) the RF sync
read:rf?	none	Returns the state of the RF sync
set:mode #	0, 1	Set the trigger mode to continuous (0) or single-shot (1)
read:mode?	none	Returns the state of the trigger mode
man:trig	<none>	Manually trigger the SDG II in single-shot mode

3.3.5 Full Command Description

status?

Returns the status of the SDG II as a comma-delimited list of eleven parameters. These values are listed in the following table:

Parameter	# of Characters	Value
Output 1 state	1	0 (OFF) or 1 (ON)
Output 2 state	1	0 (OFF) or 1 (ON)
Sync Out state	1	0 (OFF) or 1 (ON)
Output 1 delay	6	0000.0 ns to 9999.7 ns
Output 2 delay	6	0000.0 ns to 9999.7 ns
Sync Out delay	6	0000.0 ns to 9999.7 ns
Trigger division factor	4	0001 to 0010
BWD Switch state	1	0 (OFF) or 1 (ON)
BWD photodiode & Ext Interlock state	3	000 to 111 (see below under read:sta:bwd?)
Continuous/Single shot	1	0 (continuous) or 1 (single shot)
RF Sync state	1	0 (OFF) or 1 (ON)

set:cN

Sets the output of channel N (N=1 for Out 1, N=2 for Out 2, N=3 for Sync Out) to be enabled (1) or disabled (0).

read:cN?

Read the output state of channel N (N=1 for Out 1, N=2 for Out 2, N=3 for Sync Out) as enabled (1) or disabled (0). The output state is also displayed by corresponding LED on the front panel.

set:del:cN ####.#

Set the delay of channel N (N=1 for Out 1, N=2 for Out 2, N=3 for Sync Out) in nanoseconds (ns). The minimum increment for the SDG II is 0.25 ns. The allowed values for the last digit (after the decimal) are 0, 2, 5, and 7, corresponding to 0.00, 0.25, 0.50, and 0.75 ns respectively. Last digits other that 0,2,5,7 are rounded down to allowed values.

read:del:cN?

Returns the delay setting for channel N (N=1 for Out 1, N=2 for Out 2, N=3 for Sync Out). The allowed values for the last digit (after the decimal) are 0, 2, 5, and 7, corresponding to 0.00, 0.25, 0.50, and 0.75 ns respectively.

set:rate ####

Sets the factor by which the input trigger frequency (rep rate) is divided to produce the output trigger frequency. Allowed values are 0001, 0002, 0005 and 0010. For example, if the input trigger rep rate is 1.000 kHz, a rate of 0005 will set the output frequency to 0.200 kHz.

read:rate?

Returns the input/output frequency divisor set by the set:rate command.

read:bwd?

Returns the state (0 = off, 1 = on) of the BWD mechanical switch on the back of the SDG II.

reset:bwd

Resets the BWD latching interlock. If the BWD switch is on and both BWD photodiodes (PD 1 and PD 2) are illuminated, reset:bwd will clear the BWD latching interlock. If the BWD switch is off, reset:bwd will clear the BWD latching interlock regardless of the state of the BWD photodiodes.

read:sta:bwd?

Returns a string of three binary values. The first two values are the states of PD 1 and PD 2 (0 = off, 1 = on). The third value is the state of the +5V DC interlock (0 = latched, 1 = clear). For example, "110" indicates that PD 1 and PD 2 are illuminated but the +5V DC interlock is latched, preventing output.

set:rf #

Sets the state of the RF sync to be enabled (1) or disabled (0).

read:rf?

Returns the state of the RF sync as enabled (1) or disabled (0).

set:mode #

Sets the output trigger mode to continuous (0) or single-shot (1).

read:mode?

Returns the output trigger mode as continuous (0) or single-shot (1).

man:trig

Executes a single output event when the SDG II is in single-shot mode.

3.3.6 Limitations of RS-232 Control of the SDG II

The following functions of the SDG II cannot currently be accessed with RS-232 commands:

- The value in the Trigger Frequency display cannot be read.
- The status of the Sync Enable Error LED cannot be read.
- The state set by the BWD on/off mechanical switch cannot be changed.
- The state set by the Interlock enable/disable mechanical switch cannot be changed.

3.3.7 Typical Command Usage

The following list gives a simple control flow for the SDG II using RS-232 commands.

1. Turn on the system, then wait >5 seconds for the SDG II in initialize.
2. Issue a *status?* command to determine the state of the SDG II.
3. Enable the required outputs with the *set:cN* commands; set the required delay values with the *set:del:cN* commands; set output trigger frequency with the *set:rate* command.
4. If all interlocks are cleared, issue a *reset:bwd* command to enable output.
5. Monitor the SDG II by periodically issuing a *status?* command.

4 Regenerative Amplifier Alignment

This chapter is provided as a guide to regenerative amplifier alignment and operation. Coherent makes no representation, or warranty as to whether this procedure will be applicable to your amplifier layout. If any damage occurs to your amplifier Coherent is not responsible.

4.1 Static Regenerative Amplifier Alignment

If you have real difficulty getting the regenerative amplifier to lase then, you will have to perform a complete alignment. Do not attempt this procedure before consulting a Coherent or Coherent representative.

1. Set up the helium neon laser and two turning mirrors so that the beam can be aligned down the regenerative amplifier resonator, starting at the second Pockels cell end of the resonator. It is important that the beam is aligned parallel to the optical bench and at a height of 2½ inches above it. This is easily accomplished by partially closing both intra-cavity irises so that the helium neon beam can be referenced to them.
2. The beam should now be centered through each optical element in the resonator. To verify this, place a piece of white paper in front of the optic to be inspected, so as to block the HeNe beam from passing through the optic. Using a small inspection mirror look through the end opposite the paper. If the HeNe spot is close to an edge of the optical surface loosen the optical element mount and center the optic in the beam or refer to following sections which provide more detail for proper alignment of the critical optical elements (Pockels cell, crystal, etc.).
3. If all optical elements appear to be properly aligned, adjust the left-end high reflector to reflect the HeNe beam back along its path through both partially closed irises. Repeat this for the right-end high reflector.
4. Open up both apertures.
5. Follow the procedure described in the "Lasing Optimization" beginning of this chapter to complete the alignment of the regenerative amplifier.

4.1.1 Pockels Cell Alignment

Use white paper to see if the beam is propagating directly through the center of the input and output apertures of the Pockels cell (PC2). If it does not the Pockels cell must relocated.

Housed inside the Pockels cell is a KD*P crystal. It is necessary to align the optic axis of the KD*P crystal along the beam. The cell must be tilted about two axes to achieve this (see below), the Pockels cell mount has these adjustments on it.

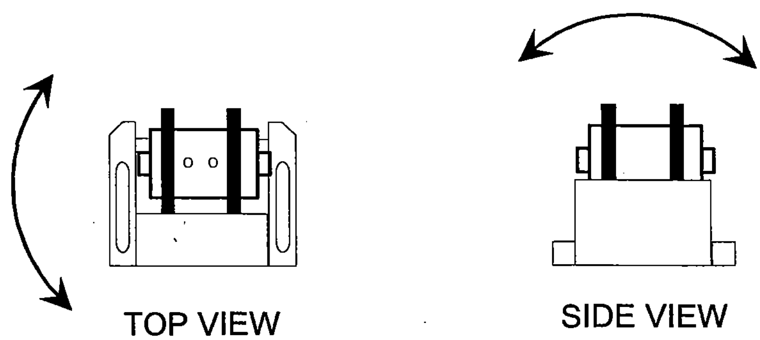


Figure 4.1: Pockels cell adjustments

Use a piece of white paper or card and place it in the beam about 3 inches beyond the Pockels cell so that you can view the beam on it. Place a piece of lens tissue in the beam directly in front of the Pockels cell to scatter the beam through the cell.

It is necessary to view the beam through crossed polarizers. Place a piece of sheet polarizing film in the HeNe beam at any point prior to the Pockels cell. Place a second piece of polarizing film in the beam immediately after the Pockels. You will see a pattern like this on the white paper:

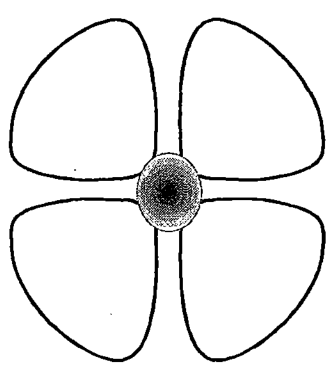


Figure 4.2: HeNe pattern following correctly aligned Pockels cell

The pattern shown above represents a perfectly aligned Pockels cell, the spot in the center being the HeNe beam. You will need to adjust the Pockels cell tilt, in both axes, to center the pattern on the beam.

1. Remove the lens tissue etc. from the beam path.

2. Check the beam height at the end of the resonator (near M2). The Pockels cell may have slightly raised or lowered the beam, if so then readjust the beam.

4.1.2 Polarizer Alignment

1. The thin film polarizer is mounted in a housing which places the polarizer at the correct angle provided that the mount which holds the housing is placed as close to perpendicular to the optical cavity as possible.
2. Look at the HeNe reflection off the polarizer and measure the beam height. If it is not 2.5", loosen the set screw which holds the polarizer housing in the mount and rotate the polarizer housing until the reflection is at 2.5".
3. Verify that the beam passing through the polarizer is not clipped. If it is, loosen the polarizer mount and translate it. Repeat step 1.

4.1.3 Laser Rod Alignment

1. If a crystal requires replacement, remove the two screws holding the top of the crystal mount to the bottom mount and remove the top mount. Carefully remove and replace the crystal. Replace the top mount but do not tighten the screws.
2. Rotate the crystal until the reflected HeNe beam (or low energy pump beam) is at 2.5". Carefully tighten the two top screws making sure the reflection remains at 2.5".
3. The crystal front face is set at Brewster's angle at the factory. As long as the bottom crystal mount assembly has not been adjusted, no realignment should be necessary. If the bottom mount has been rotated then Brewster's angle (60 degrees) should be reset.

4.1.4 Mirror Alignment

1. Make a small hole in the sheet of white paper (about 1-2mm diameter). Place this in the HeNe beam about 1' (30cm) from the first resonator mirror. There should be a back reflection onto the paper that passes directly through the hole. Note that there may be reflections from other surfaces on the resonator that could be deceiving - a white card placed directly between the mirror and pinhole will block these reflections. When the mirror is well aligned the back reflection from the mirror will be difficult to see because it passes through the hole. If the mirror is not well aligned then the back reflection will appear close to the hole. (You will be able to see this best with the lights dimmed). Make small adjustments to the X and Y adjustments to center the back reflection on the hole.
2. Repeat this process for the other resonator mirror. In this case the best position for the paper is between the laser head and the second Pockels cell. There will be several reflections from the polarizer cell which will be confusing. In this case you must determine which is the correct reflection.
3. The static optical alignment is now complete, however it is a good idea to leave the HeNe aligned until you have completed the active alignment.

4.2 Lasing Optimization

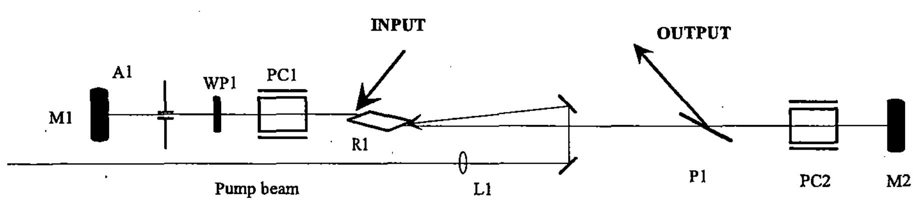
This procedure assumes that the regenerative amplifier oscillator is lasing, but requires complete optimization. If the regenerative amplifier oscillator is not lasing then it may be necessary to follow the static alignment procedure outlined below. Prior to attempted this procedure it is advisable to follow the "Daily Optimization" procedure in the preceding chapter.

Do not attempt to seed the regenerative amplifier with the cw laser beam yet. Operation must be verified as a Q-switched laser first. To do this block the seed beam while completing the procedure below.

WARNING!

All personnel within the laser room must wear laser protective eye wear at all times that the laser is operating. Even small energies from a pulsed laser system can cause permanent eye damage. Goggles should be worn of at least O.D. 4 to all lasing wavelengths.

The regenerative amplifier is a laser which acts as an amplifier when a subnanosecond pulse of intensity greater than the intracavity noise level is injected into the resonator. Hence to ensure alignment of the regenerative amplifier is optimized, the regenerative amplifier can be operated as a laser in the absence of a seed pulse:



M1, M2 Resonator mirror
A1 Aperture
WP1 Broadband waveplate
PC1, PC2 Pockels Cell

R1 Ti:Sapphire Laser Rod
P1 Broadband polarizer
L1 Pump beam lens

Figure 4.3: Optical schematic, regenerative amplifier

1. Turn on the pump laser and check the pump alignment into the Ti:Sapphire crystal.
2. Turn down the lamp energies to minimum.
3. Disconnect the BNC cables from the SDG II "OUT 2" and "OUT 3" to ensure that both Pockels cells are not triggered.
4. Remove the waveplate, WP1, by removing its entire mount as you will need to replace it in the exact same orientation.
5. Slowly bring up the lamp energy to maximum.
6. The laser will begin to lase in the "free-running" mode. If there is no lasing then make small adjustments to mirror M2.
7. Use a photodiode and observe the transmitted lasing, through the resonator mirror, M2 on an oscilloscope. The photodiode should be used with the 1MΩ, 50-100μs/division"
8. The signal should look like this:

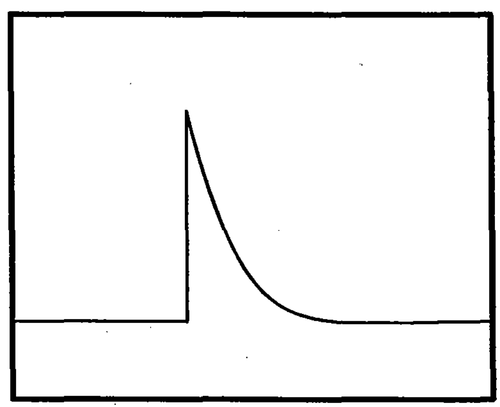


Figure 4.4: Free-running laser pulse

1. Make sure that the signal disappears when the resonator is blocked.
2. Carefully adjust mirror M2 for maximum amplitude of the oscilloscope trace.
3. **Carefully** adjust the pump beam alignment to optimize lasing.
4. Replace waveplate WP1, the signal on the oscilloscope should disappear indicating no lasing.
5. Monitor the photodiode to ensure that no lasing occurs. If there is lasing then try rotating WP1 slightly to eradicate it. Do not make large adjustments.
6. Reconnect the BNC cable to the SDG II "OUT 2" to allow the first Pockels cell to trigger. The laser should now Q-switch.

7. Change the photodiode to a 50Ω input and 50 or 100ns/division. At this time it is best to externally trigger the oscilloscope from the "OUT 1" BNC on the SDG II.

8. The photodiode position should remain the same, looking through mirror M2. You will now see the Q-switched pulse on the oscilloscope. The exact shape of the pulse will vary depending on several factors including pump energy, mode-beating, resonator alignment etc. An example of what it may look like is shown below:

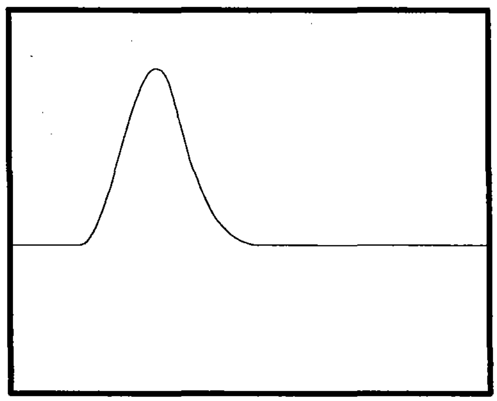


Figure 4.5: Example of Q-switched pulse

1. Adjust the crystal angle on the HG2 to optimize the 532nm energy and in turn, the regenerative amplifier Q-switched energy. This should minimize the build up time, shorten the pulse, and increase its amplitude.

2. Reconnect the BNC cable to the SDG II "OUT 3". This will allow the regenerative amplifier to be cavity dumped by allowing the second Pockels cell to be triggered.

3. If a Q-switched pulse is not present, then turn the SDG II "OUT 3" delay control clockwise until the Q-switched pulse is seen. The intracavity, Q-switched, cavity dumped pulse should look like the figure below. If the Q-switched pulse is present in its usual shape, then turn the delay control counter-clockwise to obtain the shape shown below. Measure the ejected pulse energy. The energy measured Q-switched, cavity dumped will be very close to the energy measured when the regenerative amplifier is seeded and cavity dumped. Verify that the energy measured is the same or close to the energy measured at the time of installation.

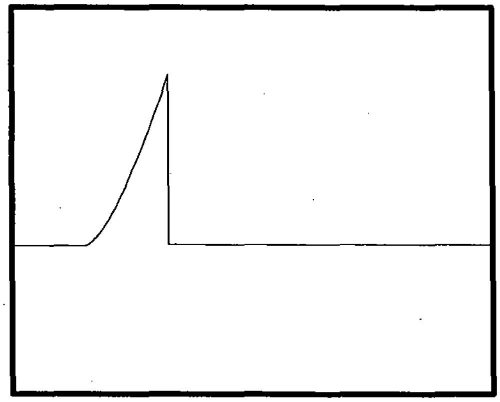


Figure 4.6: Intra-cavity, Q-switched, cavity dumped pulse. (Note - actual pulse shape depends on time at which cavity dumping takes place).

4.3 Seed Alignment

The next step is to align the mode-locked beam (the seed beam) into the regenerative amplifier resonator.

1. Turn off the pump laser. Optimize the mode locked laser performance.
2. Referring to figure 6.11, verify that the seed beam is reflecting off of the mirror (13) before being reflected off of the crystal surface (14) and into the regenerative amplifier resonator.
3. Use mirror (13) and (12) to align the beam through the aperture. Only these two mirror adjustments should be necessary to align or "walk" the seed beam through the regenerative amplifier to mirror (16).

Figure 4.7 (below) shows the seed beam alignment path into the Coherentregenerative amplifier resonator.

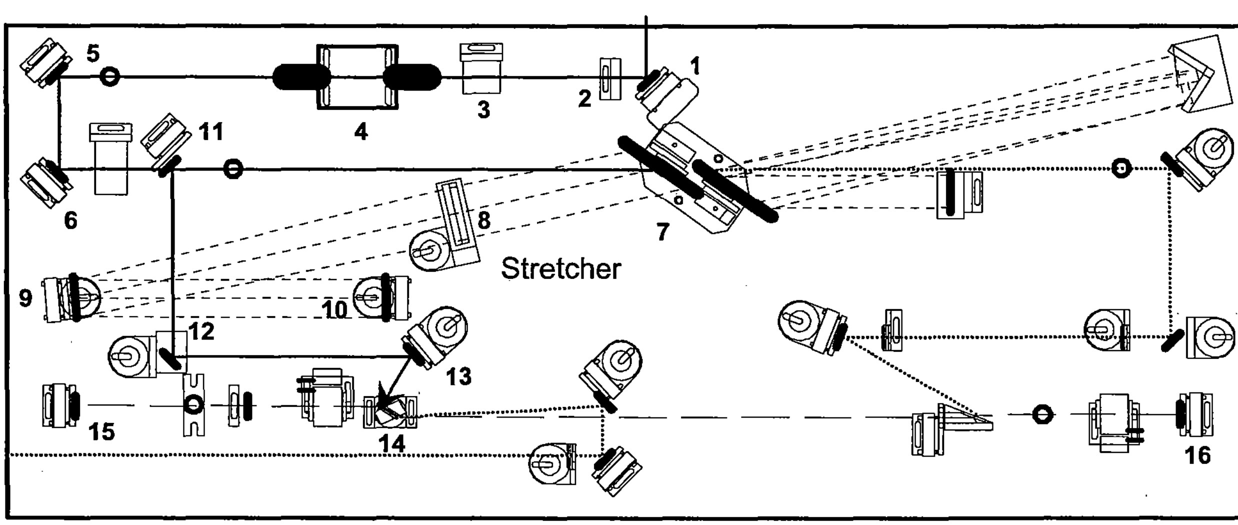


Figure 4.7: Seed beam alignment

The beam path is illustrated above and is as follows:

The input beam is turned 90^{o} by the input mirror (1), through the alignment aperture (2), through the vertical retro assembly (3) and then through the Faraday Isolator (4). It is then directed to the stretcher via alignment mirrors (5) and (6). The beam then passes through the stretcher (7), (8), (9), and (10). The beam is picked off by mirror (11). The beam is directed to the polarization rotator (12) and then into the amplifier via mirror (13) and injected into the resonator by reflection off the face of the Ti:Sapphire laser crystal (14).

An IR card should be used to quickly check the alignment of the cw beam into the regenerative amplifier. The beam is injected into the regenerative amplifier by reflecting off one face of the laser crystal (14). It is likely that the beam will have drifted slightly since the regenerative amplifier was last operated. The beam should be aligned so that it is centered on the pinhole and then on the resonator mirror (15). Enough of the beam should pass through the pinhole to be reflected back down the resonator, through all the optics (including the laser crystal) to the second cavity mirror (16). Use the IR card to ensure that the beam is clearly visible at mirror (16). Make slight adjustments to the input mirror (15), *not* the resonator mirror, until you see a beam at mirror (16). You are now ready to turn on the GCR lamps.

If you cannot see the beam it will be necessary to check the alignment through the stretcher.

4.4 Regenerative Amplification

You are now ready to begin amplifying the input pulses to the regenerative amplifier. If you are uncertain of the steps taken previous to this point, then review and/or repeat those steps if necessary. Please remember that the technical staff of Coherent will be pleased to assist. You are welcome to call or fax your questions.

1. Block the seed beam from entering the regenerative amplifier. Turn on the pump laser to its full operating pump level.
2. Make sure that the SDG II "Sync Enable" switch is in the "up" or "on" position. Disconnect the SDG II "OUT 3" BNC. This disables the triggering of the second Pockels cell. Trigger the oscilloscope externally from the SDG II "OUT 1" BNC.
3. Check the photodiode output on the oscilloscope, you should see the Q-switched pulse that was observed in step 16 of "Lasing Optimization".
4. Unblock the seed beam entering the regenerative amplifier. If the seed beam is well aligned you should see a pulse train on the oscilloscope. Below is an example of what you may see if the timing synchronization is set correctly and the seed alignment is good, but it is unlikely. (The timing synchronization will be adjusted later in this section).

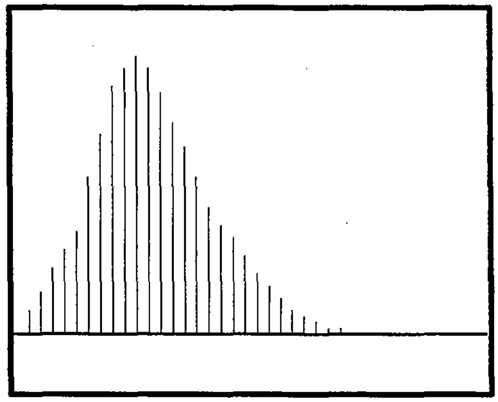


Figure 4.8: Intracavity pulse train

Alternatively, you may see a Q-switched laser pulse with mode locked pulses riding on top of it.

1. Before beginning the rest of the procedure it is important that the oscilloscope is triggered externally from SDG II "OUT 1" BNC.

2. To optimize the cw alignment into the resonator adjust the input steering mirrors into the resonator to minimize the buildup time of the pulse train while maximizing the amplitude of the earliest pulses. These are the same steering mirrors used in step 4 of "Seed Alignment".

3. Once the alignment of the seed beam is optimized you will see a pulse train that looks like that above. If you cannot achieve a pulse train like that above then make ***small*** adjustments to the SDG II "OUT 2 " delay control to optimize the timing synchronization. This adjustment sets the time that the pulse is switched into the regenerative amplifier and will eliminate the possibility of a secondary laser pulse being trapped in the regenerative amplifier.

4. Now reconnect the SDG II"OUT 3" BNC cable to allow the second Pockels cell to trigger. The timing will almost certainly be incorrect. Adjust the SDG II "OUT 3" delay control so that the intracavity pulse train now looks like the figure below.

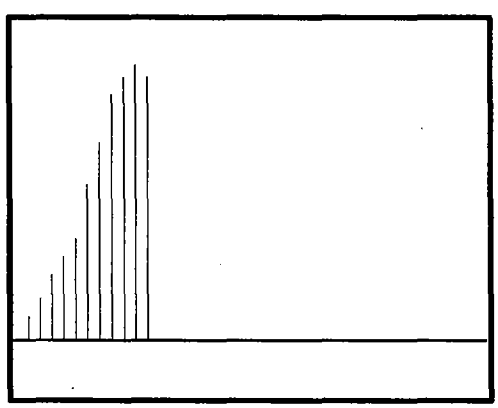


Figure 4.9: Intracavity pulse train with the timing correctly set

5. Now you must reposition the photodiode so that it is looking at the ejected pulse. Most probably you will see two pulses on the oscilloscope, separated by about 13ns, the round trip time if the regenerative amplifier resonator.

6. A small adjustment of the SDG II "OUT 3" delay control will ensure that a single pulse from the regenerative amplifier is ejected from the resonator.

7. Measure the pulse energy with a power meter. The energy measured should be close to or the same as that measured at installation.

5 Customer Service

At Coherent, we take pride in the durability of our products. We place considerable emphasis on controlled manufacturing methods and quality control. Nevertheless, even the finest instruments need occasional service.

5.1 Warranty

Coherent warrants to the original purchaser that the equipment is free from defects in material or workmanship. Coherent will, without charge, make any necessary repairs or replacement of parts to remedy such defect within one year, or 90 days in the case of optical surfaces, provided that Coherent in writing of the nature of such defect within one year, or 90 days for optical surfaces, following the date of original sale of the equipment. The foregoing warranty does not cover equipment which has been damaged by accident or improper use. Coherent does not assume any liability if adaptations are made or accessories attached to the equipment which impair or alter the normal functioning of the equipment. Any repair or adjustment by persons not expressly authorized by Coherent shall relieve Coherent of all obligations. The limited warranty and remedy contained in this paragraph are the only warranty and remedy pertaining to the equipment. COHERENT DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING WARRANTY OR MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. Coherent shall in no event be liable for any incidental, consequential or other damages or costs, lost profits or inconvenience occasioned by loss of the use of the equipment or labor expended by persons not so authorized by Coherent.

5.2 Return of the Instrument for Repair

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

We encourage you to use the original shipping boxes during shipment. If shipping boxes have been destroyed or lost, we recommend you order new ones. We can return instruments only in Coherent containers.