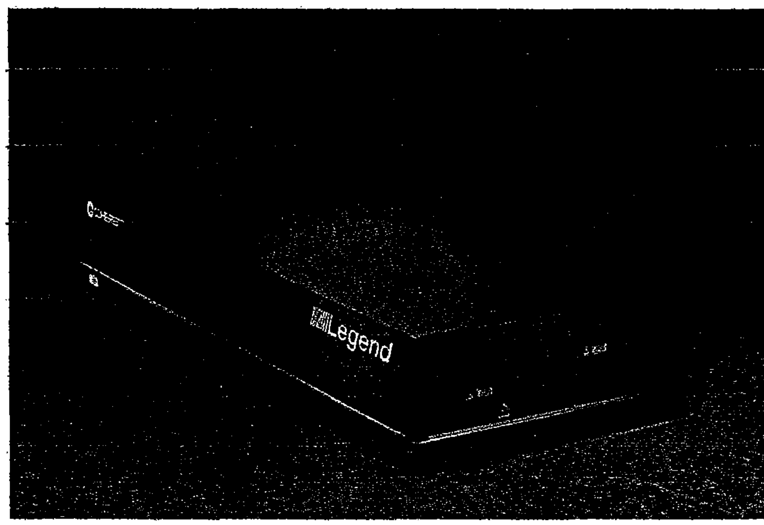
COHERENT®

USER MANUAL



LEGEND-USP-HE

ULTRA-SHORT PULSE TI:SAPPHIRE AMPLIFIER WITH PULSE STRETCHER AND COMPRESSOR

Preface

Copyright

Disclaimer

This manual provides information regarding the operation and maintenance of the Coherent Legend-USP.

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

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

If you have any technical questions or problems, please contact Coherent:

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Specifications

Legend-USP Titanium Sapphire Regenerative Amplifier System[1]	
OUTPUT CHARACTERISTICS:	
Pulse Duration	<35-50 fs FWHM
Pulse Broadening	<150% of the input duration
Energy at 1 kHz	>1.0 mJ (after compression)
Energy at 5 kHz	>0.3 mJ (after compression)
Beam Diameter	10 mm (nominal)
Energy Stability (8 hours)	<1% RMS
Polarization	Linear, horizontal

[1] Specifications subject to change without notice. Specifications on purchase order supercede all other published specifications.

Table of Contents

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.
- Work in high ambient illumination. This keeps the eye's pupil constricted, thus reducing the possibility of eye damage.
- Never look directly into the laser beam.
- Avoid looking at the beam; even diffuse reflections are hazardous.
- Use an infrared detector to ascertain whether the laser beam is on or off before working on the laser.
- Work with the lowest beam intensity consistent with the application.
- Operate lasers only in well-marked areas with controlled access. Be sure to post appropriate warning signs, clearly visible to all.
- Limit access to the laser system only to qualified personnel who are essential to its operation and who have been trained in the principles of safety. When not in use, lasers should be shut down completely and made off-limits to unauthorized personnel.
- Provide enclosures for beam paths whenever possible.
- Terminate the laser beam with an appropriate energy-absorbing target.
- Shield unnecessary reflections and scattered laser radiation.
- Avoid blocking the output beam or any reflections with any part of your body.
- Set up the laser so that the beam height is either well above or well below eye level

1.3 Electrical Safety Precautions

The following precautions should be observed by anyone when working with potentially hazardous electrical circuitry:

- 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. 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 touched accidentally.
- Always use approved, insulated tools when working on equipment.
- Special measurement techniques are required for this system. A technician who has a complete understanding of the system operation and associated electronics must select ground references.

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

Warning!

This user information is in compliance with section 1040.10 of the CDRH Performance Standards for Laser Products from the Health and Safety Act of 1968. Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.

Danger! Laser Radiation

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

1.1 Hazards

Hazards associated with lasers generally fall into the following categories:

- Exposure to laser radiation that 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:
  - X-radiation from faulty power supplies
  - Pressurized lamps, hoses, cylinders, etc.
  - Pressurized liquids and gasses.

1.2 Optical Safety Precautions

The special nature of laser light poses safety hazards not associated with light from conventional sources. The safety precautions listed below are to be read and observed by anyone working with the laser. At all times, ensure that all personnel who operate, maintain or service the laser are protected from accidental or unnecessary exposure to laser radiation exceeding the accessible emission limits listed in 'Performance Standards for Laser Products,' *United States Code of Federal Regulations*, 21CFR1040 10(d).

The following precautions are to observed at all times:

- 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

1.4 Interaction From Other Lasers

1.4.1 Mode-Locked Laser

The Legend-USP uses a cw mode-locked laser as a seed beam source. The beam from the cw laser is hazardous. Refer to the Operator's manual provided with this laser for additional safety information.

1.4.2 Nd:YLF Laser

The Legend-USP uses a pulsed, frequency doubled Nd:YLF laser as a pump source. The beam from the pulsed Nd:YLF laser is hazardous. Refer to the Operator's manual provided with this laser for additional safety information.

1.5 Protective Eye Wear

It is recommended that laser-safe eye wear attenuated to the wavelength of 1047 nanometers and 523.5 nanometers with an optical density (OD) of 7 or higher at each wavelength be worn at all times when the Legend-USP laser is operating. Although during normal operation of the laser, the operator should not be exposed directly to diode laser emission, hazardous diode radiation is present in the laser diode pump head. Consequently it is recommended that the eye wear selected for use with the Legend-USP should also provide optical attenuation of OD 7 or higher at the diode emission wavelength of (797±2) nm.

1.6 Controls

Any modification or use of the Legend-USP laser which changes, disables, or overrides the function of the engineering controls and safety features invalidates the Class IV certification of the laser described in this manual. The safety features incorporated in the Legend-USP are described below in the section entitled 'CDRH Compliance'.

1.7 CDRH Compliance

The output powers and energies of the Legend-USP laser are hazardous. The following safety features incorporated in the Legend-USP conform to Federal performance standard as required by 21 CFR 1040.10(h)(1)(iv):

Key Switch
A separate key switch is provided to enable power to the laser. The key cannot be removed from the switch except in the OFF position. This assures that use of the laser by unauthorized or unqualified personnel can be prevented.

Protective Housings
An internal cover is installed to cover the laser beam path until it exits the optical cavity

at the front (output) port. The diode-pumped head is also contained within its own internal housing to shield the user from stray diode light and to protect the laser diodes from exposure to dust and electrostatic discharge. The Legend-USP laser should not be operated with the internal covers removed, or displaced, except when necessary during required service functions such as optical realignment. In particular, removal of the diode pump head cover will invalidate your warranty.

Remote Interlock Connector

The remote interlock connector (marked 'INTERLOCK') at the rear of the power supply cabinet enables the user to connect an external interlock (such as a switch on the door to a laser room, for example). This interlock circuit should be used to terminate laser action automatically if anyone enters the laser operating area. This function causes the diodes to switch off when the interlock contacts are opened. Lasing can only be resumed by closing the external interlock circuit contacts and then cycling the key switch to clear the interlock function. The laser should NOT be operated unless the remote interlock function is in use.

Emission Indicators

Three emission warning indicators are used on the Legend-USP laser. After the user presses and holds the laser 'ON' button on the remote control box, an LED indicator on the remote control box flashes to warn personnel that the laser is about to emit laser light. An indicator light on the front of the laser bench also lights any time current is supplied to the laser diodes. This warns the user that the user may be exposed to hazardous laser diode emission inside the laser, even though the laser cavity may not be emitting green or infrared laser light. A third indicator light on the front of the laser bench lights when the laser is activated and the intracavity shutter is opened. This warns that the laser is about to emit laser radiation. All emission indictors remain on as along as the laser is capable of lasing. The indicators light several seconds prior to actual emission to give nearby personnel time to avoid exposure to laser radiation.

Beam Safety Shutter

A solenoid-actuated safety shutter is mounted in the optical cavity to interrupt laser action when necessary. The shutter is actuated when the laser 'ON' button is activated on the remote control box.

Beam Attenuator (Output Port)

A manually operated shutter mounted on the laser output port is provided for blocking of the beam if required.

Location Of Controls

Controls for operation of the Legend-USP laser are located on the remote control box so that operators need not be exposed to laser radiation during operation of the laser.

Warning Labels

Certification and warning labels are affixed to the Legend-USP laser to verify compliance with 21 CFR 1040, to provide information on the wavelength and power emitted, and to warn the user against accidental exposure to laser radiation. The location and type of warning logotype labels used on the Legend-USP laser power supply and bench are shown in Figure 2.1

Operating Instructions
This manual contains instructions for operating and maintaining the Legend-USP laser safely.

1.8 Sources of Additional Information

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

1.8.1 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 GOVERNMENTAL 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

1.8.2 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 System Start-Up and Shut-Down

2.1 Unpacking and Installation

Your Legend-USP was packed with great care, and its container was inspected prior to shipment. Upon receiving your system, inspect the outside of the containers immediately. If there is any major damage (holes in the containers, water damage, crushing, etc.) insist that a representative of the carrier be present when you unpack the contents.

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

The Legend-USP can now be moved to the location in which it will be installed.

Warning!

Do not attempt to install the laser yourself, or remove the lid covering the optical cavity of the laser head. Either action, if unauthorized, will void your warranty, and you will be charged for the repair of any damage incurred if you attempt installation yourself.

2.2 Start-Up Procedure

1. Turn on the external city water supply.
2. Turn on the system chiller.
3. Turn on the Millennia laser and initiate the start-up procedure as described in the Seed Oscillator manual.

   Ensure that the unit is operating under the standard performance specification as stated by Coherent.
4. Remove the Legend-USP external, black Plexiglass covers.
5. Turn on the pump laser as described in the "Pump laser manual"
6. Override the mechanical shutter (closes in absence of the top covers) that allows the 527nm pump beam to propagate to the Ti:Sapphire rod in the Regen cavity.

7. Ensure "enable on" switch that provides the trigger signal to the Pockels cell drivers, located on the front panel of the SDG, is disabled (downward position).
8. Power up the Synchronization Delay Generator (SDG) by toggling the switch located behind the SDG unit to the "1" position.

2.3 Daily Performance Optimization

Following parameters are check points that should be followed on a day to day basis in order to ensure that the entire system is well optimized as a whole.

1. Following sufficient warm-up time, ensure Seed Oscillator is well Mode-locked and performing within system specification. Typical oscillator bandwidth should be 35nm centered at 800nm.
2. Ensure good performance from the Pump laser pump source i.e.: power and stability.
3. Ensure Regen amplifier performance.
4. Good seed alignment of the seed source into the Regen amplifier.

2.4 Shut-Down Procedure

1. Disable the trigger signal to the Pockels cell drivers by switching the toggle switch, located on the front panel of the SDG, to the **downward** position.
2. Power down the Synchronization Delay Generator (SDG) by toggling the switch located behind the SDG unit to the **"0"** position.
3. Turn "off" the Pump laser pump laser as described in the Pump laser manual.
4. Power down the Seed Oscillator lasers as described in the Seed Oscillator manual.
5. Turn "off" the system chiller.
6. Turn "off" the external city water supply.
7. If not in place already, replace the Legend-USP black, external Plexiglas covers back onto the unit.

3 Stretcher Alignment Procedure

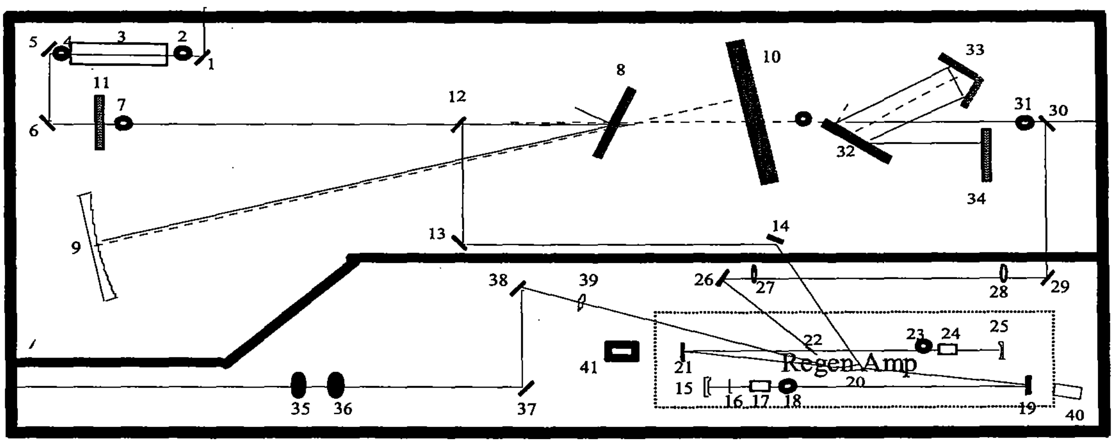

Fig. 3.1 Legend-USP layout

The layout of the Legend-USP Sub-30 fs Ti:sapphire Amplifier is shown in Fig. 3.1. The system consists of three main parts. The first part is the stretcher including the components from #8 to #11 (see also Fig. 3.2). The second part is the regen amplifier, which is the components from #15 to #25, and the last part is the compressor, which consists of the components from #32 to #34. The alignment procedure of these three main parts will be discussed in details in the following chapters.

3.1 Stretcher Alignment Check

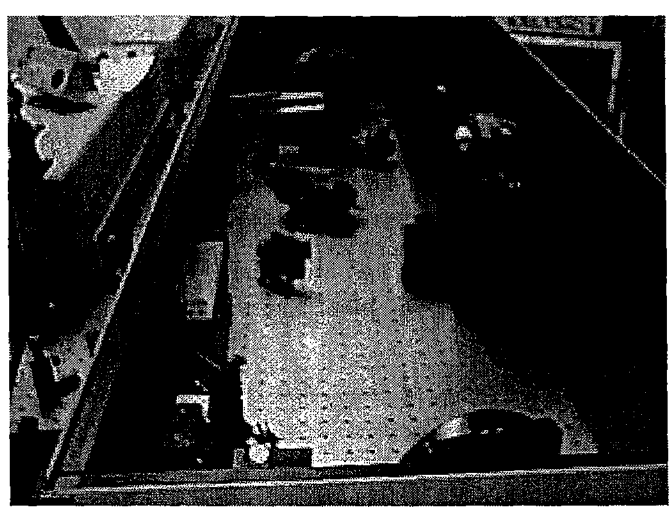

Fig. 3.2 The photo of the stretcher.

Warning!

When handling the Stertcher/Compressor grating block, always use finger cots in order to minimize the chance of accidently touching any part of the grating surfaces.

5. Disable the High Speed Drivers from firing by toggling the "Output Enable" switch located on the front panel of the Synchronization Delay Generator, to the downward position.
6. Toggle the mechanical shutter switch located on the front panel of the Pump laser remote box to the "off " position disabling any laser light from emitting from within the laser cavity.
7. Set the wavelength of the Seed Oscillator at or near the peak (i.e. center wavelength @ ~ 800nm). Mode locking is not necessary at this time.
8. Depress the mode-lock enable button
9. Momentarily close and open mechanical shutter to the Millennia laser if step a fails to cause Seed Oscillator to loose mode-lock.
10. Collapse fully reference iris #2 and #4 located on both sides of the Faraday Isolator (comp. #3).
11. Using an Infared viewer, ensure that the Seed Oscillator output beam is propagating simutaneously through the center of the two collapsed irises. If it is not, one will need to steer the beam using the external routing mirror mount located at the output of the Seed Oscillator and mirror #1.
12. Make vertical and horizontal adjustments to the external mirror mount so that the beam is clearly propagating directly through the center of iris #2. Conversly, make the necassry adjustments to both the X and Y axis of mirror #1 so that the beam is propagagting through the center of iris #4.
13. Continue going back and forth between the two mirror mounts mentioned above, while making the necassary X and Y adjustments until the beam is through the center of the two aperatures simutaneously.
14. Open **completely** iris 2 and 4.
15. Wearing finger cots and taking great care not to touch the grating surface. Use a 3/16 ball driver to carefully unscrew the two ¼ -20 screws that secure the top sub-plate to the rotation stage of the stretcher block (#8) as shown in the following picture.
16. Place the subplate housing the grating in a safe and secure location.
17. Place the removable reference iris into the post holder situated directly in front of the stretcher vertical retro mount #7. Collase the iris fully and make sure that the iris apearture is square to the in-coming Seed Oscillator beam.
18. The beam height following the two 45 degree dielectric mirrors should be at 3.5". Using an infared viewer, check to see that the Seed Oscillator beam is propagating directly through the center of the removable iris. If it is not, make the necassry X and/or Y adjustments to the 45 degree mirror/mount (#5) so that the beam is through the center of the aperature.
19. Move the removable iris into the second iris post holder at location #31, situated directly in front of the square 1"x 1" turning mirror #30. The Seed Oscillator beam should again be propagating

directly through the center of the removable iris. If it is not, make the necessary adjustments to the 45 degree mirror/mount #6 until it is. Iterate between steps 9-11 until the beam is propagating directly through the iris center when the iris is situated at both positions.

20. Once the above conditon is acompplished, place the removable iris back into the iris post holder at location 7. Ensure that the iris opening is again square to the in-coming beam and fully collapsed.
21. Momentarily close the mechanical shutter located on the seed input panel.
22. Using finger cots, place the stretcher garting block back onto the rotation stage of the assembly. Re-secure the subplate by screwing the two ¼-20 screws back to the rotation stage.

3.2 Checking Alignment/Setup of the Stretcher Block

Warning!

When handling the Stertcher/Compressor grating block, always use finger cots in order to minimize the chance of accidently touching any part of the grating surfaces.

1. Open the mechanical shutter, allowing the Tsuanmi beam to propagate into the Legend-USP.
2. Unlock the rotation stage set screw located at the base of the grating assembly as shown in Fig. 3.3.
3. Using an infared viewer or an IR card, rotate the upper portion of the grating stage so that the surface of the stretcher grating appears to be retro reflecting the Seed Oscillator beam back towards the iris at location 7. See grating orientation shown below in Fig.3.4

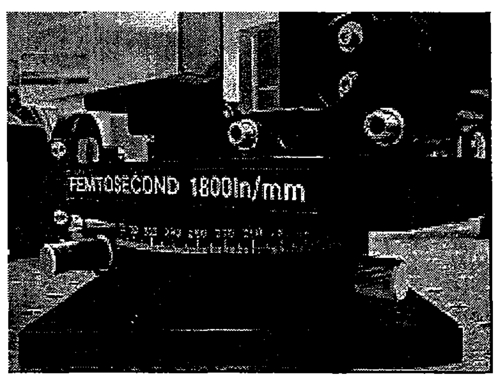

Fig. 3.3 Rotation set screw indicated by arrow as shown above

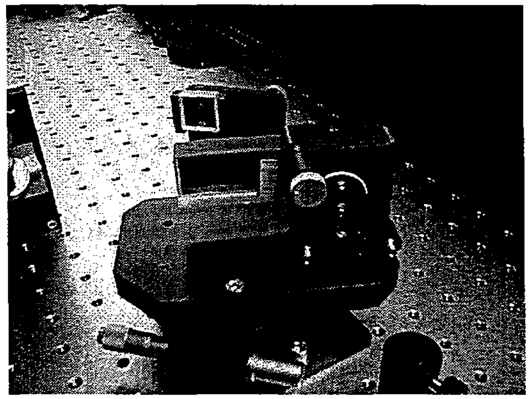

Fig. 3.4 Stretcher grating alignment for the zero order surface reflection.

4. At this time it is not important that the retro reflection is exactly through the iris .What is important is that the retro reflection coming off the grating is propagating back to the iris at the same height as it is going into the stretcher assembly.

   Once the zero order surface reflection is at or near the iris, relock the rotation set screw. Make the necessary adjustment to the "fine" rotation adjustment screw located on the rotation stage as to place the zero order reflection where it is visible near the iris.

   If the zero order reflection appears to be off in height (3.5"), using a 1/8 balldriver make an adjustemnt to the vertical axis of the mirror mount holding the stretcher grating.

5. Unlock the rotation set screw.

6. Rotate the grating assembly clockwise while looking for the first order reflection from the stretcher grating to be propagating back to the iris at location 7.

7. Lock the rotation set screw once the reflection is near the iris. If the retro reflection appears not to be at the same height as the iris center, loosen the two 3/32 screws that contain the retainer rings (see Fig. 3.5) behind the mirror mount just enough to allow coarse rotation of the entire grating mount. Using a 1/16 ball driver, loosen slightly the set screw holding the grating holder within the mirror mount aperature. With one hand, rotate the grating/holder so that the first order retro reflection appears to be propagating back to the iris center beam height.

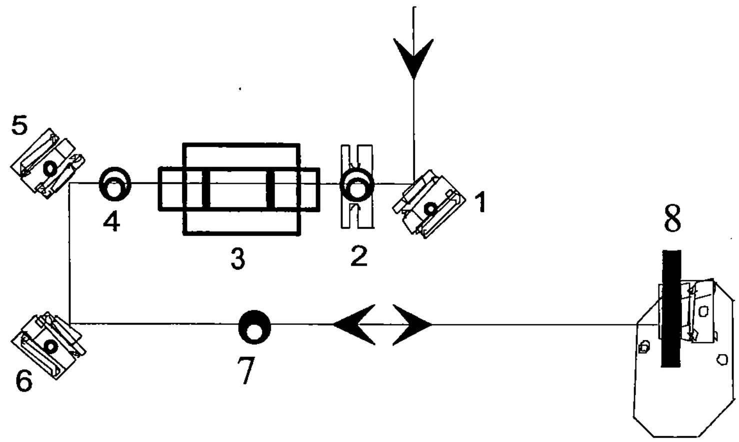

Fig. 3.5 Two 3/32 screws that lock the retain rings behind the mirror mount are used to adjust the grating rotation in the vertical plane.

8. Unlock the rotation set screw and again rotate the entire grating assembly so that the zero order retro reflection is again visible near the aperature of the iris. Lock the set screw. Again check to see that the grating reflection is still at the same height as the iris. If it is not, then again make a vertical adjustment to the mirror mount.

9. Unlock the rotation set screw and rotate the grating block so that the first order reflection is again near the iris. Check to see that it is still at the same height as the iris center. If it not, re-do step 5.

10. Iterate between step 3 and 7 until both the zero and first order reflections are propagating off the grating surface at the same height as the iris center.

11. Once the zero and first order reflections appear to be at the same height, tighten both the 1/6 set screw and the two 3/32 balldriver screws. Check to see that after both have been tightened, that the height of the two order reflections has not changed relative to the iris center. If one or both has, reloosen the screws and attempt to compensate by off-setting the height that the beams propagate prior to tightening the the screw.

3.3 Checking the Setup of the Large Reflective Gold Mirror

1. Using an infared viewer, rotate the grating assembly so that the first order reflection of the stretcher grating appears to be stricking the center (horizontally) of the large gold reflective mirror.

2. Using the viewer, observe the stretcher grating surface. With the removable iris still located directly in front of the vertical retro reflector, one should see two spots located near the center of the grating surface. See Fig. 3.6.

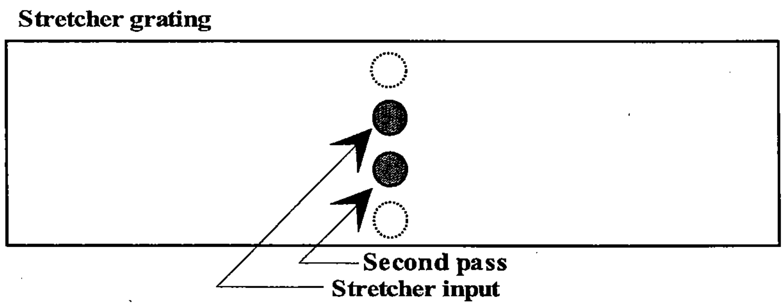

Fig. 3.6 The top spot is the seeding beam from Seed Oscillator. The second spot is the beam reflected from the retro-reflection mirror behind the stretcher grating.

3. If the iris were not in place and the setup of the stretcher was ok, one would see 4 spots lined vertically over one another. Each spot representing one pass within the stretcher setup as shown in Fig. 3.7.

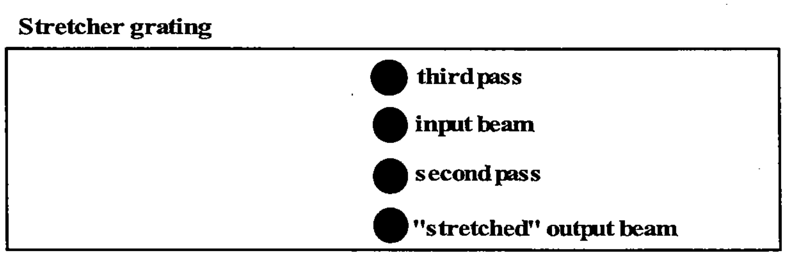

Fig. 3.7 Four spots on the stretcher grating.

4. Tweak the vertical micrometer adjustment knob (Fig. 3.8) located behind the large gold mirror mount clockwise until the surface reflection from the large gold mirror appears to be in the same condition as shown above.

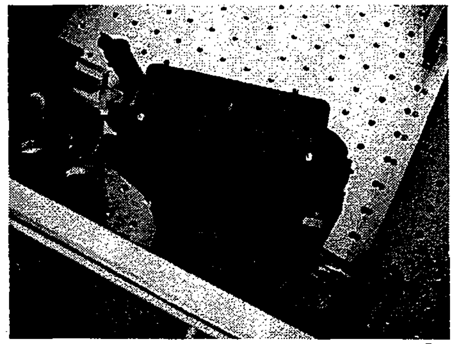

Fig. .3.8 This picture shows the vertical micrometer knob for the 6" diameter gold mirror.

In making the above adjustment, the purpose of the procedure is to:

a) check the setup of the large gold mirror <u>horizontally</u>

b) check the mechanical integrety of the vertical axis of the large gold mirror mount ensureing that the beam does not appear to be moving horizontally as the vertical adjustment is being made. It is very important that it **<u>only</u>** move vertically. If it is not moving vertically, the stretcher setup will not be optimized leading to potential problems recompressing.

If the beam is moving horizontally while making a vertical adjustment following step 4, with the mount in place,

- check the tightness of all the 3/16 screws on the mount.
- Ensure the mirror is flat within the holder and secure via the nylon tip set screw located at the top of the mount

Ensure the micrometer adjustment screw tip is lubricated using, for example, Krytox grease

5. If after doing step 4, the beam from the large gold mirror appears to be off horizontally (not lining up as shown in Fig. 3.6) on the grating surface by more than ½ a cm, one will need to make a coarse adjustment by loosening the baseplate to the large mirror mount and physically rotating the entire mount the amount nesassary in order to setup the mirror so that the two spots line up vertically as shown in Fig. 3.6. If the two spots are off set by less than ½ cm then simply adjust the 'fine" rotation micrometer knob so that they line up vertically.

6. Readjust the vertical micrometer knob to the large mirrror mount counter clockwise forcing the beam from the large gold mirror to go up and over the grating stage assembly ultimately stricking the lower most part of the 1" × 7" dielectric retro reflector (#10). Position the beam on the 1" × 7" mirror (Fig. 3.9) so that it is @ 3-4mm above the bottom edge of the mirror.

If the mechanics of the large mirror mount are sound, the beam from the large gold mirror should be stricking the above mirror at or near the bottom of the mirror and centered horizontally. If it is not, loosen the nylon tip set holding the 1" × 7" mirror and position it within the mount so that the beam is near center (horizontally).

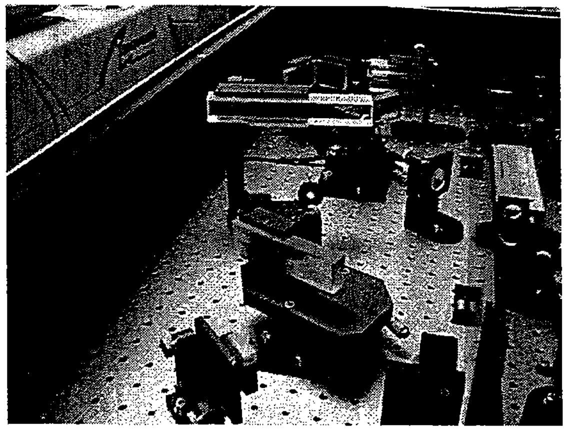

Fig. 3.9 The arrow shows the 1" x 7" retro-rflection mirror behind the stretcher grating.

7. With the viewer, following the above step, observe the stretcher grating once again. Again one should see the two spots lined up vertically. If the lower spot appears to be off horizontally, adjust the horizontal axis of the 1" × 7" retro reflector so that the lower spot is located directly below the input spot horizontally. Tweek if necessary the vertical axis of the 1" × 7" retro reflector so that the lower spot is @ 3-4mm below the input spot.
8. Remove the "removable" iris from within the iris holder.
9. Observe the stretcher grating surface once again. One should now see four spots lined vertically over one another as shown following step 3 above.
10. If the upper and lower spots appear to be off horizontally with respect to the two inner spots (see Fig. 3.10), adjust the horizontal axis of the upper mirror mount of the vertical retro assembly so that the upper and lower spots line up.

A second check point to observe is at the 1"×7" retro mirror location. If the vertical retro reflector is aligned correctly both in the X and Y-axis, one should only see one spot. If two spots are visible, tweak the X and/or Y-axis of the vertical retro reflector so that the second spot visible is super imposed upon the main beam. When this is the case, all four spots should line up vertically.

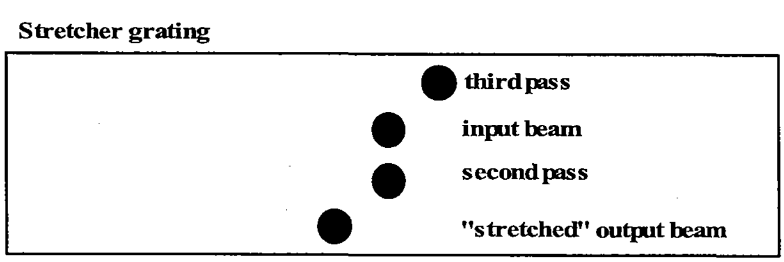

Fig. 3.10 The misalignment of the 1" x 7" reflection mirror.

11. Mode-lock the Seed Oscillator and ensure optimum performance. When this is the case, one should be able to observe the following pattern (Fig. 3.11) on the grating surface. If the two "strips" appear shifted horizontally, make a slight rotation to the grating block so they appear as shown below.

Stretcher grating

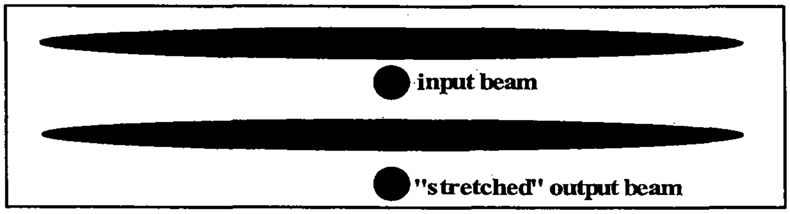

Fig. 3.11 The optimum performance of the spectrum pattern on the stretcher grating.

3.4 Spatial Chirp Free Alignment

The stretcher setup (distance of retro reflector to large gold mirror) is preset at Coherent prior to shipment. However, if at installation, the Seed Oscillator is setup greater than 3.5' away, the divergence of the beam entering the Legend-USP is probably going to be different from the divergence of the Seed Oscillator used at the factory. Some reoptiminzation of the stretcher setup may be necessary.

Operation of the Pump laser will not be necessary at this time.

3.4.1 Preparation and Setup of the Spectrometer

1. Ensure that the Seed Oscillator is performing to system specification and well Mode-locked.
2. Ensure that the beam from the Seed Oscillator is well collimated. Reroute the beam from the Seed Oscillators present location and allow the beam to propagate 6 meters or more to the far field. If the layout of the Seed Oscillator is 3 feet or more away from the time the beam exits from the Seed Oscillator to the time the beam enter the Legend-USP, a 1:1 telescope is recommended (for instances two 100mm broadband lenses). Install the telescope, ensuring that the beam is well collimated thereafter.
3. Setup a spectrometer at the output of the Legend-USP or somewhere appropriate on the system bench.
4. Observe the spectrum from the output of the Seed Oscillator. Note the bandwidth and wavelength in its current operation. Typical output spectrum from the Seed Oscillator should be as smooth as possible with no apparent modulation as shown in Fig. 3.12.

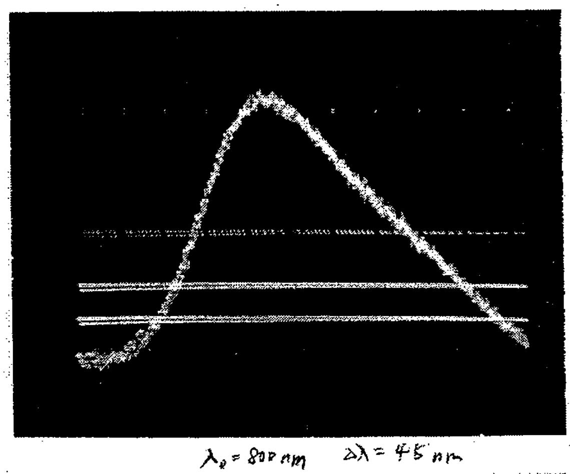

Fig. 3.12 Typical Seed Oscillator Spectrum peak @ 800nm. Bandwidth ≈45nm (calibration = 10 nm/div)

5. Remove the output panel of the Legend-USP by backing out the corresponding set-screws located on the two support brackets.

6. Place a mirror between mirror #12 and #13 and setup an external turning mirror to direct the stretched output beam into the spectrometer as shown in Fig. 3.13.

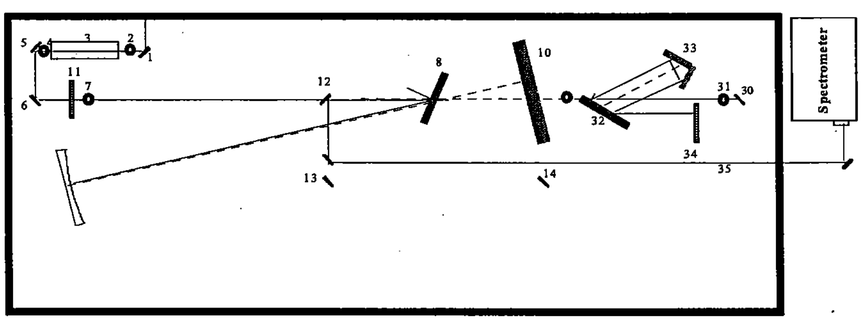

Fig. 3.13 Spatial-chirp-free alignment setup.

7. Setup the spectrometer to be able to monitor the spectrum from the stretcher using an oscilloscope.

8. Connect a BNC cable from the "Trigger out" of the spectrometer to the time base of the oscilloscope. Set the time base to 1ms/div.

9. Connect a second BNC cable to one end of the Spectrometer "signal " out. Connect the other end to the oscilloscope amplifier base. Set the amplitude of the monitored spectrum such that the signal is not saturated.

10. Tweak the horizontal axis of the <u>external</u> mirror used to route the beam into the spectrometer. Observe the spectrum on the oscilloscope. If the Stretcher is not setup correctly, there will be a spatial chirp (spatially varying spectrum). This spatial chirp is caused by the fact that the 1"x 7" mirror (#10) is not exactly at the actual focus of the large curved gold mirror (given the input divergence). Upon tweaking the external mirror, the signal present on the oscilloscope should not

"sweep" left or right on the screen. If this is the case, one will need to optimize the distance of the 1"x 7" mirror relative to the gold mirror so that the spectrum immediately collapses when adjusting the external mirror.

3.4.2 Spatial-Chirp-Free Setup Procedure

1. Ensure Seed Oscillator is well mode locked
2. Ensure stretcher is prematurely setup following the " Stretcher alignment check" procedure.
3. Reference, if possible, the base plate of the 1" × 7" mirror mount to the breadboard in its current position. As a second reference, with the Pump laser shutter closed and the Seed Oscillator beam blocked from entering the Legend-USP, using a tape measure, measure the exact distance between the surface of the large gold mirror and the surface of component #10, while in its current position.
4. Loosen the 3/32 screw securing the 1" × 7" mirror mount (#10) to the breadboard. Loosen it such that the base plate remains flat to the bench but not so snug such that the mount will not be able to slide back and forth.
5. If after loosening the base plate the monitored spectrum signal on the oscilloscope has changed, use an infrared viewer to observe the stretcher grating. The alignment on the stretcher grating may appear to be changed vertically. If this is so, tweak the micrometer (vertical axis) located at the back of the large gold mirror so that the grating alignment appears normal. This should recover the monitored signal back on the oscilloscope.
6. Slide in one direction, the mount housing the 1" × 7'' mirror, by millimeter increments.
7. Using an infrared viewer, observe the grating surface. Ensure that the strips appear to be centered to the grating aperture after each increment change. If they are not, reposition them horizontally by adjusting the entire 1" × 7'' mirror mount.
8. After changing distance by a millimeter and optimizing for any horizontal shift, tweak the horizontal axis of the external mirror to check the spatial chirp on the oscilloscope.
9. The further or closer the 1" × 7'' mirror is to the optimum distance of the actual focal length, the broader the monitored spectrum will appear to sweep across the scope screen when adjusting the horizontal axis of the external mirror. Fig. 3.14 and 3.15 show the spectrum before and after the stretcher.
10. After correcting for the 'spatial chirp" in the stretcher, lock the 1" × 7'' mirror/mount to the breadboard, ensuring that the strips on the grating are lined up correctly.
11. Tweak the micrometer adjustment of the gold mirror so that all the four passes within the stretcher are fitted within the grating aperture without clipping..
12. Remove the mirror placed between the mirrors #12 and #13.
13. Follow the procedure "optimizing the seed beam to the Regen cavity".

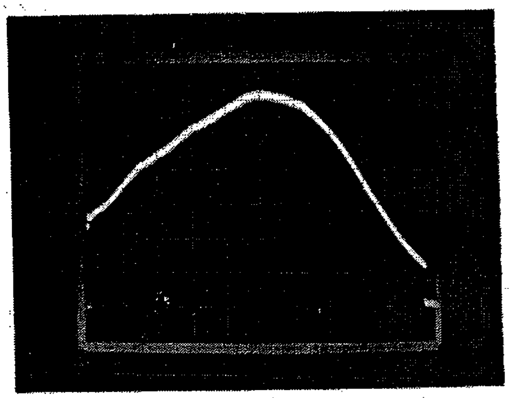

Fig. 3.14 Typical spectrum measured from Seed Oscillator. (Center wavelength @ 795 nm, Bandwidth = 35 nm, calibration is 4.4 nm/ms)

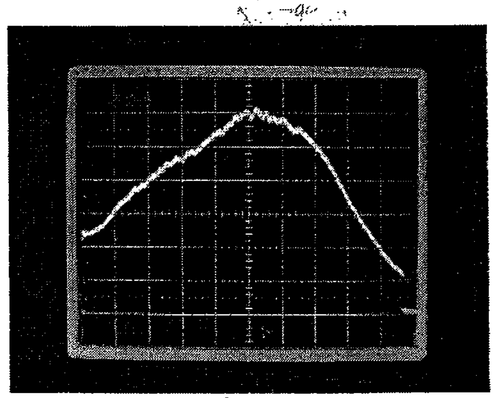

Fig. 3.15 Typical spectrum measured after the stretcher. (Center @795 nm. Bandwidth = 31nm)

4 Regen Alignment Procedure

4.1 Regen. Alignment

Handle all optics while wearing finger cots.

The following procedure explains in detail how to do an alignment of the Legend-USP Regen cavity only when the intracavity alignment has been grossly misaligned.

Since most optics will need to be removed from their holder(s) at this time, visually inspect all optics carefully to ensure that no other optics may have also damaged when damage to the rod occurred.

If upon inspection, some of the optics are found to be dirty, clean using methanol/acetone at this time.

Materials needed:

- lens tissue
- Hemostats
- Methanol/acetone
- two sheets of polarizer sheets
- two Reference blocks with crosshair target set at 2.5"
- 45 degree turning mirror/mount

1) Using a 3/16-ball driver, remove mirror #15 of the regen cavity from within its mount. Place it near the mount on top of a piece of lens tissue with the coated side facing upward as not to scratch the coating.
2) For reference purposes, if not already, inscribe a mark on the white Teflon holder relative to the position of the setscrew at the top of the mount. Remove the ¼ waveplate (#16) from within its holder.
3) Ensure that reference iris #17 is completely open.
4) Remove Pockels cell #18 from within its holder by:

Note: prior to completely removing the Pockels cell from within their mount, note the current orientation of the cell so that it is replaced back in its original setup. The Pockels cell windows have a slight wedge so the orientation (placement) of the Pockels cell will deviate the beam passing through the cell horizontally by 5mm in either direction.

A. Indexing the base of the Pockels cell mount in their current position as to maintain a reference. Unscrew the two ¼-20 screws securing the mount to the breadboard and remove the entire assembly and place away from the cavity as allowed by the cable lengths.

B. Removing only the Pockels cell from within mount. Follow "a-f"

a) Ensure SDG is turned off. High voltage present at Pockels cell leads if unit not turned off.

b) Un-plug the 120vac plug leading from the SDG to the input panel of the Legend-USP.

c) Using a 3/32 balldriver, remove the four screws located on top of the Pockels cell High voltage cover.

d) Using a 8/32-socket head driver, remove the two hex nut screws securing the High Speed Driver High Voltage leads to the Sol Gel Pockels cell.

e) Using the 3/32 ball driver loosen the support bracket(s) that secures the cell within the mount.

f) Remove the cell from within the mount and place in secure location away from the Regen cavity.

5) Remove the zero degree turning mirror (#19) that folds the Regen cavity from within its mount. Also place at or near the mount.

6) Remove component #41 that serves as the beam dump used to dump the residual 527nm beam after pumping the Ti:sapphire rod

7) Remove the vertical plate of component #13 by unscrewing the two 8/32 screws located at the base of the mount. Doing so will minimize replacement of the vertical plate once the polarization rotator is re-assembled upon completing the alignment of the Regen cavity.

Upon removal of the vertical plate, the output of the stretcher beam, as it takes a 90 degree turn off of component #12, should now be propagating towards the side panel closest to the Regen cavity.

8) Tweak the vertical axis of mirror #12 so that the beam coming out off the 1"x 1" square mirror is propagating along the tabletop at 2.5".

9) Taking a separate 45 degree mirror (dielectric broadband, gold or silver coated)/mount. Position it such that the beam from the 1"x1" square mirror is turned 90 degrees, propagating along side the panel, towards the output end of the Legend-USP as shown in Fig. .4.1.

Note: conveniently, one can use mirror/mount #14 to serve as the component for use as the second turning mirror for optically aligning of the Regen cavity using the stretched output beam as the alignment source. If one chooses this component as the second alignment mirror/mount, flip the mount 90 degrees upon its base plate and at the same time rotate the variable base plate so that the round variable locking ring is located directly in front of where the actual mirror is located within the mount. Reposition component #14 behind the Regen cavity as shown on the following diagram.

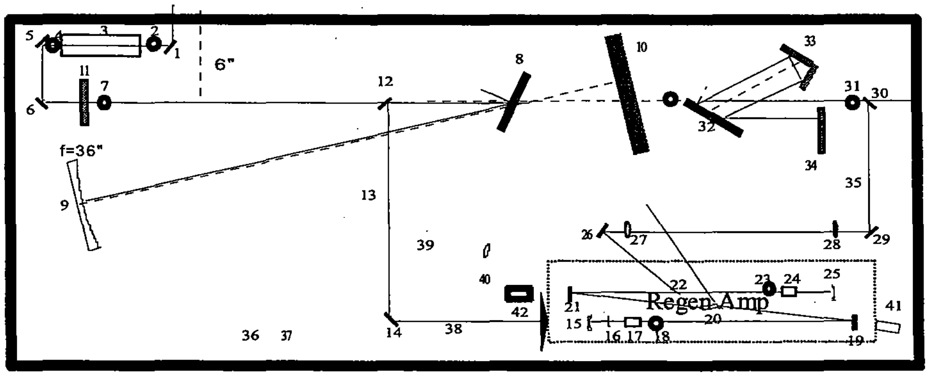

Fig. 4.1 Use mirror #14 as a turning mirror for the pre-alignment of the regen cavity.

10) Set a block with a cross pattern at exactly 2.5" above the Legend-USP (serves as a reference target) breadboard directly on top of the last hole of row #2. Place the block with its bottom line of the cross pattern centered directly to the hole center.

11) Without permanently locking component #14 to the breadboard, in a coarse manner, maneuver mirror mount #14 in its new location such that the intercepted stretched output beam appears to be propagating parallel to the Regen side panel along hole pattern #2 of the Legend-USP bench.

    Use the reference block mentioned above as the far field reference target.

12) Using a second reference block, place the cross hair target directly on top of the hole (hole pattern #2) closest to component #14. Observe where the beam is relative to the cross pattern. Move the mount according to the direction the beam needs to go relative to the cross pattern.

13) Remove the block.

14) Once the position of the mount is such that the beam is close to the referenced holes along row #2, using a 3/32 screw, lock component #14 to the bench so that it is secure.

15) Once the mount is secured to the tabletop, observe where the beam is relative to the reference cross hair on the mount located towards the output panel of the Legend-USP. The beam should be sticking the cross hair target center. If it is not, make the necessary adjustments to the X and Y-axis of mirror/mount #14 so that it is.

16) Place the second reference block (or relocate the block nearest the output panel) directly on top the hole referred to in step 10. Observe where the beam is relative to the center of the cross hair. If it is not centered to the cross hair target, make the necessary adjustments to the X and Y-axis of the 1"x1" mirror/mount #12 so that it is

17) Continue steps 10-12 until the beam is perfectly centered to the crosshair patterns at both locations along row #2 of the breadboard.

18) Position the mirror mount #15 (if necessary) so that the "exposed" mirror aperture of the mount is centered to the in-coming "stretched" beam.

19) Place the ¼ waveplate back into its holder. Ensure that the beam is propagating directly through the waveplate center. If it is not, loosen the base plate and reposition the mount so that it is. Slightly cock the mount off horizontally so that there are no surface reflections from the waveplate propagating back towards the Stretcher setup.

20) Again, remove the waveplate from within its holder.

21) Close reference iris #18 completely. Observe where the beam is relative to the iris center. The iris should be perfectly collapsing upon the propagating beam . If it is not, mechanically adjust the iris both in the X and Y-axis so that it is.

22) Place Pockels cell #17 back into it's mount, in the original orientation that the cell was in prior to commencing the cavity alignment. Resecure the cell back into its holder following the reverse order as stated in step 4A-a-f

Using a white business card, ensure that the beam is propagating directly through the center of both input and output apertures of the Pockels cell. If it appears not to be, one will need to relocate the cell by loosening the two 3/32 balldriver screws securing the mount to the breadboard.

23) Housed inside the Pockels cell is a KD*P crystal. It will be necessary to align the optical axis of the KD*P crystal along the propagating beam. The cell will need to be tilted about two axes to achieve this. (see Fig. 4.2).

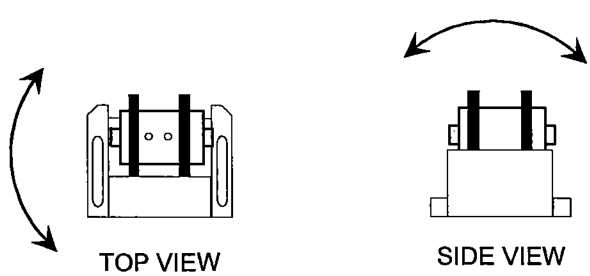

Fig. 4.2 Adjustment for the Pockels cell

24) Place a white business card mid way between component #19 and #17.

25) Place two pieces of cross-polarizing film directly in front of both input and output apertures of the Pockels cell

26) Place a piece of lens tissue between the input aperture of the cell and the polarizer sheet in order to scatter the beam through the cell. Using an infrared viewer, observe the pattern on the white business card.

One should see a pattern as the one shown in Fig. 4.3.

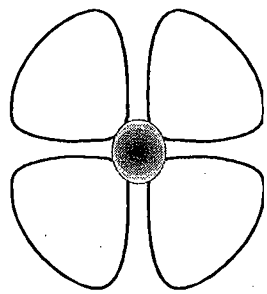

Fig. 4.3 Scattered pattern after the Pockels cell sandwiched between two cross-polarizer if it is aligned correctly.

27) If the observed pattern does not appear to look like the pattern above, an adjustment to the X and/or Y-axis of the Pockels cell mount will be needed (See Fig. 4.4). Use a 1/8-ball driver to make the adjustments.

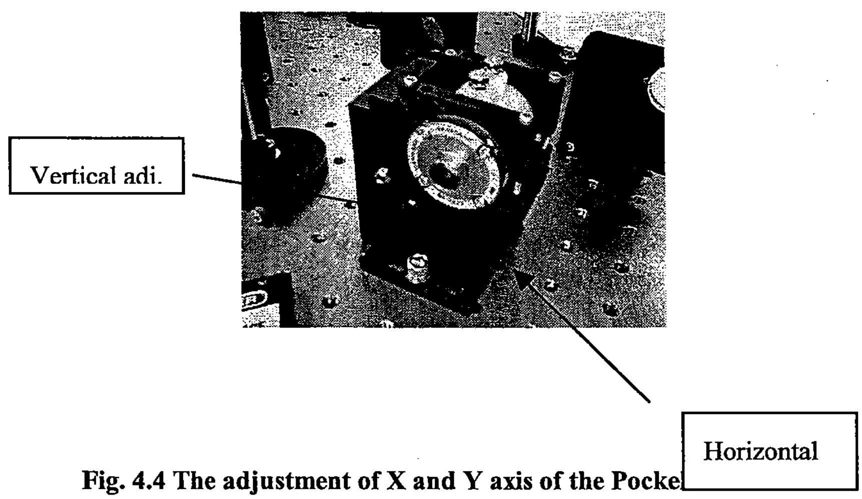

Fig. 4.4 The adjustment of X and Y axis of the Pocke

28) Remove two-polarizer sheets and the lens tissue from around the Pockels cell apertures.

29) Remove the white business card from within the beam path allowing the beam to propagate towards mirror #19.

30) Reinstall the zero degree mirror back into its holder. Secure within its mount using the 1/16 balldriver.

31) Index the Ti:sapphire rod mount to its present position on the breadboard.

32) Using a 3/32 balldriver, loosen the two screws securing the mount to the bench. Remove and place out and away from its current position.

33) Place the reference block with the cross hair target directly in front of component #21. Check to see that the beam coming from folding mirror #19 is propagating parallel to the bench top at 2.5" above. If it is not, tweak the vertical adjustment of the zero degree mirror #19 so that it is.

34) Place the Ti:sapphire rod /mount back into its indexed position.

35) Assuming the angle of the Ti:sapphire rod is correct in its present location, place a piece of lens tissue directly in front of rod side facing component #19.

36) Place a reference block with a white business card tapped or leaning against the block 2-3 inches away, located on the other side of the rod.

37) Using an infrared viewer, observe the pattern created by the lens tissue. One should be able to see the rod aperture relative to the beam propagating through the rod (in this case scattered). If the beam does not appear to be centered, tweak the horizontal adjustment of mirror #19 so that it is.

38) Remove the reference block from within the Regen beam path following the rod.

39) Remove the lens tissue from in front of the other side of the Ti:sapphire rod.

40) After the beam has propagated through the rod, the beam should strike the inside edge of the second zero degree mirror (component #21), at this time the beam will fold back propagating towards the output panel. The beam should at this time be at 2.5" above the breadboard top.

41) At this time, remove mirror #25 from within its mirror mount.

42) Remove photodiode #41 from its present position.

43) Place the reference block with the crosshair target at 2.5" so that it is located behind the mount corresponding to mirror #25.

44) If the beam from mirror #21 is not striking the reference block at the 2.5" mark, tweak the vertical adjustment of mirror mount so that it is.

45) Collapse fully iris #23. If upon closing the iris, the center of the iris is not collapsing upon the beam, position the height of the iris so that it does so.

46) For the horizontal axis of component #21, tweak it so that the beam is passing through the iris center

47) At this time, using a white business card, observe the passing of the beam through the broadband dielectric polarizer (#22). The beam should be passing through the polarizer center. Use an infrared viewer to verify this. If it does not appear to be, loosen the 3/32 screw securing the mount to the table, and slide the base plate (keeping the mount square to the input/output panel) of the mount vertically until the beam is passing through the center of the component.

48) Resecure the baseplate to the bench.

49) Following the iris, the beam should be propagating through the center of Pockels cell #24. If the beam does not appear to be so, loosen the baseplate screws and slide the mount vertically so that it is.

50) Follow steps 24-26. Set the pitch and yaw (vertical and horizontal axis) of Pockels cell #24 using two polarizer sheets/lens tissue.

51) Place mirror #25 back into its holder and secure by tightening the mount set screw using a 1/16 balldriver.

52) Using an infrared viewer, observe collapsed iris #23. Look for the retro reflection to be propagating from the surface of mirror #25 back to the collapsed iris. If it does not appear to be going back through the iris center, adjust the vertical and horizontal axis of mirror #25 so that it is.

53) Fully open iris #23.

54) Collapse iris #18.

55) Using the infrared viewer, look for the retro reflection from mirror #25 propagating back to the center of iris #18. Make, if any, adjustments to component #25 so that the retro reflection has propagated also through the iris center.

56) Open fully iris #18

57) Insert optic #15 back into its holder.

58) Collapse fully iris # 4.

59) Again using the infrared viewer, look for the retro reflection from mirror #15 propagating back through the stretcher setup towards iris #4 of the Faraday Isolator setup.

This completes the alignment of the Regen cavity.

Pump the Regen cavity with the 527nm-pump beam from the Coherent Pump laser and refer to the procedure "Optimizing the Regen cavity".

4.2 Spectral Improvement

1) Block the seed from propagating into the Regen cavity. Interrupt propagation by closing the mechanical shutter or by blocking the seed into the Regen using a beam block.

2) Use an external turning mirror/mount, and position it between component #29 and the 1"x1" square mirror (#30). Direct the regen output beam into the Spectrometer.

3) Monitor the Q-switch spectrum out of the Regen on the Oscilloscope. It should appear as shown in Fig. 4.5.

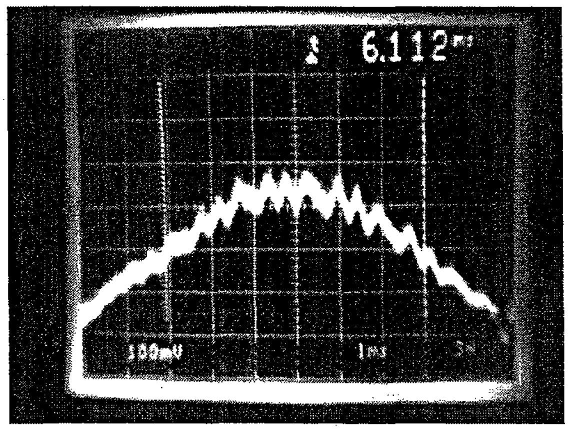

Fig. 4.5 Typical spectrum from Regen cavity

4) The output Spectrum from the Regen should be as smooth as possible although it will never be as smooth as the Seed Oscillator output in comparison.

   Various parameters of the system could induce modulation across the spectrum. In the regen, the various parameters that could potentially modulate the spectrum are:

   a) Misalignment of the Pockels cell(s)

   b) Inappropriate setting of the ¼ waveplate in the Regen

   c) Incorrect ¼ wave voltage to the Pockels cells

4.2.1 Ensuring Modulation Free, "free-running" Spectrum

In order to ensure that all parameters above are optimized correctly, it is best to look at the spectrum in the absences of some of the contributing parameters. To do so, do the following:

1. Disconnect the BNC output cables corresponding to "output 1 and output 2" of the SDG. Doing so allows the triggering of the scope for monitoring the Regen (free-running) intracavity light.

2. In its present position, using a black marker, inscribe a reference mark (if one is not there already) relative to the set-screw securing the ¼ wave plate holder to the mount. Doing so will allow replacement of the wave plate to its original position when one is done.

3. Observe the free-running spectrum on the oscilloscope after removing the wave plate. It should appear as shown in the previous photo. If the spectrum appears to be modulated, a vertical and/or horizontal adjustment to one or both Pockels cell will need to be made depending on how severe either Pockels cells is misarranged. Example of misalignment of the Pockels cell #1 by less than a ¼ turn of a ball driver in the horizontal (yaw) axis can be seen in Fig. 4.6.

4. Tweak the two cells individually such that the spectrum appears the least amount modulated. If gross adjustments are made, it may be necessary to tweak the end mirror corresponding to the Pockels cell that has been adjusted in order to recover the optimization of cavity alignment.

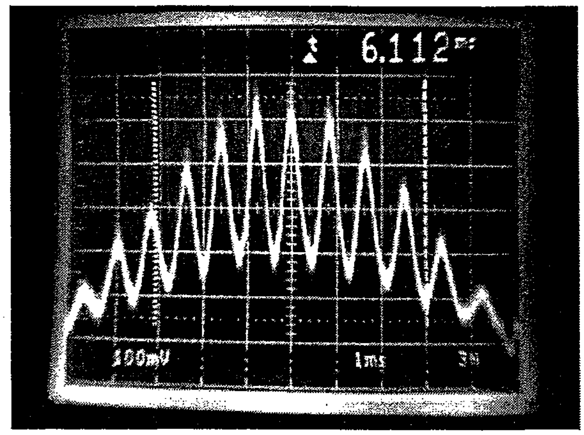

Fig. 4.6 Pockels cell #1 miss-alignment

4.2.2 Ensuring correct orientation of ¼ waveplate and ¼ wave voltage

1) Replace the ¼ waveplate back to its original position as dictated by the inscribed black reference mark.

2) Reconnect the BNC cable to "output 1" enabling the firing of Pockels cell #1.

3) Observe the Q-switch spectrum on the oscilloscope. Ensure that the spectrum is not modulated after insertion of the waveplate into the Regen cavity. If the spectrum appears to be modulated, make slight rotations to the ¼ waveplate with emphasis of smoothing the modulated spectrum. Fig. 4.7 is an example of the Regen spectrum modulated as a function of slight ¼ waveplate misalignment.

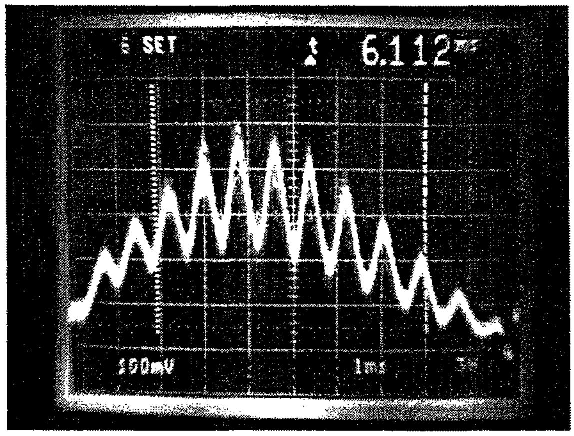

Fig. 4.7 Q-Switch spectrum modulated as a function of ¼ waveplate orientation

4) Tweak the potentiometer on the high voltage power supply(HVPS) that varies the high voltage to Pockels cell #1 while observing the Q-switch spectrum. Again it should not be modulated as a function of voltage. If modulated, the spectrum will appear similar to the photo above. Slight tweaks to one or both parameters should ultimately yield a nearly modulated free spectrum.

4.2.3 Observing the Regen spectrum after seeding the Regen cavity

While still observing the Q-switch spectrum (Fig. 4.8), allow the seed beam to propagate into the Regen cavity. In doing so, two things should happen; upon seeding the Regen, the Seed Oscillator spectrum should center itself to the Regen spectrum. Observe this case while monitoring the oscilloscope. If the seeded spectrum does not collapse upon the center of the Regen spectrum, the Seed Oscillator wavelength is offset to the Regen. Tweak the slit of the Seed Oscillator and/or the x-axis of the optical components #14 so that the bandwidth of the seeded spectrum is maximized and central wavelength matched the peak of the unseeded reg. spectrum. (see Fig. 4.9)

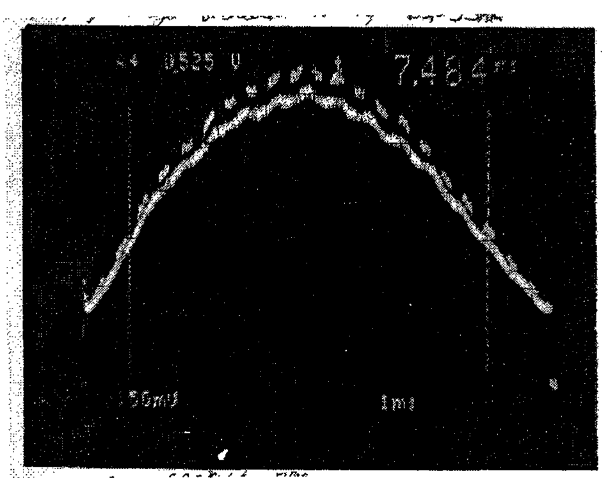

Fig. 4.8 Unseeded reg. Spectrum. (center @ 800nm. Bandwidth =33 nm)

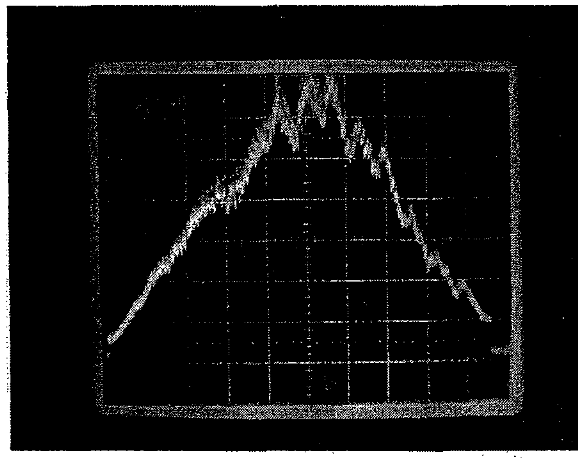

Fig. 4.9 Reg. spectrum after seeding. (center @805nm,Bandwidth = 26 nm)

5 Optimizing Seed Alignment

5.1 First Procedure to Optimize Seed Beam into RA Cavity

1. Following sufficient warm up time, ensure Mai Tai is well mode-locked and performed within system specification.
2. Ensure good performance from the Evolution pump source (i.e.: power and stability).
3. Ensure RA cavity is well optimized in the absence of the seed pulse.
4. Monitor the RA cavity radiation using the Coherent fast photodiode situated behind mirror #25. The typical Q-Switch pulse is shown in Fig. 6.18.

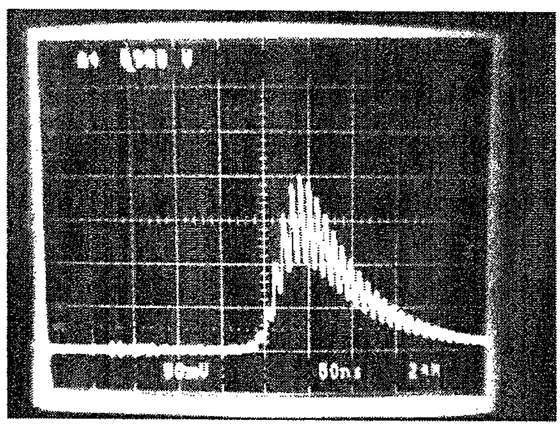

Figure 6.18 RA Cavity Q-Switch pulse

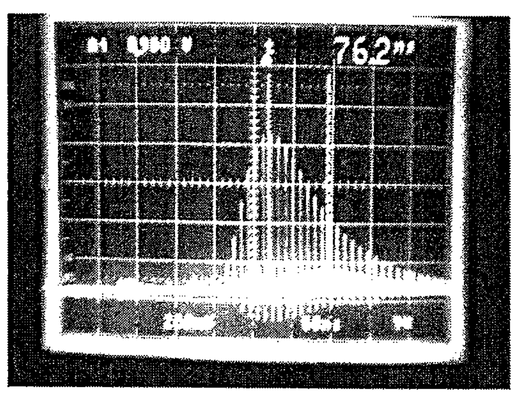

Figure 6.19 RA Cavity "seeded" radiation

5. Delay out the switching time to Pockels cell 2 (#24) so that the SDG digital readout is more than 500ns.
6. Provided that the Mai Tai is optimized and well Mode-locked, allow the beam from the Mai Tai to enter the Legend-USP by opening the mechanical shutter of the Mai Tai with computer.
7. If the alignment of the stretched output beam into the RA cavity is optimized, one should see the greatest amount of buildup reduction between the Q-switch signal and the seeding of the Mai Tai pulse into the RA cavity (See Fig. 6.19).

   The difference in buildup between the two conditions is typically >55ns. When this is the case, the seed beam should be "co-linear/superimposed" with the intra-cavity light of the RA.

5.2 Second Procedure to Optimize Seed Beam into RA Cavity

1. Ensure that Steps 1-7 above are satisfactory.
2. Momentarily toggle to the **"off"** position the **"output enable"** switch located on the front panel of the SDG. Doing so will not provide trigger signals to the High Speed Drivers consequently disabling the RA cavity from emitting laser light.
3. Roll out the timing to **"output 2"** such that the digital display indicates 500ns.
4. Take a white card and place it directly in front of component #14 (between components #14 and #15).
5. Using an infrared viewer, locate the "stretched" output beam as it strikes the card.
6. Switch the **"output enable"** switch back to the upward position enabling the firing of the Pockels cell #1.
7. Using the IR viewer, observe where the depolarized light coming from the Ti:sapphire rod is relative to where the beam from the stretcher is on the card. If the Depolarized light from the rod does not appear to be superimposed upon the stretched output beam, tweak the vertical and/or horizontal axis of mirror #15 so that it does.
8. Move the card from in front of component #15 and place it as close to the rod as possible without interrupting the RA intra-cavity light.
9. Again using the IR viewer, observe where the "stretched' output beam is striking the card relative to where the depolarized light coming from the Ti:sapphire rod beam is.
10. If the two beams are not super imposed upon one another at this point, tweak the X and/or Y-axis of mirror #14 so that it is.

Warning!

Take great care not to accidentally limit the "stretched" spectrum. The reduced spectrum may cause the damage of the optics in the RA.

11. Continue iterating between steps 4-10 until both beams are superimposed on one another at both locations.

    At this time, the RA cavity should now be "seeded". While observe the buildup reduction on the scope, tweak both the vertical and horizontal adjustments of mirror #14 to finalize the seed alignment.

5.3 Third Procedure for Checking Seed Alignment to RA cavity

1. Ensure that the RA cavity is well optimized in the absence of the seed beam, and the two intra-cavity irises are aligned to the intra-cavity light. (Upon collapsing the iris, its center should symmetrically collapse around the laser cavity light). If this is not the case, reposition the irises in both the X and Y-axis. Check and reposition the two irises one at a time but **ONLY** do so when the RA cavity is optimized in both power and spatial profile.
2. Toggle to the "off" position the **"output enable"** switch located on the front panel of the SDG. Doing so will not provide trigger signals to the High Speed Drivers consequently disabling the RA cavity from emitting laser light.
3. Collapse fully the two intra-cavity irises (#18 and 23)
4. Using an infrared viewer, observe the two iris apertures as the seed beam is allowed to propagate into the RA cavity. The seed beam should be propagating directly through the center. If this is not the case, tweak component #14 to center beam to iris #18 and then tweak mirror #15 so that the seed beam is centered to iris #23. Continue iterating between the two mirrors until the beam is passing through the center simultaneously.
5. Open fully the two irises.
6. Roll out the timing to **"output 2"** such that the digital display indicates 500ns.
7. Switch the **"output enable"** to the upward position.
8. Observe Q-switch radiation from RA cavity using the Coherent photodiode.
9. Allow seed beam to propagate into RA cavity.
10. While observing the buildup reduction make final tweak to the X and Y-axis of mirror #14 while looking for the greatest buildup reduction.

This completes the various procedures for optimizing the seed beam into the RA cavity.

5.4 Cavity Dumping a Pulse

While observing the regen cavity light with the photodiode, roll back the timing via "output 2" of the SDG until the pulse prior to the "main" pulse is seen "cavity dumped" as shown in Fig. 5.3.

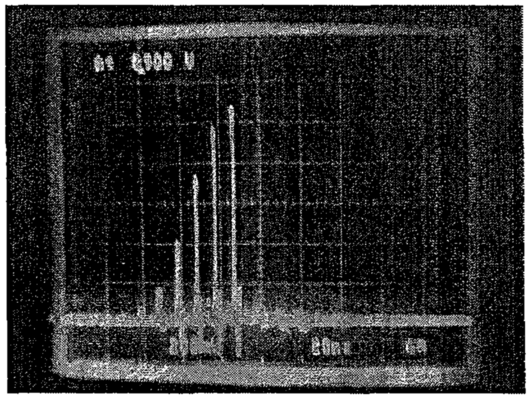

Fig. 5.3 Cavity dumped pulse

6 Compressor Alignment Procedures

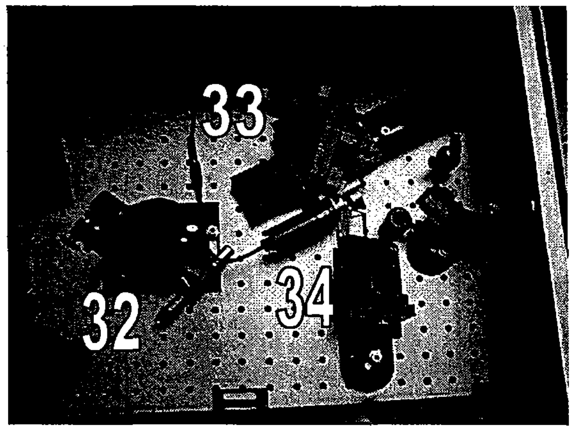

Fig. 6.1 Top view of the compressor

Fig. 6.1 shows the top view of the compressor, which consists of one grating (#32), one horizontal retro-mirror set (#33), and one vertical retro-mirror set (#34). Moving the component #33 back and forth compensates the second order dispersion, and rotating the component #32 compensates higher order dispersion (i.e. 3rd and 4th order). Therefore, by adjusting the components #33, and #32, one should be able to compensates the phase distortions introduced by the stretcher and reg. Amplifier up to the 4th order, and get the shortest pulse duration. Typical pulse duration measured with single shot autocorrelator (SSA) is shown in Fig. 6.2.

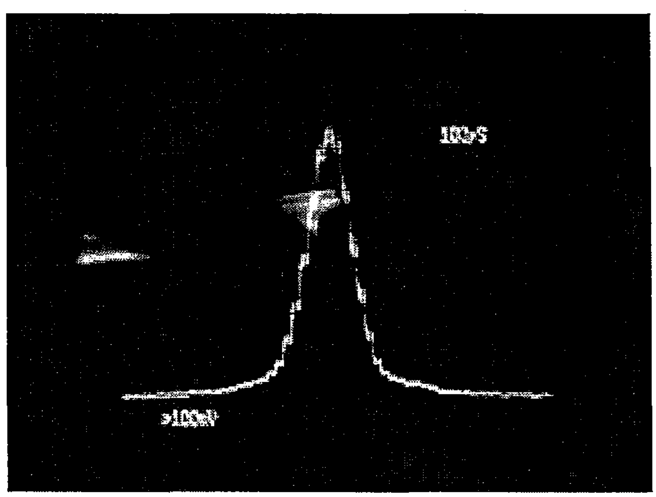

Fig. 6.2 Pulse duration = 40 fsec measured from SSA using Gaussian deconvolution. (Calibration is 44 fsec/100μs before deconvolution)

Before tuning the compressor, one should do the following alignment procedure for the compressor:

1) Close the Pump laser shutter.

2) Disable the Legend-USP High Speed Drivers.

3) Close the seed beam input shutter.

Warning: Failure to block the seed beam while performing this part of the procedure will result in major damage to optical components in the regen. This damage is not covered by the warranty.

The unseeded output of the regen is used for the first part of the compressor alignment.

4) Remove the grating assembly as in step 7 of the stretcher alignment procedure.

5) Install the removable reference iris in location #31 and adjust the aperture opening so that it is ~ 4mm.

6) Open the Pump laser shutter.

7) Enable the Legend-USP High Speed Drivers and adjust the timing of Pockets cell #2 so there is cavity dumping of the Q-switched pulse.

8) Use mirror #26 to center the beam on the iris at position #31.

9) Disable the High Speed Drivers.

10) Move the iris to position #7. This part is the reverse of the stretcher alignment steps 9-11.

11) Enable the High Speed Drivers.

12) Use mirror #30 to center the beam on the iris.

13) Iterate between steps 5 - 12 until the beam is centered on the iris at both locations.

14) Leave the iris in the #31 location after the beam has been centered at both iris locations.

15) Disable the High Speed Drivers.

16) Close the Pump laser shutter.

17) Install the grating assembly as in step 14 in Section 3, which is the stretcher alignment procedure.

18) Open the seed beam input shutter.

19) Adjust the rotation of the grating assembly so that the stretched beam pattern on the grating appears as shown in Fig. 6.3. Use an IR viewer to verify this.

Stretcher grating

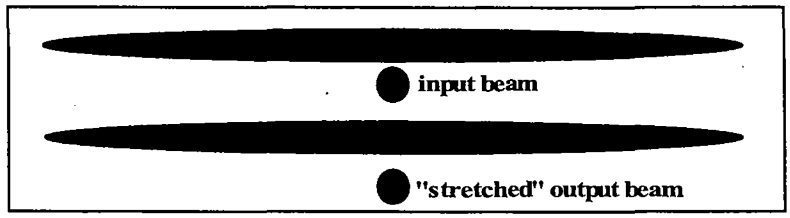

Fig. 6.3 Spatially dispersed spectrum on the stretcher grating

20) Close the seed beam input shutter.

21) Disconnect the trigger BNC for High Speed Driver #2 on the SDG (output 2).

22) Block assemblies #33 and 34.

23) Open the Pump laser shutter.

24) Enable the High Speed Drivers. This will produce a Q-switched pulse.

25) Open the seed beam input shutter. If the seed beam alignment is not optimized for maximum buildup reduction, refer to the procedure "optimizing seed alignment" in Section 5.

26) Connect the trigger BNC cable for High Speed Driver #2 on the SDG and adjust the timing for selecting the proper pulse to be switched out of the Regen cavity.

27) Verify that the seeded regen. output beam is still centered on the iris.

28) Using the IR viewer to look at the grating, one should see a round spot (input beam) on the lower right side of the grating. If the input beam is not on the grating as shown in Fig. 6.4, go back and check the alignment through the iris'.

Note: On chance that the grating has been removed from its mount and put back in, there are reference lines on top of the grating showing how the grating is positioned side to side in the mount

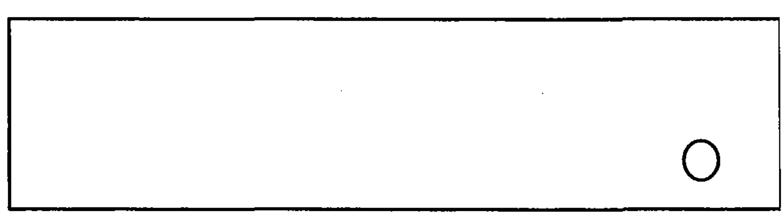

Fig. 6.4 Input beam on the compressor grating

29) Unblock assembly #33 and use IR viewer to look at the grating. One should see the spectrum to the left of the input beam. The spectrum has to be on the same y-axis as the input beam. Use the x-axis screw of assembly #33 so that the input beam and the spectrum are on the same y-axis. See Fig. 6.5.

Do not make adjustments with the y axis screw on mount #33

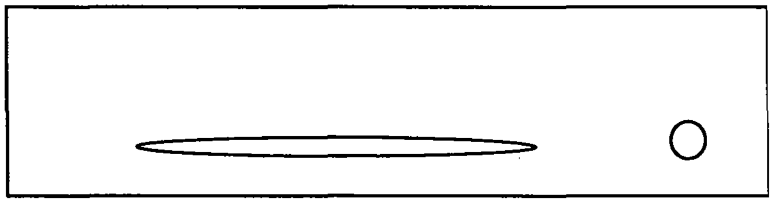

Fig. 6.5 The input beam and the spatially dispersed spectrum by the compressor grating

30) The spectrum should also be centered in the remainder of the grating. See Fig. 6.6. To center the spectrum from side to side on the grating, loosen the 1/4 x 20 screw at the back of assembly #33 and slide the assembly so that the spectrum is centered on the grating.

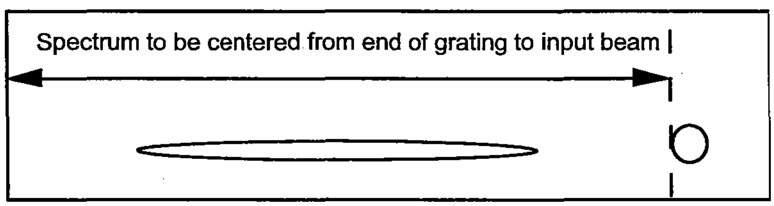

Fig. 6.6 Correct position of the spectrum

31) Unblock assembly #34. Using the IR viewer, one should see the input beam and spectrum on the bottom and the same pattern directly above. See Fig. 6.7.

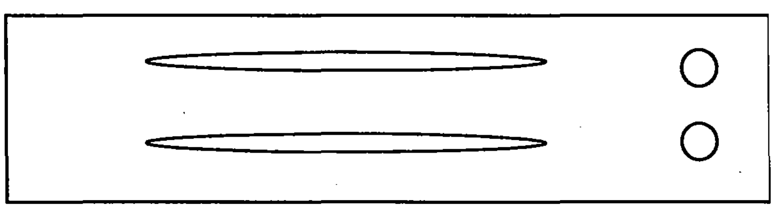

Fig. 6.7 Correct position of the spectrum on the grating after four path through the compressor

32) If the top two beams are not directly above the bottom two beams, the assembly #34 needs to be rotated. Loosen the 1/4 x 20 screw securing the assembly to the breadboard and rotate the entire mount so that the top two beams are directly above the bottom two beams.

Do not make adjustments with the y axis screw on assembly #34

33) The top spectrum and spot should be in the same y-axis. If they are not, adjust the x-axis screw on assembly #34 so that they are on the same y-axis.

34) The top spectrum and output spot are centered on the grating in the space above the bottom beams. See Fig. 6.8. To center the beams, assembly #34 may be moved vertically.

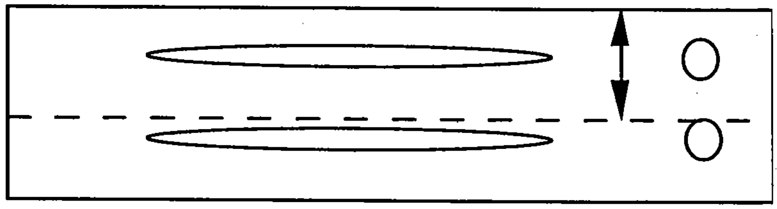

Fig. 6.8 Correct position of the returning spectrum

35) Look at the output beam. There should be no clipping of the beam. Slight adjustments to mirror #34 and mirror #30 may be made if clipping is observed.

36) If adjustments are made with these mirrors, go back and look at the grating with the IR viewer. Verify that the beams are aligned as in Fig. 6.7 and 6.8. If large adjustments are necessary to get rid of any clipping of the output beam then the above procedure needs to be repeated.

7 Replacement Parts

Stretcher			
Component #	**Part #**	**Optical Description**	**Quantity**
1	705-2527	Dielectric HR mirror, 750-900nm, 1" 45 Dg.	1
2	400-0848	Mech. Iris	1
3	799-1753	Ti:sapphire optical Isolator	1
4	400-0848	Mech. Iris	1
5	705-2527	Dielectric HR mirror, 750-900nm, 1" 45 deg	1
6	705-2527	Dielectric HR mirror, 750-900nm, 1" 45 deg	1
7	400-0848	Mech. Iris	1
8	710-2513	Spectragon. Grating, 30x110x16mm, 1200ln/mm	1
9	705-3447	Mirror, 6" dia, f = 36" Reflective gold	1
10	705-4673	1"x7" Dielectric HR,750-900nm,0 deg.	1
11	705-2528	1"x3" Dielectric HR,750-900nm,45 deg.	2
12	705-2526	1"x1" Dielectric HR,750-900nm,45 deg.	1
13	705-2527	Dielectric HR mirror, 750-900nm, 1" 45 deg	2
14	705-2527	Dielectric HR mirror, 750-900nm, 1" 45 deg	1

Regen Amplifier Cavity			
15	703-3641	CVI mirror, +90cm HR, 0 deg.	1
16	709-2215	1/4 Waveplate, 0 order QWPO-825-05-4	1
17	712-0793	Sol Gel Pockels Cell, 700-1000nm	1
18	400-0848	Mech. Iris	1
19	705-2176	Dielectric HR mirror, 750-900nm, 1" 0 deg	1
20	711-0750	1/4" x1" Ti:sapphire rod	1
21	705-2176	Dielectric HR mirror, 750-900nm, 1" 0 deg	1
22	708-0795	Kimetic BB polarizer, TFPK,528-RW-28	1
23	400-0848	Mech. Iris	1
24	712-0793	Sol Gel Pockels Cell, 700-1000nm	1
25	703-3641	CVI mirror, +90cm HR, 0 deg.	1

Telescope (8x)			
26	705-2176	Dielectric HR mirror, 750-900nm, 1" 0 deg	1
27	702-3649	Lens, -50mm, BB, KPC040 AR.16	1
28	701-0818	Lens, +400mm, BB, KPX115-AR.16	1
29	705-2527	Dielectric HR mirror, 750-900nm, 1" 45 dig	2

Compressor			
30	705-2526	1"x1" Dielectric HR,750-900nm,45 dig.	1
31	400-0848	Mech. Iris	1
32	710-4735	Richardson Grating, 30x110x16mm, 1500ln/mm	1
33	705-4385	1.5"x3" Dielectric HR,750-900nm,45 deg.	1
33.5	705-4734	1.5"x2" Dielectric HR,750-900nm,45 deg.	1
34	705-2528	1"x3" Dielectric HR,750-900nm,45 deg.	2

8 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.

8.1 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.

8.2 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.