System Components

CPA-1000, Version 3.1

Latest Upgrade: June 10, 1996

This manual contains information on the subsystems forming the CPA-1000, including:

- Oscillator pump laser Argon: Spectra-Physics BeamLok™ model 2060, Coherent, Inc. model 310, or Innova® 90
- Femtosecond oscillator NJA-5, version 1
- Pulse stretcher PS-1000, version 3
- Regenerative amplifier TRA-1000, version 3
- Pulse compressor PC-1000, version 3

Clark phone customer service

313-426-2803

Tracy

Contents

Graphic Symbols Explained

The following graphic symbols are used throughout this manual to draw your attention to situations or procedures that require extra attention. They warn of hazards to your eyesight, damage to equipment, and necessary performance specifications.

Performance Specifications. You should follow these instructions without deviation.

Serious bodily harm, including permanent eye damage, may result from exposure to radiation either present in the area, or radiation that may be created when executing the alignment step detailed along side it. Eye protection required.

Graphic to draw your attention to a warning or important note.

Wear protective gloves when handling gratings or aspheric mirrors. Skin oil on gratings may make the grating worthless.

Take care! This is an electrical hazard.

1. Eye Safety

The lasers you will be working with are sources of intense optical radiations. Their safe use depends on your being aware of their unique characteristics and treating them with the respect due to instrumentation that can cause serious bodily harm.

At almost every stage of the system alignment procedure, the intensity of the beams from the Argon-ion laser, the ORC-1000 Nd:YAG laser, the NJA-5 Ti:Sapphire oscillator, and the TRA-1000 Ti:Sapphire Regenerative Amplifier can cause serious damage to the eye, including loss of vision, when viewed directly or when reflected off another object.

The radiation generated and amplified by the Ti:Sapphire is in the near IR wavelength range where the sensitivity of the retina is minimal. When the Ti:Sapphire laser is operating in the near infrared, the weak appearance of the beam may **mislead** you into believing it is of low intensity and therefore of little concern. However, serious and permanent eye damage can still occur.

The various wavelengths, pulse energies, and operating power emitted by the lasers forming the CPA-1000 system are listed in Table 1-1. Use this table and good sense to decide what level of eye and skin protection is needed.

Table 1-1

Laser parameters affecting the user's safety

Laser	Wavelength (nm)	Power	Pulse Energy
Argon-ion	460-520	< 20 W	Continuous wave
Nd:YAG ORC-1000	532	< 65 W	< 25 mJ
Ti:Sapphire Oscillator NJA-5	700-1000	< 2W	< 20 nJ
Ti:Sapphire Regenerative Amplifier TRA-1000	700-1000	< 5 W	< 5 mJ

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- **Post the laser parameters (shown in the preceding chart) near the laboratory to alert everyone to the presence of laser radiation.**

- **Assemble and operate this system in an enclosed room. Periodically inspect the area for stray beams and reflections. Block those that propagate outside of the work area during assembly and alignment. Avoid uncontrolled reflections.**

- **When servicing the system do not wear jewelry (*for example*, rings, chains, etc.) that might pass through the laser beam line. Uncontrolled reflections may result!**

The laser beams can remain collimated over large distances and remain a hazard far from the original source. Clearly mark the door to the room with warning signs and interlocks connected to the two pump lasers to prevent accidental exposure to the beams.

- **Post warning signs that alert everyone to the presence of laser radiation.**

Do **NOT** operate the system while untrained personnel are present. Warn anyone in the area where beams are located of the dangers associated with laser beams. **Verbal warnings** help to ensure that others in the area are *not* injured by stray radiation.

- **Limit access to the equipment to trained personnel who have a need to use it.**

2. Site Preparation

2.1 Laser Room

The CPA-1000 system is designed to operate under standard laboratory conditions.

- The laboratory site must be easily accessible, because some large pieces of equipment will have to be moved to the site, including the optical table(s) and the various laser power supplies.
- Water and electricity must be available (see below).
- The room temperature must be stable to +/- 2° C, and the humidity level must be maintained at all times below the condensation point.
- The site must be reasonably free of sources of vibration.
- The site must be clean. The cleaner the facility, the less often cleaning of the optics will be required.
- The airflow in the room (air conditioning) must be directed away from the lasers. Turbulent airflows will disturb the laser system and degrade its short term stability.
- The laser table must be well lit. If an overhanging platform is located above the table, it may be necessary to install some additional lights. The light level control must be easily accessible as some of the alignment steps call for a darkened room.
- The table temperature must be stable to +/-2° C.
- The table top surface must provide some type of anchorage points located on a regular basis (such as a 1" or 25 mm grid).
- For safety, the laser site access must be restricted (see Chapter 1, Eye Safety).

2.2 Utility Requirements

2.2.1 Argon-Ion Laser

For your convenience, we provide the following information for the most commonly found argon-ion lasers (Spectra-Physics BeamLok™ 2060, Coherent Innova® 310, Coherent Innova® 90). Please refer to your argon-ion original manufacturer's manual for update information and for instrucperformance, and prevent premature tube failure due to reduced cooling efficiency. Any such system must meet or exceed the cooling requirement listed above.

2.2.3 Coherent 310

Electrical Connections

- 3Ø, 208 VAC (± 10%).
- The system draws a maximum of 65 A.

Do not exceed the input voltage. Use a transformer to bring it to within the specified range.

- The service box should be less than 3.6 m (12 ft.) from the power supply.

Water Connections

Cooling water may be supplied from an open-loop system consisting of a tap water source and a direct connection of the outgoing flow to a drain. The diameter of the incoming service line should be at least 15.9 mm ($^5/_8$ in.). All hose connections are U.S.A. garden hose variety.

- The minimum flow rate is 9.5 l/minute (2.5 gal/min).
- The inlet temperature must be stable to ± 1.0º C.
- The inlet temperature must be stable in the range 10–35º C (50–95º F).
- The differential pressure range is 152–276 kPa (22–40 psi).
- The maximum static input pressure is 620 kPa (90 psi).

The water pressure must be stable throughout the work period. Large pressure changes, even for short periods, will affect the stability of the Argon-ion laser and the Ti:Sapphire oscillator. If your water system is subject to frequent pressure changes you should install a pressure-regulating tank ahead of the Argon-ion laser.

- The water hardness should be < 100 ppm calcium.
- The pH level should be in the 6.0 to 8.0 range.
- The maximum particulate size should be < 200 µm (diameter). A water filter is provided with the Argon-ion laser. It must be installed in the water supply line. The direction of the flow is marked on the filter case.
- The heat load is < 21 kW (1224 BTU/min).

A closed-loop cooling system can be used to regulate the pressure, temperature, and flow rate of the cooling water, and to avoid buildup of scale in the plasma tube. This can enhance the stability of the laser, improve its performance, and prevent premature tube failure due to reduced cooling efficiency. Any such system must meet or exceed the cooling requirement listed above.

2.2.5 ORC-1000 Nd:YAG Laser

Electrical Connections

US Version 60 Hz, 3Ø, 208 VAC (+5% – 5%).

The system draws a maximum of 30 A/leg.

European Version 50 Hz, 3Ø, 400 VAC (+5% – 5%).

The system draws a maximum of 20 A/leg.

The three phases must deliver the same amount of electrical power to the power supply (*that is,* the same voltage). Phase imbalance will result in optically noisy operation of the ORC.

Do not exceed the input voltage. Use a transformer to bring it to within the specified range.

The service box should be less than 3.6 m (12 ft.) from the power supply.

US Version (4 Wires)

- Connect the green lead of the power cable to the GROUND.
- Connect the White, Red, and Black wires to the lines. The sequence is important. A phase sensor is build into the ORC-1000 power supply. If the phase sequence is incorrect, the sensor will disable the power supply.
- If after connecting the power supply, and placing the relays located at the back of the power supply in the ON position, the power supply does not turn on, exchange any two phases. (This should invert the phase rotation).

European Version (5 Wires)

- Connect the Blue wire to the Neutral
- Connect the Green/Yellow wire to the Earth Ground (NOT the Neutral)
- Connect the two Black wires, and the Brown wire to the lines. The sequence is important. A phase sensor is built into the ORC-1000 power supply. If the phase sequence is incorrect, the sensor will disable the power supply.

connectors. These connectors should be included with the CPA-1000 system.

- The required flow rate is very low. Typically a few liters per hour.
- The maximum inlet temperature is 24º C (75º F). For optimum stability, the temperature must be stable to ± 1º C during the work period.
- The pH level should be in the 7.0 to 8.5 range.
- Install a water filter if high level of undissolved solids are present

Water Connections for Pockels Cell Assembly (TRA-1000)

The Pockels cell assembly requires water cooling when operating above 100 Hz. (A thermal sensor will shutdown the unit if the temperature exceed a preset value). Little water flow is required for the Pockels cell assembly even when operating under the worst conditions of 5 kHz.

We recommend using the same water line to cool the Ti:Sapphire rods and the Pockels cell.

Nitrogen

The oscillator and regenerative amplifier need to be slightly pressurized with clean, oil-free, water-free Nitrogen.

- The Nitrogen must be provided at a pressure no higher than 0.2 Bar (2.9 PSI) through a 1/4" OD, 1/8" ID tubing.

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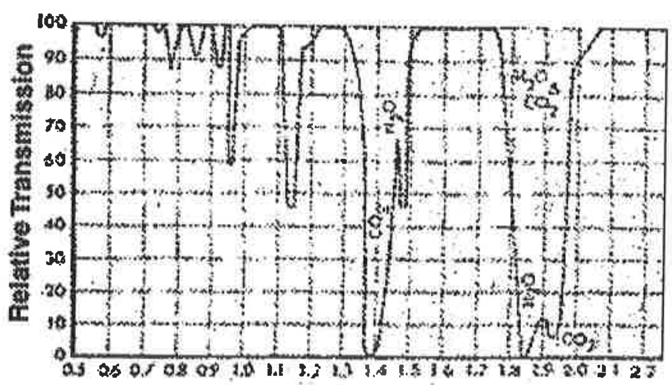
The Nitrogen over pressure is used to keep the optics clean of dust contamination (especially in the regenerative amplifier) and to lower the water vapor level in the oscillator (extremely important if you work above 900 nm). *For optimum long-term stability the oscillator needs to be pressurized with dry Nitrogen at all times.*

Figure 2-1

Water Vapor Absorption



In order to lower the Nitrogen consumption, the NJA-5 oscillator and the TRA-1000 Amplifier are fitted with low flow valves.

3. System Overview

3.1 System Layout

The CPA-1000 system supplied from Clark-MXR, Inc. is a laboratory tabletop-based system designed to produce femtosecond pulses of "white" light at kilohertz repetition rates. The system is comprised of:

- One Argon-ion laser
- One NJA-5 Ti:Sapphire self mode-locked oscillator
- One PS-1000 Pulse Stretcher & Isolator
- One ORC-1000 frequency-doubled Nd:YAG
- One TRA-1000 Ti:Sapphire regenerative amplifier
- One PC-1000 Pulse Compressor & White Light Generator (optional)
- Associated isolation and transport optics.

A 4' x 8' table is the minimum size that is able to accommodate the entire system. A larger, 4' x 10', table is recommended.

The following section describes the overall positioning of the various subsystems forming the CPA-1000.

3.1.1 Temperature Stabilization

To improve long-term stability, the CPA-1000 system is provided with a build-in internal temperature stabilization system. Use the following procedures to set up the temperature controller.

1. Press the "INDEX" switch on the temperature controller located in the side panel of the laser enclosure (See Figure 3-E). The green characters "*SP1*" will blink. The red number is the set temperature in centigrade the laser should run under.

2. Press "Up" or "Down" selector to make the necessary temperature adjustment. After selecting the "set point", press the "Enter" switch. Finally press the "Index" switch.

For NJA-5 and TRA-1000, the "set point" should be no more than 5 degrees and for PS-1000 and PC-1000, the set point should be no more than 2 degrees Celsius above medium room temperature, which should be within ± 2° C, or intra-enclosure vortex may disturb the NJA-5.

Initially the entire system enclosure may take up to 12 hours to reach its thermal equilibrium. It is important that the system temperature be fully stabilized before proceeding with the rest of the alignment procedure.

3.2.3 Transport Optics Argon — NJA Initial Position

Refer to Figure 3-1 for the positioning of the Transport Optics. The beam propagating from the polarization rotating periscope to the NJA-5 oscillator must be perpendicular to the NJA-5 , and should enter through the small aperture located on the back side of the NJA-5 enclosure.

The distance from the periscope enclosure to the NJA-5 enclosure varies slightly with the Argon-ion model. It is typically 8" (20 cm).

3.2.4 Argon-Ion Initial Positioning

Refer to Figure 3-2 for the positioning of the Argon-ion laser.

The Argon-ion laser is placed parallel to the table main axis, with the output facing towards the closest table edge.

The water-cooling hoses and power umbilical cord should lay closely along the side of the Argon as shown on Figure 3-2. The turning radius at the end of the argon enclosure should be "tight."

1. Lock the Argon-ion laser using the foot clamps provided by the manufacturer.

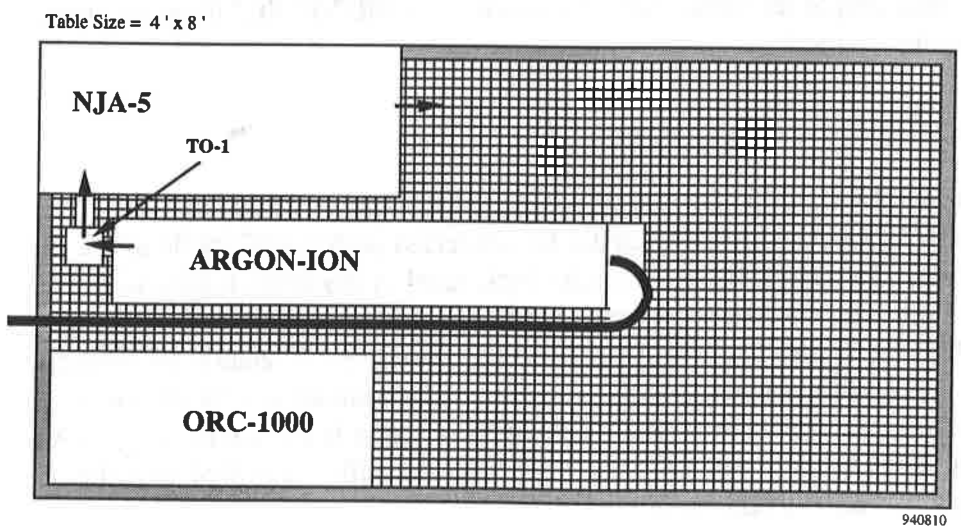


Figure 3-2

Position of Argon ion, ORC-1000, and NJA-4 Lasers.

3.2.5 ORC-1000 Nd:YAG Initial Positioning

Refer to Figure 3-1 for the positioning of the ORC-1000.

The ORC-1000 is placed parallel to the table's main axis, with the output facing towards the most distant table edge.

must be in line with the input port of the TRA-1000 module, *also located on the long side.*

Under these conditions, the distance between the PS-1000 stage and the NJA-5 stage should be approximately 2.5"–3.0" (6–8 cm).

3.2.9 PC-1000 Initial Positioning

Refer to Figure 3-1 to position the Pulse Compressor stage PC-1000.

Position the PC-1000 module at the end of the Pulse Stretcher PS-1000, leaving only 1 or 2 millimeters between the two units. The short side of the PC-1000 should be flush with the table edge.

3.2.10 Connecting the Water Cooling

Refer to Figure 3-3 and 3-4 (see utility requirements in Chapter 2, Site Preparation).

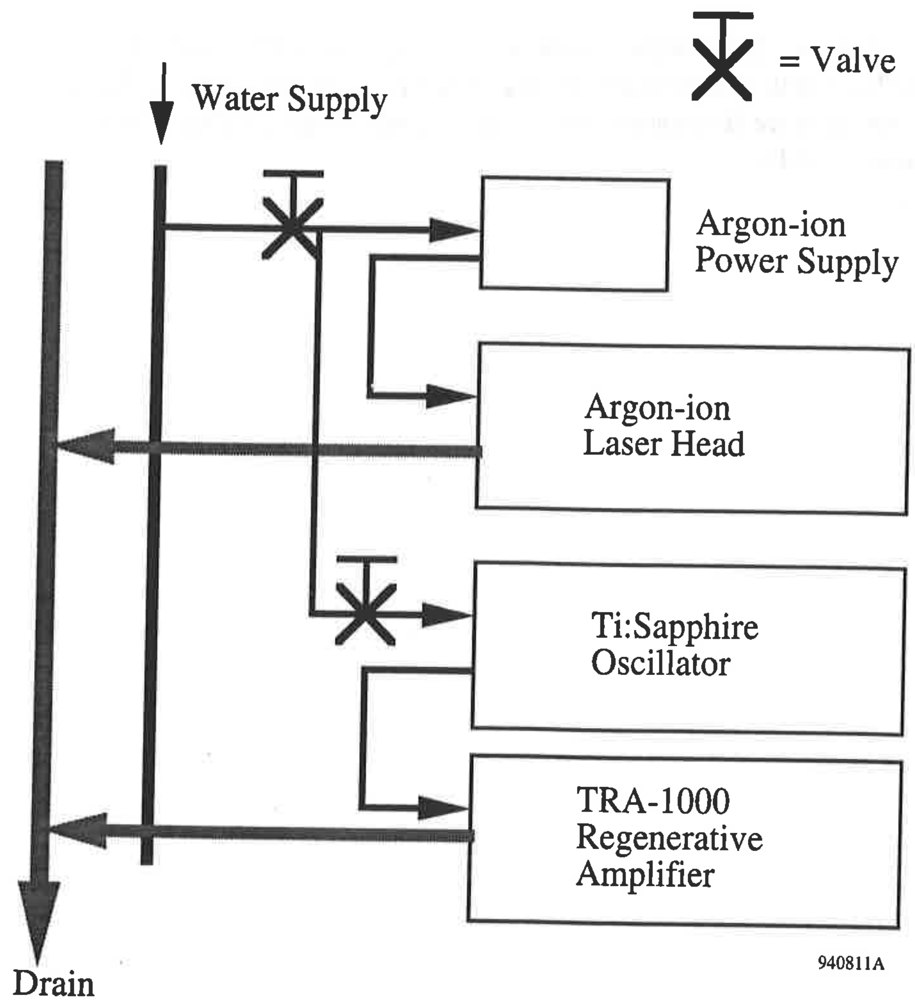
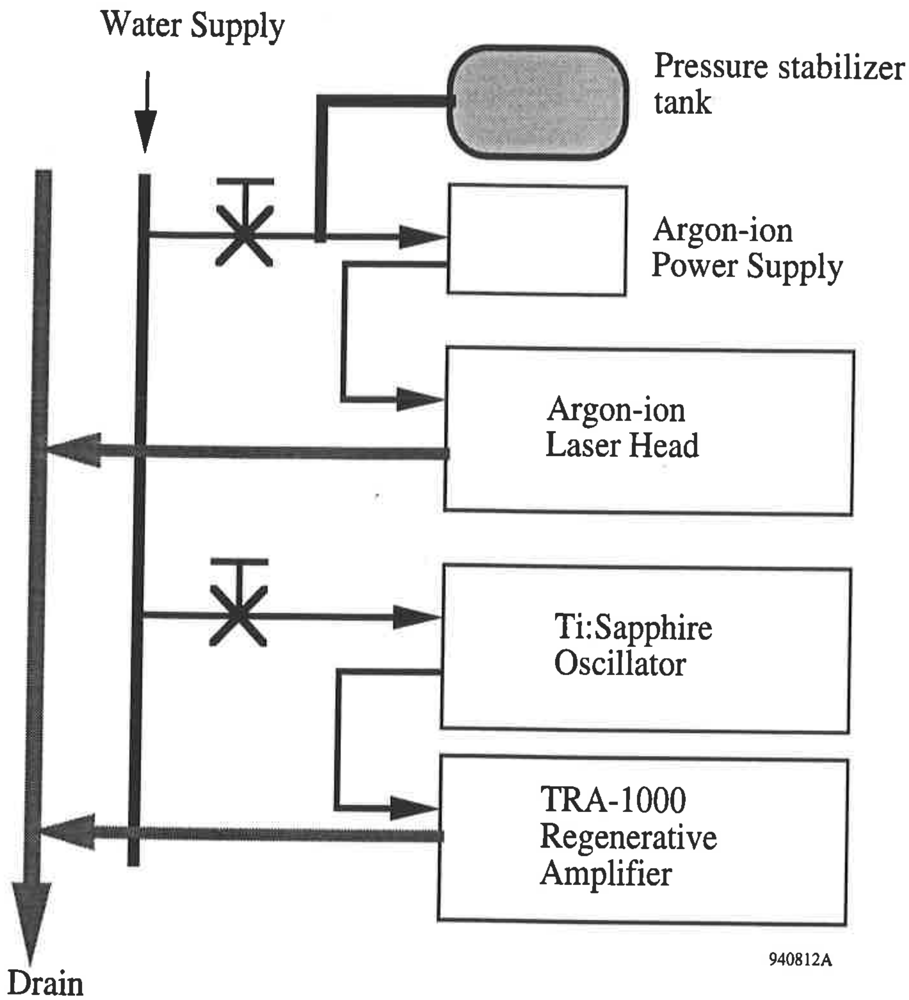


Figure 3-3

Water connections for the CPA-1000 System.

Figure 3-4

Preferred alternate water connections (shown here with a pressure stabilizer tank.)



3.3 System Alignment Sequence

We recommend that you start with the alignment of the oscillator. You should proceed with the alignment of the stretcher stage only after becoming familiar with the oscillator. Next, you will learn to set up the regenerative amplifier and ORC-1000 Nd:YAG pump laser. Finally, you will align the compressor stage.

4. NJA-5 Installation and Alignment

4.1 Positioning

The NJA-5 Ti:Sapphire Oscillator is fully tested before shipping. Read the NJA-5 Oscillator manual thoroughly, then install the oscillator before proceeding with the assembly of the other modules forming the CPA-1000.

■ **Special attention must be devoted to the safety warnings posted at various steps of the alignment.**

Install the Argon-ion laser and the NJA-5 Oscillator on the optical table as indicated in the System Layout section of Chapter 3, System Overview.

Fasten both the Argon ion and the NJA-5 securely to the optical table using the brackets supplied with the Argon and the slotted round hold down clamps supplied with the NJA-5.

4.2 Water and Electrical

At this stage of the installation if you have not already done so, you must install the required water and electrical service to the Argon ion laser, and become thoroughly familiar with the operation of the Argon laser using the manual(s) supplied with it.

Follow the instructions of Chapter 3, System Overview.

4.3 Transport Optics

To perform the instructions provided in this section, you need to have the following parts:

- One periscope assembly "TO-1"
- Two beam tubes

In addition you will need the alignment tool provided with each system (shown in Figure 4-1).

With the Argon-ion laser running at very low power, adjust the height of the upper periscope mirror holder so that the Argon beam strikes approximately on the center of the upper mirror.

Adjust the lower mirror mount so that the exiting beam is at a constant height of 4.25 in. (10.8 cm) above the table, and direct the beam into the NJA-5 Oscillator entrance aperture and the reference mark located on the opposite panel (see NJA-5 manual for details). Use the alignment tool shown in Figure 4-1 to insure that you are operating at the correct height.

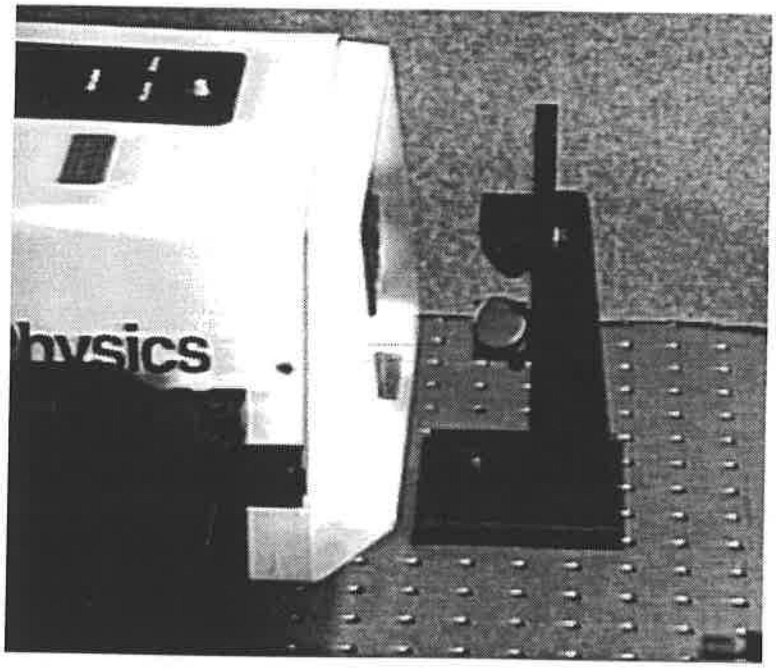


Figure 4-3

Argon-ion periscope, shown here without its enclosure. Note that for safety reason the periscope has to be enclosed during normal operation.

Install the periscope top cover, as well as the beam tube located between the Argon laser and the periscope assembly, and the beam tube placed between PER-1 and the NJA-5 Oscillator.

- **This is necessary for eye safety, and for the system to meet its performance specifications.**

Note that any air turbulence will significantly affect the pointing stability of the Argon-ion beam. It is critically important that the two beam tubes designed to cover the argon beampath be installed at all times. The NJA's long-term stability specification cannot be met if the beam tubes are NOT fully in place.

From here on follow the NJA-5 manual. Once you have learned to align it, you may proceed with the alignment of the other modules forming the CPA-1000 laser system.

5. Pulse Stretcher & Isolator Stage: PS-1000 (Femtosecond)

5.1 Safety

■ **Be careful! Remember that the IR wavelengths emitted by the Ti:Sapphire Oscillator are almost beyond the range of human vision. What appears as a low intensity red beam is in fact a very high intensity beam!**

5.2 Positioning

The Pulse Stretcher & Isolator is located directly after the NJA-5, as shown in Figure 5-1.

The functions of the Pulse Stretcher & Isolator module PS-1000 are to:

- Stretch the Oscillator pulses
- Provide some isolation between the Oscillator and the rest of the CPA-1000
- Act as a "switch-yard" for the entire CPA-1000 system. The inputs and/or outputs of every subsystem forming the CPA-1000 ensemble are routed through the PS-1000 module.

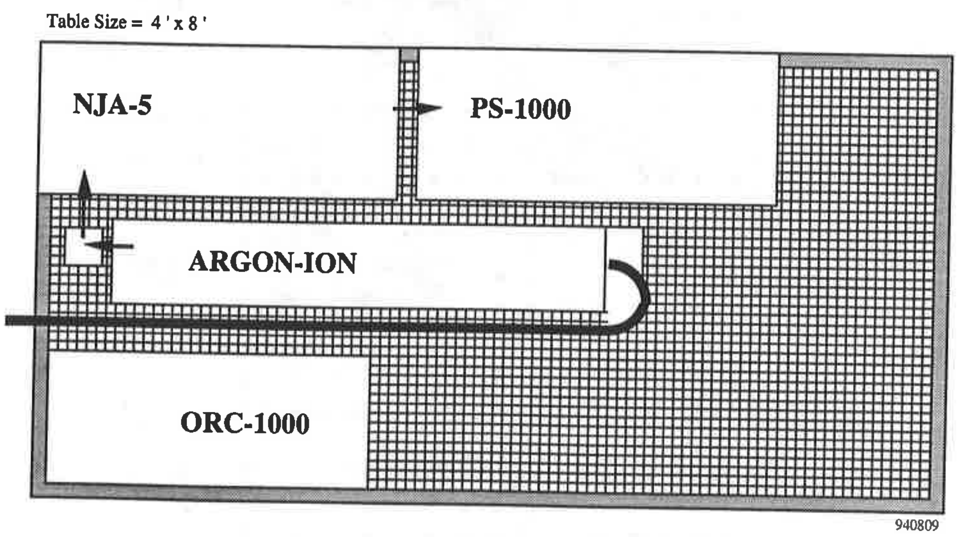


Figure 5-1

Location of PS-1000 Pulse Stretcher & Isolation Stage.

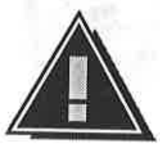
5.3 PS-1000 — Alignment through the Isolator

■ **Be very careful when handling the diffraction grating. Wear protective gloves to avoid contaminating the grating with skin oil and other debris. The grating may be worthless if you touch it!**

The alignment of the Pulse Stretcher & Isolator PS-1000 is performed using the output of the NJA-5. The Oscillator should be mode-locked and stable.

1. Place the PS-1000 Stage on the optical table so that the NJA-5 beam is centered on the input aperture of the enclosure, as indicated in Figure 5-1.

2. Leave approximately 3 inches between the NJA-5 and the Pulse Stretcher & Isolator Stage. Insert a beam tube between the NJA-5 and the PS-1000.



■ **This is necessary for eye safety, and for the system to meet its performance specifications.**

3. Secure the base plate to the optical table using the clamps provided. It should be possible to locate at least one mounting hole on the optical table by rotating each clamp cover plate.

4. Install the grating (GA33) and aspherical mirror (MA34).

Mirrors TM21 and TM22 form a so-called "dog-leg." This optical arrangement (dog-leg) is used at the entrance of all modules forming the CPA system. Its function is to decouple the various modules while providing a convenient method for adjusting the beam between the modules.

■ **Apertures PH23, PH29, and PH41 have been factory adjusted. Do NOT move them under any conditions. Polarizers POL25 and POL28 have been factory adjusted. Do NOT move them.**

The beam first propagates through the Isolation section of the PS-1000.

5. Using mirror TM21, position accurately the NJA-5 beam at the center of PH23

6. Follow by positioning the beam at the center of PH29 using mirror TM22 (do NOT use mirror TM21 for this step).

7. Repeat the previous two steps until the beam passes precisely through the center of both apertures simultaneously.

8. Once this is done, fully open the apertures PH23 and PH29.

Figure 5-3

Initial beampath through stretcher

TM30 to TM31 to MA 32 to GA33 to MA34 to MA35

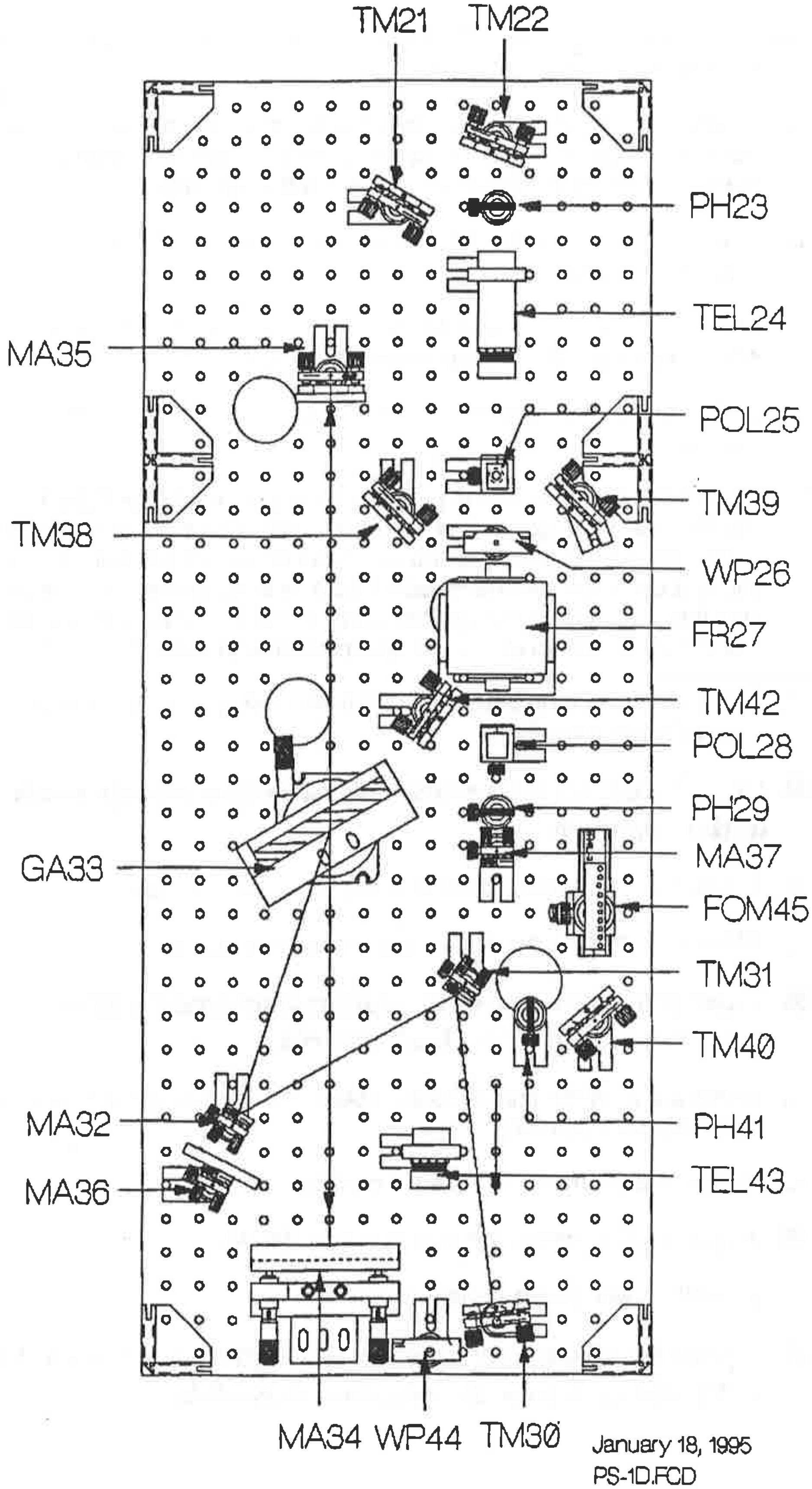
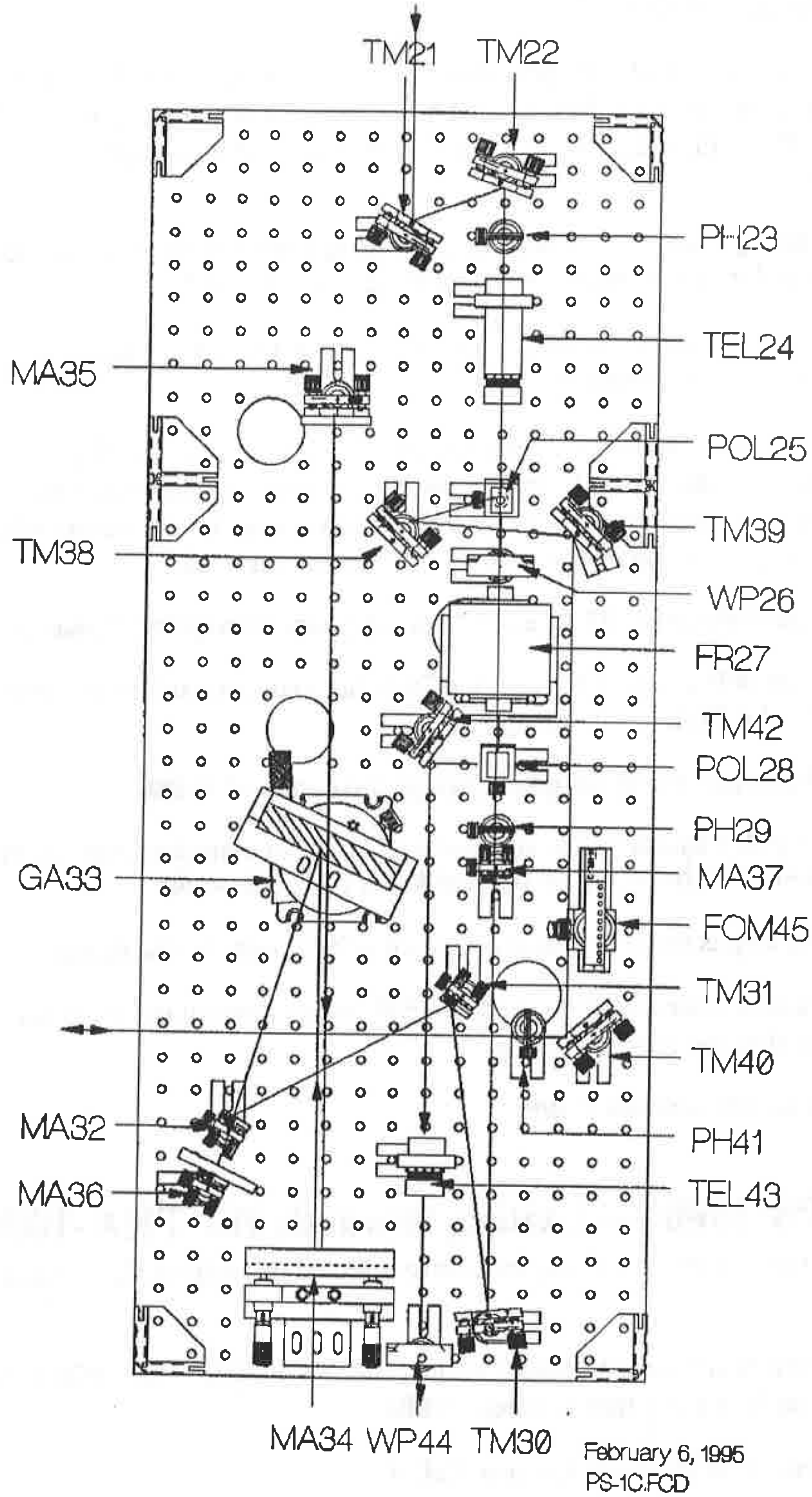


Figure 5-4.

Beampath through stretcher

MA35 to MA34 to GA 33 to MA 36



17. Adjust the mirror mount MA34 to redirect the diffracted beam towards MA35. The beam should be centered on MA35 (it will pass slightly above GA33).

18. Adjust the mirror mount MA35 to redirect the beam onto its own path (towards MA32). Adjust slightly the vertical tilt of MA35 to send the beam above MA32 and onto MA36.

2. Check that the beam reaches TM40 at the standard beam height of 3.75". Use the alignment tool.

At this point you need to make sure that the waveplate WP26 is aligned correctly.

3. Place a power meter between TM39 and TM40.
4. Rotate WP26 slightly to maximize the power output.

■ **Note: The waveplate was factory pre-aligned. Its orientation may already be optimized.**

From TM40 the beam propagates towards the regenerative amplifier. Two pinholes PH41 (located in the PS-1000) and PH66 (located in the TRA-1000) are used to position the injection beam with respect to the amplifier. This alignment procedure is covered in Chapter 6, Regenerative Amplifier.

5. Before proceeding further, check that all mechanical components are fully secured, especially the post holders.

■ **WARNING: The stretched beam may now be exiting the PS-1000, propagating in the direction of the TRA-1000. Place a beam block to intercept this beam.**

After amplification the beam will be sent back through the PS-1000. This amplified beam will be used to align TM42, TEL43, and WP44. This procedure is covered in Chapter 6, Regenerative Amplifier.

5.6 PS-1000 — Residual Spatial Chirp

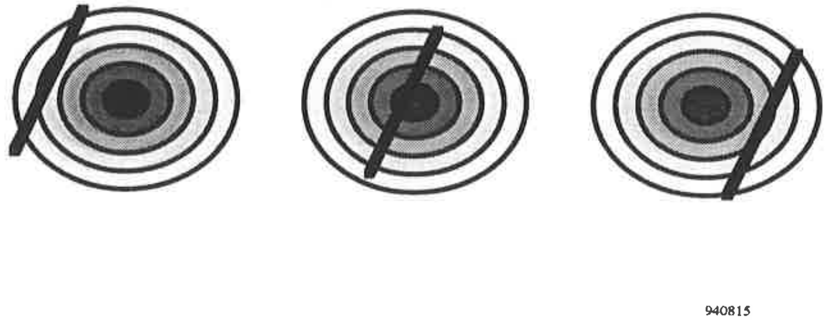
The outgoing beam should appear uniform and free of spatial chirp.

1. Place the concave alignment mirror provided with the NJA-5 between the PS-1000 and the TRA-1000 Regenerative Amplifier (see Figure 5-5).
2. Project the reflected beam onto a screen located several meters away from this mirror.

■ **Be extremely careful! Block the beam at the level of the table. At NO time should the beam be projected outside of the table area.**

Figure 5-6

Example of residual lateral chirp as seen at the level of the white screen.



5. Block the beam between the following two mirrors: TM39 and TM40.

You need to do this to prevent the beam from going into the TRA-1000 while you do the initial alignment of the Regenerative Amplifier.

6. Regenerative Amplifier (Femtosecond)

The Regenerative Amplifier alignment procedure is divided into five steps:

1. The regenerative baseplate is positioned with respect to the ORC-1000 pump source and the rest of the CPA-1000 system.
2. A short linear cavity is aligned (Short cavity consists of an end cavity mirror assembly, a Ti:Sapphire rod assembly, and an output coupler mirror assembly).
3. After the short cavity is successfully made to lase, its output is used to align a longer cavity (including two folding mirror assemblies, a polarizer, and the Pockels cell).
4. The "long" folded cavity is made to lase.
5. The Pockels cell is activated, and the seed oscillator pulse is injected, amplified, and cavity-dumped.

The first four steps of the alignment procedure do not require an operating NJA-5 oscillator. The fifth step requires that the modelocked oscillator operates reliably and that the pulses be stretched to a duration > 200 ps.

■ **Injection of unstretched seed pulses in the amplifier will result in immediate catastrophic failure.**

6.1 Safety

■ **Be careful! The output of the Regenerative Amplifier is extremely powerful. However, the near IR wavelength emitted by this unit is *almost* beyond the range of human vision. What appears as a low intensity red beam is in fact a very high intensity beam.**

6.2 Support Equipment

The following user-provided equipment is necessary to align the Regenerative Amplifier:

- Power meter (reading up to 15 Watts)
- Oscilloscope (bandwidth ≥ 300 MHz)
- Infrared viewer

Included with the Clark-MXR Regenerative Amplifier package are a fast photodiode, an alignment tool, a polarizing sheet, a filter blocking the green pump and transmitting the 800 nm Ti:Sapphire output.

1. Place the Regenerative Amplifier parallel to the long axis of the table, with its input port lined up with the output port of the ORC-1000. The edge of the TRA-1000 enclosure should be flush with the table edge. The spacing between the ORC-1000 and the Regenerative Amplifier is approximately 3". The exact longitudinal position is obtained by lining up the Pulse Stretcher & Isolator Stage output port with the seed pulse input port of the Regenerative Amplifier (see Figure 6-1).

2. Insert the short beam tube provided with each unit between the ORC-1000 and the Regenerative Amplifier.

■ **Note: This beam tube should be parallel with the table main axis. If it is not, check that the TRA-1000 is flush with the edge of the table. Then reposition the ORC-1000 if necessary.**

3. Insert the long beam tube provided with each unit between the Regenerative Amplifier and the Stretcher & Isolator Stage PS-1000.

4. Secure the Regenerative Amplifier baseplate by the holding points located on the baseplate.

Do NOT move the TRA-1000 after this initial positioning.

6.4 Alignment of the Pump Beam

The alignment of the pump beam starts with the ORC-1000 operating in the cw-mode (*that is*, Q-switch turned off) at the lowest power level possible (current knob turned fully counterclockwise).

Figure 6-2 shows the internal layout of the TRA-1000.

■ **In order to avoid dangerous back reflections the periscope assembly PA51 must have its safety shield installed on top of the upper mirror holder at all times.**

EYE PROTECTION REQUIRED

1. Turn on the ORC-1000 — Lowest power (current knob turned fully counterclockwise), cw-mode (*that is*, Q-switch turned off).

The periscope should redirect the ORC-1000 output beam from its approximately 6" height to the standard 3.75" above baseplate.

2. Place a beam stop in front of the redirected beam.

■ **In the next step be extremely careful. Avoid reflections. Wear the appropriate safety glasses.**

In the following steps, do NOT move the alignment pinholes PH52 and PH53. These two pinholes are critically important for the alignment of the Regenerative Amplifier.

3. If necessary, adjust the periscope mirrors so that the outgoing beam is 3.75" above the baseplate. Use the alignment tool.
4. Check that the beam passes through the two alignment pinholes PH52 and PH53. If necessary, adjust the periscope mirrors.
5. Fully open pinholes PH52 and PH53 after this initial alignment.

EYE PROTECTION REQUIRED

The beam must be at a constant 3.75" above the baseplate, roughly parallel to the edge of the baseplate, and should now pass through the center of the lens assembly LA54 and the end cavity mirror assembly CM55. The beam should then enter the Ti:Sapphire rod located in the rod assembly RA56 and emerge on the opposite side.

■ **The curved side of the lens must be facing towards the periscope assembly.**

The distance between the center of the lens mount LA54 and the mirror assembly CM55 has been adjusted in factory. It should not be changed.

A dichroic mirror (R= 0.5 meter) should be in the mirror assembly CM55. The HR coated side must be facing away from the periscope assembly.

This ends the ORC-1000 pump beam alignment procedure. Make sure that all mounts and posts are fastened.

6.5 Alignment of the Short Cavity

Now, create a short cavity, then make it lase.

Dust particles landing on the Ti:Sapphire rod faces may cause some surface burns. In order to avoid this phenomena, the Regenerative Amplifier is provided with a Nitrogen flow system providing a small overpressure at the level of the rod assembly. This system should be connected to a source of clean Nitrogen at all times when operating the Regenerative Amplifier.

■ **CAUTION: Do NOT exceed 1 watt.**

The pump beam must be centered on the Ti:Sapphire rod. Fumes and solid debris may be generated if the beam is misaligned and hits the Ti:Sapphire rod assembly instead of the rod itself. If this occurs, *immediately close the YAG shutter*. Clean the Ti:Sapphire rod faces. Restart the alignment procedure making sure that the pump beam goes through the Ti:Sapphire rod.

Be careful. The regenerative cavity may lase immediately. The red output may be difficult to see in the presence of the residual green pump.

9. To monitor the near-IR lasing, place the short wavelength cutoff filter (provided with the Regenerative Amplifier) after mirror assembly CM57.
10. Place a white target after the short wavelength cutoff filter. The red output should now be clearly visible at the level of the white target.
11. If lasing is not visible, scan mirror assembly CM57 up and down, right and left until lasing occurs.
12. Make the mode TEM_{00} using CM57 (use CM55 only if necessary).
13. Turn down the power to reduce the near-IR beam intensity.
14. Remove the white target.

You will use the beam provided by the short cavity to align the long cavity.

6.6 Long cavity — Pockels cell alignment

Before proceeding with this step, you need to read the Pockels cell system manual.

The distance between the center of the Ti:Sapphire rod and Mirror Mount CM58 has been adjusted in the factory. It should NOT be modified.

The beam reflected by CM58 should propagate toward CM60, then to CM61. A small fraction of the light will "leak" through CM61. This leakage will be used to monitor the Regenerative Amplifier cavity.

1. Check that the beam is horizontal (3.75" from baseplate) and strikes CM61 roughly in its center.
2. Install the Pockels cell assembly (PCA63) as shown in Figure 6-4. The Pockels cell assembly PCA63 may be factory installed.
3. Check that the beam goes through the center of the Pockels cell.
4. Secure the Pockels cell assembly.

The input RF signal will be provided by the photodiode that monitors the oscillator. This insures that the driver will always be synchronized with the oscillator. (This is the same signal that goes to the self-starting oscillator electronic package NJA-5.)

2. Turn on the power to the Pockels cell driver keeping the high voltage switch in the OFF position.
3. Check that you have a TTL level signal at each of the three "AUDIO" outputs. The frequency of these signals is adjusted by selecting the proper RF divider.
4. Select a 1000 Hz repetition rate (this may have been set at the factory).
5. Connect the output labeled "AUDIO 1" to the ORC-1000 power supply input marked "EXT MOD" (located on the back panel).
6. On the front panel of the ORC-1000 power supply select "EXT."

The ORC-1000 should now operate at 1000 Hz, synchronized with the NJA-5 oscillator.

7. Check this using the photodiode provided with the Regenerative Amplifier.
8. Connect the Pockels cell driver output labeled "AUDIO 2" to the Pockels cell driver input marked "DELAY IN."
9. Set "DELAY 1" to 160 00 where the 160 corresponds to basic clock period (each equals 4 x the NJA-5 round trip time) and the 00 corresponds to a fine analog delay (with each unit equal to a fraction of one nanosecond).
10. Set "DELAY 2" to 261 00.
11. Set "DELAY 3" to 161 00.

The stretched seed pulse and the amplifier beam should now be collinear, *but counter-propagating* (see "Transport Optics — Seed Pulse").

6.6.2 Aligning the Pockels cell Crystal Axis

The Pockels cell will now be aligned to act as a STATIC quarter waveplate (half-wave plate in double-pass). This is done using the regen short cavity beam.

1. Check that the short cavity beam is aligned through the polarizer and the Pockels cell.

For the following alignment steps, you may have to remove the mirror CM61 from its mount.

Figure 6-6

Alignment of the Pockels cell — "Maltese Cross".

You should be able to identify the main beam (probably close to the center of the Maltese cross) and at least one full ring as shown in Figure 6-6.

7. Using the two adjustment screws of the Pockels cell assembly support, position the Pockels cell so that the main beam appears located on one of the bisectors, quarter way between the central dot and the first ring of secondary dots (see Figure 6-6).
8. Note that there are four similar positions. Any one will do.
9. Remove the scatterer, the polarization sheet, and the white screen.
10. Replace the CM61 assembly.
11. Turn on the high voltage of the DT-505.

6.7 Long cavity — General alignment

1. Position the alignment tool between CM60 and POL62. Center the small diameter hole located at a height of 3.75" on the amplifier beam.
2. Slide the alignment tool to center the "large" hole located at a height of 3.75" on the amplified beam. (The small aperture introduces too much loss for the next steps.)
3. Place the white target and the previously used cutoff filter after CM61.
4. Place the photodiode provided with the TRA-1000 so that it can monitor the white target.
5. Optimize the photodiode alignment to get a signal of approximately 500 mV (50 Ω load).

The photodiode output will saturate at around 2.0 Volts.

6. Align CM61 so that the laser beam from the short cavity is retroreflected towards the alignment pinhole.
7. Scan CM61 up and down, left and right, until increase lasing occurs. Use the photodiode to monitor this jump in lasing power.

6.9 Transport Optics — Seed Pulse

The Q-switched beam from the Regenerative Amplifier (long cavity) should now be made collinear with the seed injection beam line.

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1. Center TM64 on the beam rejected by POL62. There are two, sometimes three, beams coming from the POL62. The one you want to use is the one further away from the ORC-1000. This beam may be very weak or even nonexistent if POL62 and PCA63 are well aligned — you may have to slightly detune the Pockels cell (PCA63) to see it. (Check that the polarization of this beam is indeed vertical.)
2. Point TM64 to send the amplifier beam to TM65 to send the amplifier beam towards the Pulse Stretcher & Isolator PS-1000 side port.
3. Align TM65 so that the regenerative beam is centered on pinhole PH41 in the PS-1000 Module (see Figure 6-7).

4. Center the amplified beam onto the pinhole PM67 using the mirror TM64.

5. Repeat the two previous steps until the seed beam goes simultaneously through PH41 and PH67.

The amplified beampath is now perfectly defined. (*that is,* centered on pinholes PH41 and PH67).

For the following steps turn off the pump beam and unblock the oscillator beam and the stretcher in the PS-1000.

6. Using TM39 center the *seed* beam (*that is,* the oscillator beam) onto PH41.

7. Using TM40 center the *seed* beam onto PH67.

8. Repeat the two previous steps until the seed beam goes simultaneously through PH41 and PH67.

The stretched seed pulse should now be collinear (but counter-propagating) with the Regenerative Amplifier beam.

9. If not already done, place a long beam tube between the PS-1000 module and the Regenerative Amplifier.

■ **Absence of this beam tube will degrade the system stability and create a safety risk to the user.**

10. Open fully PH41 & PH67

6.10 Transport Optics — Towards PC-1000

You can now finalize the alignment of the Pulse Stretcher & Isolator PS-1000 Module.

1. Turn on the ORC-1000 *if it isn't already on.*

As shown in Figure 6-8, the pulse train coming from the Regenerative Amplifier enters the Pulse Stretcher & Isolator PS-1000 Module centered on PH41. The beam then goes to TM40, TM39, TM38, and POL25. From there it is routed to POL28 (through the Faraday rotator FR27). At the level of POL28, the amplified pulse train makes a sharp turn towards TM42.

2. Check that amplified beam does indeed follow the path described above.
3. Check that the beam is not clipped by any optical components.
4. Point TM42 to direct the beam towards the center of the input face of telescope TEL43. The beam should be at a constant height (3.75" inside the module).
5. You may have to slightly translate/rotate TEL43 to insure that the beam is centered on the input face and on the telescope optical axis.
6. Check that the beam coming out of the telescope is collimated and round. If this not the case, the amplified beam is not going through the center of TEL43 or is not parallel to the telescope optical axis. Adjust the alignment of TEL43 if necessary.

- **Do NOT change the spacing between the lenses forming TEL43. This is a critical parameter that has been factory adjusted.**

The Pulse Stretcher & Isolator PS-1000 is now fully aligned.

7. **Check that all pinholes are fully opened (PH23, PH24, and PH41).**

6.11 Injection

6.11.1 Setting the Injection Timing

1. **Block the seed laser.**
2. Turn on the high voltage switch on the Pockels cell driver. The HV will come on after a short warm-up period.

The Regenerative Amplifier should start lasing once the HV comes on.

5. Optimize the cavity and Pockels cell alignment to maximize the energy in the Ti:Sapphire pulse. As a result the buildup time should be reduced. Only slight changes in Pockels cell alignment should be required.

6. Turn off HV to check that lasing is still prevented when no fire order is sent to the Pockels cell. Once this condition is satisfied, turn on the HV again.

7. *Double check that the seed pulse is stretched in time!* Unblock the seed laser.

The build up time should be reduced as lasing now starts from a seed pulse instead of noise. You should see a strong modulation of the Ti:Sapphire pulse, as shown in Figure 6-9B. *The period of this modulation should match the Regenerative Amplifier round-trip time.*

8. Place a beam block at the exit of the PS-1000 after WP44.

9. Adjust the Pockels Cell to maximize the modulation depth. Only minor adjustments should be needed.

10. Align TM64 and TM65 to further maximize the modulation depth and to optimize the injection alignment to reduce the buildup time. If the Q-switched envelope is not smooth, the laser is not running in a single transverse mode. Slightly realign the Regenerative Amplifier using CM61 only to achieve a smooth pulse envelope. *A slow photodiode may not be able to fully follow this modulation.*

11. Progressively reduce “DELAY 2” until you cut the tail end of the Ti:Sapphire pulse train.

The Ti:Sapphire pulse train should be cut sharply as shown in Figure 6-9C. A long trailing end usually indicates that the Pockels cell is not correctly aligned.

12. Place the photodiode at the exit of the PS-1000 stage.

13. Observe the pulse coming out of the Regenerative Amplifier. Be careful to avoid unwanted reflections that may make the final adjustment difficult.

14. Adjust “FINE DELAY 2” in order to cavity-dump a single pulse.

15. Adjust “FINE DELAY 1” in order to maximize the injection of the seed pulse.

6.12 Optimizing your Regenerative Amplifier.

After completing the initial injection and the cavity dumping of your amplifier, you can often drastically improve the performance (contrast ratio, beam quality) of your system with a few simple steps.

6.12.2 Beam Quality

The beam coming out of the Regenerative Amplifier should have a near perfect TEM_{oo} profile. Departure from this ideal shape can generally be traced down to one of the following:

1. Clipping of the outgoing beam. Check that the alignment pinholes are fully opened.
2. Check that beam is centered on the various mirrors and other optical elements that are on its path.
3. Presence of dust on the Ti:Sapphire rod. Clean the rod with Methanol or Acetone. Use the Nitrogen flow overpressure to avoid this!
4. Presence of dust on one of the transport mirrors. Clean with Methanol or Acetone.

Finally, if the pump energy exceeds 12 mJ per pulse the Regenerative Amplifier may be lasing in two or more transverse modes.

6.12.3 Pulse Energy

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■ **Do NOT extract more than 1.6 mJ (as measured BEFORE the Compressor stage). It is quite easy to extract more energy from the Regenerative Amplifier. However, this is likely to damage the cavity mirror(s) and/or the transport optics.**

7. Pulse Compressor: PC-1000 (Femtosecond)

7.1 Safety

- **Be careful! Remember that the IR wavelengths emitted by the Ti:Sapphire oscillator and greatly amplified by the regenerative amplifier are *almost* beyond the range of human vision! What appears as a low intensity red beam is in fact a very high intensity beam! Be aware of the beam propagation paths within and external to the modules!**

7.2 Positioning

The Pulse Compressor is the last module forming the CPA-1000. The PC-1000 Pulse Compressor is a one grating, all reflective design. It is designed to work precisely with the Clark-MXR Pulse Stretcher & Isolator PS-1000 and requires a grating matched to the stretcher grating.

The compressor is shipped with the mechanical components pre-mounted. Some of the optical components are packed separately for protection during transit.

Figure 7-1 shows the overall positioning of the compressor module within the CPA-1000 system.

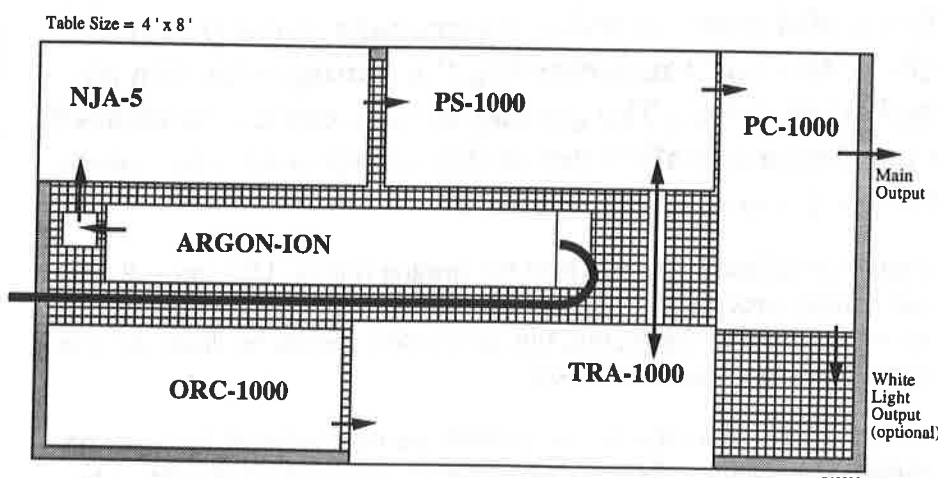
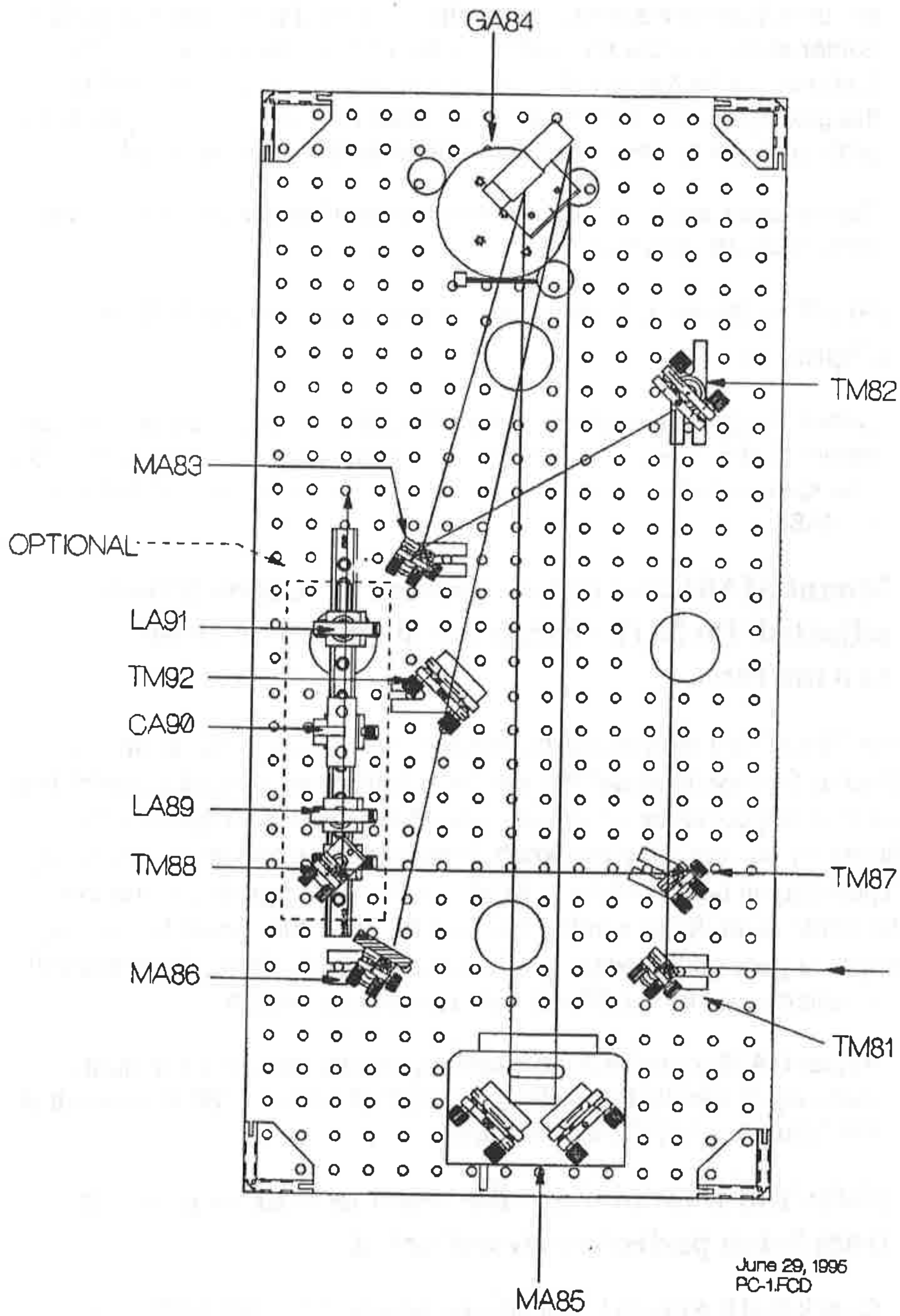


Figure 7-1

Location of Pulse Compressor.

Figure 7-2

Pulse Compressor — Internal Layout.



The next step is to set the grating groove orientation to be perfectly vertical (grating GA84).

4. Place the alignment tool between MA86 and GA84, with its vertical slit centered onto the beam.

5. Rotate the grating holder to the normal position.

7.4 Optimum Compression

7.4.1 Final Pulse Width (FWHM)

The last operation consists of optimizing the distance between GA84 and MA85, and the angle formed by MA83, GA84, and MA85 in order to generate the shortest pulses.

This last step requires the use of a good autocorrelator.

1. Measure the autocorrelation pulse width.
2. Increase spacing between GA84 and MA85 by a few millimeters.
3. Measure again the autocorrelation pulse duration.

If pulse duration is shorter than the original measurement, repeat the above procedure. If not, decrease spacing between GA84 and MA85. When you are getting close to the optimum value, you will have to change the distance between the grating by a fraction of a millimeter.

7.4.2 Final Pulse Shape (Wings)

If you have a good autocorrelator you will be able to detect the presence of "wings" under the pulse. It is generally desirable to minimize this feature. Optimizing the angle MA83, GA84, and MA85 will drastically reduce the intensity of the pulse "wings".

1. Very slightly adjust the angle formed by MA83, GA84, and MA85 by changing the pointing direction of mount TM82 (translating the beam at the level of mount MA83 a few mm to its left).
2. Adjust the horizontal tilt of MA83 to insure that the beam hits GA84 at the same location as previously (*that is,* above the rotation axis).
3. Adjust the rotation angle of GA84 to redirect the beam towards MA85. The beam should now be propagating on the same path as previously with the angle MA83, GA84, and MA85 being slightly larger than its original value.
4. Measure again the autocorrelation pulse shape.

If pulse duration is shorter than the original measurement, repeat the above procedure. If not, decrease the angle MA83, GA84, and MA85. When you are getting close to the optimum value you will have to move the beam at the level of MA83 by a fraction of a millimeter.

■ **Note: You will have to re-optimize the Compressor if the number of round-trips in the regenerative amplifier is changed.**

8. White Light Generator (Optional, for Femtosecond)

8.1 Location

The continuum generator is located within the compressor as shown in Figure 8-1.

The incoming beam position is controlled using the mirror assemblies TM87 and TM88, as shown in Figure 8-1.

8.2 Description

The continuum generator is composed of two lenses (LA89, LA91) and one water cell (CA90).

The incoming lens LA89 is coated. The outgoing lens is uncoated.

The water cell should be located with its center at the focal point of the first lens.

■ **Focussing the beam on the cell body and windows will result in permanent damage.**

1. Degass the water for better results.
2. Once the full system is aligned and the compressor has been optimized to produce short pulses (< 200 fs), then the water cell can be replaced with a thick piece of fused silica or undoped Sapphire. This will result in a more stable "white light."

■ **Using a solid instead of the water cell to generate the "white light" before optimizing the pulse duration will result in bulk or surface damage to the continuum generator.**

9. Femtosecond Operation — Wavelength Tuning

The CPA-1000-100T system tuning consists of the following steps:

1. Make sure that the system is running properly. Disable the cavity dump, then insert the BRF into the regenerative cavity at the Brewster angle for the wavelength within the mid-range. Tune the BRF so that the injection is recovered. For the wavelength beyond the standard range, change the optics in the regenerative amplifier. Follow the manual to align the regenerative amplifier cavity (*see* Chapter 6). Insert the BRF into the regenerative amplifier cavity at the Brewster angle. Use the 5 mJ pump from the regenerative amplifier pump laser.
2. Tune the oscillator to the desired wavelength according to the oscillator manual. Use the stretcher grating angle to ensure that this is the desired wavelength. A chart is provided with the system for wavelength vs. angle at the Littrow.
3. Rotate the stretcher grating to align the stretcher to the wavelength.
4. Rotate the BRF until the injection is reached.
5. Cavity dump early so that a low intensity is dumped out of the regen for compressor alignment. Align the compressor (*see* Chapter 7).
6. Optimize the output the same way that you would optimize the standard system.

10. Picosecond Operation

10.1 Introduction

In this chapter, we explain how to align the picosecond option.

10.2 System Description

The CPA-1000 system may be used to generate nearly transform limited picosecond pulses with output pulse energies greater then 500 μJ around 800nm.

This is achieved by spectral filtering of the NJA oscillator femtosecond pulse output in the regenerative amplifier with the use of birefringent tuning elements (BRF). This technique provides wide system tunability due to the ability to prevent the build of amplified spontaneous emission (ASE) while safely reducing the pulse spectrum, *hence increasing the pulse duration*. The technique generates extremely clean temporal pulses >1 ps FWHM (assuming a Gaussian pulse shape) from 720 nm to 920 nm* with little or no residual ASE.

* When equipped with the proper cavity and transport mirrors.

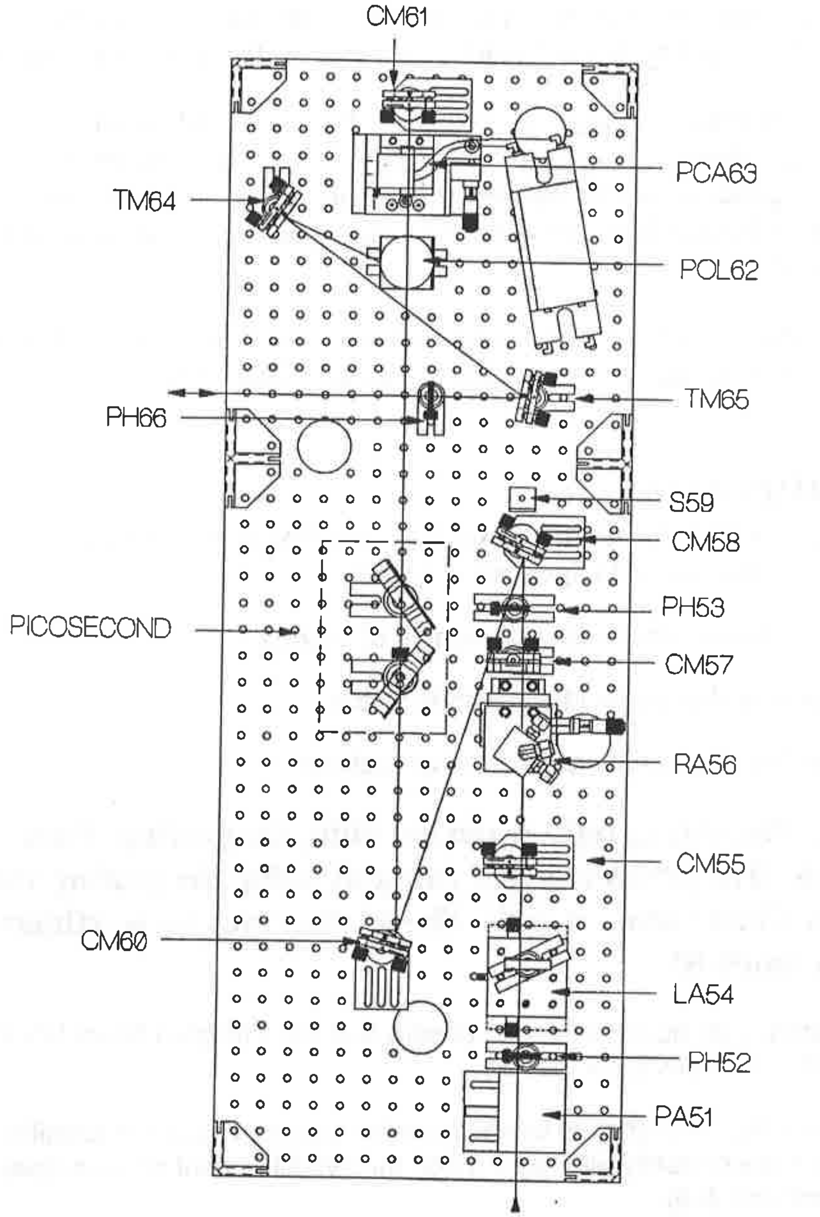
10.3 Stretcher Alignment

As with the standard CPA-1000 system, femtosecond pulses are first "chirped" by the stretcher to prevent optical component damage in the amplifier. A higher frequency grating is used in the stretcher to achieve higher stretching ratio to ensure that the amplified pulse width in the regenerative amplifier is within the safty range. It is convenient to use the stretcher with the grating input angle as is in the case of femtosecond operation. However, when the 2000 lines per mm grating* is used at a *positive* angle (to Littrow) as shown in Figure 10-1, the geometry provides even higher stretching ratio. This chapter will describe the latter case. When using the longer wavelength optics set the 1400 line grating should be used because the Littrow angle of the 2000 line grating becomes too large to use. In any case, the alignment procedure is the same as in the case of femtosecond operation.

*Your CPA-1000 system must be equipped with the picosecond option in order to produce Fourier-transform limited picosecond pulses.

Figure 10-2

TRA-1000 with intracavity BRF.



The function of these BRF's is to narrow the spectrum of the circulating amplified pulse, hence increasing its recompressed temporal profile. This is analogous to gain narrowing.

The degree of spectral narrowing is dominated by the band pass characteristics of the BRF and the number of round trips the pulse experiences before being switched out of the amplifier cavity. The BRF (filter) units are designed to narrow the bandwidth progressively in the amplifier to ensure near transform limited picosecond output pulses at the output of the compressor.

It is important to note that once optimal alignment of the injection is achieved, then these injection mirror mounts should not be altered in the subsequent steps.

Although injection is now achieved, bandwidth restriction is not ensured. This is because the BRF axes must be properly aligned to the intracavity radiation polarization to ensure proper bandwidth narrowing.

10.6 BRF Alignment

This is the most difficult stage in the alignment procedure and some practice may be needed.

The basic alignment requirement is that the filter axes should be suitably aligned to ensure that good spectral filtration and correct wavelength operation occurs simultaneously.

The axes of both filter units should finally be parallel to each other.

1. Rotate the broad band filter (this is the thin one) without moving the narrow band filter *in the rotation stage with the fine tuning adjustment.* Observe the injection pulse train, you will see the injection periodically being lost and returning.

At certain orientations of this plate you will find that small rotational adjustment will effect the injection radically, you are trying to find the point at which this seems the most sensitive to rotation. This should correspond to the position where the output is spectrally narrow which may be checked by using the compressor grating.

2. Rotate the narrow band filter (this is the thick one), trying to find the point at which it seems the most sensitive to rotation.

As you rotate this unit you should be able to see that you can tune the amplifier output wavelength through ~ 4nm (within the pass band of the broadband BRF). Iteration between the two filters should then result in the minimum spectral width of the amplified output. This may take a few iterations and a little practice, but ultimately familiarity will allow you tune the system over the entire tuning range of the CPA-1000 system and allow you to vary the output pulsewidth (by altering the spectral narrowing achieved with the BRF).

3. Observe the amplifier output directly with a spectrometer or indirectly during the bandwidth minimization with the compressor grating.

The beam should hit the compressor grating as per standard compressor alignment procedure. Provided that the system was previously aligned and the grating axes and lines are orthogonal to the beam (see Chapter 7), then no further alignment will be required apart from grating rotation and retroreflector assembly translation.

10.8 Optimization and System Tuning

Pulse width optimization is exactly the same as with the femtosecond system while spectral narrowing requires correct orientation of the BRF units. It is quite safe to experiment with these filters as no damage to any optics should result from any orientation provided the rest of the system is correctly aligned and the amplifier output power does not exceed 1 mJ (as measured at the INPUT of the compressor).

1. Rotate the BRF units (once injection is obtained) to minimize the spectral output width.

2. Adjust the compressor grating and retroreflector assembly to minimize the pulse width.

Note that the latter is quite insensitive and may be moved many mm before any obvious change in the autocorrelation results. The grating angle however *is* sensitive.

3. Rotate the BRF narrow band filter first, then carefully adjust the broad band unit to fine tune (~4 nm) the system.

It is possible to select the required spectral components, because the spectral width of the injected pulse is initially broad.

4. Rotate the compressor grating and translate the retroreflector assembly if necessary to optimize the pulse width.

Further tuning is achieved by tuning the oscillator, then stretcher, BRF filters and the compressor.

11. Operation

■ **IMPORTANT: All temperature stabilization systems in the CPA-1000 sub units should be powered at all times.**

11.1 Daily Start-up Procedure

11.1.1 Argon-ion Pump Laser & NJA-5

After turning on the water cooling to the Argon-ion laser *and* the NJA-5, proceed following the instructions provided by the Argon-ion laser manufacturer.

■ **Optical pumping of the NJA-5 without adequate cooling may result in irreversible Ti:Sapphire rod assembly seal failure.**

Always operate the Argon-ion laser at the same power (current) level.

1. *Wait* until the Argon has reached its operating temperature.

The beam pointing stability of the Argon may change drastically during the warm-up period. Most Argon-ion lasers require a one-hour warm up period to reach their full pointing stability. *Do yourself a favor — Wait* until your Argon is fully warmed up before continuing with the start-up procedure of the CPA-1000 system!

Once the Argon has reached its operating temperature check the performance of the NJA-5 oscillator.

2. Place a power meter in front of the oscillator.
3. Check that the power is within a few percentage points of the previous day's operating level.

If the power is lower, optimize using only the end-cavity mirror.

■ **Do NOT try to realign the output coupler.**

4. Connect the photodiode to an oscilloscope and verify that the NJA-5 is modelocking properly.

11.1.2 PS-1000 Pulse Stretcher & Isolator

There is no daily turn-on procedure for the passive PS-1000.

Make sure that the beam is correctly centered through the two alignment pinholes if you have to realign your oscillator. If necessary use the two mirrors TM21 and TM22 to center the beam. Do NOT move the alignment

11.1.5 PC-1000 Compressor

There is no daily turn-on procedure for the passive Pulse Compressor PC-1000.

This unit should already be aligned if you have not changed the operating wavelength of the oscillator or the number of passes in the regenerative amplifier.

11.2 CPA-1000 Optimization

Once you've completed the turn-on procedure instructions, your CPA-1000 will have a clean, energetic pulse.

Refer to Chapter 7 for additional optimization information.

To realign the Pulse Compressor, you will need an autocorrelator to optimize the pulse duration and pulse shape (see Chapter 6).

11.3 Shutdown Procedure

The CPA-1000 is designed to operate for extensive periods without having to be shut down.

■ **CAUTION: You should close the ORC-1000 shutter and block the NJA-5 output when leaving the system unattended.**

At the end of the work period, the shut down procedure should take only a few minutes.

11.3.1 ORC-1000

1. Record the operating current level.
2. Close the shutter.
3. Press the "POWER OFF" switch.

After a brief cooling period (10 seconds or so), turn the power key to the "OFF" position. You should NOT have to turn off the Q-switch unit. It is powered through the ORC-1000 main power supply.

11.3.2 TRA-1000

1. Record the operating setting of the DT-505 (injection and cavity dumping settings).
2. Turn off the photodiode.
3. Turn off the DT-505 (HV and Power).

12. Troubleshooting

The CPA-1000 system is designed to exceed all specifications provided it is operated as stated in the manual. Problems with the system may occur in three main categories: pulse energy, pulse width (and shape), and beam quality.

These three categories are often the most important, are reasonably independent and are fairly easy to diagnose and fix.

PULSE ENERGY The pulse energy that a given system should produce out of the compressor is defined by the system specifications. These specifications vary from system to system depending on pulse width specifications and repetition rate. To maximize the output pulse energy from any of the systems (including the ps version) the following guidelines are given.

Problem	Solution
1. Low pulse energy **(femtosecond system).**	1. Check that the correct pulse is being switched out (adjust timing and/or injection path). 2. Check for the correct switch in timing. 3. Check the ORC output energy. 4. Check the ORC rep rate. 5. Ensure that the ORC is Q-switching correctly. 6. Check the oscillator wavelength (tune as required).
2. Amplitude noise on output — should be 2% RMS or less **(femtosecond system)**	1. Check oscillator (spectrum, pulse width and power should be stable) 2. Check injection (no cw background) and alignment of amplifier 3. Check DT-505 operation (correct rf input power, switch out delays, injection timing) 4. Check proper orientation of Pockels Cell (inhibits amplifier lasing when HV is off and shows no output leakage when the switch out timing is at maximum). 5. Check repetition rate (1 to 5 kHz typical) 6. Check ORC output for correlation between its output amplitude fluctuations (if any) and that of the CPA-1000 system.

Problem	Solution
6. If no pulse compression is apparent at the output of the compressor **(femtosecond system)**	1. Check that you are making eight passes of the stretcher. It is possible to make four, twelve or even sixteen if incorrectly aligned. Adjust MA 32 to correct.
7. The pulse has "wings" or sub-pulses on the autocorrelation trace **(femtosecond system).**	1. Check the autocorrelation of the seed oscillator. 2. Check that the spectrum in the stretcher is not being clipped. 3. Ensure that the spectrum in the compressor is not being clipped. 4. **START** Check that the spectrum from the stretcher is smooth and Gaussian like (not top hat). 5. Rotate the compressor grating on its stage slightly and adjust the length of the compressor (repeat as required) 6. Adjust the horizontal control on the confocal mirror mount in the stretcher (third order dispersion adjustment), then adjust the length of the compressor (go back to **START** as required). 7. Check for grossly excessive bandwidth from the seed source, it should be comparable to the specified bandwidth. 8. Check for spatial chirp being imposed on the injection beam by the stretcher and remedy as per CPA-1000 alignment.

Problem	Solution

SPATIAL BEAM QUALITY The spatial beam quality of the CPA-1000 system should near TEM_{00} with little or no spatial chirp. Problems with the beam quality are split into separate categories (*that is*, problems with the amplifier or stretcher/compressor system). The PS system beam quality should be identical to that of the FS system. If sudden degradation in the beam quality is observed then suspect damaged optics due to dust, clipping of the spectrum in the stretcher or over pumping the amplifier.

Problem	Solution
11. Poor spatial mode out of the amplifier (check before compressor when cavity dumped)	1. Check for misaligned amplifier resonator (optimize by reducing buildup time.) 2. Check for damaged optics (most likely are the rod and pump through optic). 3. Check for thermal overloading (cat's eye output mode) of the rod. Reduce ORC average power and see if mode improves. If so (at normal ORC power) move amplifier focusing optic (usually away from the rod) while optimizing the cavity alignment.
12. Poor spatial mode out of the stretcher.	1. Check for proper beam collimation on the input to the stretcher. 2. Check for clipping in the stretcher. 3. Check for spatial chirp at the output (adjust as described in the manual to remove). 4. Check oscillator mode.
13. Poor spatial mode out of the compressor.	1. Check amplifier mode. 2. Check stretcher output mode (into compressor). 3. Check for correct compressor alignment. If the mode entering the compressor is good, but the mode exiting is elliptical it is possible that the 90 degree retroreflecting mirrors are misaligned. Check that these are at 90 degrees to each other. Check that these mirrors' axes are parallel to the table surface. Check that the beam is passing through the center of TEL 43 in the stretcher. 4. Check for damaged optics including grating.

13. TRA-1000, Location of Labels

In accordance with CDRH regulations, the location of the various safety labels that should be affixed to your TRA-1000 are shown in Figure 13-A. Do not remove these labels.

Please refer to Chapter 1 for detailed Eye Safety information.

Figure 13-A

Location of safety labels.