User Manual for Femtosecond Cr:Forsterite Oscillator Model CrF-65/P

CONTENTS

CAUTION!!! Important Operating Concerns

BEFORE THE PUMP LASER IS TURNED ON

- Make sure the temperature controller is turned ON
- Make sure the cover is REMOVED from the output of the fiber collimator

CHECK TO SEE IF THE PUMP BEAM IS INCIDENT ON THE CRYSTAL MOUNT

NEVER move the pump beam from the crystal mount to the crystal surface. It WILL damage or destroy the crystal. If the pump beam is incident on the crystal mount, follow these procedures:

1) Block pump beam
2) Clean crystal surface
3) Reduce pump power and realign beam on crystal surface
4) Increase pump power

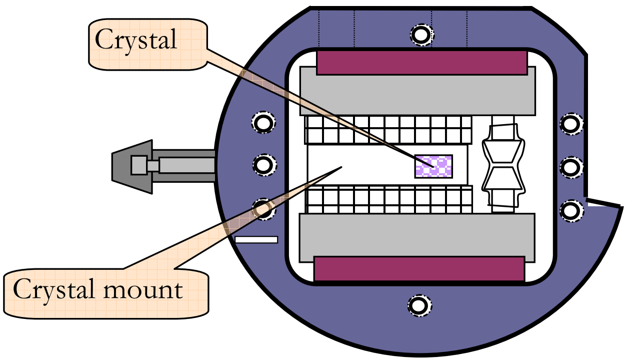


Figure 1.1: Interior of crystal housing.

TURRNING ON THE LASER SYSTEM

!!! ORDER IS IMPORTANT !!!

TURN ON THE SYSTEM

1) Turn ON Nitrogen circulation
2) Turn ON water circulation
3) Turn ON Temperature Controller
4) Turn ON Pump Laser

TURN OFF THE SYSTEM

1) Turn OFF Pump laser
2) Turn OFF Temperature controller
3) Turn OFF water circulation
4) Turn OFF nitrogen circulation

Contents of shipped laser system

Below is a list of the components that should be shipped with the laser system. Review the list and the components shipped to verify the laser system is complete.

TABLE 2.1: CONTENTS OF TRANSPORT BOX 1

№	Element	Description	Q-ty	Content
1	Laser	600x40x25mm	1	See Table 2.2
2	Pump Laser	Is fixed to CrF-65 Laser breadboard	1	
3	Water& Nitrogen Tubes	Connects crystal housing with water and nitrogen circulation system	1	

TABLE 2.2: CONTENTS OF LASER

№	Element	Description (see pictures in directory "your laser")	Q-ty
1	M1*	Output coupler	1
2	M2*	Spherical mirror(R=104mm), HT@1064nm, HR@1250nm	1
3	M3*	Spherical mirror(R=104mm), HR@1250nm	1
4	M4*-M8*	Flat mirrors HR@1250nm	5
5†	M9* (for ES)	Spherical mirror(R=200mm), HR@1250nm	1
6	Cr*	(3x3x16mm)	1
7	L*	Focusing Lens AR@1064nm (f=100mm)	3
8	D1* -D3	Diaphragm	1
9	P1*-P2	Cavity prisms to compensate CVG	2
10†	Clamps	Attach laser to table	4
11†	Rod Holder	To fix Electrical Starter (ES) on optical table	
12	POP*	Pump Output	
13	Tube	tube to cover pump lens	1
14	Sl*	Slit	
* - Elements with mounts **† - REMOVE these elements from laser box**			

TABLE 2.3: CONTENTS OF CABLE PACK

№	Element	Description (see pictures in directory "connections")	Q-ty
1	Cable K1	K1 (connect Cr:F-65 and Temperature Controller "sensors")	1
2	Cable K2	K2 (connect Cr:F-65 and Temperature Controller "TEC connector")	1
3	Cable K3	K3 (connect Power Supply of Pump Laser "interlock" and Temperature Controller "shutter")	1

4	Cable K4	K4 (connect fan and Fiber Laser)	
5	Cable K5	K5 (connect Power Supply of Pump Laser and Fiber Laser)	2
6	Cable K6	K6 (connect Cr:F-65 and Electrical Starter)	1

TABLE 2.4: CONTENTS OF TRANSPORT BOX 2

№	Element	Description	Q-ty	Content
1	Power Supply of Pump Laser	600x40x25mm	1	
2	Cable Pack		1	See Table 2.3
3	ES	Electrical Starter with power adapter.	1	

Installation

1. INSTRUCTIONS

Step 1: Check Components

Before you begin the setup and operation of the Cr:Forsterite Laser System, be sure to check the shipping (Chapter 2) list for all optical components and cables.

Step 2: Install laser breadboard and box

Attach the Laser Breadboard and Laser Box to an optical table (see Figure 3.1). Notice that the screw-nuts tighten in the opposite direction that the mounting screws and the base screws tighten.

Step 3: Connect cables and secondary components

Connect all the cables and secondary components, including the Fiber Pump Laser, Power Supply, Temperature Controller and Electrical Starter. Connect the water and Nitrogen supply to the Crystal Housing.

Step 4: Mount and align optical components

Install the optical components and align laser.

2. INSTALLING LASER BREADBOARD AND BOX

Attach the Laser Breadboard and Laser Box to an optical table (see Figure 3). Notice that the screw-nuts tighten in the opposite direction that the mounting screws and the base screws tighten.

1) Place the Cr:Forsterite Laser on the optical table and in an area suitable for operation.

2) Use the four **Base screws (1)** to adjust the beam height and alignment of laser beam. The Laser Breadboard should be parallel to the optical table.

3) Attach the four **Base screws (1)** to the optical table using the **Clamps** and **M6 Screws (2).**

4) Tighten the four **Screw-nuts (3)** to secure the **Base screws (1)** to the Laser Breadboard.

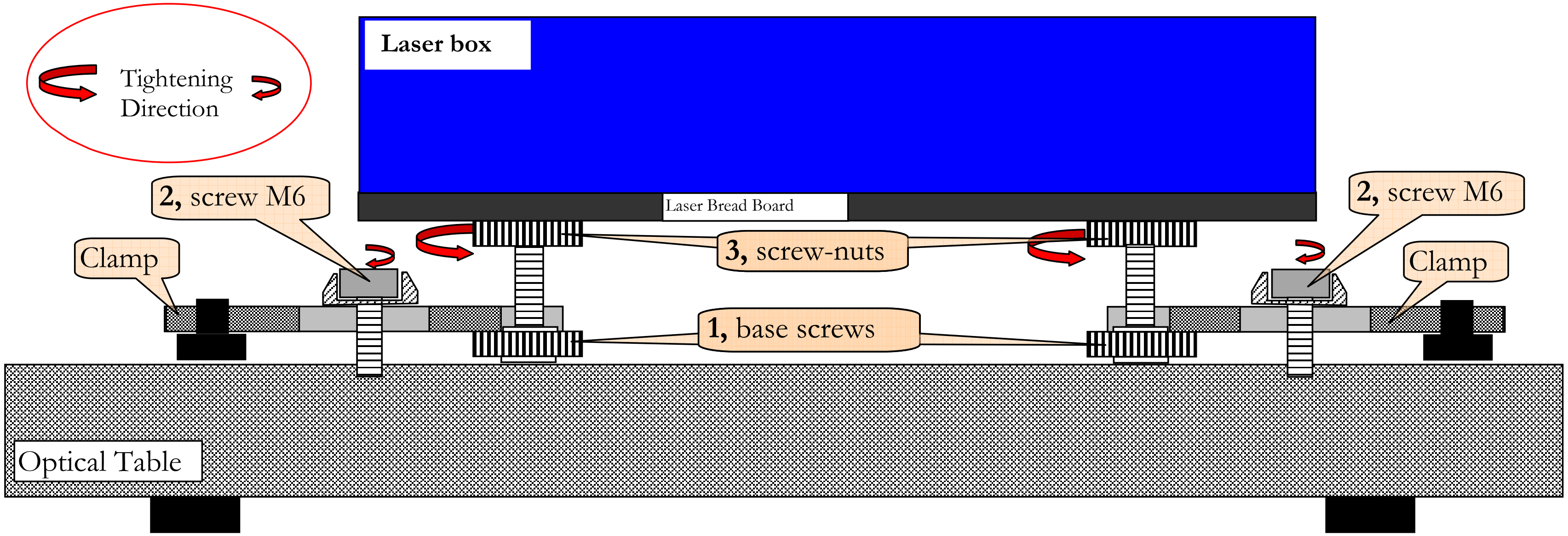


Figure 3.1. Schematic for mounting laser system on optical table.

3. CABLE CONNECTIONS

Figure 4 depicts the Crystal housing and the connection tubes for the Nitrogen gas and cooling water. Figure 5 shows how the cables should be attached to the secondary components of the laser system. Refer to Figure 2 for a picture of the cables.

- Cable K1 connects the sensors of temperature of Cr:F crystal and water radiator in laser head to the Temperature Controller
- Cable K2 connects the TE elements (thermo-electrical element in laser head) to the Temperature Controller
- Cable K3 connects Power Supply of Pump Laser "interlock" and Temperature Controller "shutter"
- Cable K4 connects the Pump Laser to the cooling fan for the Pump Laser
- Cable K5 connect Power Supply of Pump Laser and Fiber Laser
- K6 connects Cr:F-65 and Electrical Starter

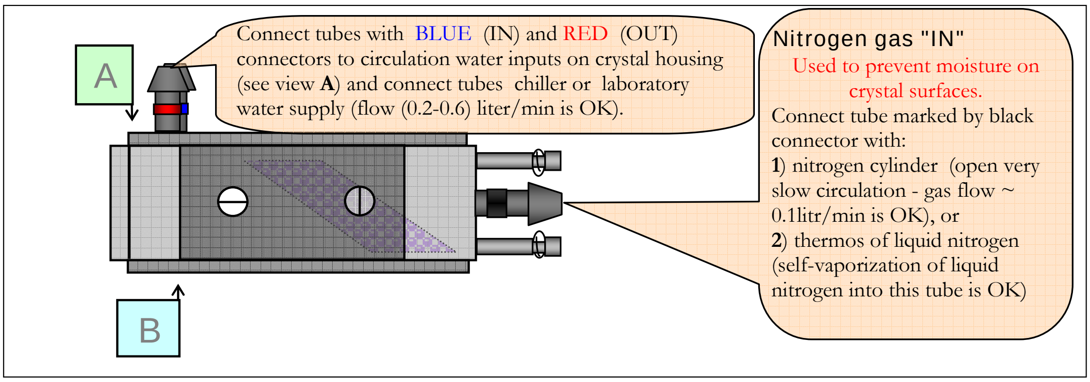


*Figure 3.2: Schematic picture of Crystal housing. Note: Please see Figure 7 for Views **A** and **B**.*
(In laser head the bottom pipe is BLUE (water "IN") and top pipe is RED (water "OUT")

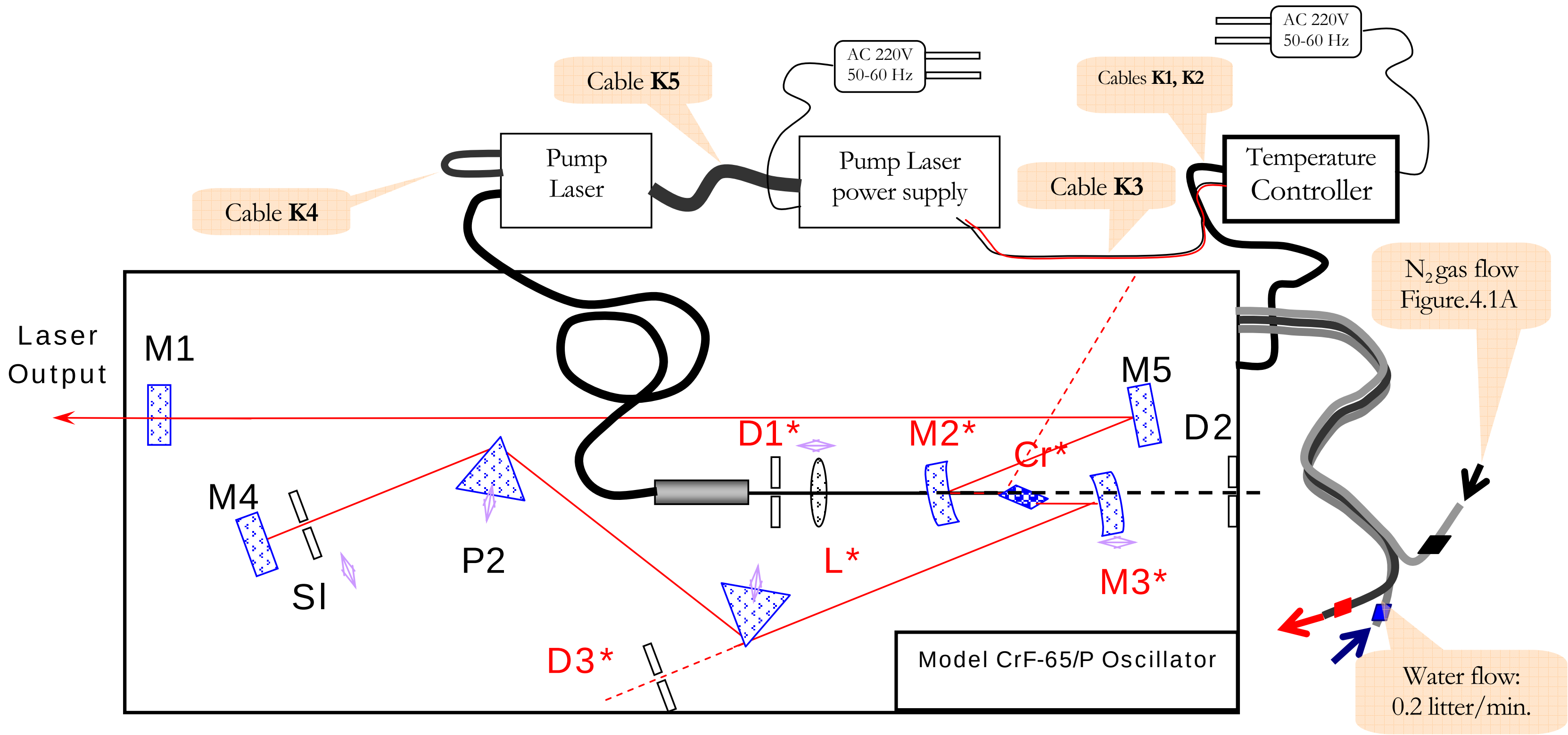


Figure 3.3: Cable and tube connections for CrF-65/P model Femtosecond Forsterite Laser.

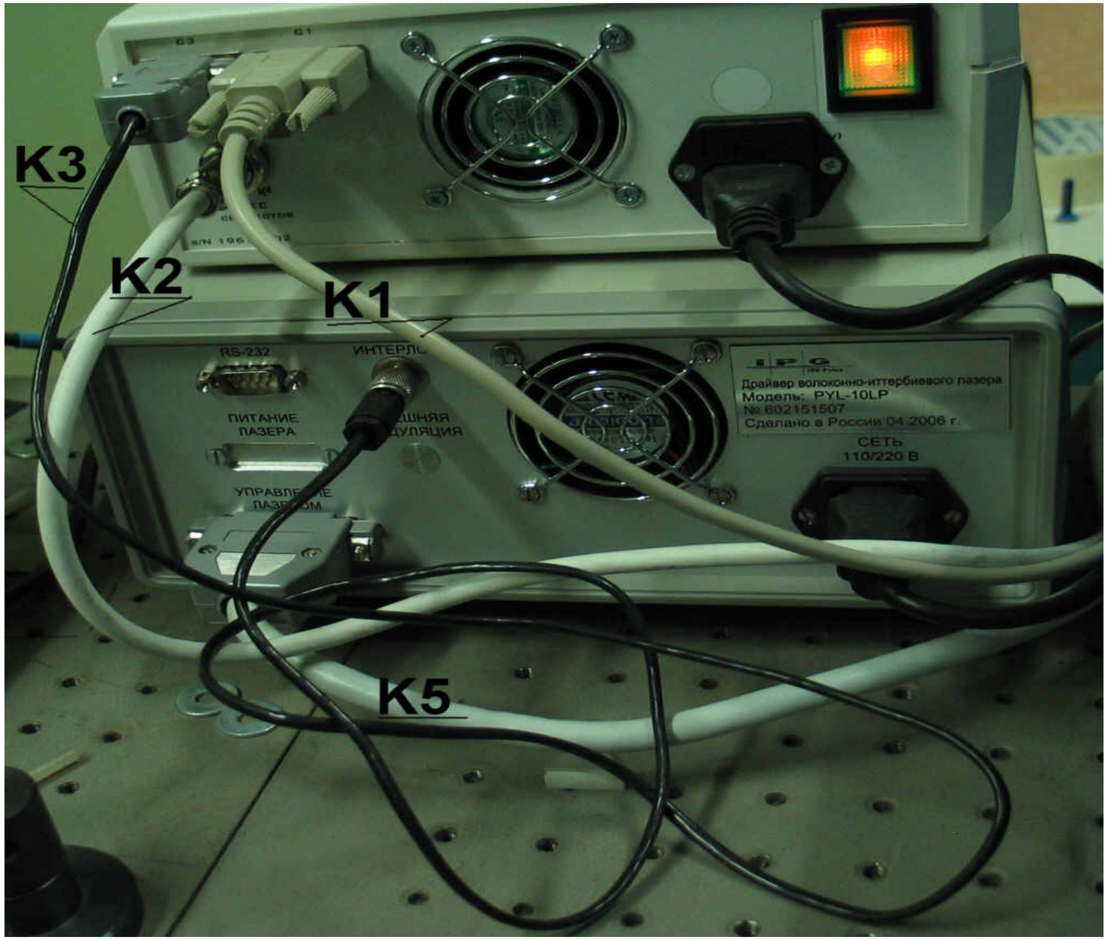


Figure 3.4: Cables connection on Power Supply of Pump laser and on Temperature controller

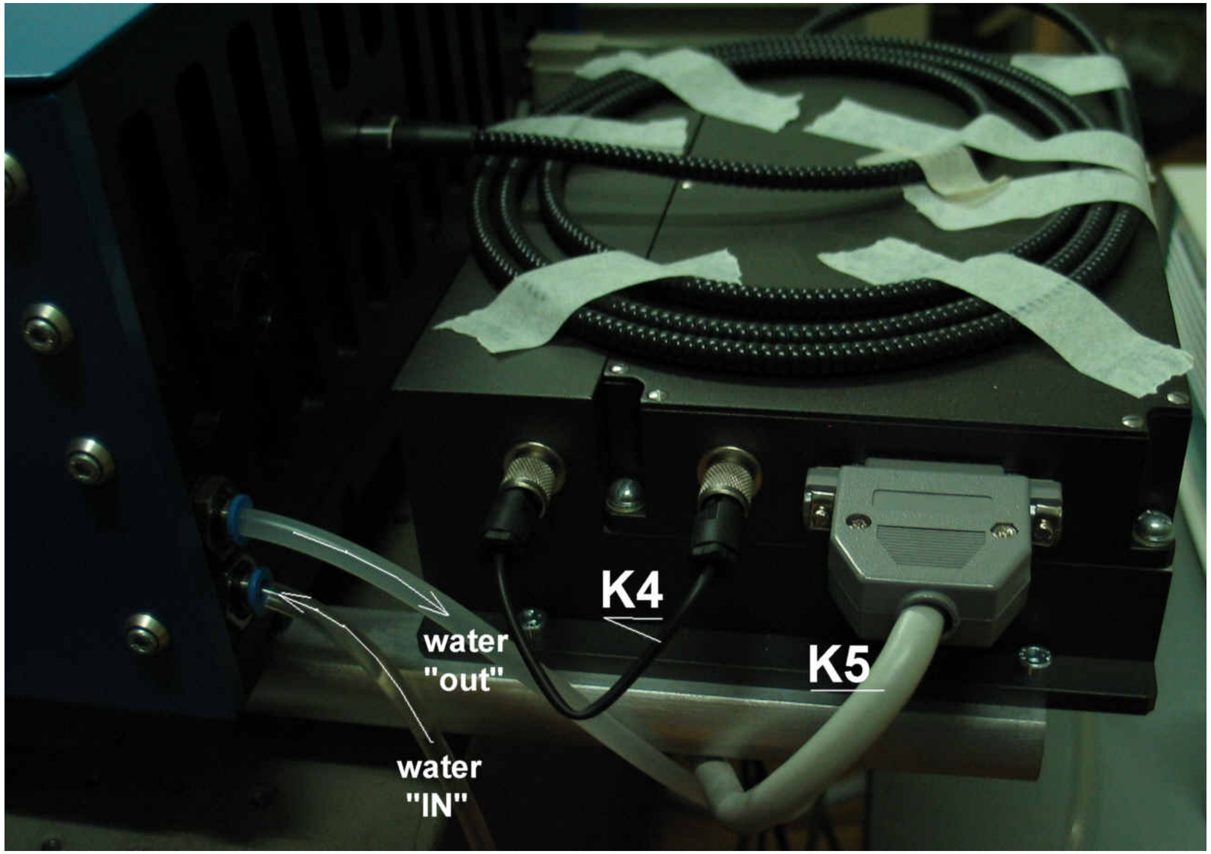


Figure 3.5: Cables connection on Pump laser and water flow direction on laser box.

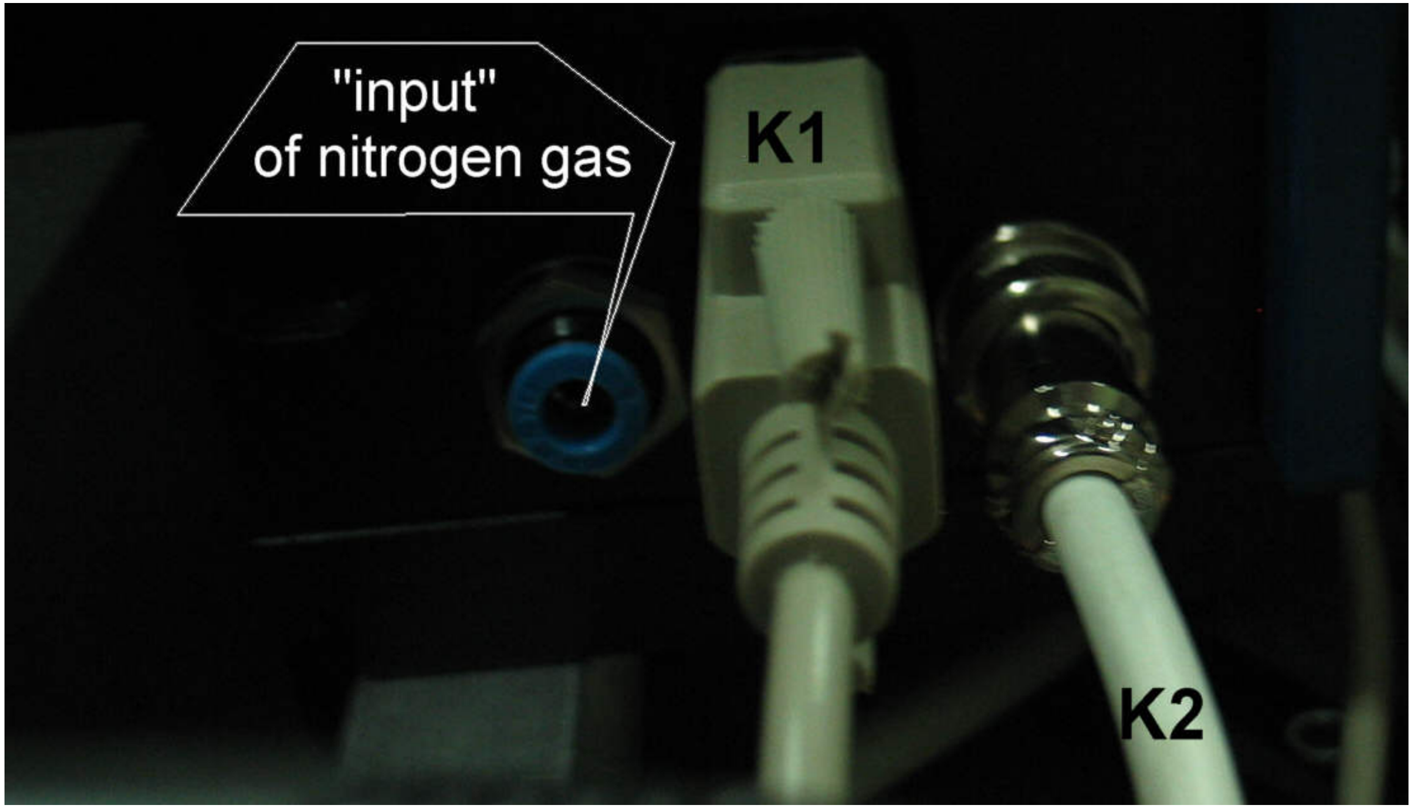


Figure 3.6: Cables connection and "nitrogen" on laser box.

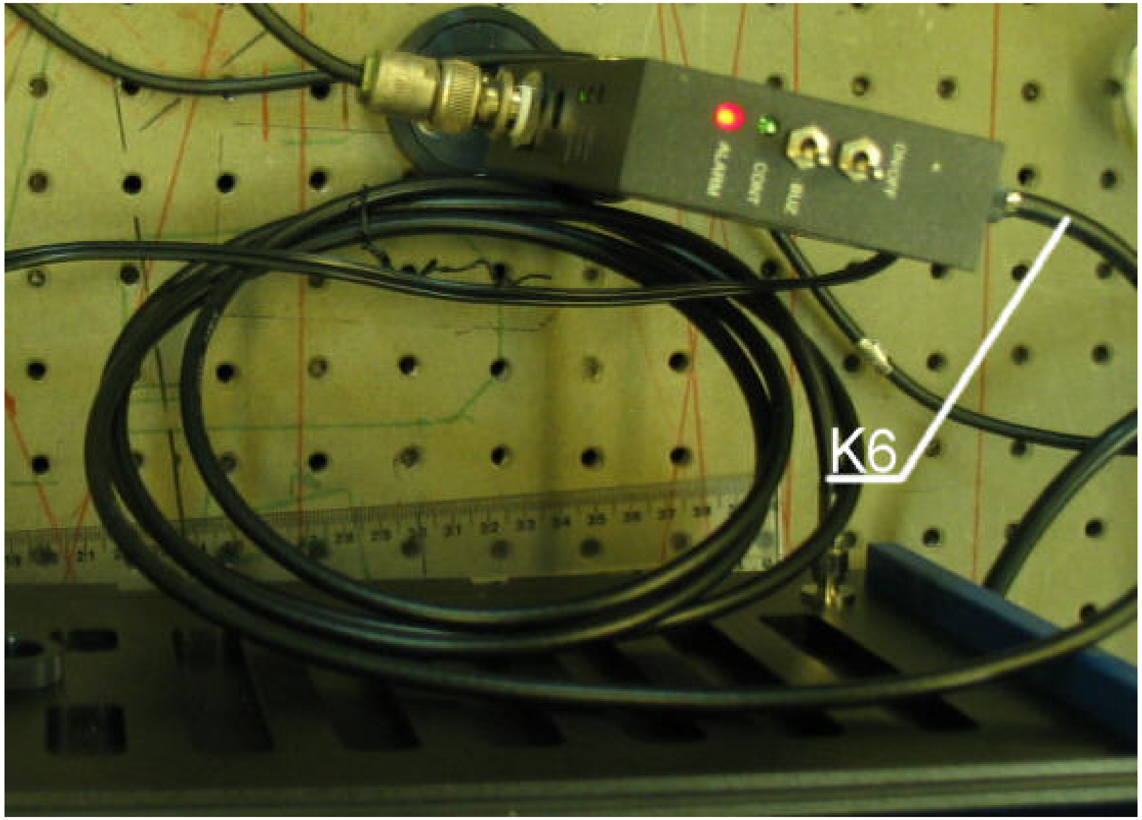


Figure 3.7: Cables connection of Electrical Starter with laser box.

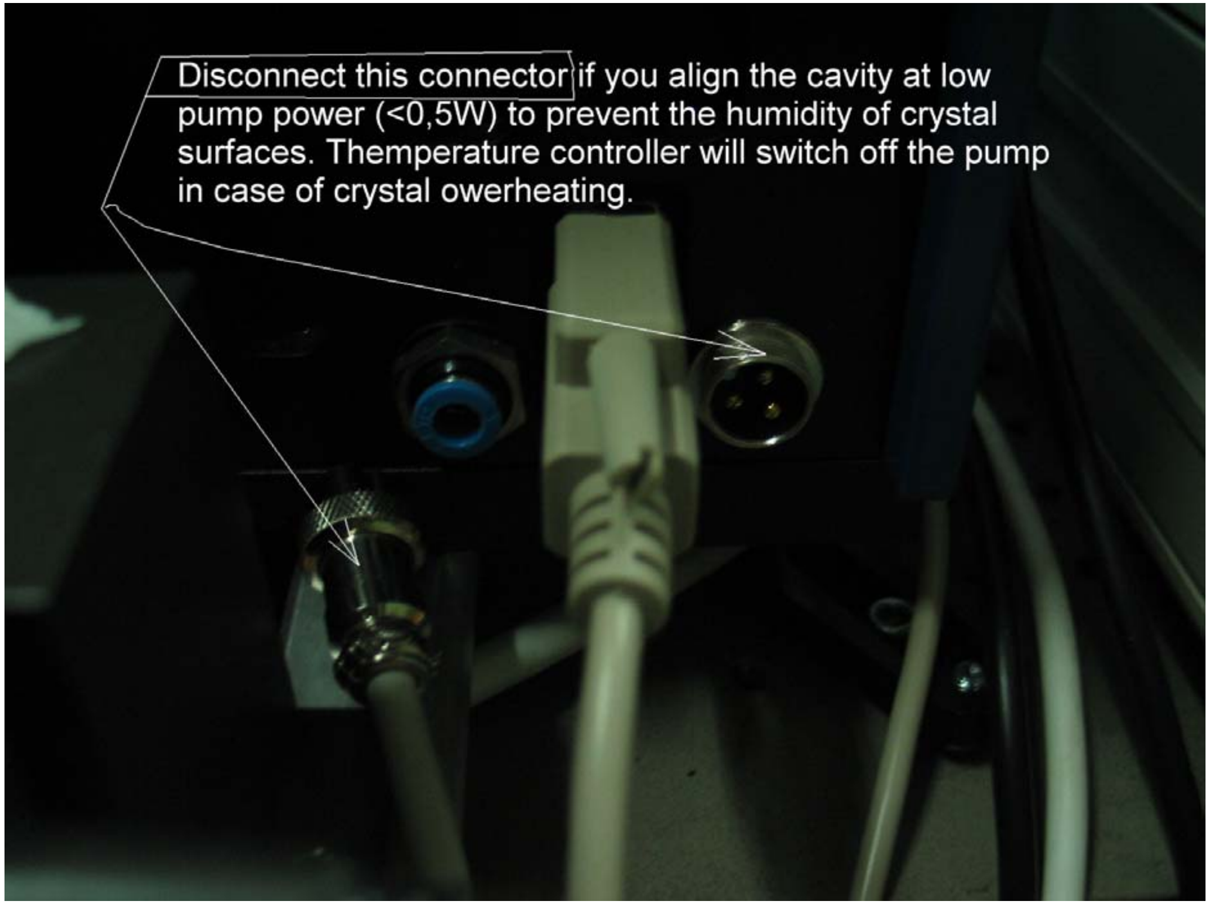


Figure 3.8: Laser operation at low (<50mW) pump power.

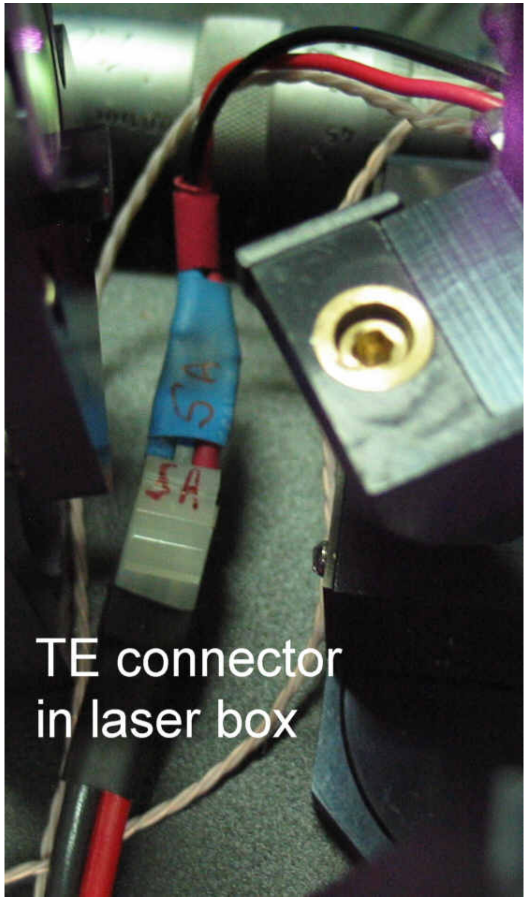


Figure 3.9: TE connector in laser box.

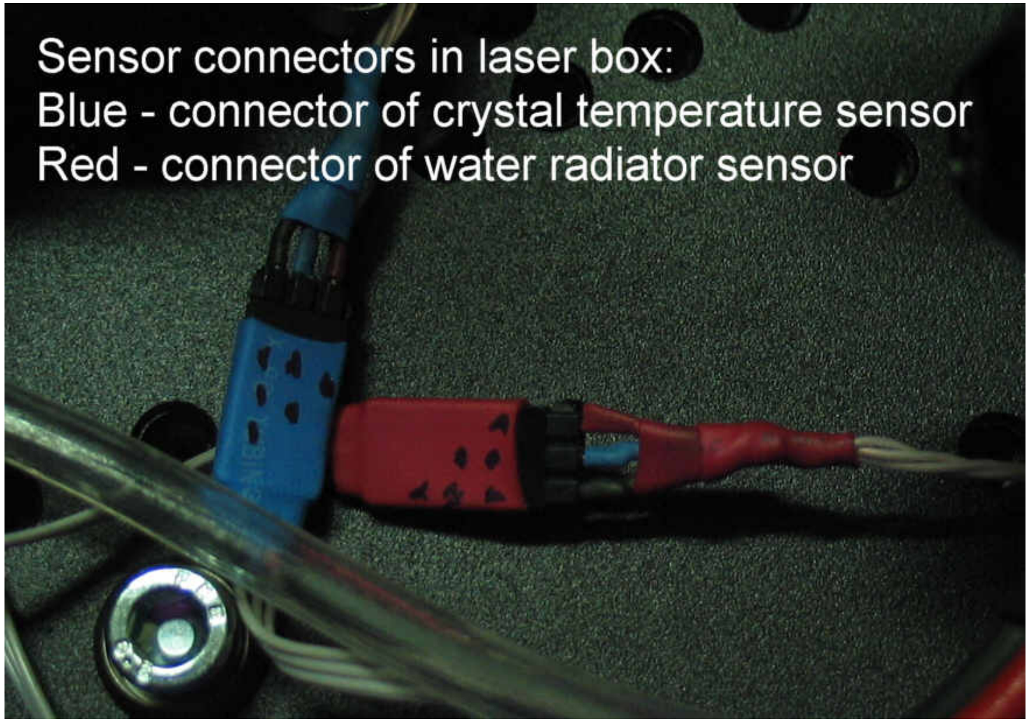


Figure 3.10: Sensors connections in laser box

4. OSCILLATOR AND INTERNAL COMPONENTS

Figure 6 shows a diagram for the standard mode of operation for the Chromium Forsterite Laser and the position of all the optical components on the Laser Breadboard. Note: The stared components are critical to the main laser beam alignment; do not remove the mounts for these components.

- **M1,M2*,M3*,M4, M5**, **M6, M7, M**8 - Laser cavity mirrors
- **K** - Collimator for fiber pump laser
- **P1, P2** - Pair of inter-cavity prisms with negative Group Velocity Dispersion (GVD)
- **Cr*** - $Cr^{4+}:Mg_2SiO_4$ Forsterite active element crystal
- **L*** -Focusing lens for the pump beam
- **D1*, D2** - Fixed diaphragms to align the pump beam along **L*** and **M3*** plane of translation
- **D3*** - Another diaphragm used to align the pump beam
- **Sl (S)** - Slit used as an aperture to block the pump beam from hitting mirror **M4**
- **R** - Alignment mark for the pump beam reflection off the crystal onto the wall of oscillator box

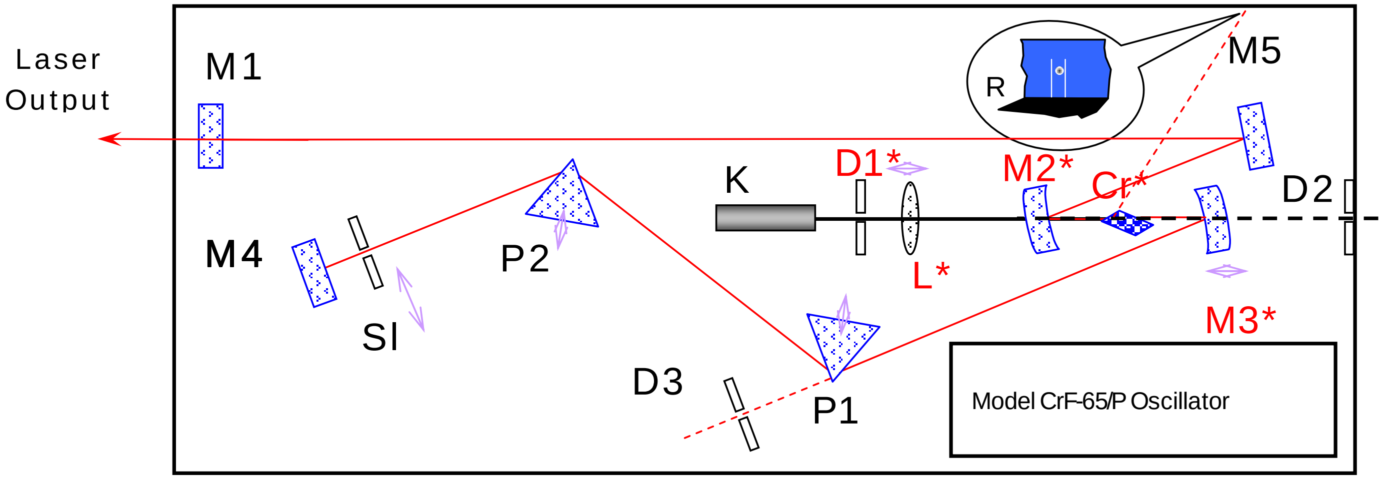


Figure 4.14: Schematic for CrF-65/P model Femtosecond Forsterite Oscillator: Mirrors M6-M8 are not shown on the picture.

** - These components set the main beam alignment on the laser breadboard. Do not remove the holders of these elements from laser breadboard!!!*

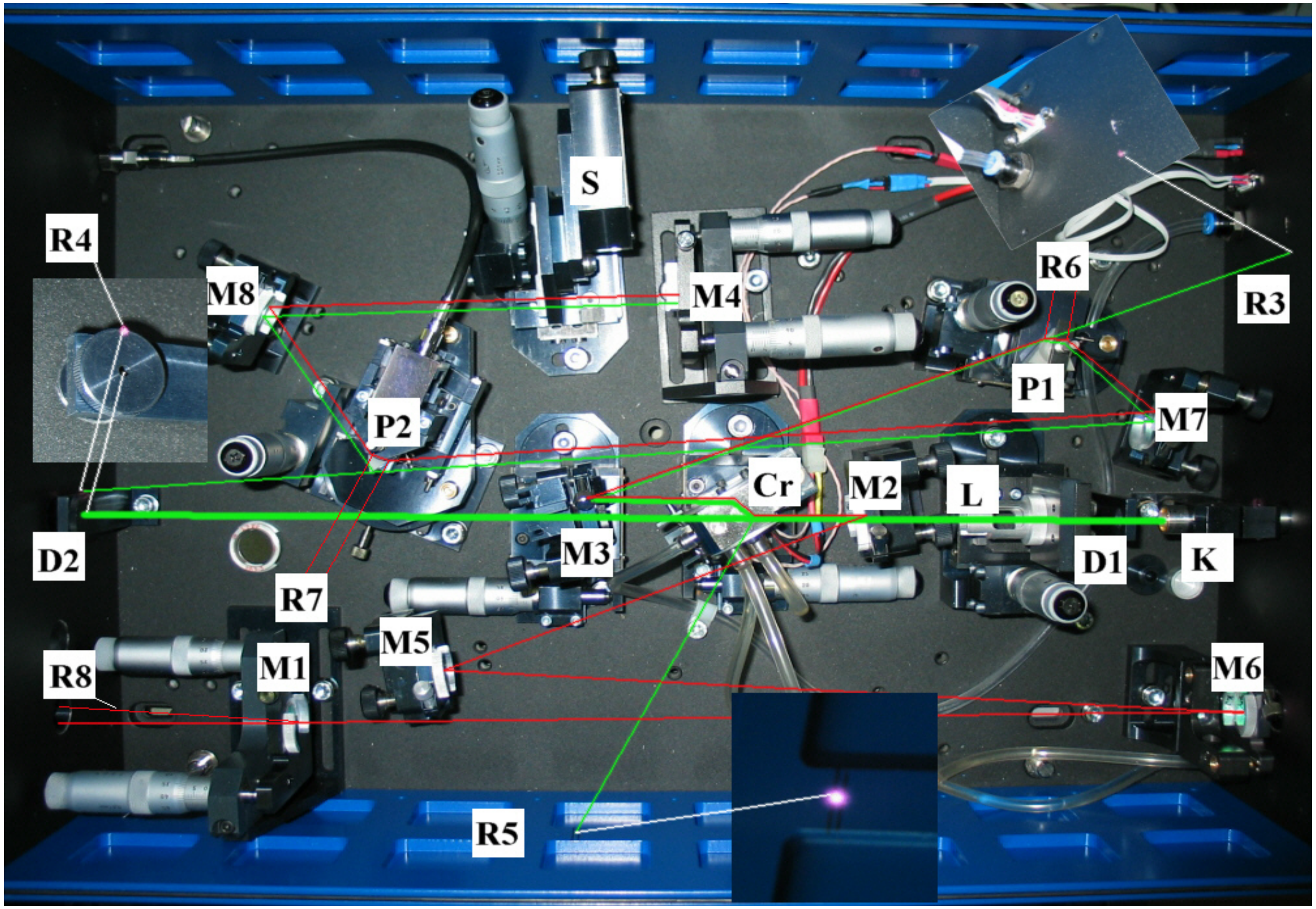


Figure 4.15: Schematic for CrF-65/P model Femtosecond Forsterite Oscillator. Green beam – pump, red beam – radiation at 1250nm

Optical Components

1. CRYSTAL HOUSING

The Crystal housing is used to protect and align the Chromium Forsterite crystal in the cavity and connects the crystal to the cooling system. There are connections for the Nitrogen gas as well as input and output connectors for the cooling water. Figure 4.1 shows the front and back views of the Crystal housing.

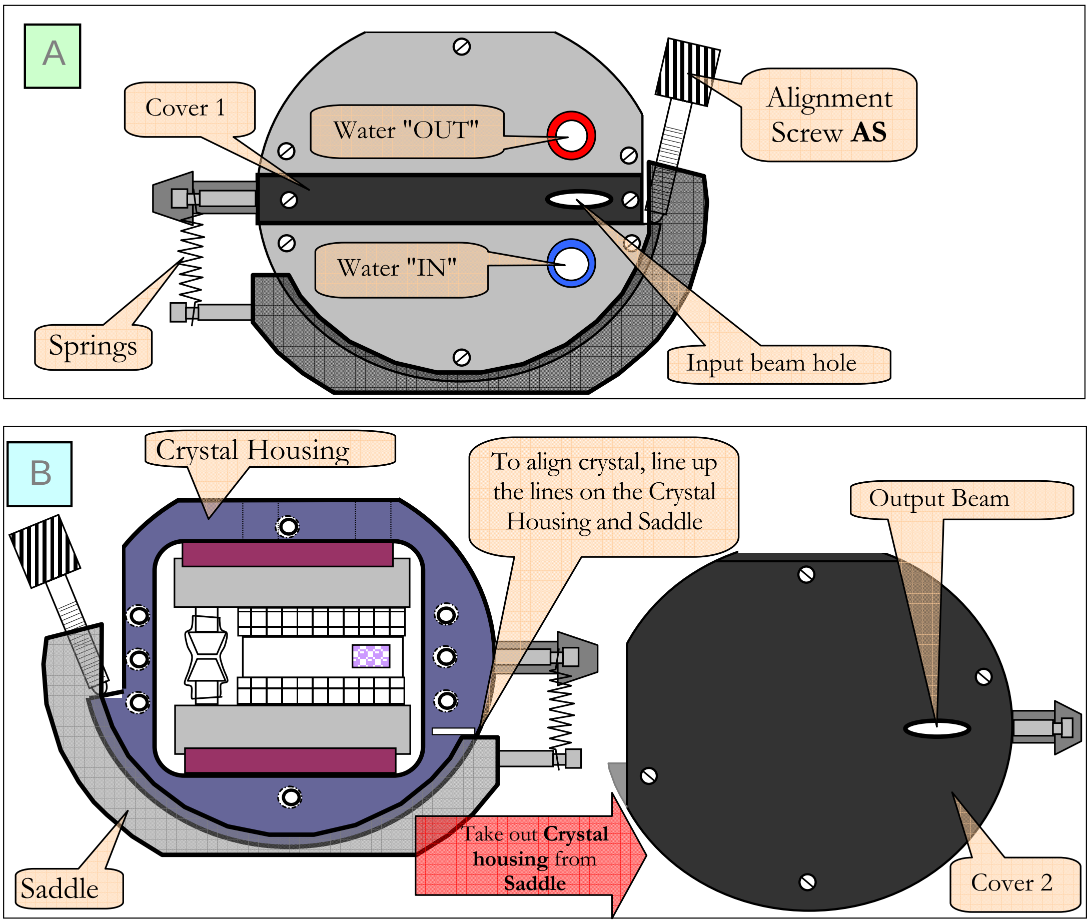
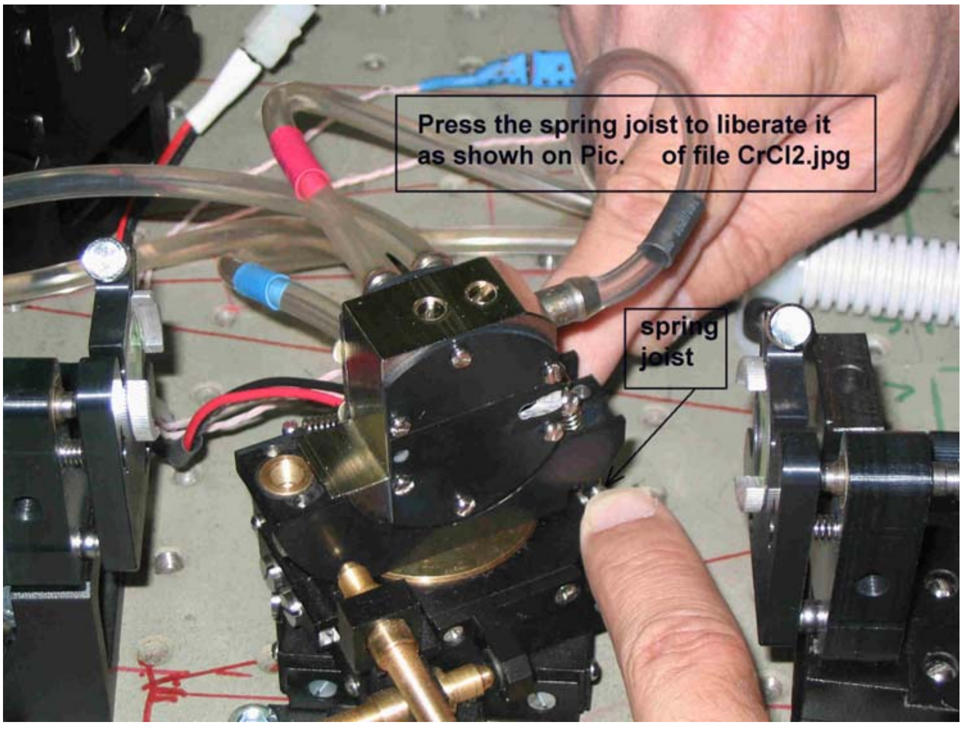
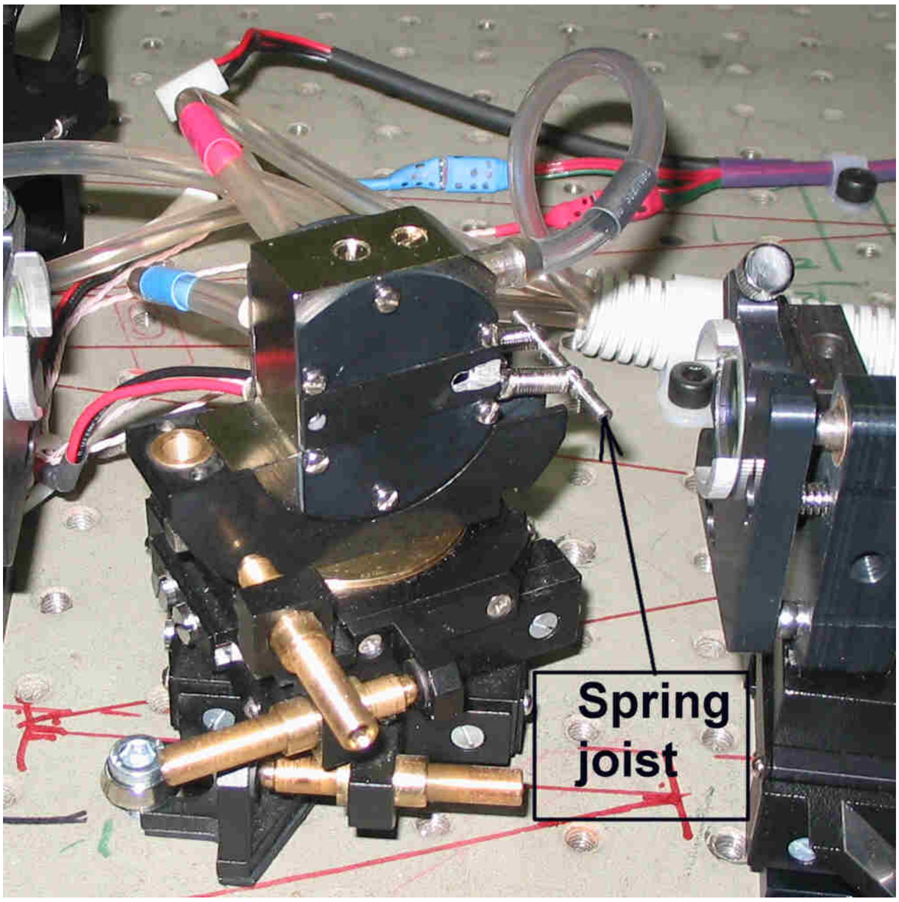
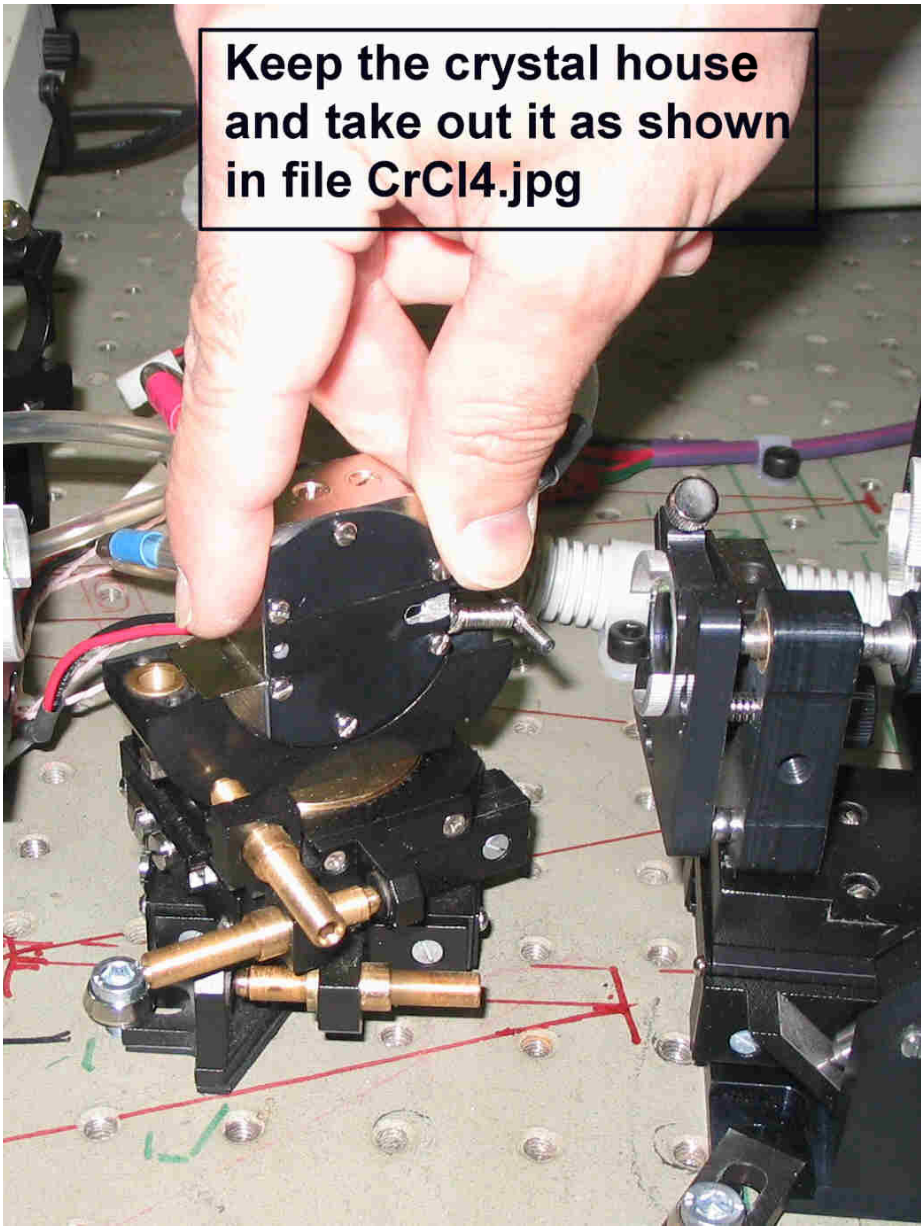


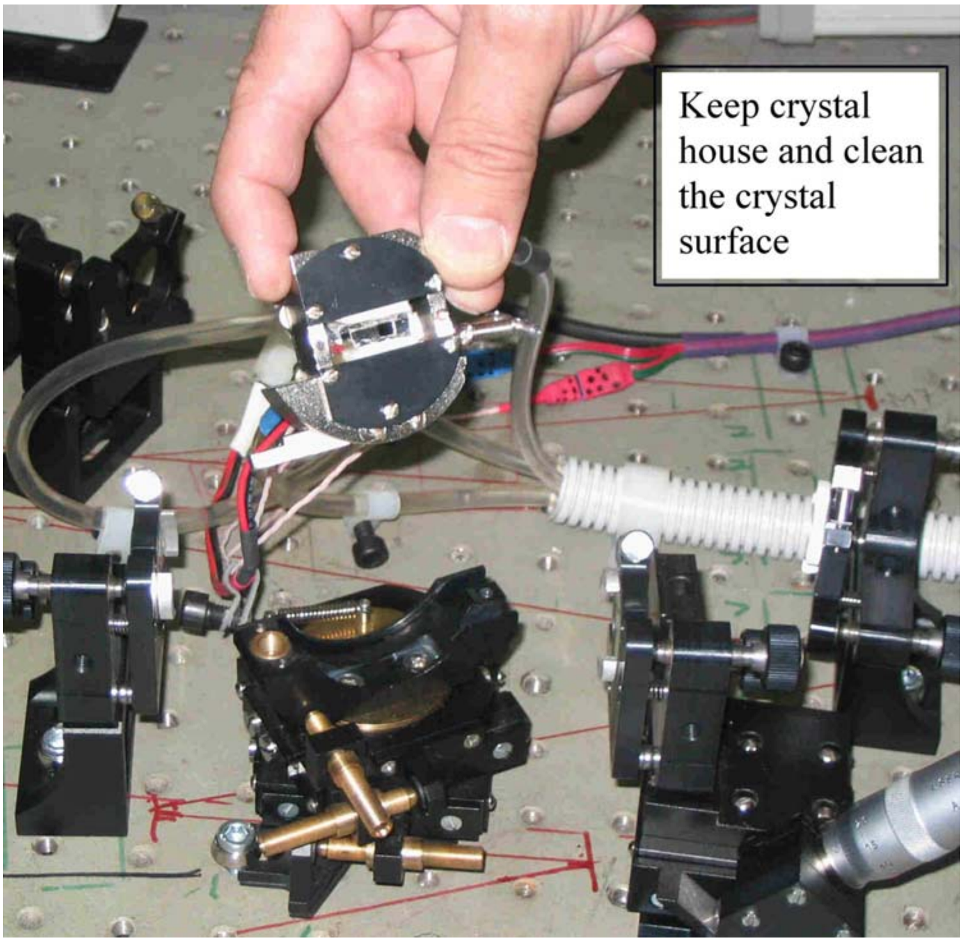
Figure 4.1: Front and back views of the Crystal housing.

CRYSTAL CLEANING




Spring
joist


Keep the crystal house
and take out it as shown
in file CrCl4.jpg


Keep crystal house and clean the crystal surface

2. FOCUSING LENS AND MOUNT

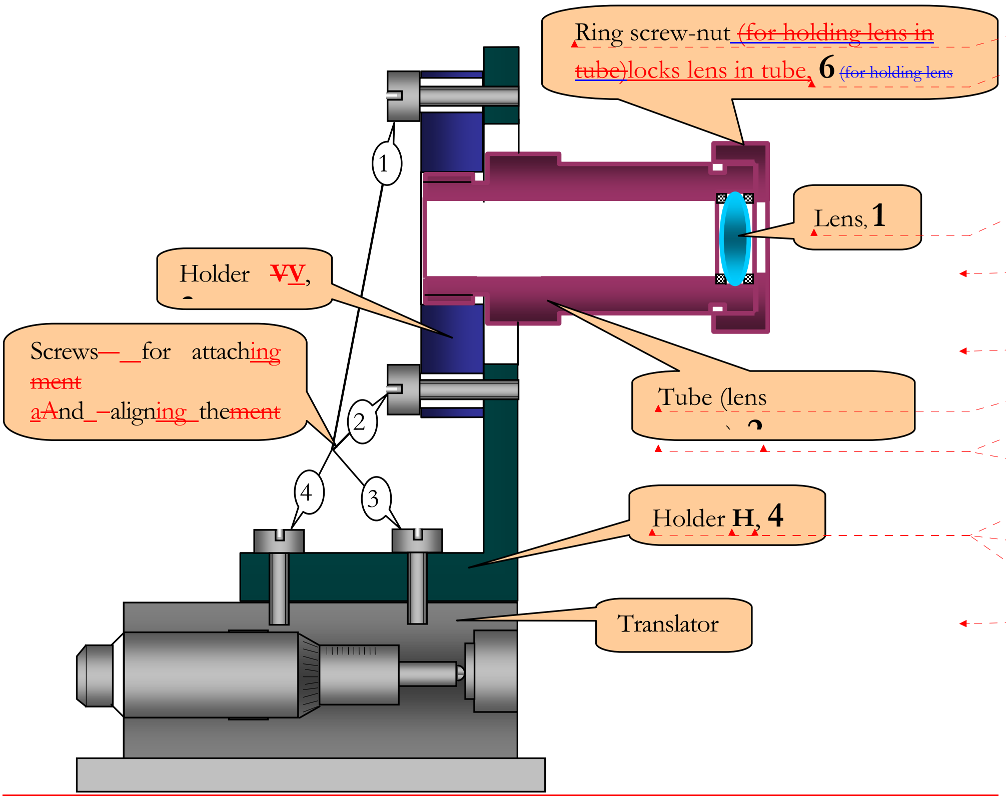


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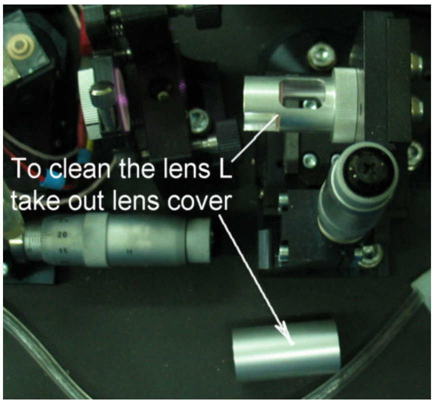
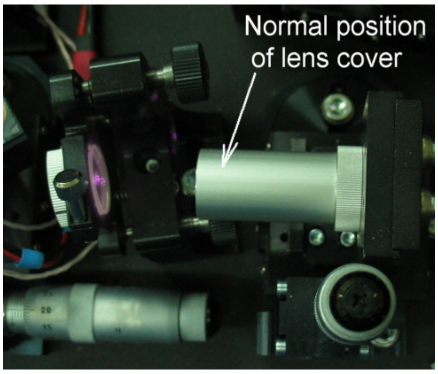
Figure 4.2: Schematic of Lens Mount .

When

~~To c~~checking ~~-~~the direction and alignment of the ~~p~~Pump Laser beam,** chapter5.2 alignment step 3* ***, remove focusing lens L ~~-~~by unscrewing ~~t~~Tube (2) from ~~h~~Holder V (3) .

L E N S ~~–~~C L E A N I N G





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PRISM MOUNTING AND CLEANING

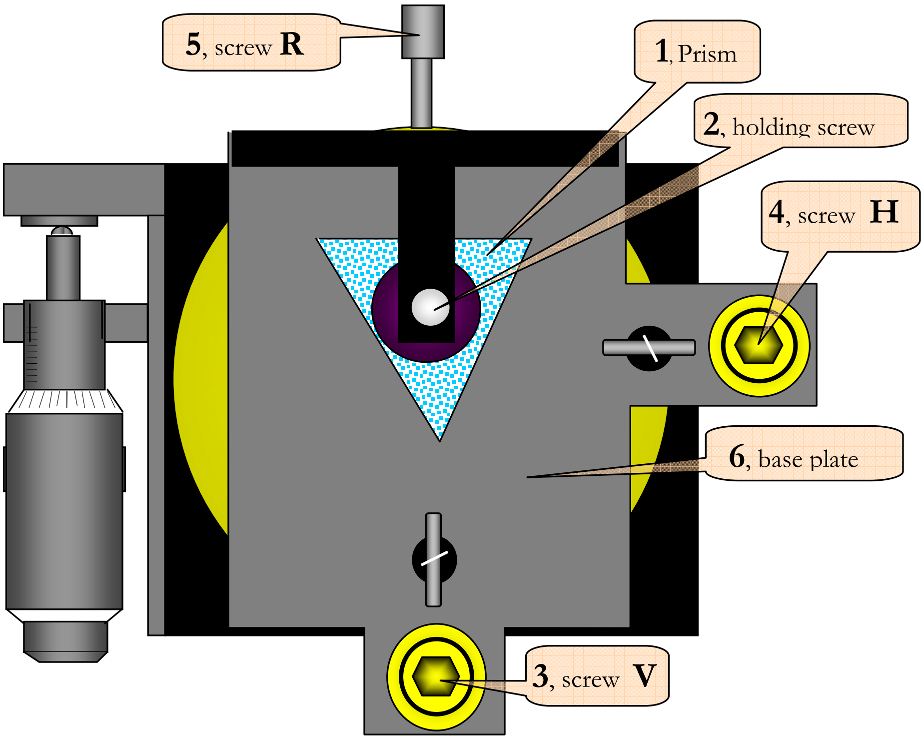

Figure 4.3: Schematic of prism mount.

MOUNTING THE PRISMS

1) Prisms **P1** and **P2** are fixed to base plate **6** using double sided tape.

2) Screw **2** is used to hold the prism in place. **!** Do NOT over tighten screw 2. This prevents force induced birefringence in glass of prism **!**

3) Screw **R** to fix rotation of base plate **6**,

4) Prism base plate has handle rotation

ALIGNMENT

Use screw **V** to align passed Pump Laser beam at 1064nm in vertical plane and screw **H** to align reflected Cr:F beam at 1250nm in horizontal plane CHAPTER 6.3 PRISM ALIGNMENT.

CLEANING PRISMS

1) Do not remove prism from base plate **6**
2) Clean prism with pure acetone or alcohol while in place

4. MIRROR MOUNTING AND CLEANING

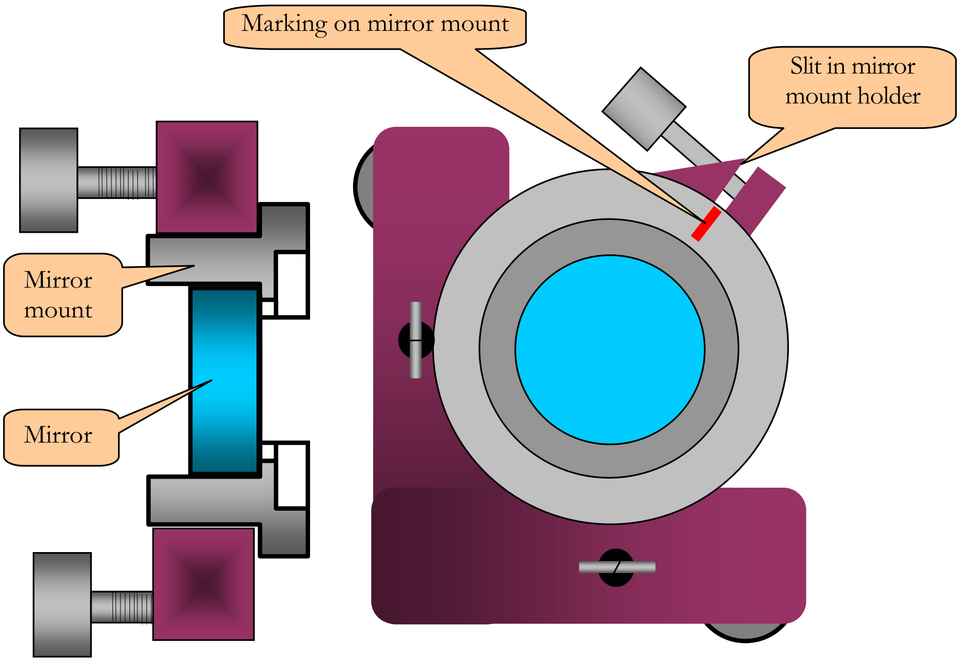

Figure 4.4: Schematic picture of Mirror mount assembly.

MIRROR CLEANING AND SETUP

1) When cleaning the mirrors, make sure to only use acetone or alcohol
2) The mirror should not be removed from the mirror mount, but the mount can be removed from the mirror mount holder
3) If the mirror mount is removed from the holder, line up the marking on the mirror mount with the slit in the mirror mount holder as shown in the picture

5. DIAPHRAGM MOUNTING

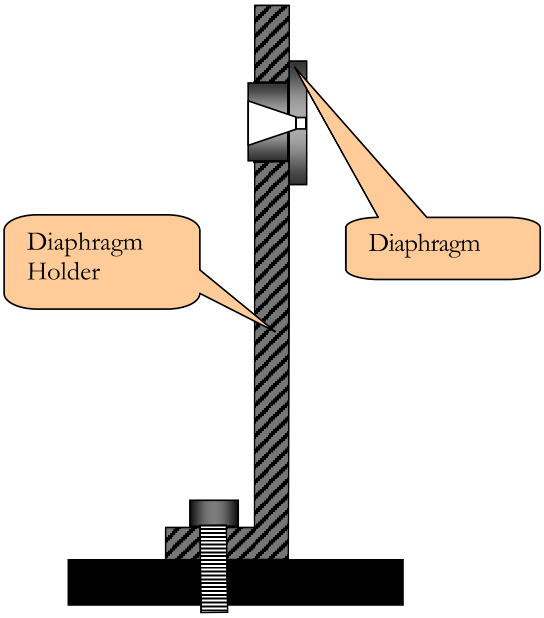

Figure 4.5: Schematic of Diaphragm and holder.

USING DIAPHRAGMS FOR ALIGNMENT

To install, screw the diaphragm into holder.

Remove diaphragms **D1** and **D4** from holders after alignment, CHPTER6.2 ALIGNMENT STEP 3, to pass all power from Pump Laser beam. Do NOT remove diaphragm holders from Laser Breadboard.

Diaphragms **D1** and **D2** keep alignment direction of the translators for focusing lens **L**, crystal **Cr** and spherical mirror **M3.** Diaphragm **D3** keeps the direction of the beam reflection from mirror **M3.**

Temperature Controller for Forsterite Laser

Contents

1. SPECIFICATIONS

- Input 220 V, 50/60 Hz, 0.5A
- Output 4.2 V DC, 6A
- The Maximum Stabilizing Temperature is equal to the temperature of the cooling water minus 5 °C
- The minimum stabilizing temperature depends on the temperature of the cooling water and the amount of pump power absorbed by the crystal
- Stabilizing temperature has an accuracy of (+/-) 0.1°C

2. ACCESSORIES

The Temperature Controller for the Chromium Forsterite Laser should come with two cables. One cable (K1), connects the Temperature Controller to the Cr:F laser. The other cable (K2), connects the Temperature Controller to the Fiber Pump Laser.

3. DESCRIPTION

The Temperature Controller consists of a thermoelectric cooling element, water cooling circulation system, and a control apparatus. The cool side of the thermoelectric element is exposed to the Chromium Forsterite crystal while the hot side is exposed to the water circulation system. As current is applied to the thermoelectric cooling element, heat is transferred from the cool side to the hot side. The water cooling circulation system removes excess heat from the hot side so that the thermoelectric element doesn't overheat. The Temperature Controller is connected to an electric shutter such that when either the cool side or the hot side gets too hot, the pump beam is blocked and the crystal is allowed to cool.

4. STARTING AND STOPPING TEMPERATURE CONTROLLER~~HOW TO TURN ON/ TURN OFF~~

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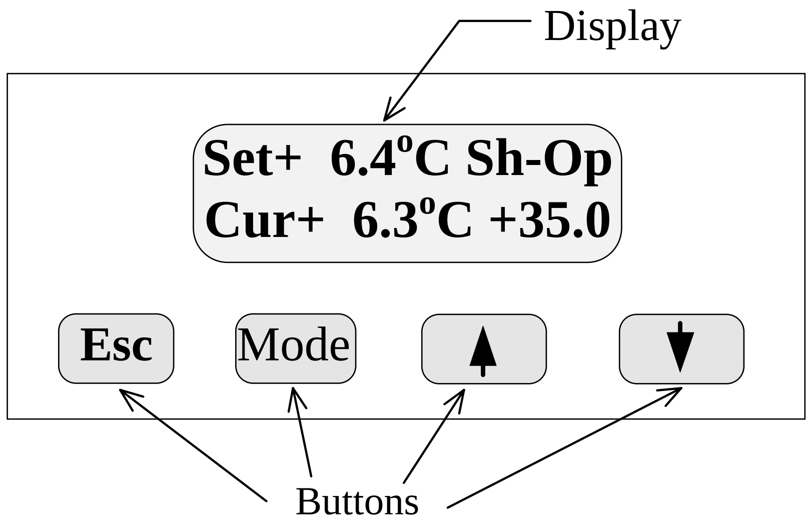
TO TURN ON.

1) Open gas flow to the Laser Crystal
2) Open water flow to the Laser Crystal
3) Turn power switch on the back panel of Temperature Controller to the ON position.
4) Set the temperatures according to Section 4.
5) Turn the Pump Laser ON.

TO TURN OFF.

1. Turn the Pump Laser OFF.
2. Turn power switch on the back panel of Temperature Controller to the OFF position.
3. Close water flow to the Laser Crystal
4. Close gas flow to the Laser Crystal

5. FRONT PANEL AND SYSTEM OPERATION

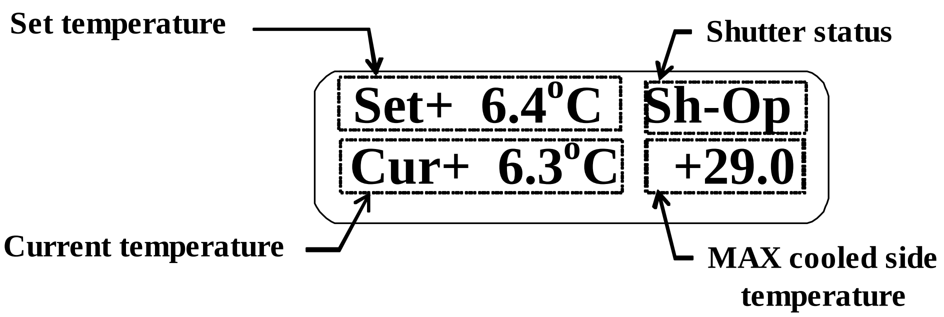


1) DISPLAY SETTINGS

There are two display settings:

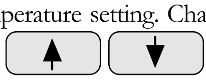
1. Cooled side setting (default setting)
2. Hot Side setting

1.A COOLED SIDE DISPLAY SETTING



In **Cooled side setting**, the display has four windows:

1) SET TEMPERATURE WINDOW

The Set Temperature Window shows the stabilizing temperature of the thermoelectric element. The Temperature Controller defaults to the previous temperature setting. Change the stabilizing temperature by pressing the **Mode** button and use the  buttons to set the temperature of the thermoelectric element.

When desired stabilizing temperature is reached press the **Mode** button twice.

!!! THE STABILIZING TEMPERATURE MUST SET BE 2-5 °C LOWER THAN THE TEMPERATURE OF THE COOLING WATER.

2) CURRENT TEMPERATURE WINDOW

The Current Temperature window shows the current temperature of the cool side of the thermoelectric element.

3) SHUTTER STATUS WINDOW

There are two positions the shutter can have:

1. **Sh-Op** – The shutter is in the open position. (Default position)
2. **Sh-Cl** – The shutter is in the closed position.

During normal system operation the shutter is in the open (**Sh-Op**) position.

To close the shutter, press the **Esc** button. Closing the shutter will block the Pump Laser beam and will cause the system to stop lasing. Press the **Esc** button again to reopen shutter.

The shutter will close automatically if the current temperature exceeds the **MAX cooled side temperature** or if the temperature of the hot side of the thermoelectric element exceeds the **MAX hot side temperature**. In either case the system will block the Pump Laser beam so the Cr:F crystal can cool to a safe level.

When the shutter is closed automatically due to over heating, the Display will show "Overheating, press any key". Make sure to check the cooling water is flowing freely, and then press any key to reopen the shutter.

!!! DON'T FORGET TO SWITCH OFF THE PUMP LASER BEAM BEFORE YOU TURN OFF THE TEMPERATURE CONTROL SYSTEM. WHEN TEMPERATURE CONTROL SYSTEM IS TURNED OFF THE SHUTTER IS LEFT OPEN.

4) MAX COOLED SIDE TEMPERATURE WINDOW

When in cooled side mode, the **MAX cooled side temperature** is displayed in the lower right of the display panel. The previously set **MAX cooled side temperature** is used as the default setting. If the current temperature exceeds **MAX cooled side temperature** the shutter will close.

To change **MAX cooled side temperature,** press the **Mode** button and use the ▲ ▼ buttons to set the **MAX cooled side temperature**. When desired temperature is reached press the **Mode** button.

The maximal value of **MAX cooled side temperature** is 55°C.

!!! THE RECOMMENDED VALUE OF THE MAX COOLED SIDE TEMPERATURE IS 25-30 °C. IF THE MAX COOLED SIDE TEMPERATURE IS NEEDED IN THE 30-55 °C REGION, CAREFULLY CHECK TO MAKE SURE THE COOLING WATER CAN HANDLE THE HEAT EXCHANGE.

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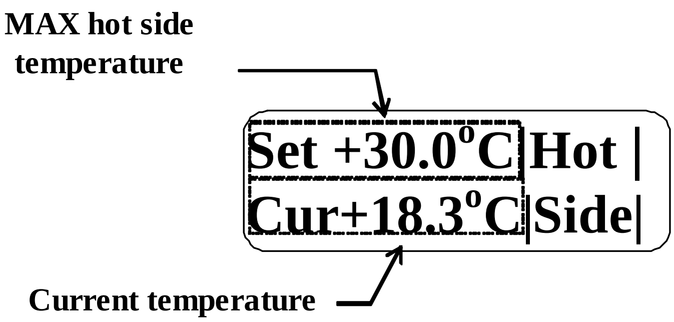
1.B HOT SIDE DISPLAY SETTINGS

To switch to the **Hot Side setting** press the **Mode** button and hold it for 2-3 seconds.



1) MAX HOT SIDE TEMPERATURE WINDOW

When in hot side mode, the **MAX hot side temperature** is displayed in the upper left of the display panel. The previously set temperature is the default **MAX hot side temperature** setting. If the current temperature of the hot side is higher than the **MAX hot side temperature** the system will close the shutter automatically.

To change the **MAX hot side temperature,** press the **Mode** button and use the ▲ ▼ buttons to set the **MAX hot side temperature**. When desired temperature is reached press **Mode** button. The maximal value of **MAX hot side temperature** is 55°C.

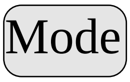
!!! THE RECOMMENDED VALUE OF THE MAX HOT SIDE TEMPERATURE IS 25-30 °C. IF THE MAX HOT SIDE TEMPERATURE IS NEEDED IN THE 30-55 °C REGION, CAREFULLY CHECK TO MAKE SURE THE COOLING WATER CAN HANDLE THE HEAT EXCHANGE.

2) CURRENT TEMPERATURE WINDOW

The current temperature window shows the current temperature of the hot side which is cooled by the water circulation.

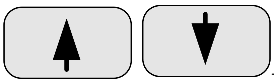
5.2 BUTTONS

- Opens and closes the shutter



1) Long pres, 2-3sec, changes display setting from cooled side temperature mode to hot side temperature mode .

2) Short press to change temperature setting for current mode (cooled side or hot side).



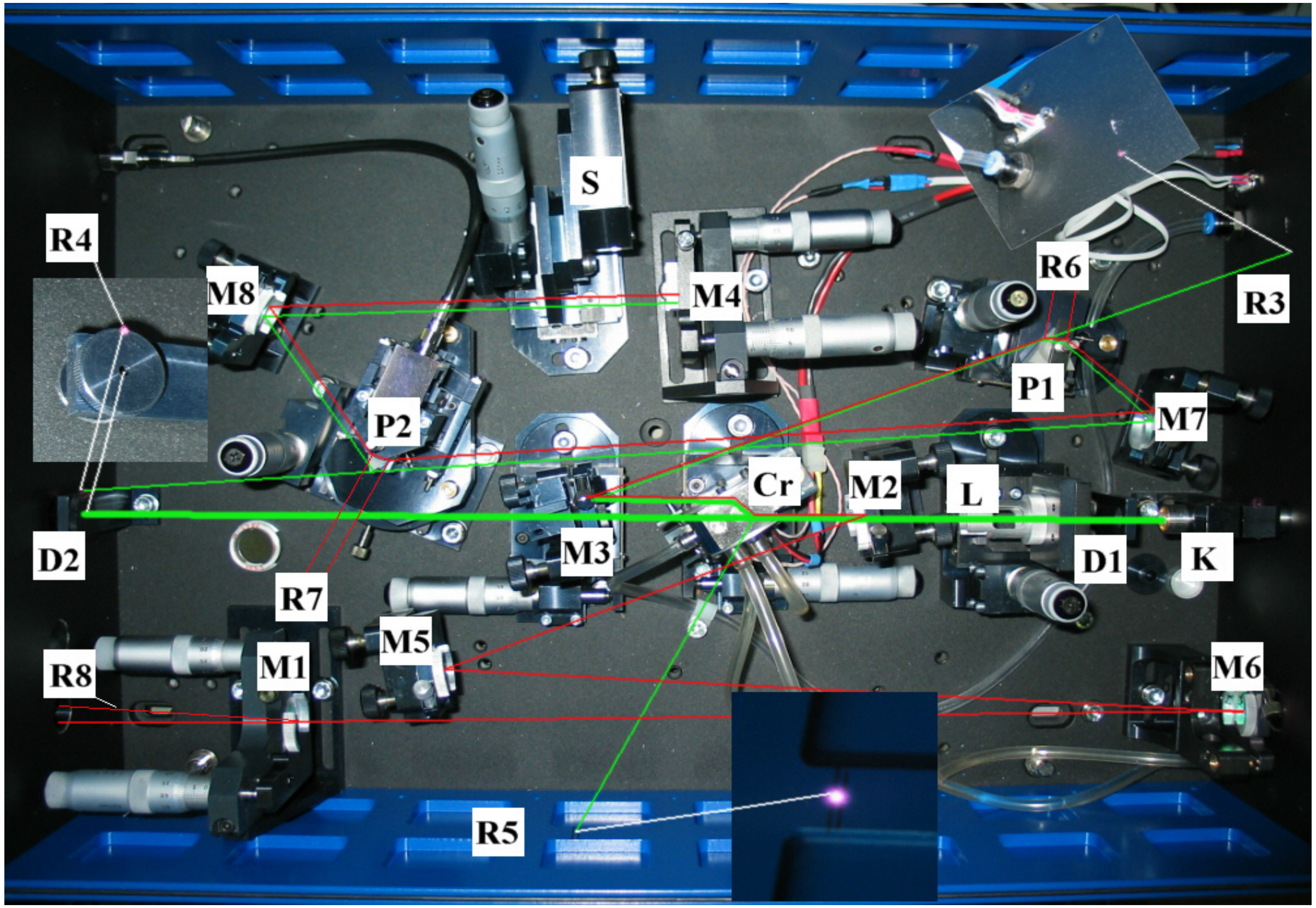
- Adjusts the temperature setting; stabilizing temperature or MAX temperatures depending on display mode.

Cr:Forsterite Laser Cavity Alignment and Optimization

Contents

1. BEFORE YOU BEGIN

CAVITY ALIGNMENT OF YOUR LASER



Optical cavity of your laser is a standard cavity of femtosecond laser (see optical schema of the laser). Two concave mirrors (M2 and M3) with radiuses of curvature 100mm and two flat mirrors (M4 - 100 % shape reflecting and M1 – output coupler) comprise the confocal optical resonator of the laser. The flat mirrors M5 - M8 make the resonator more compact. The chromium forsterite crystal Cr, pumped through a lens L and mirror M2 by light with a wavelength of 1064 nm emits broadband radiation in a range around 1250 nm, and also plays a role of element for shaping a lens on an optical Kerr effect serving for a synchronization of modes of generated broadband radiation in the range of 1250 nm. Two prisms, (P1 and P2) compensate the positive group velocity dispersion of pulse spectral components in the crystal and create the conditions for Kerr-lens mode-locking. The optical slit Sl serves for selecting the wavelength of radiation of the laser in femtosecond regime of generation in the range 1230-1270 nm.

The diaphragms D1 and D2 fix the translation direction (axes) of optical elements (of a lens L, mirror M3 and crystal Cr). Along the same axes the pump radiation propagates. The listed above translators should have an axes of migration conterminous with the axes of propagation of pump radiation. It is necessary that at translation of optical elements, during searching for the femtosecond condition of generation, the misalignment of the resonator of the laser does not occur, as of axes of the resonator to axes of distribution of the pump radiation.

The holders of the elements D1, D2, L, M2, Cr, M3 and the holder of a collimator of the pump laser are fixed to the breadboard of the laser so that the listed above conditions are observed. **Please NEVER unscrew and remove the holders of the listed above elements (D1, D2, L, M2, Cr, M3, and holder of pump laser collimator) from the laser breadboard!** If they must be unscrewed from the breadboard for any reason it is possible to restore their positions following the instruction that is omitted in the general alignment procedure of the laser.

The diaphragm R5 (R5 is a mark on the laser box) captures the reflection of pump radiation from the input crystal surface (to check it: reduce the pump power up to possible minimum level, and take out the central cover of the laser head (see Crystal cleaning).

Use the diaphragm D3 for monitoring the height of propagation of the beam in the resonator of the laser and alignment of elements according to general alignment procedure of the laser.

Place diaphragm D3 between M5 and M1 mirrors to observe the reflected spot of a super-luminescence from the mirror M1 while aligning it.

Before switching the laser on please make sure that the cover of the pump laser collimator is removed and the diaphragm D1 is screwed out of the holder!!!

The Laser Alignment section gives step by step directions for the setup and alignment of the Femtosecond Cr:Forsterite Laser oscillator and the Fiber Pump laser. Be sure to read and understand the Temperature Control System, CHAPTER 5, before turning on the Pump Laser.

!!! Please start with ALIGNMENT STEP 1 THROUGH TO ALIGNMENT STEP 6 only if laser was completely disassembled, otherwise go straight to ALIGNMENT STEP 7!!!

You should provide all alignment procedure with radiation of pump beam at pump power <50mW. Temperature controller must be operated, but TE crystal cooling must be "turned off" as shown in the figure 3.8.

2. INITIAL CAVITY ALIGNMENT

ALIGNMENT STEP 1(PLEASE GO TO ALIGNMENT STEP 7 IF THE LASER WAS NOT COMPLETELY MISALIGNED)

Before aligning the oscillator cavity make sure that the following components can be assembled with their holders in accordance with the procedures in CHAPTER 4, OPTICAL COMPONENTS :SETUP AND CLEANING.

If any of the following components are installed remove them from the Laser Bread Board following the directions in Chapter 4.

- Focusing lens **L** and its holding Tube CHAPTER 4.2.
- Dichroic mirrors **M2** and **M3** installed in mounts CHAPTER 4.4.
- Slit **Sl** in holder CHAPTER 4.5
- Cr:F crystal **Cr** installed and aligned in the crystal housing CHAPTER 4.1

ALIGNMENT STEP 2

Using any two of the aluminum mirrors **A1** and their appropriate holders direct a He-Ne laser beam through the *center* of diaphragms **D1** and **D2** as shown in ***Figure 6.1***. Place a screen 3-5 meters from **D2** and mark the position of the He-Ne beam.

Place focusing lens **L** (in its tube assembly) in the oscillator cavity. Center the He-Ne beam on focusing lens **L** and check the He-Ne beam position on the screen. If necessary adjust **Holder V** and **Holder H** so that the beam position on the screen is the same with and without lens **L** in place. Now move lens **L** over the full travel range of its translation stage. The center position of the He-Ne beam on the screen should not change as lens **L** is translated, see ***Figure 5.2***.

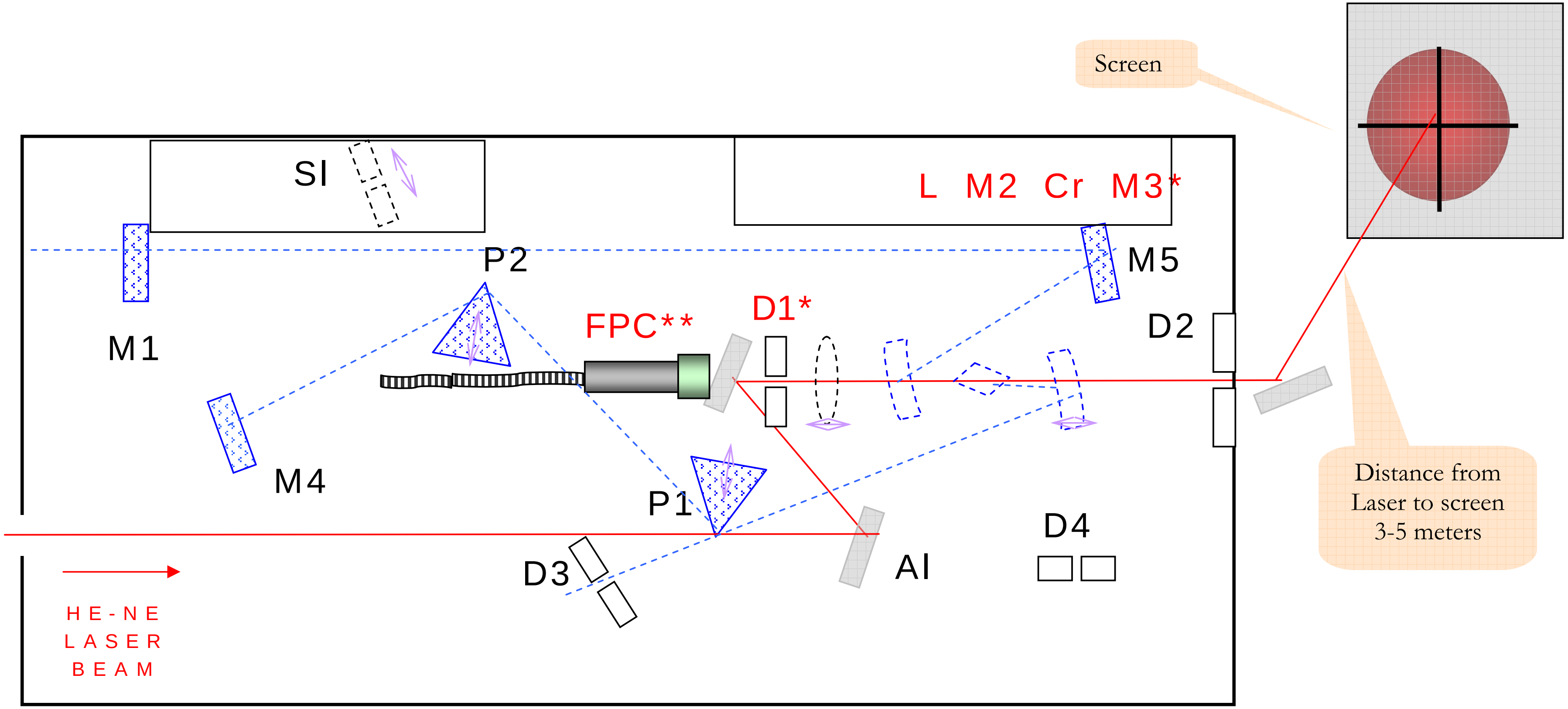


Figure 5.1 Oscillator cavity alignment using He-Ne laser.

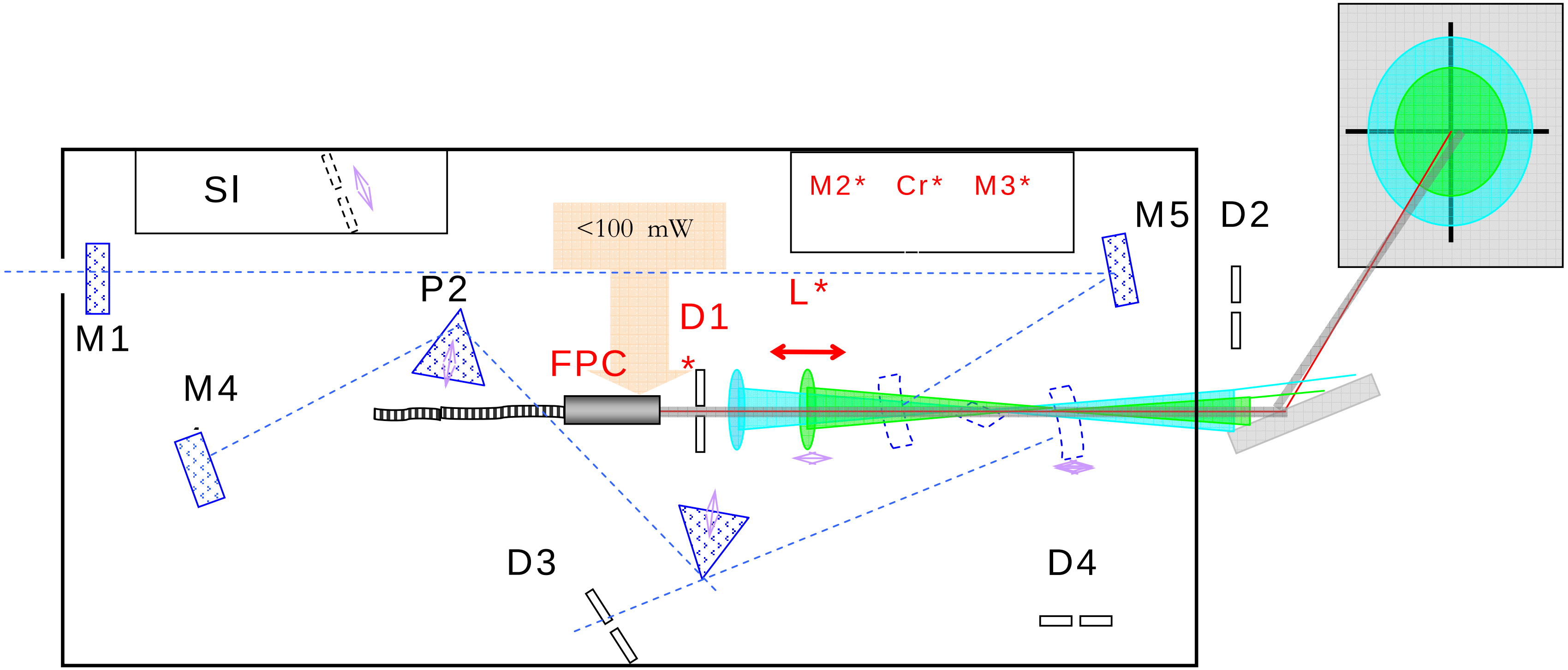


Figure 5.2. Alignment procedure of laser cavity.

ALIGNMENT STEP 3

Remove He-Ne steering mirrors. Turn on cooling water and nitrogen gas.

!!! Remove cover from Pump Laser collimator!!!

Set Pump Laser output power to less than 100mWatts. Turn on Pump Laser.

Check position of Pump Laser beam on the screen, it should be the same as the position of the He-Ne laser used for alignment in ALIGNMENT STEP 2. Check beam position with and without focusing lens **L** in place. Also check position with and without the diaphragm **D1** and **D2**.

If necessary install correction lens CL to correct the divergence of Pump Laser beam. Check that with divergence correction lens in place Pump Laser beam has the same position on screen as before. (Only for external pump laser).

ALIGNMENT STEP 4

Install the cavity mirrors **M2** , **M3** and the Cr:F crystal, **Cr**. Remove **Cover 1** and **Cover 2** from crystal housing as shown in CHAPTER 4.1.

Make sure that the Pump Laser beam is centered on the input surface of the crystal. The reflection of the Pump Laser beam off the input surface of crystal **Cr** should hit point **R** on the wall of the laser box. ***Figure 5.3***.

ALIGNMENT STEP 5

If necessary rotate the polarization of Pump Laser beam.

To find correct polarization rotate the face plate **FPC** within its holder to obtain the minimum reflected power from the input surface of crystal **Cr** at point **R**. as shown in ***Figure 5.3***. Lock **FPC** in this position.

ALIGNMENT STEP 6

Install diaphragm **D2** and the **Beam Dump** on the holder of **M3** after the mirror. Uninstall diaphragm **D1**, just the DIAPHRAGM NOT THE HOLDER!! Replace **Cover 1** and **Cover 2** on the crystal housing as shown in CHAPTER 4.1.

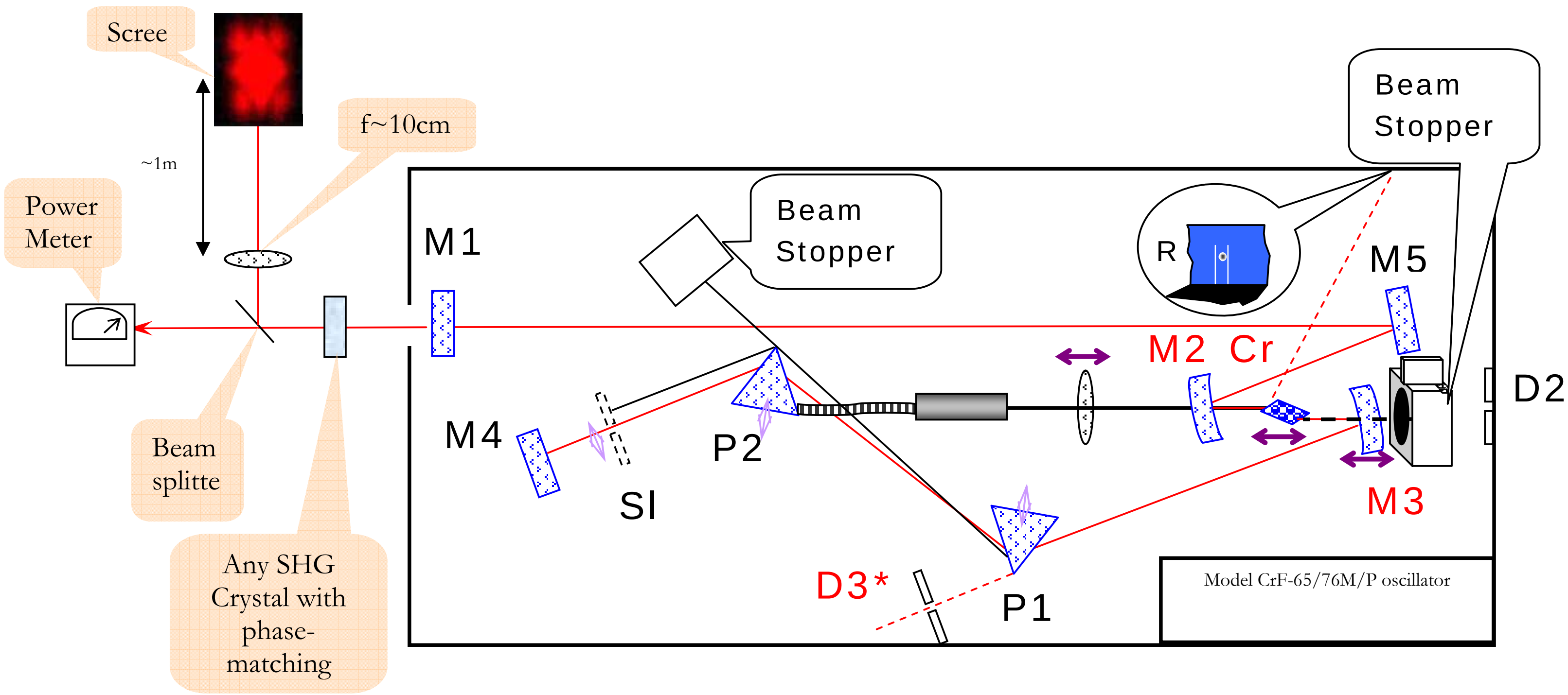


Figure 5.3. Alignment procedure of laser cavity.

ALIGNMENT STEP 7

Start here if laser already set up or has been just shipped from the factory

Turn on cooling water and nitrogen gas.

Remove **Cover 1** and **Cover 2** from crystal housing , ***Figure 4.1***

Set Pump Laser output power to less than 100 mWatts. Turn on Pump Laser.

Make sure that the Pump Laser beam is centered on the input surface of the crystal **Cr**. The reflection of the Pump Laser beam from crystal should hit point **R** on the laser wall ***Figure 5.3***.

Turn off pump laser.

Replace **Cover 1** and **Cover 2** on crystal housing CHAPTER 4.1.

ALIGNMENT STEP 8

Switch on temperature controller and set the Max cooled side temperature to +9 °C above the current crystal temperature (most likely 9 °C above room temperature) CHAPTER 5.

Comment [N1]: WTF

Set Pump Laser power to 7-8 Watts. Switch on Pump Laser.

ALIGNMENT STEP 9

- Pump Laser wavelength is 1064 nm.

- Cr:F oscillator wavelength is 1250nm

Move prism **P1** towards the focusing lens **L** until it is out of the Pump Laser beam path. A portion of the 1064 nm Pump Laser beam will reflect off mirror **M3**. Direct this beam through the diaphragm **D3**.

Put the prism back in the beam.

ALIGNMENT STEP 10

The 1064nm Pump Laser will excite the Cr:F crystal and an amplified spontaneous emission or superluminescent beam will propagate through the system.

Align prisms **P1** and **P2** as shown in section 6.3 PRISM ALIGNMENT.

Once the prisms **P1** and **P2** are aligned send the 1064nm back reflection from mirror **M4** to mirror **M1**. The 1064nm reflection off mirror **M2** should be approximately in the center of mirror **M5** and the 1064nm reflection from M5 should be centered on **M1**. Adjust the alignment until the back reflection from **M4** is superimposed on the spot from the Cr:F crystal superluminesces at **M1**.

The beam height in the oscillator cavity can be controlled with **D5**. Use **D5** to observe and align the back reflection.

Comment [N2]: Wtf2

ALIGNMENT STEP 11

Align prisms **P1** and **P2** as shown in section 6.3 PRISM ALIGNMENT.

Install the slit **Sl** after mirror **M4** to block the reflected portion of the Pump Laser ***Figure 5.5***. Place **Beam Stopper 2** after prism **P2** to block the nonrefracted portion of the Pump Laser, see ***Figure 5.3***.

Align mirrors **M1** and **M2** to obtain the maximum output power from the system. Translate the focusing lens **L** along the beam path until maximum output power is reached.

Align prisms **P1** and **P2** as shown in section 5.3 PRISIM ALIGNMENT.

Translate mirror **M3** along the beam path readjusting mirrors **M1** and **M2** for maximum output every time **M3** is moved. Measure and record the maximum output power for each position of **M3**. This will show the stability domain of the Femtosecond Laser in CW mode.

ALIGNMENT STEP 12

Place a second harmonic generation (SGH) crystal with phase matching at 1250nm in the Laser Output beam see ***Figure 5.3***. Observe the second harmonic at 625nm.

Move mirror **M3** to position of maximum CW output power.

Slightly shock prism **P2** with the starter handle while simultaneously moving mirror **M3**. Watch for bright red spot (625nm) on screen. The appearance of the 625nm red spot indicates an increase in SHG. The Laser is now mode locked and femtosecond pulses are being generated.

3. PRISM ALIGNMENT

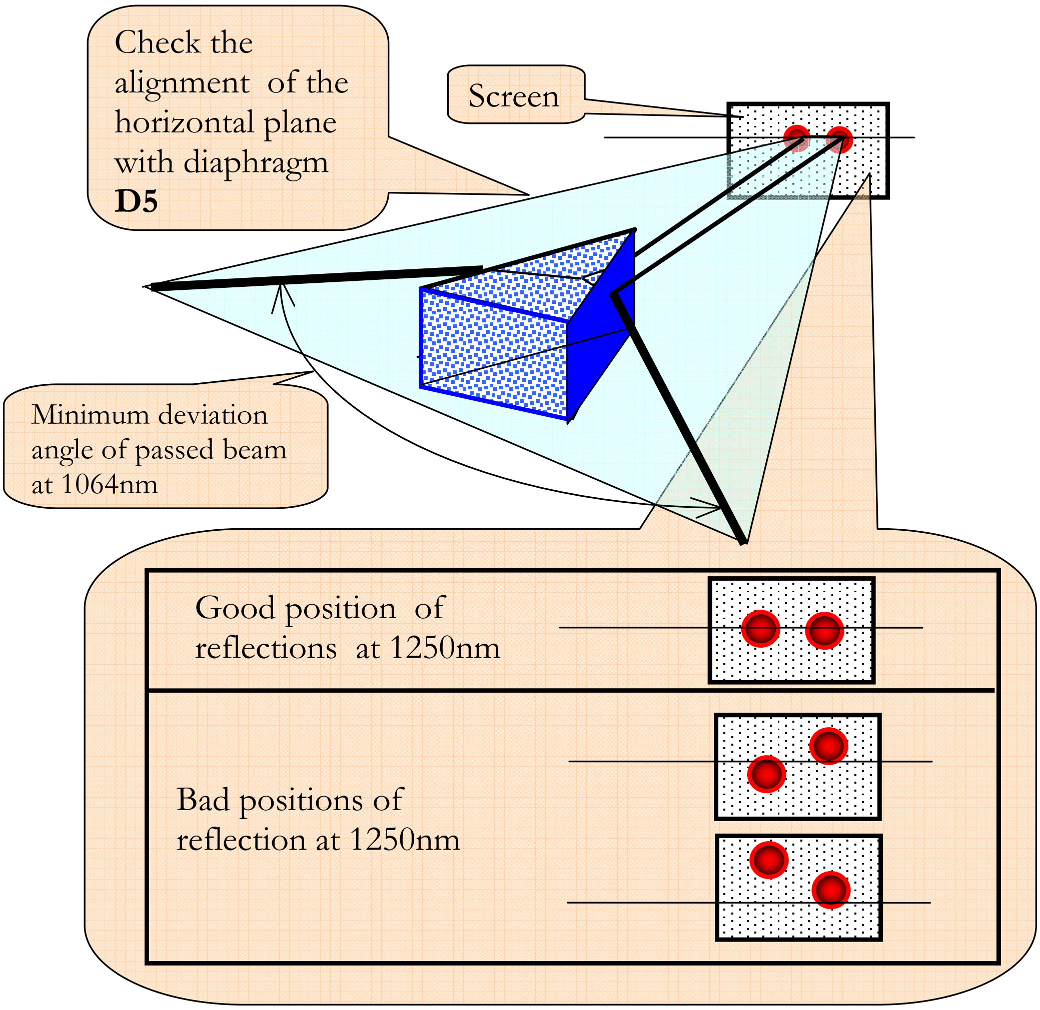


Figure 6.4 Aligning prisms P1 and P2.

ALIGNING THE PRISMS P1 AND P2

Refer to CHAPTER 4.3. Rotate the **Base Plate 6** by using **Screw 5**. Vertically align the Pump Laser beam passed by the prism with **Screw V(3).** Diaphragm **D5** is used to control the height of the beam. Using **Screw H (4)** align the reflections of the emitted beam (1250nm) as shown above ***Figure 6.4***. Repeat several times realigning mirror **M1** to maximize the output power each time, 6.2 ALIGNMENT STEP 11.

Comment [N3]: Not sure M5?

4. BEAM SLIT ALIGNMENT

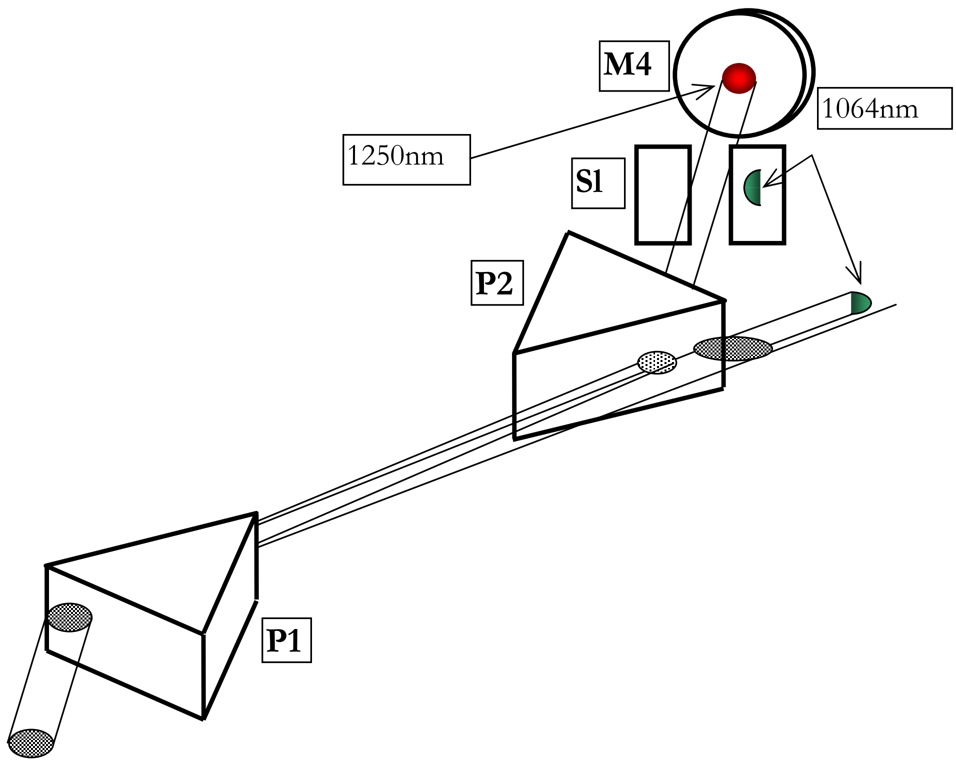


Figure 6.5. Beam positions on prisms and slit.

Figure 6.5 shows the recommended positions of the Pump Laser beam (1064 nm) and the Forsterite Laser (1250nm) beam on the prisms P1 and P2, the slit Sl, and mirror M4.

The Pump Laser beam is cut in half at the edge of prism **P2**. The remaining Pump Laser beam is blocked by slit **Sl**. This prevents parasitic feedback between mirror **M4** and the Pump Laser cavity. Feedback can result in instabilities in the CW operation of the Pump Laser and the disruption of femtosecond pulse generation.

5. OPTIMIZING OUTPUT

Position mirrors **M1** and **M2** for maximum output power during femtosecond generation. Translate the focusing lens **L** and the Cr:F crystal **Cr** along the beam path until maximum output power during femtosecond generation is reached.

Realign beam on prisms **P1** and **P2** in accordance with CHAPTER 6.3 so that the amount of SHG (red 625nm) light and the output power during femtosecond generation are both maximized. Place a beam splitter, focusing lens and screen in the Laser output beam as shown in ***Figure 6.5***.

With the Femtosecond Cr:F Laser in CW mode move mirror **M3** to the point where the laser output on the screen is in "**Fish Mode**" (see ***Figure 6.6.c*** and ***6.7***). This is the best position for femtosecond pulse generation. A slight displacement of the starter handle on prism **P2** will mode lock the laser cavity and initiate femtosecond pulse generation, ***Figures 6.6*** and ***6.7***.

The mode structure pictures in ***Figures 6.6*** and ***6.7*** were obtained with a 10 cm focal length lens and a screen placed 1 meter after the lens. Translation distance of mirror **M3** will depend on cavity length and the relative position of the crystal **Cr** between mirrors **M1** and **M4**. Position ***5.7.a*** corresponds to the shortest distance between **M2** and **M3.**

Figure 6.6 Mode structure

OUTPUT MODE SPATIAL STRUCTURE OF CR:F LASER FOR CW AND FEMTOSECOND GENERATION

Pictures in ***Figure 6.6*** show the general mode structure evolution as mirror **M3** is translated.

The mode structure will depend on pump beam parameters and cavity alignment.

The position for optimal femtosecond pulse generation is **6.6.c.** When the mode profile is in **"fish mode**". See ***Figure 6.7*** for the mode structure as M3 is translated around this point.

Femtosecond pulse generation will be acceptable at positions ***6.6.b*** and ***6.6.d.***

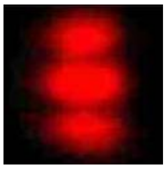
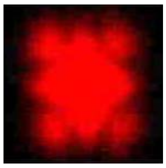
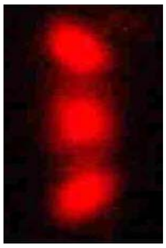
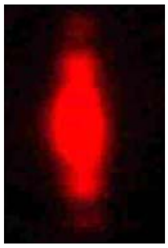
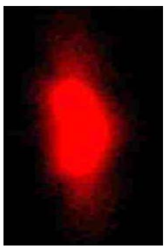
Figure	Relative position of M3		Laser in CW Mode	Laser in Femtosecond Mode
6.6.a	5.68 mm			
6.6.b	7.67 mm			
6.6.c	8.25 mm			
6.6.d	9.36 mm			
6.6.e	10.68 mm			
6.6.f	11.87 mm			

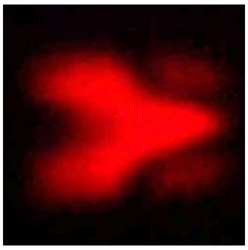
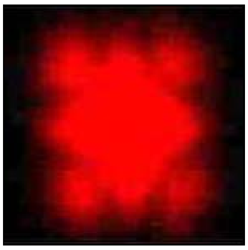
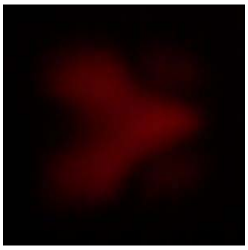
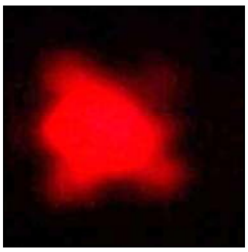
Figure	Position Relative to Mirror M3	CW Mode Profile	…ration …le
6.7.a	8.1 mm		
6.7.b	8.2 mm		
6.7.c	8.3 mm		
6.7.d	8.4 mm		

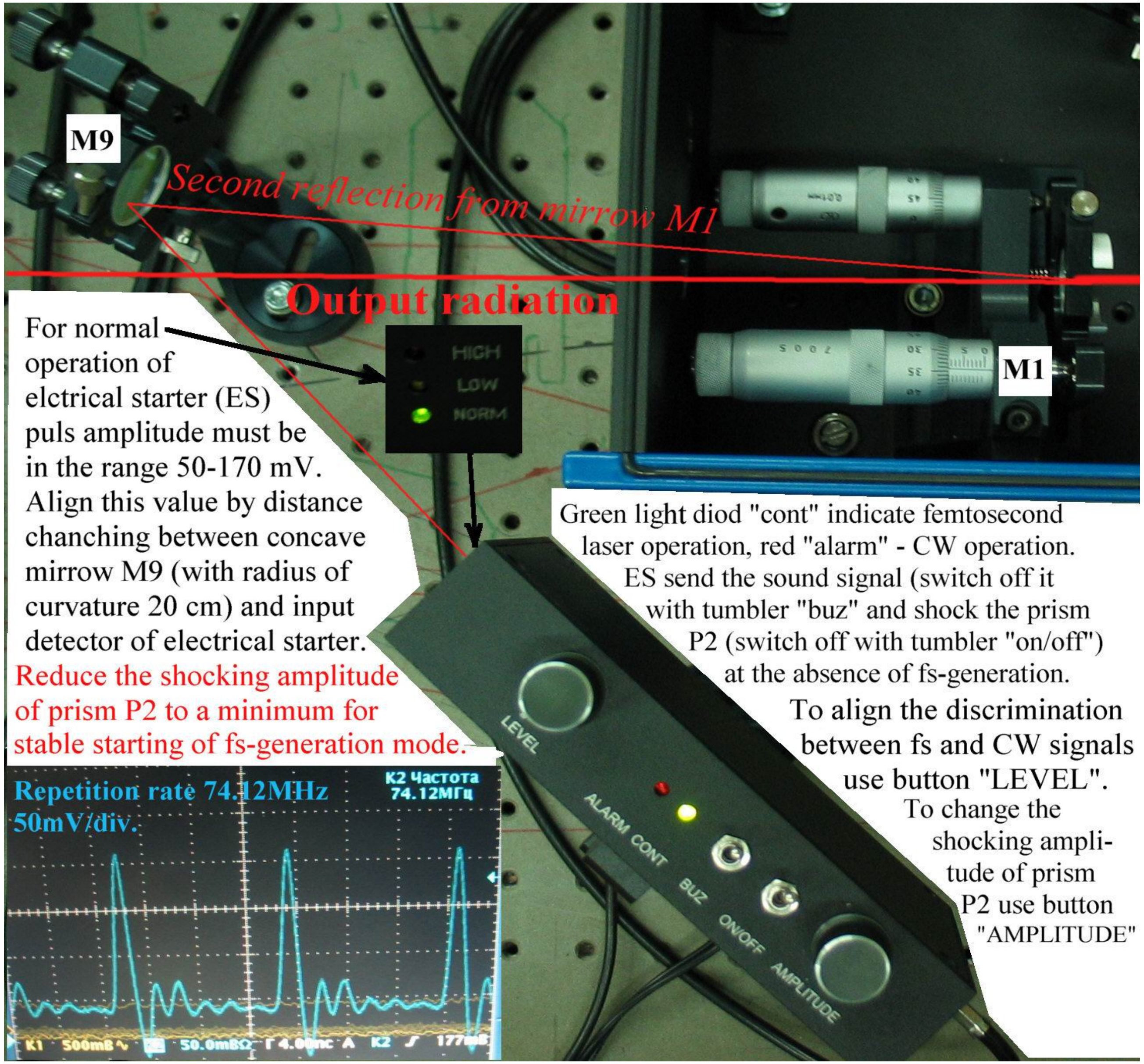
Figure 6.7 Fish mode.

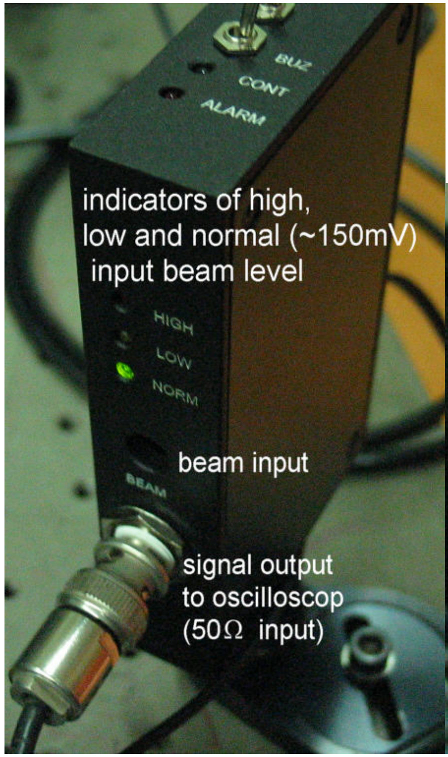
Possible spatial structure of "fish mode" of Cr:F laser. All pictures can be obtained with the same laser and optics, but for different pump and cavity alignment.

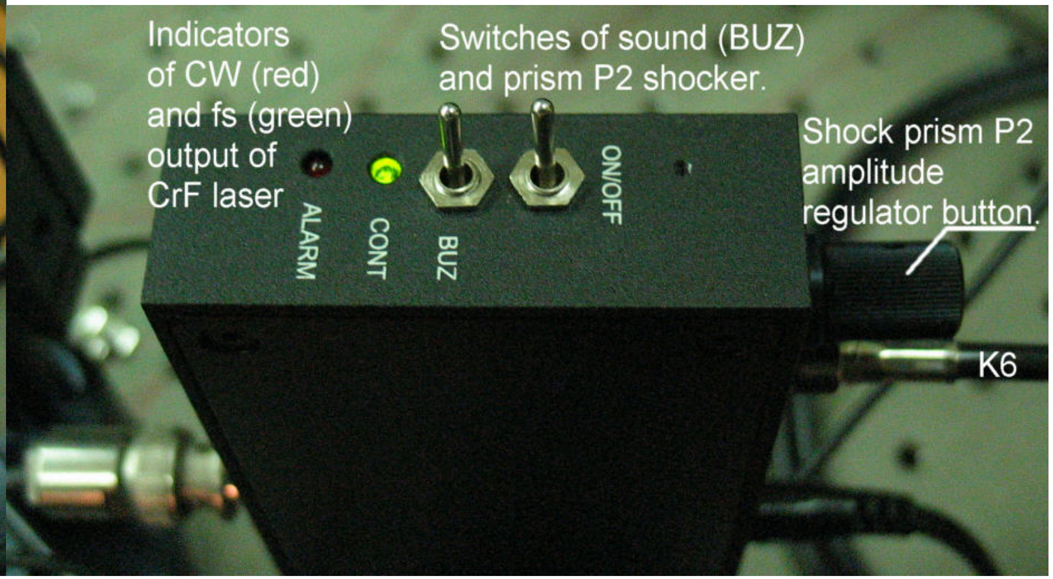
Test Configuration and Laser Test Data.

See Test Data of laser in files of folder "TEST DATA" (TD) that accompanies this manual.

Electrical Starter




BUZ
CONT
ALARM
indicators of high,
low and normal (~150mV)
input beam level
HIGH
LOW
NORM
beam input
BEAM
signal output
to oscilloscop
(50Ω input)


Indicators
of CW (red)
and fs (green)
output of
CrF laser
Switches of sound (BUZ)
and prism P2 shocker.
Shock prism P2
amplitude
regulator button.
ALARM
CONT
BUZ
ON/OFF
K6