Operation Manual for Reflectivity Measurement Setup of Free Electron Laser Facility at Jefferson Lab

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Contents

1 Introduction

This document is written to explain the operation procedure for the reflectivity measurement setup at Free Electron Laser Facility (FEL) of Jefferson Lab. The construction of this system was a joint effort between Hall C, FEL, detector group of Jefferson Lab and University of Regina. The system is intended to measure the reflectivity for Hall C Heavy Gas Čerenkov mirrors between 200-400 nm wavelength at normal atmospheric condition. The system can be purged with pure N_2 vapour and measure the reflectivity below 190 nm.

For more information on the methodology of the system and the first reflectivity result, please see the Hall C technique report [1]. This operation manual only explains the procedure.

2 FEL EPICS Interface

2.1 Main FEL EPICS Menu

The system control interface is a part of the FEL Experimental Physics and Industrial Control System (EPICS).

Fig. 1 shows the FEL Menu (blue) and FEL Main Menu (red). Those menus should appear by default on the desktop of any FEL computer. To access the FEL Menu:

`Application Menu` → `Acc Tool` → `mymenu`

To access the FEL Main Menu:

`FEL Menu` → `EDM`

Note that do not close the prompted terminal windows.

2.2 Accessing lock-in Amplifier Control Interface

The main lock-in amplifier interface can be accessed as follows:

`FEL Main Menu` → `Optics` → `Autocorrelator`

Fig. 2 shows the SR530 lock-in amplifier control interface, but the settings are not configured here. The red boxed button is access to the expert control interface shown in Fig. 3. In the expert control interface, the purple box on the left indicates the incoming reference frequency and the one on the right shows the system status. The system status should be checked constantly during data acquisition in case of overloading, if overloads, sensitivity must increase.

The red boxed regions are the critical settings for the amplifier. Display mode should use R, θ mode, where R is signal magnitude and θ is the phase difference between the reference and signal.

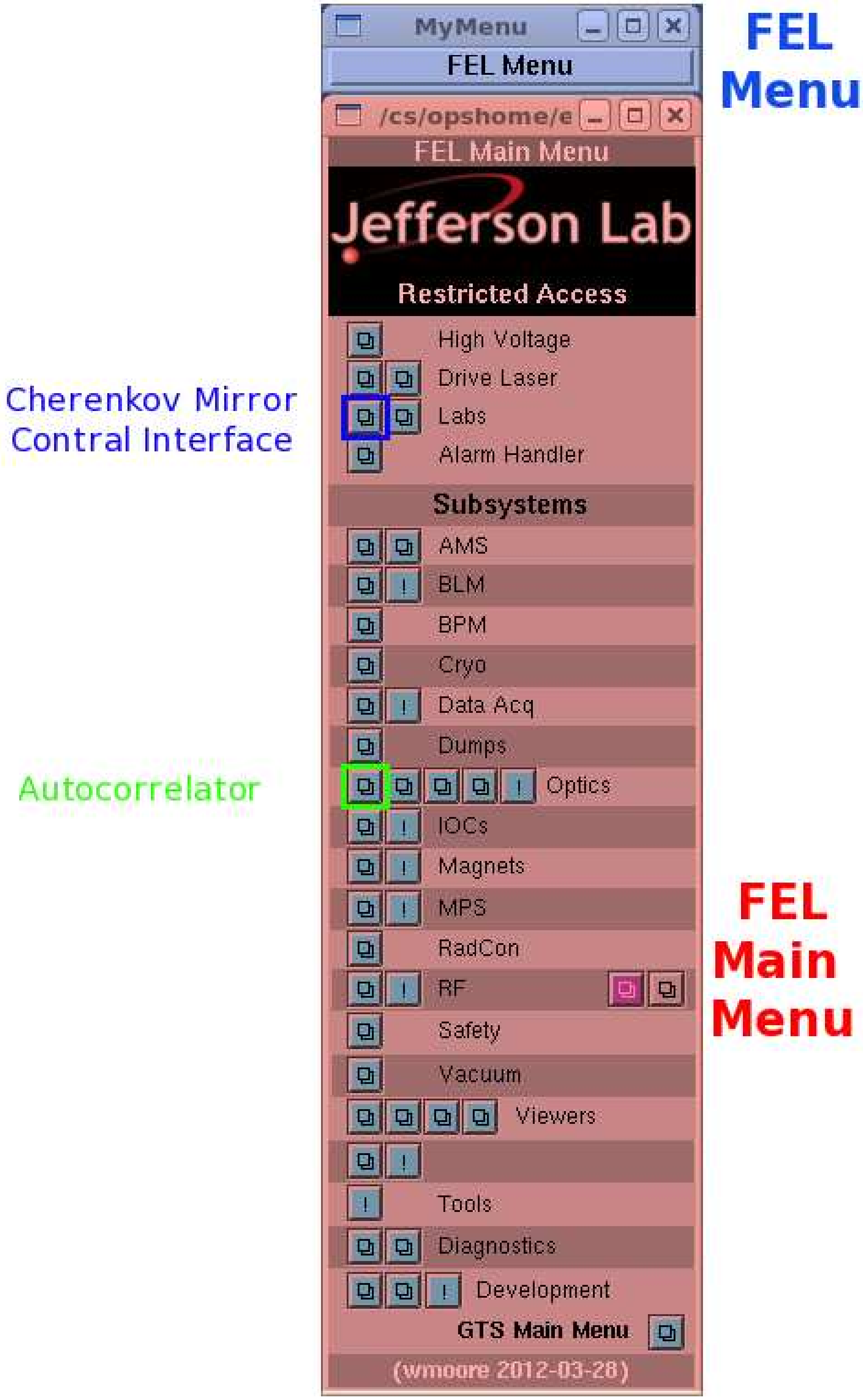

Figure 1: FEL Menu is in blue; FEL Main Menu is in red. The green boxes are the buttons to access labeled control interfaces.

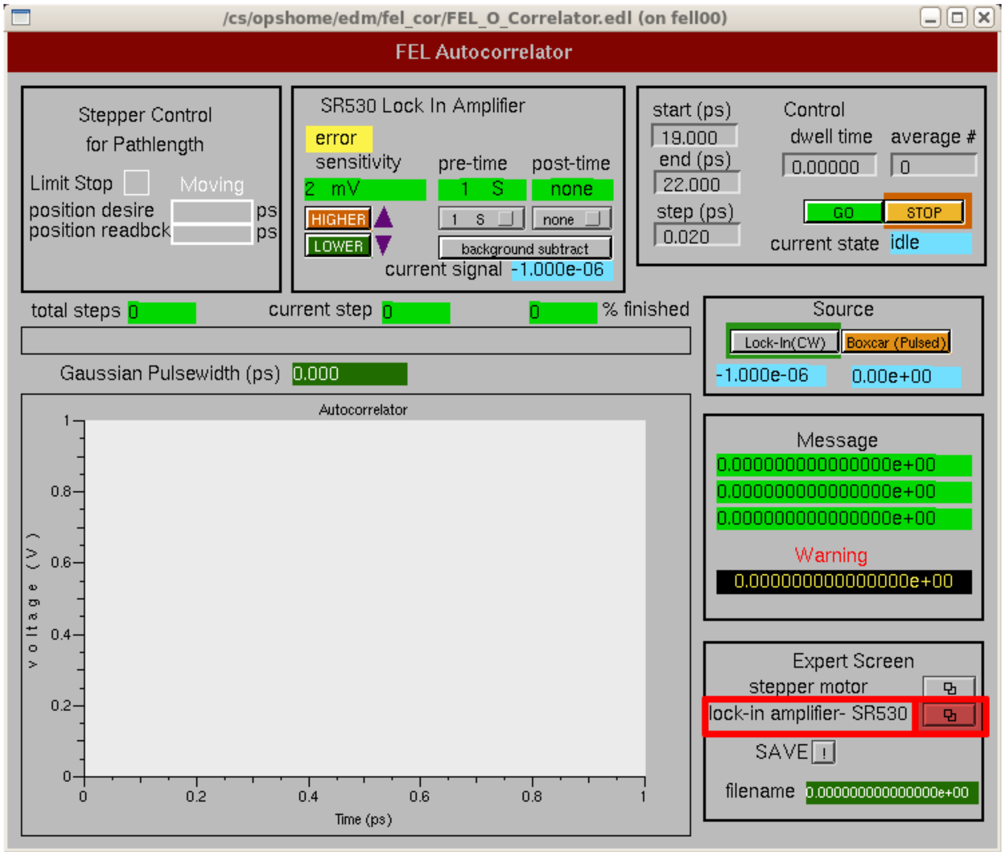

Figure 2: Main SR530 lock-in amplifier interface.

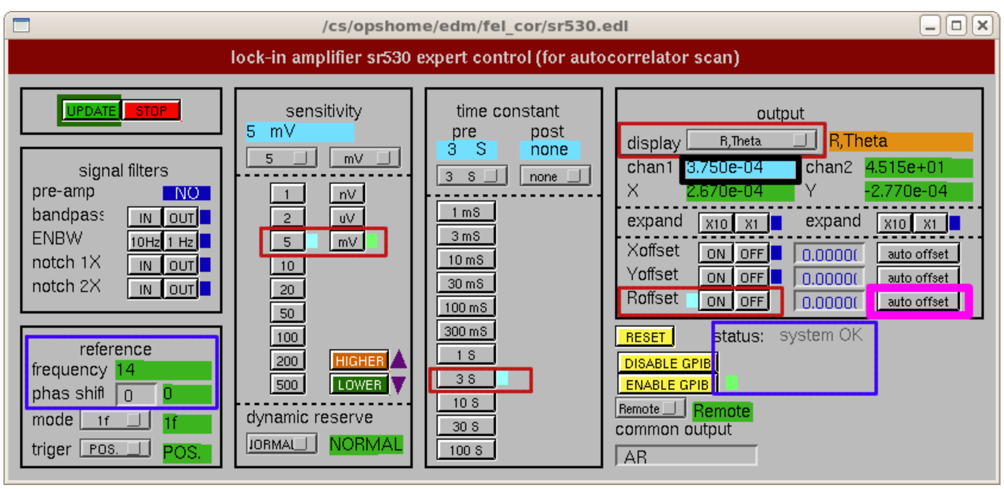

Figure 3: Expert Control Interface for lock-in amplifier.

Output channel 1 displays R and channel 2 displays θ. Sensitivity needs to be set to the lowest value which does not overload the signal. The favorite time constants are 1s and 3s depending on the dwell time setting for the monochromator. All setting outside of boxed regions should be kept the same as Fig. 3.

2.3 Data Acquisition

There are two ways to record the signal output from the lock-in amplifier: VUV monochromator control and striptool graph. Both methods are very useful, VUV monochromator control can directly plot signal strength vs the wavelength; striptool plots the signal strength vs time. It is recommended to use both programs at the same time, the former for the data analysis and later for signal monitoring.

2.3.1 VUV Monochromator and Stepper Motor Control Interface

VUV monochromator control and stepper motor control interface can be accessed as follows:

`FEL Main Menu → Labs → UL5: cherenkov`

The VUV Monochromator control interface is shown in Fig. 4. The plotting program is shared between several experiments, therefore before taking any data, one must check if the lock-in amplifier output is connected to the ADC Channel #16 located in the main control room. The ADC will amplify the lock-in signal by factor of 2000. Contact Wesley Moore of FEL for help if the channel readout is not working correctly.

Before operation, one need to check the wavelength shown in the interface corresponds to the wavelength reading on side the monochromator. There are many ways to calibrate the wavelength. One of the simplest way is to switch the control option from REMOTE to LOCAL on the monochromator control box, and set the wavelength in the interface (Fig. 4) the same as the monochromator value, then switch back to control option. All settings outside of the boxed area should not be changed.

There are two ways to operate the monochromator in the red boxed area in Fig. 4:

- Goto: One have to specify a desired wavelength and click on GO button. This method is useful for the alignment.

- Wavelength Scan: One have to specify the start and end wavelength. The scanning steps are defined by number of points option, dwell time controls measurement duration at each step. Delay start option will count down specified number of seconds before wavelength scan starts. To obtain more reliable measurement, the monochromator dwell time should be 10 times larger than the lock-in amplifier time constant setting.

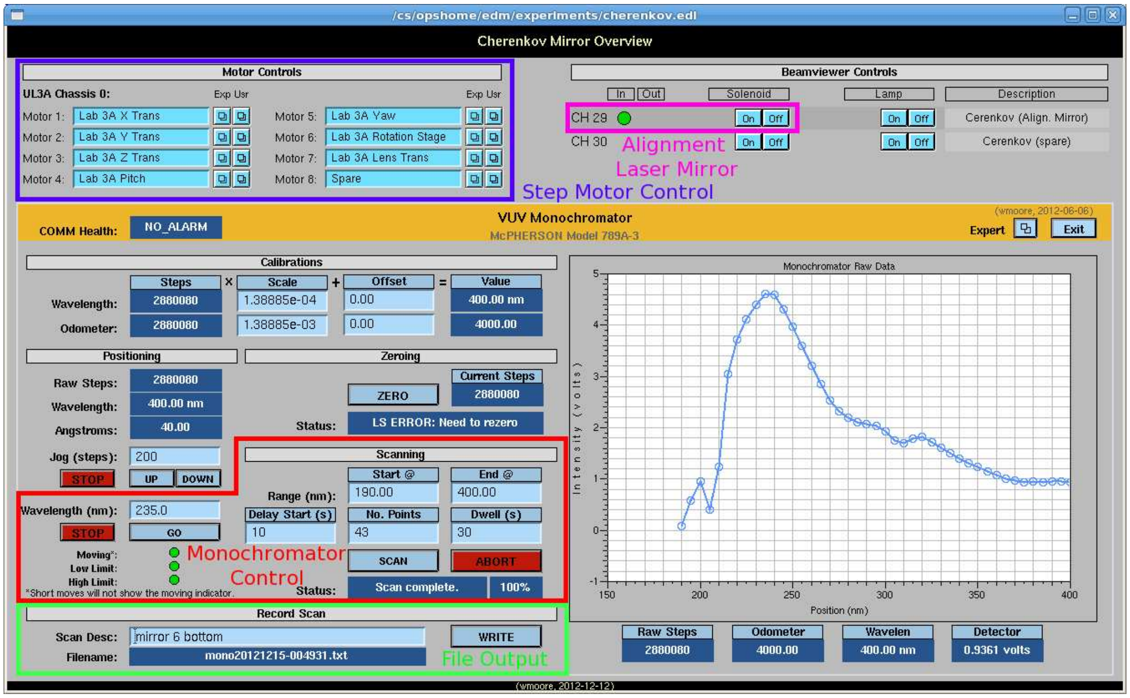

Figure 4: Monochromator control interface. Blue box: stepper motor control; magenta box: alignment laser control; red box: monochromator wavelength control; green box: file output.

In the green box, user can enter measurement description and write the plotted data to a file. To access saved data see Sec. 2.4.

In top part of the monochromator control interface, the stepper motor controls for the translation stage are circled in blue box. The individual stepper motor control menu can be accessed by clicking on the expert mode button (Exp) besides the motor description. The collection of all stepper motor expert menus are shown in Fig. 5, all settings outside of the boxed areas must not be changed. The upper red box shows the current stepper motor positions, and lower specify the movement steps; the left/right arrow button will decrease/increase the specified movement. Each unit of movement corresponds to 1 mm or 1° of movement. Note that after entering new value into the boxes, one have to immediately press ENTER on the keyboard, otherwise the number will be unchanged. The STOP button can stop the movement immediately in case of any mis-operation. There are limit switches to protect all stepper motors, however, operator should check the system position before operating. The purple box contains the offset values, it can be set to any convenient value to the data taking. The holding current option should any to modified by the FEL control system experts.

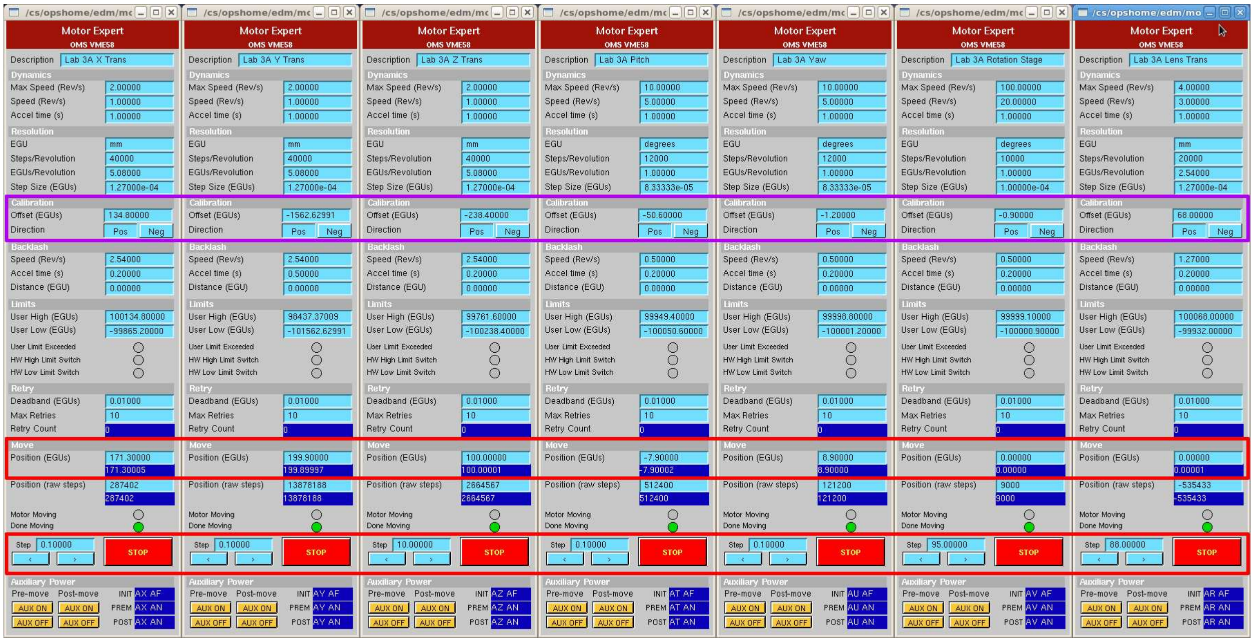

Figure 5: Individual stepper motor expert control interfaces.

2.3.2 Laser Alignment Mirror

The magenta box in Fig. 4 shows the reflection mirror control for the alignment laser. Option ON for inserting and OFF for removing the laser alignment mirror.

2.3.3 Striptool

Accessing striptool:

`FEL Menu` → `Ops Tools Menu` → `Strip Tools`

The striptool control interface is shown in Fig. 6. The striptool can not pick up the signal output channel automatically, so one have go back to the lock-in amplifier expert interface Fig. 3, click on output chan1 inside black box with mid mouse button (wheel) and drag it into the black boxed area in Fig. 6, then connect the channel. The channel ID is shown in the green box. The modify button will allow user to change maxima, minima on the Y axis and precision of the plotted data. Note that precision must be set to 6 or 7 in order to output meaningful data.

Fig. 7 shows a typical striptool plot of the wavelength scan. The control for x axis (time scale) is on the left bottom corner. To dump the plotted information, one can right click on the plot and choose dump option. Accessing the striptool data file see Sec. 2.4.

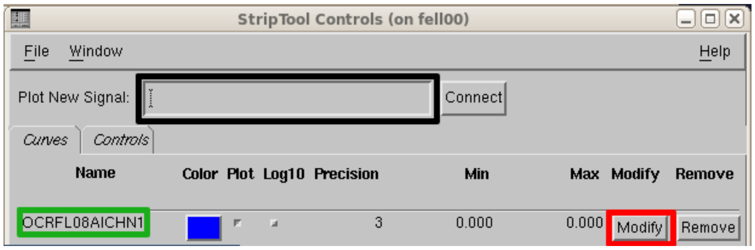

Figure 6: Striptool control interface.

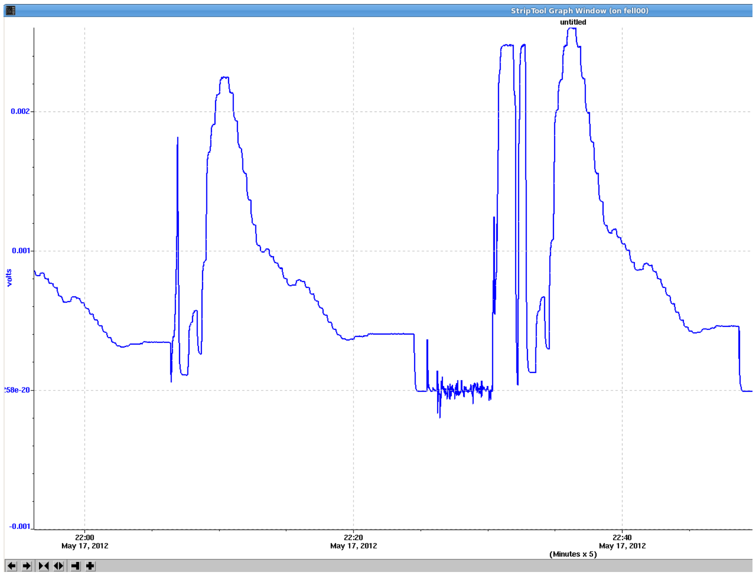

Figure 7: Striptool plot interface.

2.4 Accessing Data File

The monochromator data files are stored under:

`/cs/op/iocs/DATA/fel_monochrom/`

The striptool data files are stored under:

`/cs/op/lib/stripTool/`

A USB drive can be used on any FEL computer for transferring data.

3 System and Mirror Alignment

We performed wavelength scans between 190-400nm at three different modes as listed below:

- No Reflection (NR) Mode: UV Lamp → Monochromator → Focusing Lens → Detector.

	No Reflection Mode	Flipper Mirror Reflection Mode	Test Mirror Reflection Mode
d_o	31cm	31cm	22.2cm
d_{l-f}	-	42cm	43.3cm
d_{f-d}	-	27cm	-
d_{l-d}	69cm	-	-
d_{f-m}	-	-	34cm
d_{m-d}	-	-	60cm
d_i	69cm	69cm	137.3
A	6mm×5mm	6mm×5mm	8mm×7mm
$T_{flipper}$	-	105.75°	10.75°

Table 1: The key parameters for all measurement modes. d_o: Distance between beam out slit of monochromator to focusing lens. d_{l-f}: Distance between focusing lens and flipper mirror. d_{f-d}: Distance between flipper mirror and detector. d_{l-d}: Distance between focusing lens and detector. d_{f-m}: Distance between flipper mirror and test mirror. d_{m-d}: Distance between test mirror and detector. d_i: Total length of light path from the lens and detector (The sum of d_{l-f}, d_{f-d}, d_{l-d}, d_{f-m} and d_{m-d} for each mode). A: Focused beam spot at the detector at 225 nm wavelength. $T_{flipper}$: Flipper mirror angle according to the rotation stage angle indicator.

- Flipper Mirror Reflection (FMR) Mode: UV Lamp → Monochromator → Focusing Lens → Flipper Mirror → Detector.
- Test Mirror Reflection (TMR) Mode: UV Lamp → Monochromator → Focusing Lens → Flipper Mirror → Test Mirror → Detector.

Table 1 shows the distances between important components in all three modes. For more explanation on different measurement mode please see [1]. The peak signal of the current lamp is at 225 nm, therefore the system was aligned at this wavelength.

3.1 Monochromator

Normally, operator do not have to adjust the incoming and outgoing slit of the monochromator. Incoming slit should be wide open, and outgoing slit is 3 mm×2 mm. Operator should see Michelle Shinn and Chris Gould to check if the 200 nm blaze grating is used. During the alignment, monochromator lid should be removed. The incoming light should reflect in the center of first mirror, one can place a business card in front of the mirror to make sure.

3.2 Level Monochromator Light

The table of monochromator need to be leveled. The F1.5 lens and UV lamp need to be at the same height as the incoming slit of the monochromator. The outgoing light from the monochromator must pass through center of the focusing lens. One way to check this is set the monochromator to 225 nm and place a business card in front of the focusing lens to see UV glowed light at one end of the lens translation table, then move the lens to the other end to check the light hits the same location. In addition, operator can use FMR mode to check the vertical position variation of the reflected image, at both ends of the translation table, where a perfect alignment would have no variation.

3.3 Fix Detector Position

At FMR mode, The UV light incidence angle to the flipper mirror is 47.5°, therefore the angle between incoming and outgoing light is 95°. The focusing lens is 31 cm away from the monochromator slit. The detector position should be fixed at the focal point for 225 nm wavelength. The detector position should be constant during all measurements.

3.4 Matching Laser to UV Light Path

After the UV light from the monochromator is adjusted to be horizontal, the alignment laser has to match the UV light path. When pneumatic mirror holder drops down, it blocks the UV light and reflect the laser light to follow the UV light path. The laser light will give clear indication where the UV light hits after reflection. The reflected laser for both FRM and TMR modes should hit the center of the ceramic detector socket (between two metal connections) after adjusting the mirror position and angle. After the alignment, the laser needs to be switched off and the pneumatic mirror holder should rise to pass through the UV light.

For the laser alignment reflection mirror control, see Sec. 2.3.2.

3.5 Fine Mirror Alignment

Although the laser would indicate where the UV light hits on the detector, the image may not be focused. Operator must check the image in front of the detector with a business card. If the image is not focused, adjust the Z position of the mirror. Some small yaw and pitch angle is also needed to bring the focused image to the center of the detector.

3.6 Switching Modes

The steps for switching between the measurement modes are simple. At FMR mode, the flipper mirror is at 105.75° and focussing lens is 31cm form the monochromator slit. Operator have to access the stepper motor expert control interfaces for Rotation Stage and Lens Trans, then decrease the flipper mirror rotation and lens position by 95° and 8.8cm correspondingly. In order to preserve the same testing condition for both FMR and TMR measurements, system has to be controlled remotely from other user lab.

3.7 Optical Chopper

Thorlab MC100 Optical Chopper is placed in front of the detector, the chopping rate is 14Hz. When it is turn on, wait for 5s and press FREQ UP button on the right hand side of the control box, then the chopping rate should be automatically restored. For any operational difficulties please see the MC100 manual or contact Michelle Shinn.

3.8 Setting Signal Offset

The signal offset is the baseline signal come from the background, it is around 1.6×10^{-5}V. The simplest way to set the signal offset at FMR mode is to rotate flipper mirror to 200.75° (105°+95°), then go to lock-in amplifier expert control interface shown in Fig. 3 and press auto offset button inside the magenta box. This will automatically subtract the baseline signal from the all measurements.

4 Remarks and Safety

4.1 Operation Safety

During the alignment, operator must wear clean room gloves and the UV photo-diode detector must be dis-mounted from the ceramic detector for safe keeping.

Before taking anything measurement, the operator should:

- Wear UV protection glasses, it should have the label: CO_2, 5,000-11,000 nm OD $>$ 7, 190-360 nm OD $>$ 9.
- Check all cables and gas pipe connections.

- Check limit switches for all stepper motors, and possibility for colliding components. This step is extremely important.

The UV radiation warning sign needs to be posted on the front door; the cover of the D2 lamp must be install after the alignment; all personnel in the user lab during the D2 lamp operation must wear safety gaggles, Only the operator during the alignment is required to wear UV protection gaggles. For more information on the safety issues including the UV radiation level, please contact Michelle Shinn.

After the measurement, operator should restore the mirror holder to the lowest Y position to prevent any power failure.

4.2 User Lab 5 Safety

User Lab 5 of FEL is shared resource among several groups, and it is extremely important to respect the safety requirements of other experiments. The Reflectivity Setup operator must take User Lab 5 Safety Training, General Laser Training and eye examination, to be allowed access to User Lab 5 when laser experiments are in operation. Contact Steve Benson for the User Lab 5 Safety Training, Dick Owens for the General Laser Training and Michelle Shinn for any General information.

4.3 Optical Equipment Maintenance

All operators must do their best not to contaminate optical equipments including: lens, coated mirror and photo-diode detector etc. All operators are forbidden to clean any optical equipments, if they are too dirty to work with, contact FEL experts for help.

4.4 Contact List

One can contact the following experts for the specific issues:

Jim Coleman & Dan Sexton: Stepper motors and electrical issues.

Wesley Moore: Stepper motor control and EPICS related issues.

Keith Blackburn: Mechanical related issues.

Chris Gould & Joe Gubeli: Equipment maintenance, control system and optical alignment issues.

Michelle Shin: General (all) requests.

5 A Quick Operation Guide

A quick guide to operate the reflectivity measurement setup:

1. Checking Equipment Status, see Sec. 4.
2. Setting up the system control and data acquisition interface, see Sec. 2.
3. Adjusting mirror position with alignment laser.
4. Checking the focused image is in the center of the active area of the detector.
5. Switching on the optical chopper & N_2 for the light box, see Sec. 3.7.
6. Switching on the UV lamp.
7. Setting signal offset, see Sec. 3.8.
8. Starting wavelength scan at FRM mode, Sec. 2.3.1.
9. Checking data quality and writing data to file (from other user lab), Sec. 2.3.1.
10. Switching the measurement mode to TMR (from other user lab), Sec. 3.6.
11. Starting wavelength scan at TMR mode.
12. Checking data quality and writing data to file (from other user lab).
13. Accessing and transferring data, Sec. 2.4.

6 Some Known Issues

6.1 Short Circuit

In the case of the translation stage movement run over the power cables for the limit switches, the broken cable will short circuit the power supply for the entire system. As the result, the system starts to shake and lose elevation.

6.2 Re-centering Stepper Motors

After some usage, the yaw and pitch stepper motor may be off-centered at zero position. One needs to untighten the set-screws on the motor holder and recenter the motor onto the clutches. After wards, one needs to test the motor moves the same amount in both directions.

One of the mean reason to cause the motor to be off-centered, is the stoppers for the mirror holder being miss-placed. In this case, any yaw movement will not be possible.

6.3 Signal Doubling

It is still a mystery, when once in a while the signal output from the lock-in amplifier seems to be doubled. The cause of this issue is unknown, when it happens, one can unplug the signal input cable to the lock-in amplifier located in the optical control room, wait for 10 sec and plug it back. The typical signal strength @ 235 nm should be around 5.3 V from the ADC channel, which is around 2.65×10^{-3} V. If the signal output is around 10 V on the ADC channel, one must stop the data taking and reset the lock-in amplifier signal input.

References

[1] W. Li, G. Huber, et. al, *Heavy Gas Čerenkov Mirror Reflectivity Measurements*, 2012.