

Procedure for performing a vertical to horizontal irradiance transfer of FEL type 1000 Watt lamps in the NUVMC Laboratory

**National Ultraviolet Monitoring Center
Department of Physics and Astronomy
University of Georgia
Athens, GA 30602**

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**Prepared by Dr M.G. Kimlin and T.E. Taylor
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Introduction

1000 Watt lamps calibrated by the National Institute for Standards and Technology (NIST) are used as primary standards for the calibration of 1000 Watt lamps of unknown spectral irradiance. These secondary lamps are used regularly as traveling standards by NUVMC for Brewer spectrophotometer calibrations. The NIST lamps were calibrated in the vertical orientation but to calibrate a Brewer spectrophotometer it is most convenient to burn the lamps in the horizontal orientation. Since the output of a 1000W lamp changes slightly with orientation due to cooling and gravity effects, it is necessary to "transfer" the irradiance of a vertical NIST lamp into the horizontal direction to obtain the irradiance of the unknown 1000W lamp.

Equipment

1. Swivilling alignment arm for positioning 1000W lamps into the vertical and horizontal orientations. Custom designed and machined by UGA machine shop.
2. X-Y-Z translation stage for mounting 1000W lamp mount to adjustable arm.
3. *SPEX* 1680B monochromator.
4. Specially designed mounting stand for *SPEX* monochrometer.
5. NM-23-6 integrating sphere.
6. Fitting port for the *SPEX* to mount the integrating sphere. Custom designed and machined by UGA machine shop.
7. Custom designed target plate with crosshairs for integrating sphere entrance port.
8. *Philips* XP2254B photomultiplier tube.
9. *Product for Research* cooled PMT housing and power supply.
10. *Newport* 271 lab jack to support PMT and housing.
11. *Stanford Research System* PS350 high voltage power supply for PMT.
12. *Stanford Research System* SR445 quad-preamplifier.
13. *Stanford Research System* SR400 photon counter.
14. 10MHz cutoff high-pass filter.
15. *UPS* power line conditioner/surge suppressor for AC power.
16. *Xantrex* XHR 150-7 power supply, modified for 8.3 Amp max output.
17. *Hewlett Packard* digital multimeter with front and rear leads.
18. *Tinsley* 10 mili-Ohm shunt (RUG-Z-R010-0.1).

19. Standard 50 cm alignment rod.
20. *Gamma Scientific* 5000-17 alignment jig.
21. Custom black box for shielding *SPEX* monochrometer from 1000W lamp.
22. Black cloth for shielding PMT from 1000W lamp and for covering optical table.
23. NIST calibrated 1000 Watt lamps.
24. Uncalibrated 1000 Watt lamps.
25. Low pressure mercury lamp.
26. A PC running Windows 3.1 with QBASIC compiler and data acquisition program.
27. Optical table.
28. Water supply and drain for cooling the PMT housing.
29. Sufficient 120 Volt AC power sources for running electronic equipment.
30. Two office fans for cooling electronic equipment.

Manuals for all equipment used in this calibration procedure should be consulted whenever there is a specific question pertaining to that instrument.

Purpose

The purpose of this procedure is to obtain irradiance values for FEL type 1000 Watt lamps to be used in the horizontal orientation for spectral response calibrations of spectrophotometers.

Procedure-General Precautions: There are several precautions that should be observed to maximize the success of the irradiance transfer procedure.

1. All of the electronic equipment should be given a substantial warm up period. Twelve hours should be sufficient time for the equipment to equilibrate.
2. Be aware of the instruments tendency to "drift". To avoid having unwanted instrument drift hidden in the data the transfers should be performed without long delays between lamp burns. The NUVMC technique to reduce this problem is to run the NIST standard lamps at the beginning and the end of the day and use an average of these values when calculating the irradiance of the traveling horizontal standards.
3. The 1000W lamp power supply and the digital multimeter should draw current from a source other than that used for the rest of the equipment. If too much current is drawn a circuit breaker may flip during the measurement, which can potentially cause damage to the lamp.

4. The alignment of the 1000W lamps with respect to the integrating sphere entrance port should be very precise, especially with respect to the z-axis, in order to provide the best possible lamp irradiance results.
5. Take care that the lamp is installed with the correct polarity each time. The positive current from the 1000W lamp power supply should always be connected to the positive lead on the 1000W lamp. The output of the 1000W lamp changes if the current flows in reverse through the lamp.
6. Take precautions to reduce reflected light from the 1000W lamp in the laboratory. Any shiny metal surfaces or white objects should be covered so as to reduce the amount of reflected light. The stray light should not exceed 1.0% of the total light during the experiment. The NUVMC uses a room with walls painted flat black and also covers the optical table with black cloth. Initial testing of the background signal should be performed in both the vertical and horizontal burn orientations. The background rod size and placement should be designed into the setup to be repeatable.
7. The mercury discharge lamp used for the wavelength calibration of the *SPEX* monochromator creates ozone molecules in the laboratory. If precautions are not taken it is possible for the ozone to accumulate inside the integrating sphere. Since ozone absorbs UV radiation the UV light from the lamp will be absorbed and will therefore produce errors in the irradiance transfer calibration. The NUVMC places the HG lamp approximately six inches from the entrance port of the integrating sphere and places an office fan on the optics table to blow air away from the integrating sphere while the lamp is on. Lamp on time is kept to a minimum.

Procedure-Instrument Setup: A diagram of the equipment layout can be seen in Figure 1. The equipment is normally left set up in the laboratory between calibrations so the following steps may not need to be performed each time.

1. Place the custom stand for the *SPEX* monochromator on the optics table.
2. Set the *SPEX* monochromator onto the specially designed stand so that the three spectrometer legs mate into the holes on the stand's posts.
3. Secure the stand to the optical table via the angle brackets so that the spectrometer is aligned approximately square with respect to the optical table.
4. Mount the integrating sphere to the entrance port on the side of the *SPEX* monochromator. A special fitting was machined so that the sphere can be

rotated 90 degrees to view the 1000W lamp in both the vertical and horizontal positions. The sphere locks in position via two $\frac{7}{64}$ " hex head set screws.

5. Mount the PMT housing to the exit port of the *SPEX* monochromator via the mounting plate with four bolts.
6. Place the lab jack underneath the PMT housing to provide support. Be sure the jack is not lifting the spectrometer off of the mounting plate.
7. Carefully insert the PMT into the housing and lock it down with three screws. Avoid exposing the PMT window to bright light.
8. Wrap black cloth around the PMT housing to reduce the amount of stray light entering the tube.
9. Place the black thermally insulated box over the *SPEX* monochromator to shield it from the direct beam of the 1000W lamp.
10. Place the PMT high voltage power supply, the PMT cooled housing power supply, the photon counter and the pre-amplifier underneath the optical table to avoid exposure of the equipment to the 1000W lamp light during the calibration.
11. Mount the swiveling lamp alignment arm to the optics table oriented such that the lamp can be positioned 50 cm from the entrance port of the integrating sphere in both the vertical and horizontal orientations.
12. Connect the lamp mount to the alignment arm via the mounting plate and two $\frac{1}{4}$ 20 bolts.

Procedure-Instrument Wiring: Figure 2 shows a wiring schematic of the instrument layout.

1. Connect the PMT housing cooler power supply to the cooled housing via the circular connector.
2. Connect the two thermistor wires to the underside of the PMT housing near the front of the unit. These wires monitor the temperature of the cooled housing.
3. Use a coaxial high voltage cable to connect the PMT high voltage power supply to the input (cathode) of the PMT.
4. Connect the output (anode) of the PMT to the first channel input of the preamplifier using coaxial high voltage cable.

5. Connect channel one output of the preamplifier to the second channel input of the preamplifier with a high voltage coaxial cable.
6. Connect the second channel preamplifier output to the 10M Hertz high pass filter with a high voltage coaxial cable.
7. Connect the output of the 10M Hertz high pass filter to the "Signal, Input 1" connector on the front of the photon counter via a high voltage coaxial cable.
8. Connect the water input of the PMT cooler housing (the top tube) to the water source via a rubber hose.
9. Connect the water output of the PMT cooler housing (the bottom tube) to an appropriate water drain via a rubber hose.
10. To provide proper cooling the water should be set to flow through the system at about two liters per minute. This rate is highly dependent on the temperature of the water. The temperature of the PMT housing should be observed for an hour or so prior to taking data and if the temperature does not meet the -38.5°C requirement the water flow should be increased.
11. Plug the PMT high voltage power supply, the preamplifier and the photon counter into the UPS power line conditioner/surge suppressor.
12. Plug all of the equipment into a 120 Volt source. Choose a circuit that does not have an existing load, and in particular a circuit other than the one which will be used for the 1000 Watt lamp power supply. This will ensure that the circuit breaker does not flip during the irradiance transfer calibration.
13. Connect the positive lead of the *XANTREX* power supply to the positive lead of the 1000W lamp mount using a 12 gauge wire. The NUVMC has a wiring harness designed specifically for the irradiance transfer setup.
14. Connect the negative lead of the 1000W lamp mount to a post on the shunt using 12 gauge wire.
15. Connect the negative lead of the power supply to the second post on the shunt using a 12 gauge wire.
16. Connect the voltage leads on the shunt to the voltage inputs of the DMM. This connection will read the voltage across the shunt, which is used to calculate the current of the circuit.

17. Connect the positive and negative posts of the lamp mount to the second set of voltage inputs on the DMM. This connection will read the voltage across the lamp and is used to determine the stability of the lamp.
18. Plug the *XANTREX* power supply and DMM into a 120 volt source. Do not use the same electrical circuit as is being used to power the photon counter, preamp, PMT high voltage supply and PMT cooler housing.
19. Connect a null modem 25 pin serial cable from the *SPEX* monochrometer to the com 2 port on the controlling computer.
20. Connect a 25 pin serial cable from the photon counter output to the com 1 port on the controlling computer.

Procedure-Configuration of *SPEX* Controlling Computer

1. Initiate the *SPEX* monochrometer with the controlling computer. The "dumb terminal" mode should be used to establish communication between the computer and *SPEX*.
2. In the "terminal mode, under the "Settings/Communications" menu set "com=2", "baud=19200", "data=8 bits", "stop bit=1", "no parity" and "no flow control". Click "OK" to activate the settings.
3. When the computer returns to the "Terminal" window press <space bar> several times to get the *SPEX* monochromator greeting screen. For detailed information on communicating with the *SPEX* monochromator via the operating software, see **Appendix A**.
4. Create a new directory on the controlling computer and copy the most recent version of the data acquisition program and QBasic compiler into this directory. The NUVMC normally uses the naming convention "MMYY", where "MM" represents the month and "YY" represents the year.
5. Run the QBasic compiler from this directory.
6. Open the data acquisition program by selecting "Open" under the "File" menu and selecting the name of the program from the list.
7. Run the data acquisition program by selecting "Start" under the "Run" pull down menu.

Procedure-Equipment Operating Parameters

1. NIST Calibrated 1000 Watt lamps; Operating current 8.2 A in the vertical orientation.

2. Uncalibrated 1000 Watt lamps; Operating current 8.2 A in the horizontal orientation.
3. *SPEX* monochromator slit size; 0.5 mm for entrance and exit slits.
4. PS350 high voltage PMT power supply; Operating at -2250V.
5. Refrigerated PMT housing; Cooled to -38.5°C.
6. SR445 Preamplifier; Channels one and two used.
7. SR400 Photon counter; "Channel *A disc level*= -20.0 mV", "*A disc slope*= falling edge", "T preset=1 second". Connected to PC com port 1; settings: 19,200 bit/s, no parity, 8 bit data, and 2 bit stop.

Procedure-Vertical Lamp Alignment:

1. Rotate the alignment arm to the lower position i.e., such that the 1000W lamp can be mounted in the vertical orientation.
2. Rotate the integrating sphere such that the integrating sphere entrance port is facing the vertically aligned 1000W lamp.
3. Align the integrating sphere port exactly perpendicular to the optics table using a 90° carpenters square. Lock the sphere via the two $\frac{7}{64}$ " hex head set screws.
4. Mount the arm which holds the diode laser onto the lamp alignment arm such that the laser is pointing toward the entrance port of the integrating sphere.
5. Tape a microscope slide to the entrance port of the integrating sphere, perpendicular to the optics table. This will aid in aligning the sphere port perpendicular to the 1000W lamp.
6. Place a piece of cardboard with a pin hole in front of the laser beam. Adjust the laser so that the reflected beam from the microscope slide comes back to the hole in the cardboard or very near to it.
7. If the alignment cannot be made it may be necessary to swivel the base plate on which the *SPEX* monochromator is mounted. Alternatively the alignment arm can be readjusted on the table to change the angle of the lamp with respect to the integrating sphere. When the alignment is properly made, remove the microscope slide from the sphere.
8. Place the cross haired target plate inside the integrating sphere entrance port. Slide the laser up or down in the laser mount to align the laser incident on the target plate cross hairs. Take care not to change the angle of incidence of the

laser on the target plate. The angle can be rechecked by following the previous step if need be.

9. Place the alignment jig in the lamp mount and align the jig using the x-y positioning of the translation stage so that the laser beam is centered on the jig crosshairs.
10. Place the standard 50 cm rod inside the entrance port of the integrating sphere such that one end rests on the inside flange. Use the Z positioning of the translation stage to align the bottom of the alignment jig 50 cm from the sphere.
11. If the alignment arm is positioned properly with respect to the *SPEX* monochromator the alignment jig will now be positioned such that all surfaces are the same distance from the entrance port of the integrating sphere. If all sides of the alignment jig are not of equal distance from the entrance port of the spectrometer the lamp alignment arm of *SPEX* base plate may need to be repositioned on the table. This will affect the previous alignments and they will therefore need to be rechecked. It may take several iterations of the alignment procedure to get all the parameters within tolerance but once the alignments are set correctly they should remain undisturbed for future calibrations.
12. After all alignments are made satisfactorily the alignment jig can be removed from the lamp mount.

Procedure-Vertical Lamp Scan

1. Place the first 1000W lamp to be burned in the vertical position into the lamp mount. Be sure that the positive lead of the lamp is set in the positive lead of the lamp mount. Normally the face plate on the lamp base is oriented away from the integrating sphere. Note that mounting the lamp backwards will run electric current through the lamp in the reverse direction which affects the irradiance of the lamp.
2. Use a lens tissue and spectroscopic grade methanol to clean the quartz envelope of the lamp.
3. Verify that the laser beam is incident approximately on the center of the lamp filament.
4. If the alignment appears to be correct the laser arm can be removed from the alignment arm by removing the four $\frac{1}{4}$ 20 screws.
5. Place a mercury discharge lamp at least six inches away from the front of the integrating sphere entrance port. Setting the lamp too close to the sphere may cause ozone to accumulate inside the sphere which will have adverse effects on the collected irradiance data since ozone absorbs UV radiation.
6. Set a small office fan on the optics table blowing air away from the entrance port of the integrating sphere to keep ozone from entering the sphere.

7. Turn off the lights in the laboratory. The NUVMC setup is in a subroom of the main room so a small office lamp is used inside the main room during the calibration.
8. Turn on power to the *XANTREX* power supply and DMM. The voltage adjustment should be turned to the maximum position and the current adjustment knob should be set to the minimum position before turning on the power. This allows for the output to be controlled in the "constant current" mode.
9. Print out a copy of Figure 3 for each lamp to be operated for the day. This log will be used to monitor the output and stability of the lamp circuit during the calibrations and serves as the log for the number of hours the lamp has been in operation.
10. Ramp up the current to the lamp to 8.2 Amps. Use Kirchoff's law ($V=IR$) and the known resistance value of the shunt to calculate the desired mV needed across the shunt in order to put 8.2 Amps to the lamp. Log the values of the shunt voltage (in milivolts), the lamp voltage, the power supply output voltage and the power supply output current on the lamp burnsheet.
11. Insert the background rod between the 1000W lamp and the integrating sphere such that a shadow is cast over the entire entrance port. Testing to ensure that the background signal is less than 1% of the full signal should have been carried out as independent testing prior to the irradiance transfer calibration.
12. Once the data acquisition program has been initiated as in the "Configuration of *SPEX* Controlling Computer" section of this procedure, the user will be prompted to input the dial setting displayed on the side of the *SPEX*. Add one to the dial readout and enter this number into the computer. Note; a wavelength accuracy alignment was performed on the *SPEX* monochrometer during the summer of 2002 following the procedure in the instrument manual. However there is still a small discrepancy between the dial readout and the actual wavelength.
13. The user will then be prompted for a new data filename. The filename convention "n-dddy.###" is typically used, where "n" = the number of times the lamp has been scanned that day, i.e. 1, 2, 3..., "ddd" is the three digit Julian day, "yy" is the two digit year and "###" is the FEL lamp number.
14. The user will then be prompted to choose to perform a mercury line calibration. Typically a new mercury calibration is always performed prior to each FEL lamp scan to ensure proper wavelength accuracy.
15. After successful completion of the mercury scan immediately turn off power to the lamp to avoid producing ozone in the laboratory. Move the lamp away from the optical path of the monochrometer and set it aside for use in the next scan.

16. Move the desk fan that was blowing ozone away from the integrating sphere entrance port off of the optics table. This fan may be used to blow on the electronic counting equipment to ensure that it is properly cooled.
17. Allow the 1000W lamp to warm up for 30 minutes prior to beginning the background scan. Monitor the lamp and the shunt voltage and make adjustments to the lamp output as needed.
18. Enter the 1000W lamp number into the computer and press Enter to begin the background scan.
19. When the background scan is completed the computer will prompt the user with a beep to remove the background rod and begin the signal scan.
20. Begin the signal scan by pressing the Enter key. Continue to monitor the lamp and shunt voltages, making small adjustments to the current control knob on the lamp power supply as necessary to keep the lamp operating at 8.2 Amps.
21. The current version of the irradiance transfer program takes ten count cycles at each wavelength from 270 to 370 nm in 10 nm increments. Five sub-scans are performed. This yields 50 data points at each wavelength to be averaged in the final calculations.
22. When the signal scan is completed the computer will prompt the user if another scan is desired. If so press "y" to continue with the program. If no more scans are needed, press "n" to abort the data acquisition program.
23. Power down the current to the lamp using the current control knob on the lamp power supply.
24. Allow the 1000W lamp to cool for several minutes before attempting to remove it. A small office fan blowing on the lamp will greatly reduce the amount of cooling time required.
25. While the lamp is cooling the mercury lamp should be turned on for a three to four minute warmup.
26. For each lamp to be burned in the vertical position repeat steps 1 through 25 in this section of the procedure.

Procedure-Horizontal Lamp Alignment

1. After all lamps have been burned in the vertical position the alignment arm can be rotated to the horizontal burn position. There is a screw knob to lock the arm in the horizontal position.
2. Rotate the integrating sphere 90° to view the lamp in the horizontal position by loosening the two hex bolts and swiveling the sphere in the mount.

3. Level the sphere with respect to the Earth by placing a small bubble level on top of the entrance port. Lock both set screws to securely fasten the sphere in the mount.
4. Follow steps 4 through 12 in the Vertical Lamp Alignment section to align the 1000W lamp with respect to the integrating sphere. The idea is to have all alignment parameters in the vertical and horizontal positions identical.

Procedure-Horizontal Lamp Scan

1. Follow steps 1 through 25 in the Vertical Lamp Scan section for each lamp to be burned in the horizontal position.

Procedure-Data Analysis

1. After all scans are completed for the day the data files should be copied off of the *SPEX* controlling computer to a machine with MS Excel or some similar data analysis spreadsheet program.
2. Copy each of the text files into one spreadsheet for ease of documentation of the data. Each scan can be saved as a separate worksheet within the MS Excel file.
3. For the first 1000W lamp calibrated, plot the mercury scan data and verify that the peak count occurs at the 296.76 nm position, plus or minus one step.
4. Plot the counts as a function of cycle number at 270 nm and 370 nm for the five subscans. Check for linearity of the counts with time. If excessive ozone was produced and collected inside the integrating sphere during HG calibrations, the counts will increase with each successive subscan at 270 nm but the counts will remain linear with time at 370 nm.
5. Average the counts from the ten cycles at each wavelength for the background scan and each of the five sub scans.
6. Average the counts at each wavelength for the five subscans to produce one set of averaged photon counts as a function of wavelength.
7. Calculate the percent background of the signal scan at each wavelength. The background should remain less than 1% of the signal scan at all wavelengths. Generally the percent background is higher in the vertical lamp orientation than in the horizontal orientation for the NUVMC irradiance transfer setup.
8. Subtract the background counts from the signal scan counts at each wavelength to produce the final photon count values as a function of wavelength to be used in the irradiance calculations.
9. Repeat steps 3 through 8 for each lamp scanned for the day.
10. Compare the photon counts of the NIST lamps from the beginning to the end of the day. The percent difference in the counts will reflect the accuracy of the

alignment of the 1000W lamp, the stability of the lamp power supply and counting circuitry and the repeatability of the spectrometer.

11. Determine if any of the NIST lamps gave bad results by plotting the ratio of the counts of two lamp and the ratio of the given irradiance values for the same two lamps. Theoretically the ratio of the counts should match the ratio of the irradiance values for any two lamps.
12. Decide if any of the data from the NIST lamps should be discarded due to anomalous values.
13. For each one of the NIST lamps selected as good data, average the photon counts as a function of wavelength from the beginning of the day and end of the day scans.
14. Calculate the irradiance as a function of wavelength of each traveling standard lamp by using the ratio technique;
$$\text{Irradiance}_{\text{unknown}} = (\text{Irradiance}_{\text{NIST}}/\text{counts}_{\text{NIST}}) * \text{counts}_{\text{unknown}}.$$

The NIST irradiance values are provided with purchase of the calibrated lamp in Watts per cm².
15. The preceding step will yield "n*m" sets of irradiance values where n=total number of unknown lamps and m=total number of NIST lamps.
16. For each unknown lamp average the sets of irradiance values calculated using the various NIST lamps. This will produce "n" sets of irradiance values.
17. Calculate the percent change since the last calibration in the calculated irradiance values of the traveling standard lamps. Plot the percent change values as a function of wavelength for each lamp. Generally the NUVMC finds a 1 to 2% change in the lamp irradiance over a six month period. This is within the error of the measurement.
18. Fit a 6th order polynomial to the calculated irradiance values. Note that a 6th order polynomial fit is appropriate for interpolating the irradiance values of the 1000W lamp due to the structure of the blackbody curve determined by the Planck radiation law, $I(\lambda, T) = 2\pi hc^2 / [\lambda^5 (e^{ax} - 1)]$, where $a = hc/kT$ and $x = 1/\lambda$. When the denominator of the Planck expression is expanded the λ is present in the first 6 terms.
19. Use the fitting equation to interpolate the irradiance values from 286.5nm to 363nm in 0.5nm increments.
20. Convert the wavelength unit from nm to Angstroms to produce irradiance values as a function of wavelength from 2865 Å to 3630 Å in 5 Å increments. This matches the range and step size of a Brewer full sky UV scan (UX scan).
21. Calculate the percent change since the last calibration in the extrapolated irradiance values of the traveling standard lamps. Plot the percent change

values as a function of wavelength for each lamp. This step is similar to step 17 above but will highlight any possible errors in fitting the polynomial to the data.

22. Disseminate the final irradiance values of the traveling standard lamps to the calibration technician for use in calculating the spectral response of Brewers during the site visits.
23. Document the MS Excel file appropriately and create a summary report of the irradiance transfer calibration.

For further information or advice concerning this SOP please contact the NUVMC at the University of Georgia at <http://oz.physast.uga.edu>

Figure 1. Schematic of 1000W Lamp Irradiance Transfer

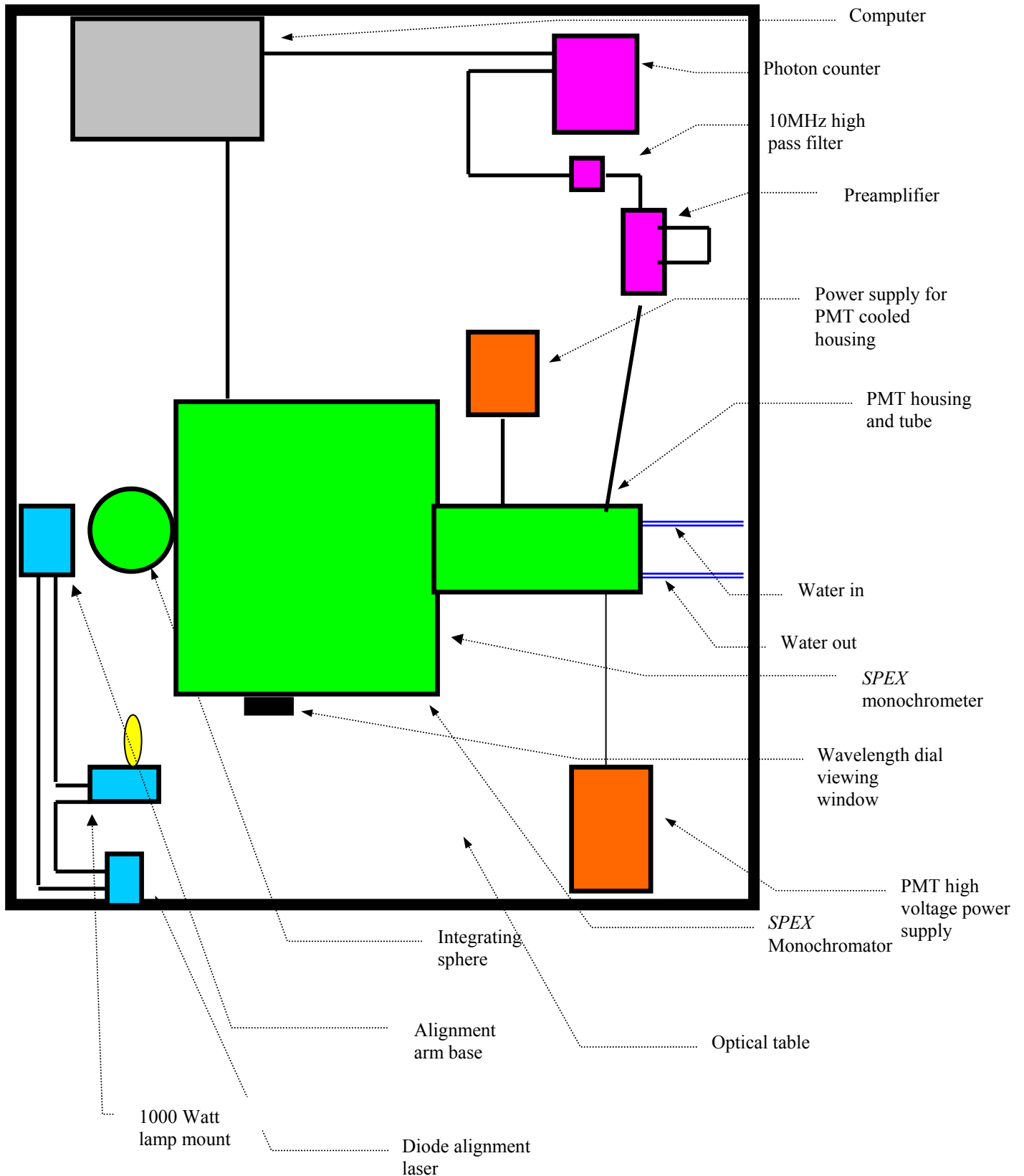
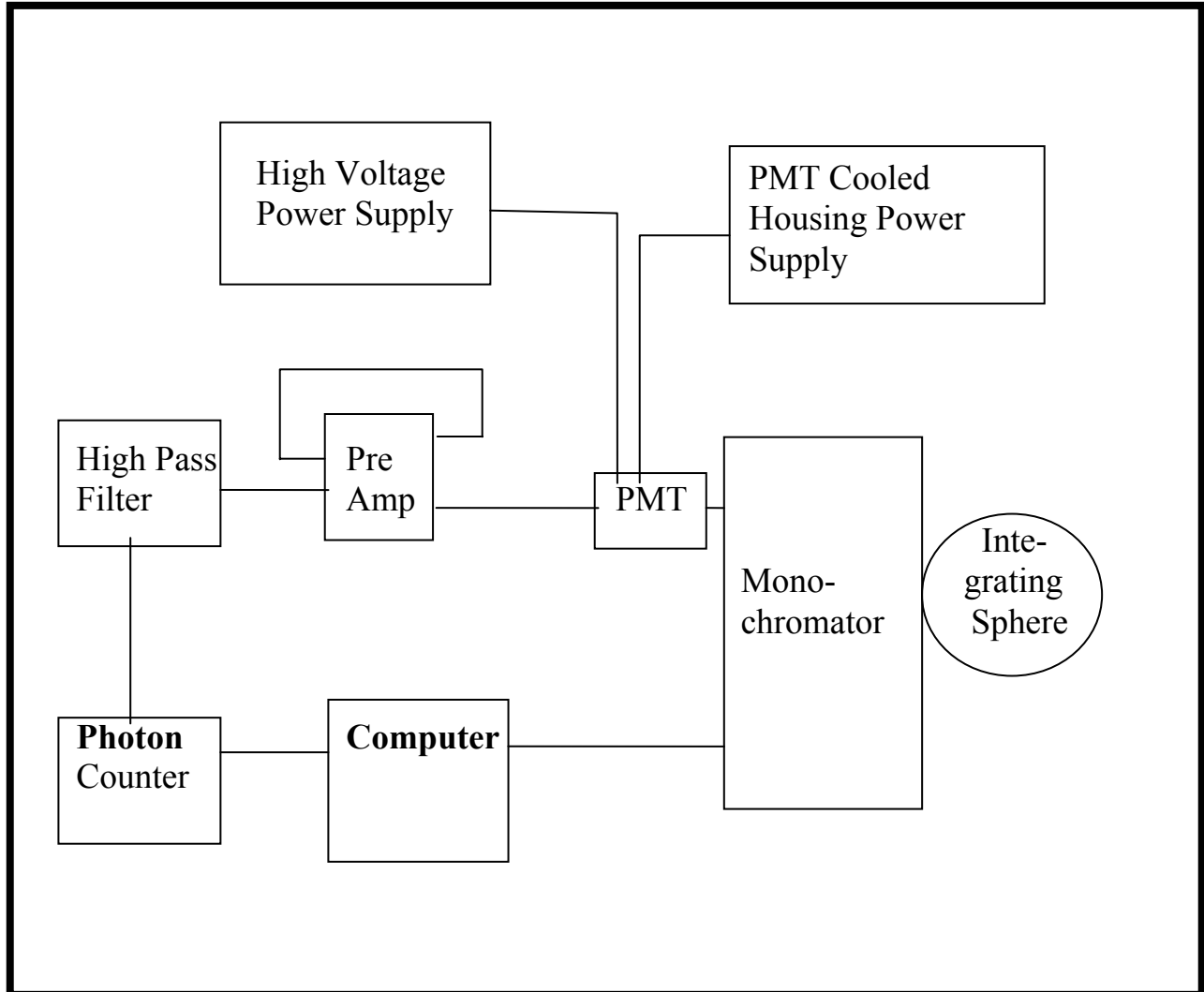


Figure 2. Wiring Diagram for Vertical to Horizontal Irradiance Transfer



Appendix A: Communicating with the *SPEX 1640B* monochromator

a. Description of the *SPEX* monochrometer:

SPEX representatives: Clément Remy (908) 494-8660 x114 or Kimberly Lopez x376.

SPEX 1680 B spectrometer

Serial Number: 1953

UGA Control Number: 477295.

Dispersion	1.8 nm/mm
Resolution	0.2 nm at 500 nm
Repeatability	± 0.2 nm
Aperture	f/4
Spectral range	185-900nm
Accuracy	0.4 nm

Gratings catalog # 3006-300A, 300grooves/mm, 300 nm blazed, serial # 1129.

Entrance and exit slits measurements; Ports, 2.75" OD, 1.875"ID. Four 6-32 screws distances at 2.375".

Panel Limits: high limit =1056.6 nm, low limit =9964.6 nm. The low limit means that the number will go below 0 and go to 9964.6 nm on the counter on the front panel. An internal Large Stepper Drive (LSD) provides an electronic link to the outside world. Gratings can be rotated as small as 0.02 nm (1200 grooves/mm grating).

The included angle is 30 degrees. The monochromator type to the software is 6. For the entrance and exit ports, the side with the height limiter is the exit side, while the side without the limiter is the entrance side. The intermediate slit is not used anymore in the 1680B, although there are some more slits sent in from the manufacturer, but they have no mounting place. Perhaps they are provided for curing serious stray light problems. Since the grating has 300 grooves/mm the dispersion will be 7.2nm/mm. To obtain the actual wavelengths the readings on the front panel should be multiplied by four for the first order and multiplied by two for the second order.

b. Communicating through a Dumb Terminal:

Hook the monochromator to either com1 or com2, then set your terminal

(in WINDOWS or other environments) to that port with baud=19.2K, data 8 bit, stop 1 bit and no parity.

After booting up the spectrometer press SPACEBAR and you should see:

```
* BOOT VER: V2.6! Press [ENTER]
```

After you press enter, you should see:

```
**!**!+ DIS Initialize! MONO1 MONO DRIVE! 0.000!+EDIT
```

Since the 1680B is not a self-calibrating spectrometer, you have to tell it where it is at by looking at the counter in the front of the monochromator. The last part is telling you that it thinks it's at 0.00 nm at this moment and is waiting for input. You can tell the monochromator where it is by issuing the *K* command. If the counter reads 200nm, type

```
K200 ENTE
```

to tell it where it's at. You will receive the following output:

```
**!**! + !+ SCAN MENU **!**!+OPT ! MONO A SCN!+OPT 0
```

You are in the scan menu. Press ENTER and you will see the default settings of the scan. First ENTER gives you:

```
START nm +SCN A! 300.000 !+EDIT
```

Whenever you see +EDIT in the screen, you can input numbers. For example, it tells you that the starting wavelength of the default scan is 300.000 nm but you can change it to any number within the monochromators range.

Press ENTER again you see:

```
END nm +SCN A! 650.000!+EDIT
```

You can input the ending wavelength that you want to use. Press ENTER again and you see:

```
nm / SEC +SCN A! 5.000 !+EDIT
```

This is for setting the speed of the scan in nm/sec. Press ENTER one more time and you see:

```
TRIGGER +SCN A!+OPT 0! OFF !+OPT 0
```

You can turn the trigger on by input 1, but it is not needed for this calibration so just leave it turned off. Once this is all set, the following commands will let you operate the spectrometer.

Glossary of commands for the 1680B terminal communication

A This will trigger the above set scan. If the spectrograph is not in the starting wavelength, it will first go to the starting wavelength, taking care of the backlash, and scan. Like all *SPEX* spectrometers, it is accurate only when scanning from shorter to longer wavelengths.

B This command lets you choose where you want to set the spectrometer wavelength. For example, you can type B200 to set the spectrometer at 200 nm, but no decimal numbers will be accepted.

C This command and the D, E, and F commands lets you manipulate the fine calibration of the wavelength. You have to type one of them first (it doesn't matter which one), and then use any one, or any combination of them. By default, C will move the wavelength relative to the current wavelength by 1 nm.

D See C. Move 0.1 nm shorter side.

E See C. Move 0.1 nm longer side.

F See C. Move 1.0 nm longer side.

I This command gives you the current version of the hardware.

K Tells the monochromator what wavelength it is at. For example, K200 tells it it's at 200 nm, though in reality it can be anywhere. Always use numbers based on the 1200g/mm grating, or consistent with the front counter readings.

S Anywhere in the control, press S gives you the scan menu.

T Shows the turret status. It must be used after the C, D, E, or F commands. Then the options 0 and 1 change the grating. You have to press ENTER after the selection for the Turret change to take place.

V This gives you the function menu. There are 4 options:

- Option 0, the increments. press ENTER gives you the A increment. default is 5, which means that the C and F commands will move the spectrometer by 50 base steps, and the D and E commands are moving the spectrometer by

5 base steps. One base step in the 1680 is 0.02 nm for the 1200g/mm grating and 0.08 nm for the 300 groves/mm grating. You may want to use smaller increments for fine adjustment.

- Option 1, monochromator initialization. Press 0 for `no'. Press 1 for `yes'. This does not do anything to the 1680 since it is not self-calibrating, but it does change the current value to 0 nm no matter where it is really at.
- Option 2, config dev. This is for the configuration of devices. You will need this menu if you have changed something. A grating, for example.
- Option 3, device list. Will show you what's installed. All higher numbers are treated as 3.

All other letters not listed are treated as ENTER.

c: Programs required to run *SPEX*

1. Qbasic compiler, "qb.exe";
2. "terminal.exe", which is already included in the Windows 3.1 software in location: C:\WINDOWS\ and is used to set up the baud rate of the *SPEX* monochrometer;
3. The *SPEX* data acquisition software program, "IRRJAN03.bas", which is attached below: This program has been modified but is based on the original "irrtran.bas" program.

```
DECLARE SUB scan (a())
DECLARE SUB cstep ()
DECLARE SUB calibration ()
DECLARE SUB delay (a!)
DECLARE SUB init ()
DECLARE FUNCTION count! ()
```

```
DIM a(16)
CLS
PRINT "this program is explicitly written for data taking"
PRINT "in the FEL lamp calibration procedure using"
PRINT "the SPEX 1680B monochromator and the SR 400"
PRINT "photon counter"
PRINT "it does not do autobauding so manual bauding through"
PRINT "the Windows terminal on com2 for the monochromator "
PRINT "to be done initially"
PRINT "all parameters on the SR400 should be manually set"
PRINT "they are:"
```

```

PRINT "A channel disc level -20.0 mV"
PRINT "A disc on falling edge"
PRINT "T preset at 1 second"
PRINT "High voltage for XP2254B at -2250V"
INPUT " Press ENTER to continue", y$
CLS

```

```

OPEN "COM1:19200,N,8,2,CS,DS,CD" FOR RANDOM AS #1
OPEN "COM2:19200,N,8,1" FOR RANDOM AS #2
CALL init
PRINT #1, "   "
PRINT #2, "   ";
FOR i = 1 TO 11
READ a(i)
NEXT i

```

```

WHILE (LOC(2) > 0)
PRINT INPUT$(1, #2)
WEND
PRINT #2, CHR$(13);
PRINT " Please be careful on the next input!!!"

```

```

PRINT "Read the wavelength (rounded to closest integer) from the
spectrometer side panel."

```

```

PRINT "Input the number here: "
INPUT LAMBDA$
PRINT LAMBDA$
ggg$ = "k" + LAMBDA$ + CHR$(13)
PRINT #2, ggg$;
CALL delay(.5)
CALL cstep

```

```

200 CLS

```

```

k = 0 ' # for blocked scan display
INPUT "Enter New Data Filename: ( create one for each new lamp) "; n$
OPEN n$ FOR OUTPUT AS #3

```

```

PRINT " "
PRINT "want new calibration? (y/n)"
INPUT "needed as the program starts and first lamp is measured"; y$
IF (y$ = "y") THEN CALL calibration

```

```

INPUT "Input lamp number"; y$
PRINT #3, y$
PRINT #3, DATE$; TIME$

```

```

INPUT "starting background scan as FEL beam is blocked. Press ENTER
when ready"; y$
PRINT #3, "dark scan"
CALL scan(a())
SOUND 1000, 50
INPUT "Take out the shutter and press ENTER"; y$
FOR k = 1 TO 5
PRINT #3, "scan #"; k
CALL scan(a())
NEXT k
CLOSE #3
b$ = "b280" + CHR$(13) 'put wavelength in final position
PRINT #2, b$
CALL delay(15)
SOUND 2000, 100
PRINT " "
PRINT " Check the spectrometer position now"
PRINT " Is it very close to 68 ?"
PRINT " If not, There might be a problem in the last scan"
PRINT " "
INPUT "this scan finished. one more: y/n?"; y$
IF (y$ = "y" OR y$ = "Y") THEN GOTO 200
END
DATA 270,280,290,300,310,320,330,340,350,360
DATA 370

```

'Newtran.bas -by mou Page 4

```

SUB calibration STATIC
DIM numbers(94)
  numb = 1
300 PRINT #2, "b293"; CHR$(13);
  CALL delay(15)
  Peak = 0: M% = 0: ' y,x parameters for the peak
  FOR i = 1 TO 94 'scan 94 x 0.08 nm across 296.728 line'
    numbers(i) = count
    PRINT #2, "e"
    PRINT #3, 293 + .08 * i, " ", numbers(i)
    CALL delay(.5)
    IF numbers(i) > Peak THEN
      Peak = numbers(i): M% = i:
    END IF
  NEXT i
IF M% < 3 OR M% > 92 THEN

```

```

    PRINT " The Peak is too close to the spectral end"
    PRINT " The program is terminated."
    END
END IF

S% = (304 - 296.73) * 12.5 + M% - 94 'cal. steps to 304 nm at 0.08nm/step

    FOR i = 1 TO S%      ' advances to 304 nm
    PRINT #2, "e"
    CALL delay(.2)
    NEXT i

    PRINT #2, "k76"; CHR$(13);      ' Tells spectrometer it is at 304 nm now.
    numb = numb + 1:
    IF numb > 5 THEN
        PRINT " Calibration failure after 5 attempts "
        PRINT " Please make sure the wavelength input is correct"
        PRINT " If the second try fails, a complete calibration is required"
        CLOSE
        END
    END IF
IF (ABS(M% - 47) > 1) THEN GOTO 300      '#47 is the steps from 293 to
296.73nm
    END SUB

FUNCTION count
    PRINT #1, "CR;CS"
10    PRINT #1, "QA1"
    INPUT #1, nt
    IF nt = -1 THEN GOTO 10
    count = nt
    PRINT nt
END FUNCTION

SUB cstep
PRINT #2, " "; CHR$(13)
PRINT #2, "v"
CALL delay(.1)
PRINT #2, CHR$(13)
PRINT #2, "1"
CALL delay(.1)
PRINT #2, CHR$(13)
PRINT #2, "s"
CALL delay(.1)

```



```
END SUB
```

```
SUB delay (a)
t0 = TIMER
WHILE ((TIMER - t0) < a)
WEND
END SUB
```

```
SUB init
PRINT #1, "  "
FOR i = 1 TO 500: NEXT i
PRINT #1, "CI0,1"
END SUB
```

```
SUB scan (a())
DIM c(10)
b$ = "b" + RIGHT$(STR$(a(1)), 3) + CHR$(13) 'preset spectrometer to s.w
PRINT #2, b$
CALL delay(30)
FOR i = 1 TO 11
PRINT a(i); "nm"
b$ = "b" + RIGHT$(STR$(a(i)), 3) + CHR$(13)
PRINT #2, b$
CALL delay(10)
  FOR j = 1 TO 10
  c(j) = count
  NEXT j
  PRINT #3, t; a(i); c(1); c(2); c(3); c(4); c(5); c(6); c(7); c(8); c(9); c(10)
NEXT i
END SUB
```