Goniospectrometer operation manual

This setup is an upgraded version from Mattias Lindh’s original setup (see Goniospectrometer operation manual v1.0 from 2019-04-03). It consists of three independent modules that are operated independently:

1. **Goniospectrometer:** It is the core module and it provides the angular spectral characterization of an electroluminescent device. In a nutshell, it consists of a spectrometer (Ocean Optics Flame), a stepper motor that provides the rotation of the device, and a second stepper motor that provides the motion of the shutter element. The shortcut Goniospectrometer in the Desktop opens the program to control the instrument.
2. **IV logger** (optional, see p. 5)**: It allows for automated electrical driving and characterization**. This can be done by connecting the device to the Keithley 2400 sourcemeter and by opening the program IV logger (by the shortcut found in the Desktop). Otherwise, the user can operate the device him/herself by plugging the source to the cable endings from the sample holder.
3. **PID or temperature-controlled stage** (optional see p. 6): this module can be used if the user wants to heat the device during the operation. It consists of a thermoelectric Peltier cell and a Pt100 thermometer coupled to the bottom surface of the device. The temperature is read using the Agilent 34461A multimeter. The power to the Peltier cell is provided by the Agilent 34401A power supply. Open the program PID, in the Desktop.

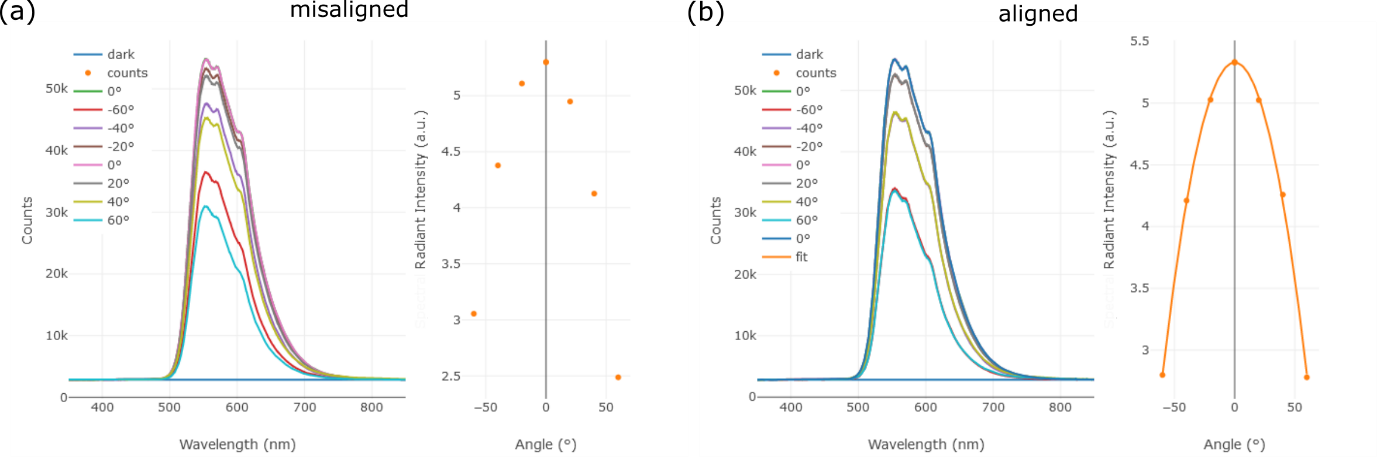
To exclude substrate-mode artifacts in the measurements, blacken the substrate edges before positioning the device in the connection jig (e.g. with a black permanent marker pen).

# Quick guide

1. Make sure the two USB-cables labeled “Arduino” and “Flame” are connected to the docking station.
2. (Optional) Connect the blue USB-cable labeled “GPIB communication” that communicates via GPIB with the sourcemeter, multimeter, and power supply in case you want to use also the IV logger or/and PID modules.
3. Connect the docking station to the laptop using the left-side docking connector.
4. Carefully turn the black plastic jig so that is normally directed to the collection lens. Move the shutter into the “closed” position, i.e. blocking the light path between the device and the collection lens.
5. Power the stepper motors by plugging the 5V transformer labeled “Gonio steppers”. Now the stepper motors become active and you cannot rotate the connection jib and the shutter anymore.
6. Open the program Goniospectrometer, found in the Desktop. It will open a tab in the Firefox browser. If the program is not loaded after 10 s, press the Reload current page button (Ctrl+R).
7. Select the correct spectrometer instance in the dropdown list “Spectrometer ID” below the graphs. It should be loaded by default, showing a name like <SeaBreezeDevice USB2000PLUS:FLMS00244>. If it does not appear, make sure the Flame-USB is connected and click REFRESH. [[1]](#footnote-1)
8. Select the correct port for the Arduino from the “Arduino COM port” dropdown list. It is loaded by default and it should read ASRL7::INSTR.[[2]](#footnote-2)
9. Start the instrument by pressing the Power Button. All the buttons should become active now.
10. (Optional but recommended) Align the zero-position of the goniometer. See the “Zero-angle alignment” section.
11. Choose an appropriate Integration time (in ms) that does not saturate the detector, but ideally, it should result in a maximum count of approximately 50 000 to 60 000 counts for your brightest spectrum. Click ACQUIRE to check the current setting.
12. Select a suitable number of spectra to average (which will apply to every viewing angle). The total measurement time for each viewing angle is the product of the Integration Time and the Number of spectra to average.[[3]](#footnote-3)
13. Select the Step angle and Max. angle (both in degrees), typically between 5 to 10° for the former and 80° for the latter. Both the positive and negative angles will be measured by default, to further compensate any zero-angle offset. The Step angle should be smaller and, ideally, a divisor of the Max. angle. Choose other combinations at your own risk!
14. Select the Folder and a Filename to save the data. Make sure the Folder exists, otherwise you will get an error. No extension for the Filename is needed.
15. Press START.
16. During the measurement, you can click UPDATE to see the plot of the progress in the graphs.
17. Wait until the measurement finishes.
18. Press the Power button in case you are finished. Otherwise, you can click again START to take a second measurement; the Filename can be the same as a timestamp is used as a prefix for the Filename.

# Zero-angle alignment

In this section, we explain how the do fine alignment of the zero-angle position (forward direction) of the goniometer using an OLED. The OLED is a SY-OLED operated beyond its lifetime LT50%, therefore it has a very stable luminance during the alignment process. Proceed as follows:

1. Place the OLED, preferably pixel labeled D4 or D1, on the connection jig.
2. Turn on the OLED using, e.g. the Keithley 2400, using a constant current of 1 mA.
3. Start the Goniospectrometer program (follow the Quick guide steps). Before powering the steppers, manually align to your best capability the jig at the forward position.
4. Select a suitable Integration time (100-125 ms should be ok), Number of spectra (ca. 20), an Angle step of 20°, and a Max. angle of 60°.
5. Press START.
6. Click UPDATE during or after the measurement has finished.
7. Even if the zero-angle was misaligned 1-3° you will notice how the positive and negative angles spectra do not overlap, especially for the higher angles, and the Lambertian-like emission (right-side plot) is off-centered (see, Fig 1a).
8. Click AUTO-ZERO and you will see how the goniometer motor moves, automatically correcting the zero-angle. Click UPDATE to see the adjusted parabola. Look at the black command prompt to know how off-centered you were. Warning, do not click AUTO-ZERO twice, as the program will apply the correction again and you will lose the alignment.
9. Click CLEAR and proceed again from step number 5. If the correction angle was not big, e.g. <5°, you should see now how the positive and negative angles spectra overlap (see Fig 1b) and a centered Lambertian-like emission.
10. Repeat steps 5-9 until you are satisfied. Normally one or two times should be more than enough.
11. Carefully remove the OLED and place your device. The powered stepper will prevent the jig to move and misalign again if done carefully.

**Figure 1.** Example of a goniospectrometer measurement when (a) the zero-angle is misaligned by -3.00°. (b) Once the zero-angle has been corrected using the AUTO-ZERO option. Notice how in (a) the spectra at positive and negative angles do not coincide and how the Radiant intensity plot is off-centered. In (b), the spectra at positive and negative angles coincided and the radiant intensity plot is centered around zero.

# Output

The data is saved in a tab-delimited file; the first three rows contain, respectively, the timestamp, the integration time (ms), and the number of averaged scans. After that, the data is saved as a M x N matrix, where M = #viewing angles + 2 is the number of rows, and N = #wavelengths + 2 is the number of columns. This file contains all the necessary numerical data for the emission but does not contain any electrical information. Post-processing can be conveniently done in Matlab (see Mattias’ “Goniospectrometer postprocessing manual.pdf” or Python (see Joan’s libraries).

|  |  |  |  |
| --- | --- | --- | --- |
| Position | | Content | Unit |
| Matlab | Python |
| (1, 1) | [0, 0] | Timestamp of the beginning of the measurement | yyyy-mm-ddTHH:MM:SS.f |
| (2, 1) | [1, 0] | The integration time of the spectrometer | [ms] |
| (3, 1) | [2, 0] | The number of averages for each viewing angle | [#] |
| (3:M, 1) | [2:, 0] | The elapsed time since the first spectra were taken | [s] |
| (3:M, 2) | [2:, 1] | The sampled viewing angles | [°] |
| (1,3:N) | [0, 2:] | The measured wavelengths | [nm] |
| (2, 3:N) | [1, 2:] | The dark spectrum | [counts] |
| (2:M, 3:N) | [2:, 2:] | The measured spectrum | [counts] |

# Hardware

The goniospectrometer program is built with an Ocean Optics Flame-S USB-spectrometer, an Arduino UNO, two BigEasyDrivers stepper motor drivers, and two (200 steps/360°) stepper motors. A Thorlabs F230SMA-A collimating lens that delivers the light through an Ocean Optics optical fiber to the spectrometer, collects the emission.

The connection jig is 3D-printed and a spring loading ensures electric contact and a stable position device. To have good temperature stability, it is also good to use the spring-loaded-coupler for the thermal stage, even it is not used. Pull the bolt(s) out and insert the McScience-style device—corner down—at the front.

Both the spectrometer and the Arduino UNO are controlled through a Pyhton-based program. The spectrometer is controlled with the Ocean Optics drivers through the python-seabreeze[[4]](#footnote-4) library. The Arduino UNO communicates with the BigEasyDrivers. The library that wraps up everything is called pyGoniospectrometer and can be found under “Python Scripts/ PyGoniospectrometer”.

The IV logger and PID also run under Python-based programs.

# Limitations

* The present layout of the goniospectrometer results in the following limitations:
* The solid collection angle is approximately 0.007 sr.
* The half-intensity spread of each collected viewing angle is < 3.4°.
* The FWHM spectral resolution of the spectrometer with a 100 um slit is < 5 nm.
* The ideality of the IRF is > 95 % at wavelengths between 530 and 1000 nm. At smaller wavelengths, the setup starts underestimating the emission. See calibration for details on how to improve in these specific wavelength ranges.

**BEWARE! The absolute numbers of the calibration of the goniospectrometer are sensitive to any alterations of the setup!**

# IV logger module

The IV logger program provides an interface to communicate with the Keithley 2400. Use the following steps to use it:

1. Make sure the blue-USB cable is connected.
2. Open the IV logger program, found in the Desktop. It will open a tab in the Firefox browser. If the program is not loaded after 10 s, press the Reload current page button (Ctrl+R).
3. Make sure the dropdown list Sourcemeter address reads GPIB0::25::INSTR[[5]](#footnote-5).
4. (optional) If you want to configure the sourcemeter via software, activate the switch Config. Otherwise, you can manually configure the instrument and the program will act only as a logger.[[6]](#footnote-6)
5. (optional) If you have activated the Config, you can now use the switch CC mode to toggle between CC mode (constant current) and CV mode (constant voltage).
6. Choose the Input current (or voltage), the Folder and Filename (without extension).
7. Click the POWER BUTTON. Now the instrument is configured and ready to start.
8. Click START to switch on the sourcemeter (if it has been configured) and start the measurement.
9. Use the CLEAR button any time to clear the real-time plot.
10. Click STOP whenever you want to stop the measurement. If Config was activated, it will switch off the sourcemeter, if not, it will only stop logging data.

# Heating-stage module (PID)

The PID*[[7]](#footnote-7)* program allows controlling the temperature of the heating-stage, which consists of the Peltier cell coupled to an aluminum pad with a Pt100 sensor.

1. Make sure the blue-USB cable is connected.
2. Place the sample using the temperature-stage coupler (Al + Peltier + screw + spring) and make sure there is good contact between the bottom side of the device and the black side of the stage. You can add some thermal paste to improve the contact.
3. Follow the steps described in the Quick guide to align and configure the Goniospectrometer.
4. Open the PID program, found in the Desktop. It will open a tab in the Firefox browser. If the program is not loaded after 10 s, press the Reload current page button (Ctrl+R).
5. Make sure the dropdown list Multimeter address reads GPIB0::23::INSTR, which corresponds to the Agilent 34461A used to retrieve the temperature.
6. Make sure the dropdown list Power source address reads GPIB0::5::INSTR, which corresponds to the Agilent 34401A used to retrieve the temperature.
7. Set the Max. power output to 3.
8. Set the temperature using the big knob.
9. Click the POWER BUTTON to start the instrument.
10. Click START. The program will start heating using a ramp of 10°C/min until the desired setpoint.
11. Use CLEAR to clear the plot.
12. You can change the setpoint using the knob any time after starting the instrument.
13. Click STOP to finish the measurement and the POWER BUTTON to switch off the instrument.

Observations

* As for now, the stage is meant for heating only. Although the program can be used to coo, the jib and coupler do not have a heat sink to extract the generated heat. Some hardware upgrade is required.
* After being used for a while at temperatures > 30°C, it might take a long time to cool down to 20°C of the lab. It is a matter of waiting.

1. Sometimes, it might happen that the spectrometer driver (USB2000) is not recognized anymore due to an outdated digital certificate issue. In that case, go to the Windows search bar, type “Device Manager” and open it. Open the Ocean Optics USB Devices tab. You’ll see an exclamation mark highlighting a driver problem. Right-click Update Drivers and select “Browse my computer […]”, then select “Let me pick […]”. Scroll down in the list until you find Ocean Optics Drivers and select any that says USB2000 (WinUSB) driver. A warning will appear; you can ignore and proceed with “Yes”. The driver is now successfully installed. Click Refresh in the Goniospectrometer program to update the available spectrometers list. [↑](#footnote-ref-1)
2. Unless somebody has swapped the “Arduino” USB cable with another port entry. In that case, you’ll need to check all the available ports until you find the one corresponding to the Arduino. [↑](#footnote-ref-2)
3. Plus some intermediate dead times. [↑](#footnote-ref-3)
4. See <https://python-seabreeze.readthedocs.io/en/latest/> [↑](#footnote-ref-4)
5. Unless someone has changed the GPIB address directly on the sourcemeter. In that case, choose the check the address given by the Keithley an choose accordingly. [↑](#footnote-ref-5)
6. In that case, the output of the sourcemeter has to be ON, otherwise you will get an error. [↑](#footnote-ref-6)
7. PID stands for Proportional-Integral-Derivative and is the algorithm that controls the temperature of the heating-stage using a feedback signal control. [↑](#footnote-ref-7)