

Application Area: Energy

LED Lights Calibration – Monochromatic LEDs

Keywords

Metrohm Autolab Optical Bench, solar cells, DSC, LED light, calibration

Introduction

In this document, a procedure to calibrate the LED light of the Metrohm Autolab Optical Bench is presented. The procedure can be applied to the single-wavelength LED lights.

For the calibration of white lights, a preliminary procedure to find the responsivity value of the calibrated photodiode is needed. Once the responsivity value is known, the procedure outlined in this document can also be used to calibrate the white lights. To learn more about the calibration of the white light please refer to AN-PV-006 on Metrohm website.

Calibration is performed in order to relate the LED light intensity to the LED driver current. In this way, it is possible to correct the light intensity values when the distance between the solar cell under test and the LED light is changed. Besides, the calibration allows to perform measurements on solar cells while specifying the light intensity values, instead of the LED driver current. The software will automatically calculate the respective value of the LED driver current.

In Table 1, the different LED lights available for the Metrohm Autolab Optical Bench are listed.

Table 1 – List of the different LED lights available for use with the Metrohm Autolab Optical Bench setup.

Color	Wavelength (nm)	Article Code
Deep Red	655	LDC655
Red	627	LDC627
Red-Orange	617	LDC617
Amber	590	LDC590
Green	530	LDC530
Cyan	505	LDC505
Blue	470	LDC470

In order to proceed with the calibration, it is important to understand the relationship between the current delivered by the LED driver and the resulting LED light intensity.

The LED driver delivers a current of up to 700 mA, here called LED driver current. This current is converted to light by the LED, whose intensity can be measured with the photodiode present in the Metrohm Autolab Optical Bench. The photodiode converts the incident light to photocurrent, which is measured by the potentiostat.

Once the ratio between the LED driver current and LED light intensity is obtained, it can be used in the software to input directly any desired light intensity value. The procedure will then automatically calculate the LED driver current necessary to obtain the desired light intensity.

Experimental Setup

The calibration is performed with a Metrohm Autolab PGSTAT204. The Metrohm Autolab Optical Bench composed of a rail, a photodiode, the LED driver. A 627 nm red LED is used in this calibration experiment. The setup is shown in Figure 1. The distance between the LED light and the photodiode is set to 20 cm. The experiment is performed in a dark environment, in order to avoid light pollution that can interfere with the measurements.



Figure 1 – Metrohm Autolab Optical Bench set up. The rail equipped with the 627 nm red LED light and the photodiode is shown on the left side. In the center, the Metrohm Autolab PGSTAT204, and on the right side the LED driver is shown.

The Procedure

In order to correlate the LED driver current and the LED light intensity, the LED light is powered with different LED driver current values, ranging from 100 mA to 700 mA. For each LED driver current, the photocurrent is recorded, as shown in Figure 2.

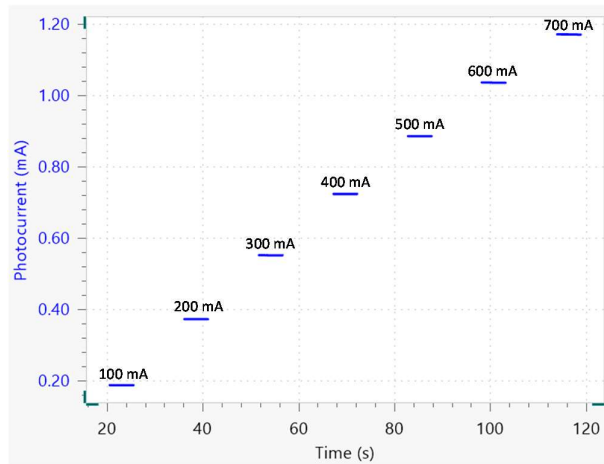


Figure 2 - Photocurrent vs. time plot, for different LED driver currents (black values mentioned in the plot).

Afterwards, the average value of each photocurrent is calculated in order to minimize the error due to small fluctuations.

In order to calculate the light intensity, the responsivity η (A/W) of the photodiode is used, defined as:

$$\eta(\lambda) = \frac{\text{generated photocurrent}}{\text{power of incident light}} \quad 1$$

A photodiode generates current (called photocurrent) when light reaches its surface. The responsivity is the ratio between the photocurrent (A) and the power (W) of the incident light. The responsivity depends on the incident wavelength λ . A plot of responsivity vs. wavelength is provided with each photodiode purchased with the Metrohm Autolab Optical Bench.

The responsivity vs. wavelength plot for the photodiode in use is shown in Figure 3. The responsivity value of the photodiode under a LED light of 627 nm corresponds to 0.318 A/W (red lines in Figure 3).

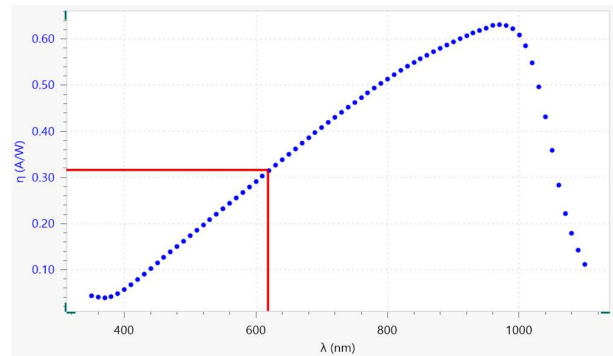


Figure 3 - Responsivity vs. wavelength plot, corresponding to the photodiode used for the calibration. The responsivity value, 0.318 A/W, and the wavelength of the LED, 627 nm, are also shown.

The last parameter needed to calculate the light intensity is the area of the photodiode, which is 0.13 cm².

Finally, the light intensity (LI) in mW/cm² is calculated with Equation 2.

$$LI = \frac{\text{av. photocurrent}}{\eta} \cdot \frac{1}{A} \quad 2$$

Where A is the area of photodiode in cm². The plot of LED driver current vs. light intensity is shown in Figure 4.

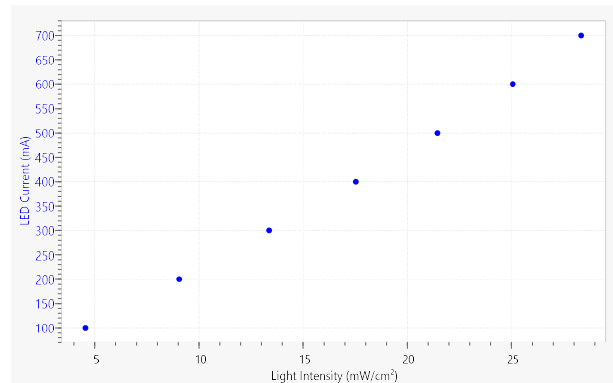


Figure 4 - LED driver current vs. light intensity plot.

Regression analysis of the data presented in Figure 4 is performed using a 4th order polynomial in order to have an acceptable correlation between data points and fitting function (shown in Figure 5).

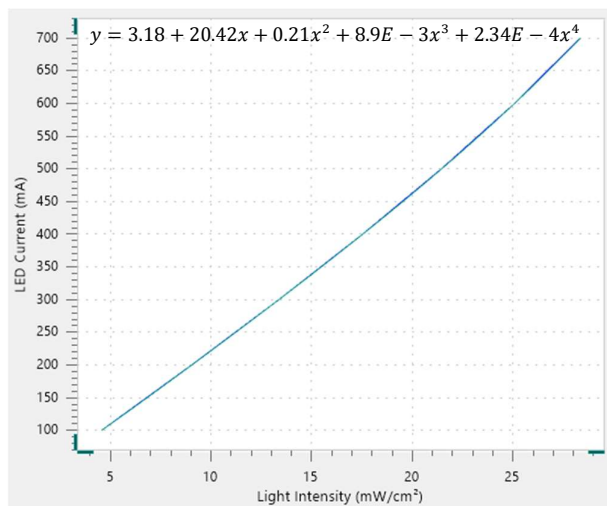


Figure 5 - Regression curve resulting from fitting the data points in Figure 4 with a 4th order polynomial function. The formula of the polynomial is also shown.

The NOVA software allows exportation of the coefficients of the polynomial function in a text file that can be imported in the procedures for subsequent experiments, for example testing of solar cells. In this way, it is possible to perform experiments with the desired light intensity, in mW/cm², specified. The software will calculate the necessary LED driver current, as explained in the following section.

From light intensity to LED driver current

This section is applicable to experimental measurements carried out on solar cells, where the LED driver current is calculated from the specified value of light intensity. The calculation is performed with the coefficients of the polynomial used to fit the LED light calibration.

The 4th order polynomial function has the following form:

$$y = a + bx + cx^2 + dx^3 + ex^4 \quad 3$$

Where y is the LED driver current in mA, and x is the light intensity in mW/cm². The units for the coefficients of the fitting polynomial are given in Table 2.

Table 2 – The coefficients of the 4th order polynomial function, with their respective units.

Coefficient	Unit
a	mA

b	mA/(mW/cm ²)
c	mA/(mW/cm ²) ²
d	mA/(mW/cm ²) ³
e	mA/(mW/cm ²) ⁴

The text file containing the above-mentioned coefficients is imported into the measurement procedure, and the desired light intensity value (*L*) is inserted. The LED driver current is calculated with the following equation:

$$LED \text{ driver current (A)} = \frac{a + bLi + cLi^2 + dLi^3 + eLi^4}{1000} \quad 4$$

The division by 1000 is necessary for the conversion of the current values from mA to A, since the LED driver handles current values in ampere. The LED driver current value is then linked to the “Autolab Control” command, as shown in Figure 6, in order to set the LED driver current.

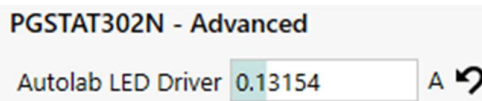


Figure 6 - The section of the “Autolab Control” command where the LED driver current calculate with Equation **Error! Reference source not found.** is linked.

Conclusions

In this document, the procedure to calibrate the LED light of the Autolab Optical Bench is presented. Different values of the LED driver current are recorded and the respective light intensities are calculated. A regression analysis with fitting using a 4th order polynomial function is performed. With this function, it is possible to designate any value of the light intensity and the software automatically calculates the corresponding LED driver current.

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For more information

Additional information about this application note and the associated NOVA software procedure is available from your local [Metrohm distributor](#). Additional instrument specification information can be found at www.metrohm.com/en/products/electrochemistry.