Why the “C“ in CIMPS ?

For photo-electrochemical experiments the exact determination of the light intensity used is essential. It is involved in the transfer function calculating the “optical” impedance of the measured system, for instance in organic solar cells, dye sensitized solar cells (DSSC) or similar photo-active materials.

The traditional technique of experimental IMPS/IMVS uses LED current as a measure of light intensity. With this method mainly three drawbacks may lead to complications or even to erroneous results.

1.) **Non-Linearity**
The relation between LED current and light intensity is not linear.

2.) **Temperature Drift**
The light intensity of a LED is a function of the temperature of the LED-chip and therefore must be considered neither as a constant nor as a linear function of the current throughout the entire experiment.

3.) **Nominal-actual comparison and phase relation**
The LED current as a measure for the light intensity considers only a nominal size for the control of the impedance measurement whereas using the light intensity itself considers the real, actual quantity.
Combining voltage and LED current (IMVS) as well as combining current and LED current (IMPS) assumes implicitly that the phase shift of the LED current is identical with the phase shift of the light intensity results in an additional phase shift between excitation and response with respect to the actual light intensity.
Replacing the LED current by the light intensity itself removes this parasitic contribution automatically (**C**IMVS and **C**IMPS-technique respectively – see below).

4.) **Ageing Effect**
The current efficiency of any LED, i.e. the relation between current through the LED and the light intensity, changes with time due to ageing effects.

Non-Linearity

Often, a linear correlation between LED current and intensity is erroneously assumed. The reality is shown in figure 1: The relation between current and light intensity of a representative LED is far away from being linear. Only in small parts of the curve the light intensity may be approximated to the current by a straight line, but the accuracy is suffering with an unacceptable amount.

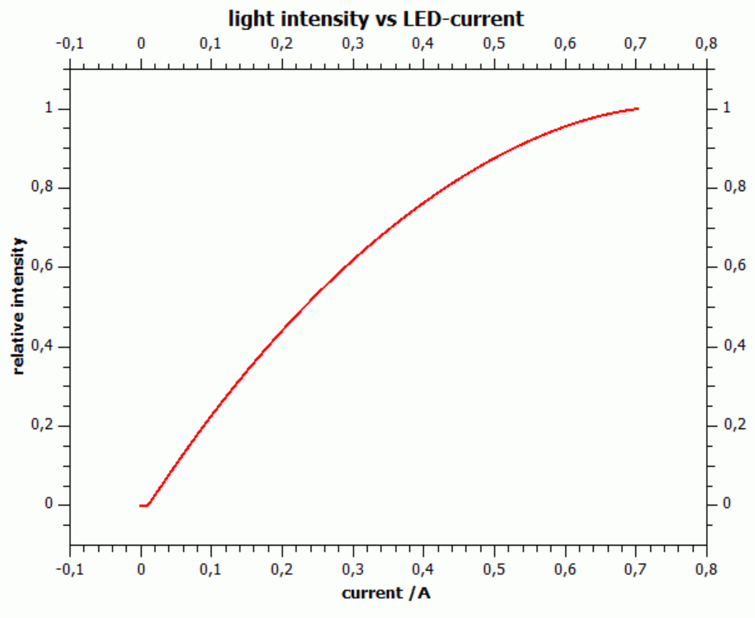

figure 1: light intensity of a Power-LED as function of current

Temperature Drift

An example to demonstrate the second drawback, the temperature dependence of the current-to-light conversion efficiency, is depicted in figure 2. The LED efficiency decreases with increasing time. Running a LED at considerable current will always result in internal heating. So even at a constant current, light intensity will change over the time of the experiment. The internal heat resistance is an inherent property of all LEDs. Typical values of 12 K/W result in considerable temperature increase when running the LED (e.g. 30K at a 2.5W LED). This drift-contribution cannot be eliminated by any external heat management as it takes place between the light emitting chip and the housing (substrate) of the LED.

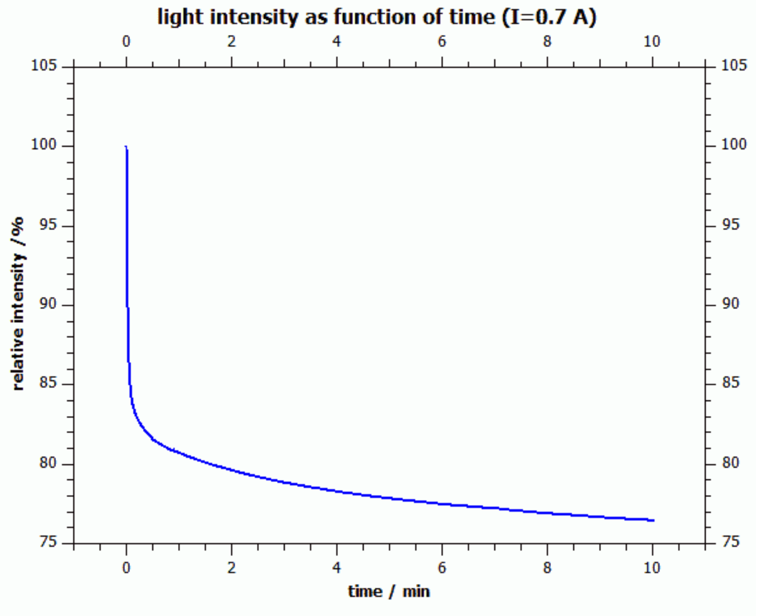

figure 2: LED light intensity of the current-to-light conversion efficiency as function of time at constant current. Drop due to internal heating.

It should be noted that an individual relationship between light intensity and time (temperature) exists for each particular current, an effect that further complicates the calculation of a general correlation between light intensity and LED current.

Nominal-actual comparison and Phase Relation

In traditional impedance spectroscopy, impedance and phase shift arise as a result from voltage and current and yield the complex transfer function. Considering “optical impedance”, one of both components is replaced. Using the LED current as a substitute for the light intensity suffers from the fact that the relation between voltage resp. current and light intensity, i.e. the phase shift, is not the actual measured quantity.

Ageing Effect

Last but not least, the change of the conversion efficiency with the ageing-time of the LED has to be taken into account. This is effect especially shows with LEDs of shorter wavelengths.

These arguments are showing clearly,
that the LED current is
not at all an adequate measure
of the light intensity.

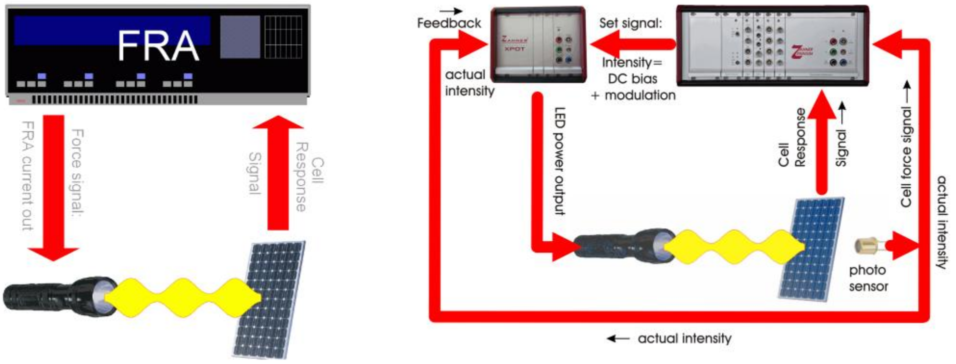

figure 3: Traditional arrangement for IMPS (left hand side) and the schematic of the CIMPS principle (right hand side), applied on a solar cell. In the case of CIMPS, a photo-diode detector feedback loop forces the light intensity at the site of the cell to follow exactly the sum of the DC- and AC-intensity set values.

The Solution

The Zahner **Controlled** IMPS/IMVS (**C**IMPS/**C**IMVS) overcomes all these drawbacks by directly and continuously controlling the light intensity. Using a calibrated sensor, the intensity is controlled actively through a feedback loop (see figure 3). This is achieved by using the potentiostatic feedback loop of the Zahner PP211/XPot in combination with a dedicated sense amplifier. Automatic safety circuits protect the LEDs from excessive current in case the feedback sensor is disconnected or accidentally shaded. Software support of the CIMPS technique not only includes direct entry of intensity in W/m² but also real time monitoring of the actual values.

Concerning the time/temperature dependence of the LED efficiency, a second advantage arises using the CIMPS technique: without active feedback, as used in a simple IMPS/IMVS system, largely increased warming up times are required. This not only extends measurement time but especially at UV wavelengths diminishes LED lifetime drastically. These warming up times can be avoided using the active feedback control of CIMPS.

High reliability & accuracy

Summarizing the improvements resulting from the CIMPS technique one has to conclude that the introduction of an active feedback using a dedicated sensor is an analogy to implementing a reference electrode in an electrochemical experiment. Without active feedback of the light intensity, i.e. when using the LED current as a direct measure, you have to accept bad reliability and a lower accuracy of your experimental results. CIMPS is overcoming all these drawbacks and lets you getting the best out of your measurements.

Question:

Concerning the LED-current as a substitute for the actual light intensity, wouldn’t it be sufficient to overcome the drawbacks by measuring the real light intensity once a time and separately, immediately before or after the experiment?

Answer:

No, unfortunately not.

By far the most important problem is not the absolute value of the light intensity but drift and degradation of the LED (and therefore the LED current) within a measurement or between two measurements.

Concerning the mechanisms in a DSSC for instance, the electron-recombination and the electron-diffusion process are assumed to determine the efficiency. Therefore, the ratio of the time constants is an eminent parameter.

However, one of the time constants is determined under short cut conditions whereas the other one is determined under open circuit conditions. Since both conditions are contra dictionary to be performed in a single measurement, the experiments must be performed consecutively. Of course, since both time constants are inversely proportional to the actual light intensity, the occurrence of drift and/or degradation within or between the measurement(s) will clearly falsify the ratio of the time constants.