The big “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, silicon cells, organic SC, etc.) or similar photo-active materials.

The traditional technique of experimental IMPS/IMVS uses LED current as a measure of light intensity implementing that with a known current the light intensity is also known. Let me compare this method with the potentiostat technique used 50 years ago. At that time, a voltage was given and the current response was measured. The voltage was not checked but it was assumed to be exactly of the size of the given value. It was assumed that the nominal value is equal to the real value. All modern potentiostats are not only measuring the response current but also the voltage at the sample site in order to have both as real values.

Not so with IMPS/IMVS. Here the nominal value of the LED current is used instead of the real value of the light intensity. Thus, IMPS/IMPS are outdated same as the old potentiostats. CIMPS is the first photo-electrochemical instrument of the new generation by feedback-controlling the light intensity instead of the LED current. It overcomes three drawbacks which may lead to complications or even to erroneous results.

1.) **Non-Linearity**
   The relation between LED current and light intensity is not linear.
2.) **Thermal 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. Thermal stability cannot be granted because the temperature changes on the LED substrate are much faster that a thermal management of the environment (e.g. cooler).
3.) **Nominal - Actual Comparison and Phase Error**
   LEDs are showing a short delay between current input and light output. This delay is not constant but depends on the bias point. When modulating the light source this delay results in a phase shift between current and light which is bigger at high frequencies than at low frequencies.
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.

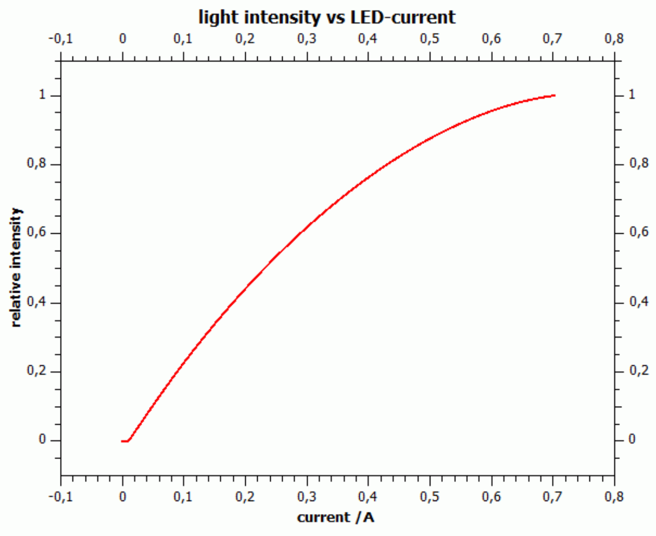

figure 1: light intensity of a Power-LED as function of current

Thermal 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 of the substrate. So even at a constant current, light intensity will change over the time of the experiment. Even with a Thermal Management a drift cannot be avoided and Thermal Stability cannot be guaranteed. 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.

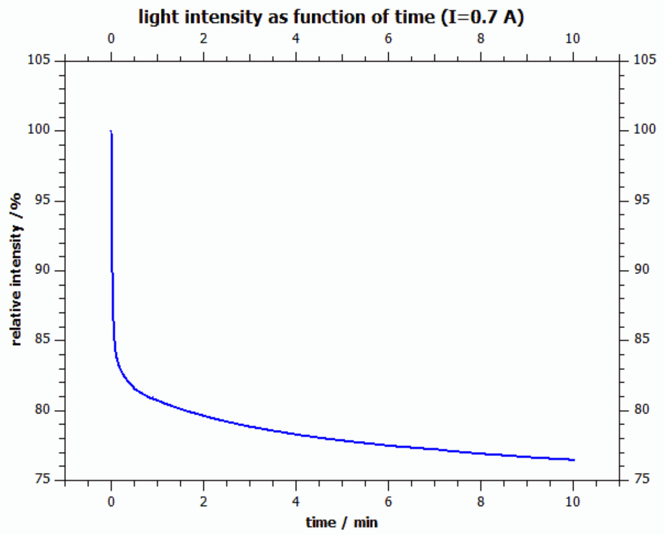

figure 2: LED light intensity of the current-to-light conversion efficiency as function of time at constant current. Drop due to internal heating.

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 Error

CIMPS is referring all measurements to the effective, in real-time measured light intensity and therefore does not suffer from a phase-shift between current and light intensity.

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
<u>not at all an adequate measure</u>
of the light intensity.

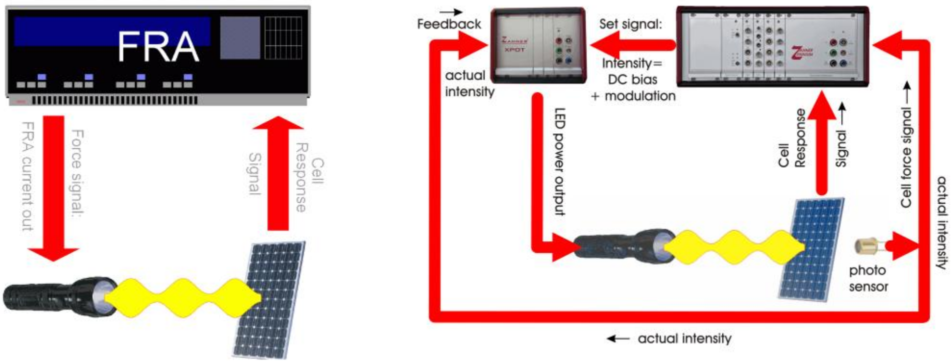

figure 3: Traditional arrangement for IMPS (left hand side) and the schematic of the CIMPS principle (right hand side), applied on a solar cell. In the case of CIMPS, a photo-diode detector feedback loop forces the light intensity at the site of the cell to follow exactly the sum of the DC- and AC-intensity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