Scientific Instrumentation
for Photons & Electrochemistry

Made in Germany
Our R&D team managed to create instruments with outstanding features, state-of-the-art hardware and an advanced software. The result is a milestone in scientific instrumentation. ZENNIUM and IM6 were developed using our 30 years of experience in producing high-precision electrochemical workstations of the high-end class. They provide a frequency range up to 4 MHz (ZENNIUM) / 8 MHz (IM6), an output current up to ±2.5 A (ZENNIUM) / ±3.0 A (IM6) and fast signal processing. Special measurement techniques guarantee an ultra high accuracy and a minimal interference with the test object.

ZENNIUM/IM6 come bundled with the outstanding THALES-Z (Zennium release) software package which offers all standard methods and more at a mouse click. This is why the ZENNIUM/IM6 can easily be adapted to very different measurement requirements. Furthermore, with the manifold options available, the ZENNIUM/IM6 is able to grow with its tasks. It is best suited for investigations on fuel cells, batteries and solar cells as well as on membranes and sensors or on coatings and laminates, to name only a few.

ZAHNER-elektrik is known to provide competent service all around the world. Our experienced specialists help you to plan, set up and analyze your experiments in electrochemistry, physics, material science and electronics.
The highest priorities for the development and production of the ZENNIUM instruments are accuracy and reliability. The accuracy map of the ZENNIUM clearly shows the high quality of the hardware. These specifications are proofed by measurements for practical use, based on the high-end components we use. They are not only calculated by the theoretical specifications of some components.

**Up to 9 Extension Card Slots**

... enhance the output up to ±120 Volts ±40 Ampere +600 Ampere (load) 50 000 Watt 64 Channels

**External Potentiostats and Electronic Loads**

... connect the Zennium/IM6 easily with external data acquisition & control devices over TCP/IP as virtual net instruments

**NetVI Interface**

... the only electrochemical workstation based on a universal modular data acquisition system

**The Modular System**

... prepare the Zennium for special fields of application like high impedances, electrochemical noise, very low capacitance, etc. and interface with 3rd-party devices (electronic loads, potentiostats, ...)

**Probes**

... expand your Zennium/IM6 optionally with plug & play cards for fast data acquisition and control output channels according to your special requests.

**ZAHNER ZENNIUM / IM6**

electrochemical workstations

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The powerful Thales software package is part of the standard equipment of each IM6 and ZENNIUM system. It provides a multitude of measuring and analysis methods.

The Thales software provides unique features for the acquisition and analysis. The most prominent examples are SCRIPT and SIM. SCRIPT offers you to program user defined combinations of all types of electrochemical measurements, mathematical analysis, algorithms, documentation and data export to a reproducible, fully automatic process. With the outstanding features of SIM you are able to create equivalent circuits and fit the measurement data to these models. The ZHIT feature of SIM helps you to validate your impedance spectra.

For evaluation only it is also possible to run Thales software package on a ThalesBox. The ThalesBox provides a single user licence of Thales. So you can process your recorded data on a simple PC or Laptop while your tests still run on the IM6 or ZENNIUM ...

- System requirements: IBM compatible PC
  - Microsoft Windows XP/Vista/7/8
  - (32-bit / 64-bit)
  - USB 2.0

**General Fields of Application**
- low impedance applications (fuel cells, batteries, super-caps ...)
- high impedance applications (coatings, laminates, membranes, sensors, corrosion ...)
- photoelectrochemical applications (silicon, dye-sensitized and organic solar cells, organic LED, semiconducting films ...)

**Look & Feel**
- electrochemical methods guide
- free scaleable application window
- Windows tooltips
- ThalesViewer (Windows Explorer extensions)
- fast online context sensitive help system
- icon navigation + direct access pull down menus
- child windows for configurable online measurement display

**Special Functionalities**
- fast multiple filter for impedance and photovoltage /current spectra
- special modeling support for solar cells
- joint multiple transfer function fitting
- SCRIPT procedures for user-defined measurement, analysis- and documentation tasks
- multi-channel measuring data acquisition and control in parallel to the electrochemical experiments

**Connectivity**
- remote control via LabVIEW VI
- integrate third-party signal acquisition devices over TCP/IP as NetVI
- ASCII data logging via online display
ZAHNER ZENNIUM / IM6
THALES Z software package

Export of ASCII text tables, vector- and bitmap graphics on all display panels

User defined realtime online display

Direct access pull down menus

Universal Screenshot Function

Remote control with LabVIEW® over TCP/IP anywhere

Output control channels

Graphic and legend preview with Windows® Explorer®

Supported Method | Option
--- | ---
Testpointing Online Display and Logging | PAD4
Parallel Testpointing Online Display and Logging | PAD4
EIS Series Measurements vs. Parameters | PAD4
Impedance Network Analysis, Simulation & Fitting | PAD4
Impedance/Parameter, Capacity/Voltage Curves | PAD4
Parallel Impedance/Parameter, Capacity/Voltage Curves | PAD4
AC Voltammetry | PAD4
Cyclic Voltammetry | PAD4
Linear Sweep Voltammetry | PAD4
Triangular Wave Voltammetry | PAD4
Cyclic Triangular Wave Voltammetry | PAD4
Chronoanamperometry With Multiple Triangular Potential Sweeps | PAD4
Stationary Electrode Voltammetry | PAD4
Chronoanamperometry With Linear Potential Sweep | PAD4
Totescan | PAD4
Steady State Current/Voltage Curves | PAD4
Multi-Cell Current/Voltage Curves | PAD4
Corrosion / Polarisation Measurement | PAD4
Polarimetry | PAD4
Chronopotentiometry | PAD4
Chronoanamperometry | PAD4
Pulse Plating | PAD4
Universal Current/Potential/Time Curves | PAD4
Time Domain Controlled Measurements | PAD4
Electrochemical Noise | PAD4
Correlation Noise | PAD4
Fast Polarography | PAD4
Differential Pulse Polarography | PAD4
Differential Pulse Voltammetry | PAD4
Stripping Voltammetry | PAD4
Standard Addition Measurement & Analysis | PAD4
Universal Measurement Data Acquisition & Control | PAD4
Universal Frequency Response Analysis | PAD4
AC-DC-AC Tests | PAD4
Layer Quality Test / Bi-Layer Test | PAD4
Fast Pulse & Transient Recording | PAD4
High Current Intermittent Measurements | PAD4
Relaxation Voltammetry | PAD4
Solar Cell Fill Factor, Efficiency, Maximum Power, OCP, ISC | PAD4
Controlled Intensity Modulated Photocurrent Spectroscopy | PAD4
Controlled Intensity Modulated Photovoltage Spectroscopy | PAD4
Charge Extraction After N. W. Dutt, L. M. Peter et. al. | PAD4
Light Transient Measurements, Chopped Light Voltammetry | PAD4
DC vs. Intensity Transfer Functions, Time Domain Measurements | PAD4
Lightemission Voltage/Current Characteristic (OPV) | PAD4
Spectral Absorption Voltage/Current Characteristic | PAD4
Photocurrent Spectroscopy | PAD4
Quantum Efficiency, Incident Photon to Charge Carrier Efficiency | PAD4
Photocurrent/ Voltage Response on Fast Light Transients | PAD4
Dynamic and Static Transmittance / Reflectance | PAD4
Synchronous Multi Spectral DRR with Parallel Impedance | PAD4
Cross Transfer Function Measurements | PAD4
Membrane Penetration Transfer Function Measurements | PAD4
Programmable Procedures | PAD4

*) Required hardware options
Electronic loads are indispensable tools in several fields of electrochemistry, for example in the research of batteries and fuel cells. The EL 1000 was designed to investigate single cells as well as complete stacks, either as stand-alone device under PC control or in combination with a workstation IM6 or Zennium for instance for impedance measurements. Adding an additional external electronic load, the power can be raised up – adding the PAD4 to the controlling workstation, individual segments of the stack can be investigated synchronously in parallel.

**Specifications**

- **Frequency range**: 10 µHz - 100 kHz
- **Current range**: 200 A / 600 A (with 3 party electronic load)
- **Voltage range**: ±4 V / ±100 V
- **Maximum power**: 1.000 W (stand-alone) scaleable with 3 party electronic load
- **Dimensions**: 470 x 160 x 446 mm

**Optional:**
- Additional electronic load for high power (< 600 A)
  - 3rd party electronic load
  - 100 V / 600 A
  - 200 A max
  - 1 kW

**Additional Methods**

- Parallel electrochemical impedance spectroscopy
- Parallel impedance/parameter capacitance/voltage curves
- Parallel testsampling online display and logging
EL1000

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Adding an additional external electronic load, the power can be raised up – adding the PAD4 to the controlling workstation, individual segments of the stack can be investigated synchronously in parallel.

ZAHNER ZENNIUM / IM6
electronic load EL1000

PAD4: 4 Channel Synchronous Impedance Converter

True Parallel Synchronous Impedance

Save time - measure up to 17 stack-cells in one run - no time mismatch between impedance spectra - record anodic, cathodic & total impedance simultaneously - measure additional transfer function signals...

The Zahner PAD4 is a 4-channel add-on card for Zahner Electrochemical Workstations. It introduces four additional parallel sampled signal inputs for cell voltage and impedance in fuel cell stacks and battery packs, with a common current. The Zahner Zennium supports up to two PAD4-cards for up to nine parallel channels, while the IM6 can control up to four cards for a maximum count of 17 parallel channels.

PAD4-cards are plug ‘n’ play – they are detected automatically on start-up. The PAD4 may be combined with the basic ECW or with the ECW controlling a slave potentiostat or an electronic load, finally providing tests on stacks of up to 100V / 600A / 50 KW.

Additional Methods

• parallel electrochemical impedance spectroscopy
• parallel impedance/parameter capacitance/voltage curves
• parallel testsampling online display and logging

Specifications

<table>
<thead>
<tr>
<th>Channels / card</th>
<th>4 individually addressable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impedance measurement:</td>
<td></td>
</tr>
<tr>
<td>Frequency range</td>
<td>10 µHz to 250 kHz</td>
</tr>
<tr>
<td>DC-potential measurement:</td>
<td></td>
</tr>
<tr>
<td>Voltage range</td>
<td>±4 V</td>
</tr>
<tr>
<td>Common mode range</td>
<td>±100 V</td>
</tr>
<tr>
<td>A/D converter resolution</td>
<td>18 bit</td>
</tr>
</tbody>
</table>

True Parallel Synchronous Impedance

PAD4 Nyquist plot of a five cell SOFC stack

Up to four PAD4 add-on cards allow the parallel measurement of up to 17 cells of a stack
The femto-Farad Probe works as a front-end to the IM6/Zennium potentiostat. Apart from its limited current capability, all basic functionalities of the Thales software are supported. In particular impedance spectroscopy can be applied. Due to the fact, that the primary measurement magnitude is the complex impedance, besides the sample capacity, resistive and DC contributions can be determined as well.

The trans-impedance principle for the determination of small capacities

SO “hot” test signal output
VGI “virtual ground” signal input
Z device under test
V, A voltage and current measurement
C \text{si} and C \text{so} parasitic stray capacitance at the input and output terminal

Additional Methods
low capacitance electrochemical impedance spectroscopy
low capacitance impedance/parameter

Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency range</td>
<td>10 µHz to 1 MHz</td>
</tr>
</tbody>
</table>
| Current auto ranging, detectable current ranges | 0 nA - ±40 nA  
±40 nA - ±400 nA  
±400 nA - ±4 µA  
±4 µA - ±40 µA |
| Voltage range                     | ±4 V                   |
| Resolution of any range           | 18 bit                 |
| Capacity offset                   | ±1 fF *)               |
| Capacity resolution               | ±0,1 fF *)             |
| Capacity accuracy                 | ±0,25% of reading ±2 fF *) |

*) current range ±40 nA, AC amplitude ±100 mV, zero DC current

Supported Methods with IM6/Zennium
• impedance spectroscopy
• simulation & model fitting
• cyclic voltammetry
• polarisation curves
• multicell multitasking voltammetry
• arbitrary current/potential/time measurements
• capacity/potential measurements
• automatic series measurements

Supported Methods with PC
• test sampling
• U vs. time, I vs. time
• current potential curves (U/I)
• cyclic voltammetry
• charging/discharging, battery cycling
• LabView virtual instrument
• DLL support available

PP201
pot/gal/oc
±20 V  
±0.1% / ±2 mV  
0 A ... ±40 A  
±0.25% / ±1 mA  
200 W  
10 µHz - 200 KHz  
1 µ - 1 K  
0 °C ... 30 °C  
IM6/Zennium+EPC42 or PC

PP241
pot/gal/oc
±20 V  
±0.1% / ±2 mV  
0 A ... ±40 A  
±0.25% / ±1 mA  
200 W  
10 µHz - 200 KHz  
1 µ - 1 K  
0 °C ... 30 °C  
IM6/Zennium+EPC42 or PC

Nanoelectrodes

Determination of the coupling capacity between two adjacent pads of a printed circuit board

Microelectromechanical systems (MEMS) and Sensors
The PP-Series potentiostats are designed to apply and sink high currents up to ±40A at a total power dissipation of up to 200W. The PP-Series potentiostats are controlled by an EPC42, a plug-in module for the Electrochemical Workstations IM6 and Zennium.

Up to four EPC42 cards can be installed in an IM6 or an Zennium. In total, up to 16 PPs can be controlled by one IM6/Zennium. Each potentiostat will hold the control parameters from one access to the next one, so that no potential or current disturbances can occur while scanning the potentiostats. If series measurements are performed with more than one PP-Series potentiostat, spectra are taken from all modules in a definable order.

The PP-Series is embedded completely in the IM6/Zennium environment. Thus, all acquisition and analysis techniques that run on the IM6/Zennium can be applied with the power potentiostats as well. The installation of one or more PP-Series potentiostats will upgrade your IM6/Zennium to an even more versatile, high-current electrochemical workstation.

The PP-Series potentiostats can also be controlled by a Windows®-PC. In this case they provide methods, summarized in the table below. They also work as a LabVIEW™ Virtual Instrument under the LabVIEW™ software. To implement the PP-Series potentiostats into existing test environment, a supporting DLL is available on demand.

You can control the PP-Series potentiostats in a mixed mode with an IM6/Zennium and a PC in parallel. Both devices can be connected and disconnected during operation.

**Supported Methods with IM6/Zennium**
- impedance spectroscopy
- simulation & model fitting
- cyclic voltammetry
- polarisation curves
- multichannel multichannel voltammetry
- arbitrary current/potential/time measurements
- capacity/potential measurements
- automatic series measurements

**Supported Methods with PC**
- test sampling
- U vs. time, I vs. time
- current potential curves (U/I)
- cyclic voltammetry
- charging/discharging, battery cycling
- LabView™ virtual instrument
- DLL support available

**Specifications**

<table>
<thead>
<tr>
<th>Model name</th>
<th>Operating modes</th>
<th>Potential range</th>
<th>Potential accuracy</th>
<th>Current range</th>
<th>Current accuracy</th>
<th>Output power</th>
<th>Frequency range</th>
<th>Impedance range</th>
<th>Ambient temperature</th>
<th>System requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP201</td>
<td>pot/gal/oc</td>
<td>±10 V</td>
<td>±0.1% / ±1 mV</td>
<td>0 A ... ±20 A</td>
<td>±0.25% / ±1 mA</td>
<td>200 W</td>
<td>10 µHz - 200 kHz</td>
<td>1 µΩ - 1 kΩ</td>
<td>0 °C ... 30 °C</td>
<td>IM6/Zennium + EPC42 or PC</td>
</tr>
<tr>
<td>PP211</td>
<td>pot/gal/oc</td>
<td>±20 V</td>
<td>±0.1% / ±2 mV</td>
<td>0 A ... ±10 A</td>
<td>±0.25% / ±1 mA</td>
<td>200 W</td>
<td>10 µHz - 200 kHz</td>
<td>1 µΩ - 1 kΩ</td>
<td>0 °C ... 30 °C</td>
<td>IM6/Zennium + EPC42 or PC</td>
</tr>
<tr>
<td>PP241</td>
<td>pot/gal/oc</td>
<td>±5 V</td>
<td>±0.1% / ±1 mV</td>
<td>0 A ... ±40 A</td>
<td>±0.25% / ±1 mA</td>
<td>200 W</td>
<td>10 µHz - 200 kHz</td>
<td>1 µΩ - 1 kΩ</td>
<td>0 °C ... 30 °C</td>
<td>IM6/Zennium + EPC42 or PC</td>
</tr>
</tbody>
</table>
### Frequency Generator & Analyzer

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Zenium</th>
<th>IM6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Bandwidth</td>
<td>DC - 5 MHz</td>
<td>DC - 10 MHz</td>
</tr>
<tr>
<td>ADC Resolution</td>
<td>3 ADGs @ 18 bit</td>
<td>3 ADGs @ 18 bit</td>
</tr>
<tr>
<td>Harmonic Reject</td>
<td>&gt; 60 dB @ 1/2 full scale</td>
<td>8 MHz @ 33Ω load</td>
</tr>
<tr>
<td>Potentialstat Modes</td>
<td>Potentiostatic, galvanostatic, pseudo-galvanostatic, rest potential, off, ZRA, FRA</td>
<td>Potentiostatic, galvanostatic, pseudo-galvanostatic, rest potential, off, ZRA, FRA</td>
</tr>
<tr>
<td>Cell Connection</td>
<td>ground</td>
<td>ground</td>
</tr>
<tr>
<td>Extension Slots</td>
<td>4</td>
<td>9 (incl. 1x EPC42)</td>
</tr>
<tr>
<td>PC interface</td>
<td>USB 2.0</td>
<td>USB 2.0</td>
</tr>
<tr>
<td>Dimensions</td>
<td>364 x 160 x 376 mm</td>
<td>470 x 160 x 376 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>12 kg</td>
<td>15 kg</td>
</tr>
<tr>
<td>Accessories</td>
<td>U-buffer, 2 cell cable set, USB-cable, power cord, manual, +Thalesbox, +EPC42</td>
<td>U-buffer, 2 cell cable set, USB-cable, power cord, manual, +Thalesbox, +EPC42</td>
</tr>
<tr>
<td>Power supply</td>
<td>230/115 V / 50/60 Hz</td>
<td>230/115 V / 50/60 Hz</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>+10°C to +30°C</td>
<td>+10°C to +30°C</td>
</tr>
<tr>
<td>Ambient Humidity</td>
<td>&lt; 60% without derating</td>
<td>&lt; 60% without derating</td>
</tr>
</tbody>
</table>

### Output Potentiostatic

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Zenium</th>
<th>IM6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Scale Voltage</td>
<td>±4 V (Main), ±10 V (U-buffer)</td>
<td>±100 nA to ±3.0 A in 10 steps</td>
</tr>
<tr>
<td>Resolution</td>
<td>125 µV (Main), 320 µV (U-buffer)</td>
<td>±100 nA to ±3.0 A in 10 steps</td>
</tr>
<tr>
<td>Accuracy **</td>
<td>±250 µV, ±0.025% of full scale (Main), ±2 mV ±0.025% of full scale (U-buffer)</td>
<td>±0.0031% (16 bit) of range</td>
</tr>
<tr>
<td>Temperature Stability</td>
<td>better 20 µV/°C</td>
<td>±1 nA to ±0.5 A in 12 steps</td>
</tr>
<tr>
<td>Compliance Voltage</td>
<td>±14 V (Main), ±120 V (with CVB120)</td>
<td>±1 nA to ±0.5 A in 12 steps</td>
</tr>
<tr>
<td>AC-Amplitude</td>
<td>1 mV to 1 V (Main), 1 mV to 25 V (CVB120)</td>
<td>±0.0031% (16 bit) of range</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>4 MHz @ 33 Ω load</td>
<td>±1 nA to ±0.5 A in 12 steps</td>
</tr>
<tr>
<td>IR Compensation</td>
<td>Method</td>
<td>Auto AC Impedance Technique</td>
</tr>
<tr>
<td>IR Compensation</td>
<td>Range</td>
<td>0 to 10 MΩ</td>
</tr>
<tr>
<td>IR Compensation</td>
<td>Resolution</td>
<td>0.012%</td>
</tr>
<tr>
<td>Small Signal Rise Time</td>
<td>250 ns to 200 µs in 5 steps, automatic selection by automatic stability control</td>
<td>250 ns to 200 µs in 5 steps, automatic selection by automatic stability control</td>
</tr>
<tr>
<td>Slew Rate</td>
<td>15 mV/s</td>
<td>±100 nA to ±3.0 A in 10 steps</td>
</tr>
<tr>
<td>Phase Shift</td>
<td>10° @ 250 kHz</td>
<td>±100 nA to ±3.0 A in 10 steps</td>
</tr>
</tbody>
</table>

### Output Galvanostatic

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Zenium</th>
<th>IM6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Scale Current Ranges</td>
<td>±100 nA to ±2.5 A in 10 steps</td>
<td>±100 nA to ±2.5 A in 10 steps</td>
</tr>
<tr>
<td>Resolution</td>
<td>±0.0031% (16 bit) of range</td>
<td>±0.0031% (16 bit) of range</td>
</tr>
<tr>
<td>Accuracy **</td>
<td>±1 nA to ±0.5 A in 12 steps</td>
<td>±1 nA to ±0.5 A in 12 steps</td>
</tr>
<tr>
<td>Current Accuracy DC **</td>
<td>±0.05% of reading @ &gt;</td>
<td>2 µA</td>
</tr>
<tr>
<td>Offset Temperature Stability</td>
<td>&lt; 10 µV/°C</td>
<td>±0.05% of reading, ±125 fA @ &lt;</td>
</tr>
<tr>
<td>Full Scale Current Ranges *</td>
<td>±100 nA to ±2.5 A in 33 steps</td>
<td>±100 nA to ±2.5 A in 33 steps</td>
</tr>
<tr>
<td>Current Accuracy DC **</td>
<td>±0.05% of reading @ &gt;</td>
<td>2 µA</td>
</tr>
<tr>
<td>Input Bias Current **</td>
<td>±1 pA (typ.) / ±5 pA (max.)</td>
<td>±10 fA (typ.) / ±125 fA (max.)</td>
</tr>
<tr>
<td>Current Resolution DC *</td>
<td>±2.5 pA</td>
<td>±10 fA (typ.) / ±125 fA (max.)</td>
</tr>
<tr>
<td>Current Resolution AC *</td>
<td>±25 nA</td>
<td>±10 fA (typ.) / ±125 fA (max.)</td>
</tr>
<tr>
<td>Input Impedance</td>
<td>Main 10 TΩ / ±5 pF (typ.)</td>
<td>±1000 TΩ / ±1 pF (typ.)</td>
</tr>
<tr>
<td>Impedance Range</td>
<td>Main 100 mΩ to 10 MΩ / 0.2%</td>
<td>±100 mΩ to 10 MΩ / 0.2%</td>
</tr>
<tr>
<td>Common Mode Rejection</td>
<td>&gt; 66 dB @ 10 µHz to 100 kHz</td>
<td>&gt; 66 dB @ 10 µHz to 100 kHz</td>
</tr>
<tr>
<td>Input Channel Phase-</td>
<td>±0.1° @ 10 µHz to 100 kHz</td>
<td>±0.1° @ 10 µHz to 100 kHz</td>
</tr>
<tr>
<td>Tracking accuracy</td>
<td>±0.25° @ 100 kHz to 4 MHz</td>
<td>±0.25° @ 100 kHz to 8 MHz</td>
</tr>
<tr>
<td>Equiv. Effective Input Noise</td>
<td>Main 2 µV rms / 200 fA rms @ 1 kHz to 10 Hz</td>
<td>20 µV rms / 30 fA rms @ 1 kHz to 10 Hz</td>
</tr>
</tbody>
</table>

* Guaranteed by design. For details refer to http://www.zahner.de application note “how to read specifications”

** In the first 6 months after factory calibration, after 20 min. warm-up
ZAHNER CIMPS
photoelectrochemical workstation

universal photo- & spectro-electrochemical workstation

Your Application Fields

- photo-electrochemical energy conversion
- semiconductors
- monolithic solar cells
- organic solar cells
- dye-sensitized solar cells
- hydride solar cells
- LEDs
- OLEDs
- electronic displays
- electronic newspaper
- electrophoretic ink

- electrochromic devices
- smart windows
- electrophoreoglass
- intelligent dimming mirrors
- suspended particle devices
- polymer dispersed liquid crystal devices

- solar induced photo-electrochemical
- hydrogen production
- waste decontamination
- fuel production
- CO₂ reduction
- artificial photosynthesis

Your Results

Our Tools

- CIMPS / IMPS
- CIMVS / IMVS
- Fast Intensity Transients
- Absorption Spectroscopy
- Emission Spectroscopy
- DC Characteristic
- C-V Measurement
- AC Impedance
- Charge Extraction
- Long Term Stability
- Standard SC Characterization
- Dynamic Transmission / Reflection
- (OIS Optical Impedance Spec.)
- EQE Measurement
- PV Conversion Efficiency
- Photocurrent Spectroscopy
- Chopped Light Voltammetry

- Photo-electrochemical Transfer Functions
- Impedance Simulation & Fitting
- Photocurrent Simulation & Fitting
- Photovoltage Simulation & Fitting
- Joint Fit of Impedance, Photovoltage and Photocurrent Spectra (TRIFIT)

- mechanisms
- kinetics
- charge carrier mobility
- total conversion efficiency
- spectral efficiency
- charge carrier...
- ... lifetime
- ... recombination time
- ... diffusion rate
- solar cell...
- ... serial resistance
- ... shunt resistance
- ... maximum power
- ... fill factor
- ... Voc, Jsc
- ... IPCE
- ... stability

- external quantum efficiency semiconductor permittivity
doping density
- spectral emission
- integral emission power
display transition time transmission/reflection DC characteristic
CIMPS is a photo-electrochemical research system for a wide field of applications. It is based on our universal electrochemical workstations Zennium or IM6, extended by special hard- and software. The basic configuration was designed with focus on static and dynamic photo-electrochemical transfer function measurement, popular in the research of alternative solar cell concepts. In particular, the dynamic transfer functions between photovoltage or photocurrent and light intensity are relevant for efficiency considerations of dye-sensitized oxide solar cells and organic solar cells. These functions are known as 'Intensity Modulated Photocurrent Spectroscopy' IMPS and 'Intensity Modulated Photo-Voltage Spectroscopy' IMVS.

Usually one is interested in the dominating time constants found by IMVS at open circuit conditions and by IMPS at short circuit conditions. Beyond this, thorough analysis and simulation of the transfer functions in combination with EIS give deep insights into the cell under test and the working mechanisms in detail.

IMPS and IMVS are determined in the frequency domain by means of a light source, which is modulated in intensity over a broad frequency range, analogous to the EIS principle. CIMPS uses light emitting diodes LED for that purpose. Different from a laser, LED do not need high modulation energy, and artifacts due to the presence of high voltage close to small measurement signals can be avoided. There is also no need for expander lenses, which must be inserted into a laser beam to illuminate electrode regions of up to several square centimetres.

CIMPS is the first complete system on the market designed especially for that purpose. Compared to the IMPS described in older literature, important improvements were made by Zahner: a control loop regulates light intensity and modulation keeping it absolutely stable. The automatic comparison between set value and sensed intensity eliminates the influence of non-linearity, ageing and temperature drift. Instead of the LED supply current, used as a substitute magnitude in the traditional set-up, the actually measured intensity is fed into the transfer function calculation, avoiding scale- and phase shift errors. As an additional advantage, CIMPS provides the automatic calibration of the illumination in natural units of intensity (W/m²), allowing instant exchange of the LED arrays of the user, light sources have to be ordered separately. Please ask for our latest list of LED arrays available in a wide range of wavelengths and for tuneable light sources.

A set of supporting functions accompanies the IMPS and IMVS feature, useful for solar cell analysis as well. The static DC-photo-voltage and photocurrent vs. intensity characteristic can be determined. Among other value, the static behaviour provides useful criteria on the relevance of the time constants, derived by IMPS / IMVS. Stability and degradation of a SC may be controlled by recording photo-voltage and photocurrent vs. time at a constant intensity. SC efficiency, fill factor, integral IPCE and maximum power determination is implemented as a standard push button function, which works together with a 3rd-party AM1.5 solar simulator.

While IMPS / IMVS are typical small signal linear frequency domain techniques, CIMPS also provides light transient experiments. They can be used in order to cross-check the frequency domain results in the time domain. They may cover also the non-linear regimes.

The CIMPS standard package consists of all components necessary for the core application. Due to the individual requirements of the user, light sources have to be ordered separately. Please ask for our latest list of LED arrays available in a wide range of wavelengths and for tuneable light sources.

The Zahner PECC cells are optimized for perfect optical as well as electrical characteristics and come with an Ag/AgCl reference electrode and a Pt counter electrode coil. The PTFE/PCTFE-based solid allows working in aggressive and non-aqueous electrolytes. A gas-tight version, allowing oxygen-free working is available. With experiments, for instance half-cell measurements, can be performed perfectly in these specially designed photo-electrochemical cells.

Apart from the core application, the CIMPS system may be extended to many other related methods by optional available peripherals. Certain 3rd-party spectrometers can be
The Zahner PECC cells are optimized for perfect optical as well as electrical characteristics and come with an Ag/AgCl reference electrode. Certain 3rd-party spectrometers can be connected directly. CIMPS is able to control these spectrometers and provides spectral resolved light emission (OPV) measurements, valuable for instance in OLED research and testing. The CIMPS-abs option may be used for spectral resolved absorption measurements, necessary for the investigation of electro-chromic processes and materials for electronic displays, OLED and organic solar cells.

CIMPS-pcs is based on our special tuneable lightsources. It opens the door to traditional photocurrent-spectroscopy PCS, spectral resolved incident photon conversion efficiency and the whole set of related spectro-electrochemical techniques. Finally, the FRA of the CIMPS system can be configured to a lock-in mode, which allows CIMPS to work together with 3rd-party chopper / monochromator units.

The components of the CIMPS package are working together in a plug & play application, including the software and an overall calibration of the system. An Electrochemical Workstation (ECW) IM6 or Zennium operates as a Frequency Response Analyser and as a support unit (Potentiostat / Galvanostat) for the cell under test. The Zahner ECWs are renowned for their high precision, ease of use and comprehensive software. One may select between two slave potentiostats (XPOT, PP211) used for the control of the light source, which differ in the output power to cover low-noise as well as high intensity applications.

The light source carrier including a fast high precision low noise photo-amplifier is positioned on an optical bench face to face with the photo-electrochemical cell. A photodiode sensor is mounted close to the cell's light inlet.

TRIFIT: joint model simulation and fitting of impedance, photocurrent (IMPS) and photovoltage (IMVS) spectra
ZAHNER CIMPS

optical methods...

Functions

Standard Solar Cell Tests
- maximum power
- fill factor
- efficiency
- IPCE

Static Photo-Electric Transfer Functions
- static photovoltage vs. intensity curve
- static photocurrent vs. intensity curve
- static photocurrent vs. cell voltage at constant intensity

Dynamic Photo-Electric Transfer Functions
- dynamic photovoltage efficiency IMVS
- dynamic photocurrent efficiency IMPS

Time Domain Measurements
- photovoltage vs. time at constant intensity
- photocurrent vs. time at constant intensity

Intensity Transients Measurements
- photovoltage vs. time under intensity transients
- photocurrent vs. time under intensity transients

Charge Extraction after N. W. Duffy, L. M. Peter et al.

Chopped Light Voltammetry

Calibration Routines for LED & OLED
- dynamic lightsource efficiency

Electrochemical Methods & Utilities
- electrochemical impedance spectroscopy (EIS)
- impedance & network analysis, simulation & fitting
- EIS series vs. parameter
  (time, potential, current, temperature, pH ...)
- impedance vs. parameter
  (time, potential, current, temperature, pH ...)
- stationary current / voltage characteristics & polarisation measurements
- cyclic & linear sweep voltammetry
- graphic, documentation & programming utilities
  ...

Please refer to the ZENNIUM® brochure for a complete list of methods

\[ P \]: Luminous intensity [W/cm\(^2\)]
\[ U \]: Photo voltage [V]
\[ I \]: Photo current [A]
\[ E \]: Light source potentiostat set voltage [V]
\[ Q \]: Charge [C]
\[ U_{oc} \]: Open circuit voltage [V]
\[ I_{sc} \]: Short circuit current [A]
\[ N_{max} \]: Electrical power [W] at the point of the maximal product \( UI \) of the solar cell current voltage curve
\[ \eta \]: number of photoelectrons
\[ \eta_{ph} \]: number of incident photons
\[ \omega \]: angular frequency [Hz]
\[ \phi \]: phase shift [rad]
\[ j \]: imaginary unit

\[ \text{rect}_p \]: periodic squarewave function

\[ N_{max}(P) \]
\[ FF = \frac{N_{max}}{P_{sc} \cdot I_{sc}} \]
\[ \eta = \frac{N_{max}}{P} \]
\[ IPCE = \frac{P_{ph}}{N_{ph}} \]
\[ F_{cp} = \frac{U(P)}{P} \]
\[ F_{tp} = I(P) \]
\[ F_{iv} = I(U) \]

\[ H(\omega) = \frac{U(t)}{P(t)} \]

with \[ U(t) = U \cdot e^{i \omega t + \phi}, \]
\[ P(t) = P \cdot e^{i \omega t} \]

\[ H_{cp}(\omega) = \frac{I(t)}{P(t)} \]

with \[ I(t) = I \cdot e^{i \omega t + \phi}, \]
\[ P(t) = P \cdot e^{i \omega t} \]

| \( U(t) \) | \( I(t) \) |
| \( U(t) \) | \( I(t) \) |
| \( Q(t) \) | \( I(U, P, \text{rect}_p, t) \) |

\[ H_{cp}(\omega) = \frac{P(t)}{E(t)} \]

with \[ P(t) = P \cdot e^{i \omega t + \phi}, \]
\[ E(t) = E \cdot e^{i \omega t} \]
SC Fill-Factor, IPCE and Maximum Power

DSSC Charge Extraction after L.M. Peter

DSSC DC vs. Intensity Transfer Function

Alternative SC DC vs. Intensity Transfer Function

Hybrid SC IMPS/IMVS Experimental Data, Simulation and Fit

DSSC IPMS/IMVS Experimental Data, Simulation and Fit

DSSC Light Transient
Photo-electrochemical Cells

PECC-1 / PECC-2

The PECC-1/PECC-2 are specially tailored for testing electrode materials with photo-electrochemical techniques. Several mounting options for samples offer flexibility for various tasks.

<table>
<thead>
<tr>
<th>Specifications</th>
<th>PECC-1</th>
<th>PECC-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical dimensions (W x D x H)</td>
<td>60 x 25 x 80 mm</td>
<td>60 x 25 x 80 mm</td>
</tr>
<tr>
<td>Optical window diameter</td>
<td>20 mm</td>
<td>18 mm</td>
</tr>
<tr>
<td>Optical window material</td>
<td>BK7 or Quartz</td>
<td>BK7 or Quartz</td>
</tr>
<tr>
<td>Sample diameter</td>
<td>max. 20 mm</td>
<td>max. 18 mm</td>
</tr>
<tr>
<td></td>
<td>25 - 40 mm</td>
<td>25 - 40 mm</td>
</tr>
<tr>
<td>Electrolyte volume</td>
<td>7.9 cm</td>
<td>&lt; 25 mm on request</td>
</tr>
<tr>
<td>Light path length in electrolyte</td>
<td>6.3 cm</td>
<td>7.2 cm</td>
</tr>
<tr>
<td>Solid material</td>
<td>Teflon (PTFE)</td>
<td>Ker-F (PCTFE)</td>
</tr>
<tr>
<td>Reference electrode</td>
<td>Ag/AgCl</td>
<td>Ag/AgCl</td>
</tr>
<tr>
<td>Counter electrode</td>
<td>Pt coil</td>
<td>Pt coil</td>
</tr>
<tr>
<td>Gas inlet/outlet</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Sample in electrolyte chamber
Sample as rear tightening plate

More than 50 monochromatic light sources from UV to IR are available for the CIMPS system. They are supplemented by high power white LEDs (up to 2000 W/m²), tungsten lamps and tuneable light sources. Apart from recording photocurrent spectra, the tuneable light source TLS03 can also be used for standard methods supplied by the CIMPS system.

All LED light sources are calibrated traceable to the national metrology institute of Germany PTB. Identification of the light sources and setting of the individual calibration data is performed by the CIMPS system automatically. So, exchanging light sources is plug and play.

Light Sources

Over 50 Monochromatic Lightsources available for CIMPS
Spectral Resolved Transmittance/Absorbance Measurement System

Extend the scope of your CIMPS system for material screening and examination of electro-chromic processes.

For this purpose CIMPS is equipped with a UV-VIS-IR spectrometer, two photo-electrochemical cells (one for the measuring object and one as reference), a high-power white LED illuminator (LED emitter or Tungsten lamp, others like D or Xenon lamp on request), Automatic spectra series vs. cell voltage, current and time. The list of series parameters may be optionally extended to any physical quantity such as temperature, concentration, pH and more. In addition to automatic triggering, each recording can be started manually after setting the electrochemical parameters. The Thales software provides versatile light spectra analysis routines which allow many useful graphic representations, zoom-, cursor-, documentation- and data export functions. Like with all Thales data file types, Windows detects the light spectra files automatically and presents info-boxes and graphic preview.

Additional Methods

- absorbance spectra vs. voltage
- absorbance spectra vs. current
- absorbance spectra vs. time
- user script controlled absorbance spectra series

Requirements: Basic CIMPS system
abs option consist of

- Two photo-electrochemical cells PECC-2
- UV-VIS-IR spectrometer
- Tungsten lamp or high-power white LED
- D or Xenon lamp on request
**Typical light intensity of TLS03 in continuous mode**

**backthinned silicon photodiode**

**Typical light intensity of TLS03 wideband mode**

*(with UV extension)*

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**Tunable Light Source: TLS03**

**Tunable Optical Light Source**

The unique and patented tunable light source, TLS03, uses dedicated LEDs as well as a linear monochromator. Different from systems using Xenon lamps which require filters and a mechanical chopper, the concept of the TLS03 provides high light intensity along with a low spectral half-width and a multitude of features unique for this kind of instruments. Furthermore, LEDs can be modulated much faster than a mechanical chopper can do.

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**ZAHNER CIMPS**

**spectro-electrochemical option pcs**

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**Photo Current Spectra: pcs**

**Electrochemical Photo Current Spectra (PCS) System**

Equipped with the tunable light source TLS03, one of the core applications of pcs is measuring the Photo Current Spectra PCS, Quantum Efficiency QE or Incident Photon Conversion Efficiency IPCE of organic and dye sensitized solar cells in the wavelength range from typical 365 nm up to 1020 nm (TLS03) with optional UV range extension, representing for the most effective range of solar light. Like the standard light sources for CIMPS, the TLS03 are based on the state-of-the-art LED technology. Switchable white background illumination helps to speed up measurements at DSSC and enables investigations on tandem solar cells. Pcs profits from the modulation capabilities of LEDs just as CIMPS does. No mechanical choppers are necessary and instead of the more noise-sensitive Lock-In-technique the advantages of coherent frequency analysis technique can be used. Pcs comes up as a plug play application fully calibrated and equipped with the outstanding comfort of Thales: spectral data can be analyzed with the on-board package "light spectra analysis", spectral data files are covered by the preview-support of the Windows file explorer and can be exported in manifold ways as high-quality vector graphics, bitmaps and ASCII data lists. You may view and export data, while measurements are running.

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**Additional Methods**

- photocurrent vs. wavelength (PCS)
- quantum efficiency (QE)
- incident photon conversion efficiency (IPCE)

**Requirements:** Basic CIMPS system

**pcs option consist of**

- tunable lightsource TLS03
  - 365 - 1020 nm
  - optional UV extension (295 - 1020 nm)

**Examples for Photocurrent Spectra and Incident Photon Conversion Efficiency Spectra of Solar Cells**
Tuneable Light Source: TLS03

Tuneable Optical Light Source

The unique and patented tuneable light-source, TLS03, uses dedicated LEDs as well as a linear monochromator. Different from systems using Xenon lamps which require filters and a mechanical chopper, the concept of the TLS03 provides high light intensity along with a low spectral half-width and a multitude of features unique for this kind of instruments. Furthermore, LEDs can be modulated much faster than a mechanical chopper can do.

Outstanding Features

- Easy Mountable
  The optical parts are arranged on an easy mountable optical bench.
- PTB-Traceable Detector
  The integrated optical sensor (PTB-traceable, PTB is the European equivalent to NIST) is used to measure and feedback-control the light intensity exactly.
- Unique Feedback Control
  This special and exclusive feature of all Zahner CIMPS systems grants you an accurate light intensity regardless of age and temperature of the LEDs. So there is no need for a reference cell and time consuming realignments of sample holders.
- No warm up time
  Using state of the art LEDs not only increases power efficiency drastically, it also eliminates the long warm up times required by Xe-lamp based systems.
- Real Sine Wave Modulation
  Unlike chopper-based systems, the TLS03 can be real sine wave modulated without harmonic distortion.
- Intelligent Control
  With its intelligent control of a multitude of LEDs of different wavelengths, the TLS03 significantly outputs more power at a certain wavelength than a system consisting of a Xenon lamp plus monochromator can do. Additionally, a switchable white background illumination helps to speed up measurements at DSSC and enables investigations on tandem solar cells.
- Wavelength Range
  The TLS03 is available with a standard wavelength range of 365 nm to 1020 nm and with an extended range of 295 nm to 1020 nm.

Benefits of TLS03 Compared to Xe-Lamp-Monochromator-Chopper Arrangements

- easy light weight "in a box"
- high power efficiency
- no warm up time, lower noise, lower drift
- higher monochromatic light intensity
- higher modulation frequency
- real sine-wave modulation without harmonic distortion
- switchable background illumination
- PTB traceable sensor integrated
- reference cell not necessary
- no sample repositioning

Outstanding Features

- high power efficiency
- no warm up time, lower noise, lower drift
- switchable background illumination
- PTB traceable sensor integrated
- reference cell not necessary
- no sample repositioning

ZAHNER CIMPS

tuneable light source TLS03

Examples for Photocurrent Spectra and Incident Photon Conversion Efficiency Spectra of Solar Cells

Photo Current Spectra:
- photocurrent vs. wavelength (PCS)
- quantum efficiency (QE)
- incident photon conversion efficiency (IPCE)

Electrochemical Photo Current Spectra (PCS) System

Equipped with the tuneable light source TLS03, one of the core applications of is measuring the Photo Current Spectra PCS, Quantum Efficiency QE or Incident Photon Conversion Efficiency IPCE of organic and dye sensitized solar cells in the wavelength range from typical 365 nm up to 1020 nm (TLS03) with optional UV range extension, representing for the most effective range of solar light. Like the standard light sources for CIMPS, the TLS03 are based on the state-of-the-art LED technology. Switchable white background illumination helps to speed up measurements at DSSC and enables investigations on tandem solar cells.

Pcs

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Additional Methods

Tuneable lightsource TLS03

- 365 - 1020 nm
- optional UV extension (295 - 1020 nm)

Requirements: Basic CIMPS system

Copper in aq. sodium acetate at pH 8.4 (measured with UV extension)

Easy Mountable

The optical parts are arranged on an easy mountable optical bench.

PTB-Traceable Detector

The integrated optical sensor (PTB-traceable, PTB is the European equivalent to NIST) is used to measure and feedback-control the light intensity exactly.

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Unlike chopper-based systems, the TLS03 can be real sine wave modulated without harmonic distortion.

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The TLS03 is available with a standard wavelength range of 365 nm to 1020 nm and with an extended range of 295 nm to 1020 nm.

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- higher modulation frequency
- real sine-wave modulation without harmonic distortion
- switchable background illumination
- PTB traceable sensor integrated
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Dynamic Transmittance / Reflectance Measurements (OIS)

Exceptional feature: assigns kinetic information unequivocally to certain colored species in a reaction chain!

Some physical systems change their optical properties under the influence of an electrical voltage or current applied. Such behavior is of high scientific interest and already reached great economic importance in the fields of electronic displays, smart windows and electronic newspapers, acting as electro-chromatic devices.

The electrical control of the absorbance may have influence on the spectral properties of such systems. Dependent on the state, color or tone may change. This can be investigated with traditional absorption spectroscopy by means of CIMPS-abs. For many applications, besides color aspects, the dynamic properties are of high importance as well. The switching time, very important for instance for displays and modulators, or the reaction time of smart windows is determined by the kinetic processes of transport- and redox-reactions or by the structural re-organization which cause the optical changes.

Dynamic Transmittance Reflectance “DTR” transfer function analysis, also known as OIS (Optical Impedance Spectroscopy), follows the ideas popular in Electrochemical Impedance Spectroscopy (EIS). The basic transfer function in EIS is given between voltage and current. Like for EIS, in DTR a bias control voltage (or current) applied to the sample is modulated with a small test signal amplitude. Differing from EIS, the sample is illuminated using a certain static intensity \( I \), and the transmitted or reflected light \( P \) is recorded and treated as response signal in dependence of the electrical excitation.

The dynamic transfer function \( DTR \) is calculated as the quotient between the response modulation signal (the relative intensity change in time \( P / P^* = TR \)) and the excitation signal (Voltage \( U \) or current \( I \), dependent on the selected mode, potentiostatic or galvanostatic).

\[
DTR_{gal} = \frac{TR}{I}, \quad [DTR_{gal}] = A^{-1}
\]

\[
DTR_{pot} = \frac{TR}{U} \cdot e^{j\phi}, \quad [DTR_{pot}] = V^{-1}
\]

\( j \) = imaginary unit
\( \phi \) = phase shift \( [\text{rad}] \)
\( * \) = amplitude symbol

DTR spectra can be understood and modelled like EIS. Time constants can be extracted and assigned to certain charge transfer, relaxation and transport processes. Their characteristic shape and phase angle helps to distinguish between them.

It is known, that EIS suffers from the ambiguity of the spectra: different mechanisms may lead to identical dynamic transfer functions. An exceptional property of DTR that the response function can be assigned unequivocally to a certain colored species. In combination with EIS, DTR may help to cancel out further ambiguities, like it can be done also in combination with IMPS/IMVS data. The main application of CIMPS-mdtr/ois is measuring frequency spectra similar to EIS belonging to a certain bias state of the system. Besides, CIMPS-mdtr/ois supports slow, quasi-static scan features determining the steady state characteristics. In order to characterize the static transmittance-reflectance behavior in dependence of the applied voltage, the sample voltage can be swept linearly between two limiting voltages under potentiostatic control. In galvanostatic mode the transmittance/reflectance-characteristic recording is displayed in form of a charge scan.
ZAHNER CIMPS
spectro-electrochemical option mdtr/ois

**Multi Spectral DTR/OIS Option: mdtr/ois**

**Synchronous Multi Spectral Dynamic Transmittance/Reflectance with Parallel Impedance Measurement System (OIS)**

Focus on up to four selective colored species in a reaction chain and determine the kinetics!

Mdtr/ois is able to acquire the DTR-spectra of more than one species in a system under test synchronously with recording an impedance spectrum. For that purpose the CIMPS instrument is extended with the multi-channel synchronous AD-converter PAD4.

The transmitted/reflected light is fed through a multi-channel photo-detector, providing wavelength bands in UV/IR and two selective bands in VIS. Four individual photo-amplifiers feed the detector signals to the inlets of the PAD4.

By default mdtr/ois works with a white high-power LED light source WLR02. A programmable multi-spectral light source MLS is optional. The emission of the MLS can be set to UV (365nm), violet (420nm), blue (445nm), green (535nm), red (630nm), NIR (740nm), IR (940nm) and white. The different wavelength bands can be selected separately in any combination. In that way, selective excitation of the system under test is performed. By using both selective light emission as well as selective light detection, crosstalk is minimized.

Parallel acquisition does not only save time. The main advantage is, that the different spectra are recorded at the same time and belong therefore to the same system state. Time drift is much less critical than in the case of sequential recording.

**Additional Methods**

- dynamic transmittance / reflectance vs. frequency
- static transmittance / reflectance vs. charge
- static transmittance / reflectance vs. voltage
- static transmittance / reflectance vs. time
- multi spectral transmittance / reflectance vs. frequency
- with synchronous parallel impedance

**Requirements**: Basic CIMPS system

**mdtr/ois option consist of**

- PAD4 4 channel synchronous AD converter
- Multi spectral sensor with amplifier
- White high-power LED WLR02
- Optional programmable multi spectral light source MLS

**Characterization of a P3HT-PEDOT:PSS polymer multilayer with DTR and EIS at 535nm and 740nm**
ZAHNER CIMPS
spectroelectrochemical option emit

**Emission: emit**

**Photo-Electrochemical Light Emission Measurement System**

Extend the scope of your CIMPS system for the examination of OPV, LED, OLED, ... Similar to the light absorbance measurement package, this option complements CIMPS by a UV-VIS-IR spectrometer to enable spectral resolved light emission measurements. For integral emission, an additional NIST traceable calibrated photodetector can be added. Like with CIMPS-abs, automatic spectra series measurement vs. cellvoltage, current, time can be performed and additional series parameters like temperature, voltage and pH can be used optionally. Of course, emission spectra recording can be triggered also manually while controlling the electrochemical parameters. Like for CIMPS-abs, the light spectra analysis package within Thales supports single / multi-spectra 2-D, multi-spectra 3-D and contour plot visualization for instance as emission, transmittance, absorbance, extinction in linear or logarithmic scale vs. wavelength or wave-number. Data export can be done in form of ASCII-data, as bitmap or as Windows®-EMF graphics via clipboard copy & paste or as file.

**Additional Methods**

- lightemission voltage current characteristic (PVI)
- spectral resolved PVI

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**Requirements:** Basic CIMPS system
emit option consist of

- UV-VIS-IR spectrometer
- or NIST traceable calibrated sensor
**Fast Intensity Transients: fit**

**Fast Light Intensity Transients Measurement System**

Extend the scope of your CIMPS system for the examination of fast kinetics in semiconductors, organic, dye sensitized and monolithic solar cells...

It is often advantageous to correlate linear dynamic measurements under frequency variation like IMPS and IMVS with measurements of transient behaviour in the time domain. Slower photo-electrochemical systems like DSSC or inorganic photo-catalytic systems can be evaluated successfully with the standard CIMPS function “Intensity Transients”. For faster processes happening for instance in silicon based or other monolithic types of semiconductor solar cells, and due to their thin layer structure also in organic solar cells, the time resolution of the standard CIMPS “Intensity Transients” is not sufficient. Photo-charge diffusion and migration time constants in such objects are too fast for a standard CIMPS system. With CIMPS-fit Zahner offers a fast intensity transients option, extending the time resolution down to 50ns.

**Additional Methods**

- photocurrent response on fast light transients
- photovoltage response on fast light transients

**Requirements:** Basic CIMPS system

**Fit option consist of**

- TR8M transient recorder
- Trigger cable

**Additional Features**

Fit uses the fast two-channel transient recorder TR8M plug-in from Zahner with a maximum 2-channel sampling rate of 20 MHz. The TR8M communicates with the internal potentiostat of the Zennium/IM6 and with slave potentiostats connected externally via an EPC42 by automatic, software controlled signal routing.

This feature is the basis for fit. The slave potentiostat, active in CIMPS controlling the lightsource in TR8M & Transient Recorder, performs light switching time constants of typically less than 50ns (off-transient) respectively 1us (on transient) can be achieved. The main potentiostat controls the cell and acquires cell voltage and respectively cell current. The signals are internally routed to the TR8M.

**Photocurrent Transient of a Monolithic Silicon Solar Cell**

**Photovoltage Transient of an Organic Solar Cell**

(Built up from Cr-Al-Cr-P3HT-PCBM-PEDOT-Cr-Au)
CIMPS-2 basic system (ZENNIUM® with PP211)
qe/ipce option (TLS03 with optional UV extension)
sample solar cell

CIMPS-QE/IPCE
GmbH & Co. KG

website: http://www.zahner.de   -   email: support@zahner.de
Thüringer Str. 12   -   96317 Kronach   -   Germany
tel:+49-(0)9261-962119-0   -   fax:+49-(0)9261-962119-99

Representative in your country:

CIMPS-Systems

Complete CIMPS-Systems

CIMPS-1 ZENNIUM® electrochemical workstation
XPot external potentiostat, EPC42 control module, optical bench sensor, photosense-amplifier-illuminator-supply unit, dummy cell
CIMPS & THALES software package

CIMPS-2 ZENNIUM® electrochemical workstation
PP211 power potentiostat, EPC42 control module, optical bench sensor, photosense-amplifier-illuminator-supply unit, dummy cell
CIMPS & THALES software package

CIMPS-3 IM6 electrochemical workstation
XPot external potentiostat, EPC42 control module, optical bench sensor, photosense-amplifier-illuminator-supply unit, dummy cell
CIMPS & THALES software package

CIMPS-4 IM6 electrochemical workstation
PP211 power potentiostat, EPC42 control module, optical bench sensor, photosense-amplifier-illuminator-supply unit, dummy cell
CIMPS & THALES software package

CIMPS-QE/IPCE CIMPS-2 basic system (ZENNIUM® with PP211)
qe/ipce option (TLS03 with optional UV extension)
sample solar cell

Options (requires CIMPS-system)

Absorption Option abs two photo-electrochemical cells PECC-2, UV-VIS-IR spectrometer tungsten lamp or high power white LED

Emission Option emit UV-VIS-IR spectrometer or NIST traceable calibration sensor

Photo Current Spectra Option pcs tuneable lightsource TLS03 (UV extension optional)

Fast Intensity Transients Option fit TR8M transient recorder, trigger cable

Multi Spectral Dynamic Multi/sois 4 channel parallel A/D converter PAD4, high power white LED, calibrated multi sensor programmable multispectral light source MLS optional

Transmittance/Reflectance (OIS) Option

NIST-Traceable Calibration Sensor SEL033 for automatic calibration procedure at the customer's lab

Photo-Electrochemical Cells

<table>
<thead>
<tr>
<th>Width x Depth x Height</th>
<th>PECC-1</th>
<th>PECC-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 x 25 x 80 mm</td>
<td>60 x 25 x 80 mm</td>
<td></td>
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<table>
<thead>
<tr>
<th>Optical Window Diameter</th>
<th>20 mm</th>
<th>18 mm</th>
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<table>
<thead>
<tr>
<th>Optical Window Material</th>
<th>BK7 or quartz</th>
<th>BK7 or quartz</th>
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<table>
<thead>
<tr>
<th>Working Electrode Active Diameter</th>
<th>max. 20 mm</th>
<th>max. 18 mm</th>
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<table>
<thead>
<tr>
<th>Solid Material</th>
<th>Teflon (PTFE)</th>
<th>Kel-F (PCTFE)</th>
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<table>
<thead>
<tr>
<th>Reference Electrode</th>
<th>Ag/AgCl</th>
<th>Ag/AgCl</th>
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<table>
<thead>
<tr>
<th>Counter Electrode</th>
<th>Pt coil</th>
<th>Pt coil</th>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Gas Inlet/Outlet</th>
<th>no</th>
<th>yes</th>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Light Inlet</th>
<th>front</th>
<th>front and rear</th>
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Lightsources

Monochromatic over 50 different LED lightsources wavelength range from 245 nm to 1550 nm

White LED arrays and Tungsten lamps

Switchable and Tuneable Lightsources wavelength range from 295 nm to 1020 nm