solartron analytical

ModuLab® XM PhotoEchem

Photoelectrochemical Measurement Sytem

Dye Sensitized Solar Cells ■ Visible Spectrum - Photoelectrochemistry ■ Visible Spectrum Semiconductor Photocatalysis

AMETEK®

ModuLab® XM PhotoEchem is a fully integrated photoelectrochemical measurement system designed for the characterization of Dye Sensitized Solar Cells. Additionally, the system can be used for development of visible spectrum photoelectrochemical systems such as Iron- Oxide mediated photo-splitting of water.

A comprehensive suite of techniques, developed by the leaders in this field for over 20 years are available. Solartron Analytical recognized that many users are unfamiliar to many of these techniques and therefore, at the heart of the product concept is the ability to analyze much of the data at one click of the mouse! No previous knowledge of frequency domain technique required. For the experienced user, the ModuLab offers the ability to build and develop new experiment types with the powerful step sequencer. The highlights of the system include:

- Range of Frequency and Time Domain Measurements techniques including IMPS, IMVS, Impedance, PhotoVoltage Decay, Charge Extraction Techniques , I-V
- 'Auto' analysis of data enabled for calculation of effective Diffusion coefficients and Electron Lifetimes at one click of a button. Suitable for users new to Frequency Domain Techniques
- NIST traceable Light Source calibration routine
- Excellent thermal management of light sources for long term stability
- Wide range of Monochromatic high brightness LED's available
- Full suite of Electrochemical Techniques including Cyclic Voltmmetry, Chrono - Methods, Galvano methods and comprehensive list of Impedance and AC Voltammetry Methods
- Auxiliary Channel Measurements for simultaneous determination of anode and cathode impedance and voltages
- Solartron Analytical FRA technology inside including single, swept and Multi-sine techniques
- Compatible with ModuLab and ModuLab XM

Comprehensive Techniques Package

A dedicated suite of software specifically developed for testing photo-electrochemical devices is included:

- Intensity Modulated Photocurrent Spectroscopy (IMPS)
- Intensity Modulated Photovoltage Spectroscopy (IMVS)
- Impedance Spectroscopy
- I-V
- Charge Extraction Methods
  - Short Circuit
  - Dark Charge Extraction
- Photo Voltage Decay

ModuLab XM PhotoEchem

Enhanced Productivity

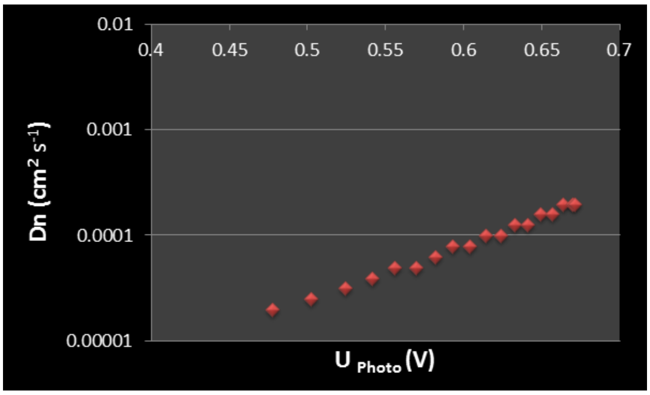
With the ability to auto-sequence techniques, the full suite of measurement possibilities can be run at a click of the mouse. Unlike other systems, the ModuLab XM PhotoEchem was designed to allow all measurements to be run in sequence without any interference from the end user. This greatly increases productivity and ease of use.

Auto - Analysis

Detailed Analysis of DSSC's Has Never Been Easier

Data can be auto-analyzed with pre-programed algorithms. Data is presented in graphical format allowing researchers to quickly evaluate their samples and provide in-depth information that is unavailable with simple I-V curve analysis alone.

Technique	Parameters
IMPS	Effective Diffusion Coefficient of Electrons
IMVS	Effective Lifetime of Electrons
Photo Voltage Delay	Effective Lifetime of Electrons
I-V	Fill Factor, Pmax, Voc, Isc, Efficiency
Charge extraction - Dark	Trapped Charge Density
Charge extraction - Short Circuit	Trapped Charge Density

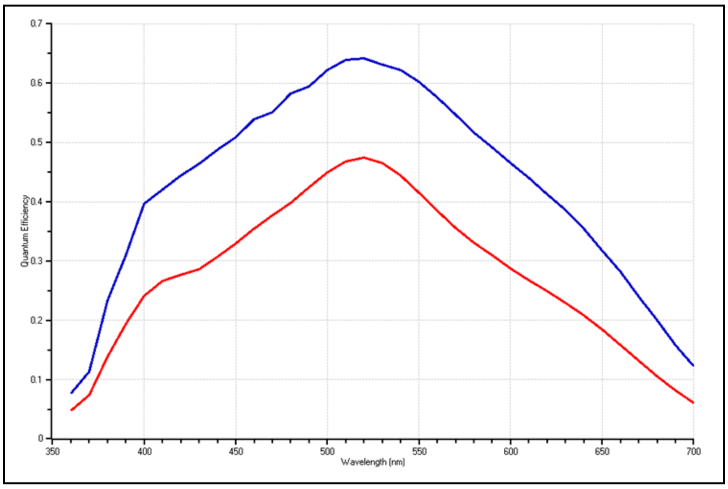


Auto Analysis of IMPS

IPCE

The IPCE (Incident Photon to Current Efficiency) add-on module allows Quantum Efficiency measurements of a wide range of photovoltaic materials. Unlike traditional light chopper based IPCE test systems, the IPCE module makes use of the Solartron Frequency Response Analyzer for improved signal to noise resolution. In addition, with built in bias rejection, white bias measurements for non-linear cells are included as standard. Features of the system include:

- Wavelength Range 350nm to 800nm
- White Light Bias source included with module
- 0.1 to 10Hz AC modulation technique for superiors noise rejection at low frequencies
- Automatic Determination of Quantum Efficiency and Short Circuit Current



IPCE spectrum of ionic liquid based Dye Cell with (Blue) and without (Red) white bias source

Optical Bench

At the heart of the ModuLab XM PhotoEchem is a collimated and highly focused, high power light source. Key features of this bench include:

- NIST Traceable Calibration of Light Sources
- High Light Intensity Measurements Excellent Thermal Stability
- Control and Measure up to 6 decades of Light Intensity
- Collimation and Focusing Optics
- Reference Detection Technique up to 100 kHz for Solid State Devices

NIST Traceable Results Packages

Each optical bench is equipped with a 10 MHz, fast Si Photodetector (specifically developed for Solartron ModuLab XM). The NIST traceable sensor inside each detector is supplied with an individual factory calibration file. End users can refer all measurements in units of power per unit area in confidence of the accuracy and repeatability of results.

Excellent Thermal Stability

Other systems might experience poor temperature management of the LED's that can lead to significant output drift during the course of experiments and therefore may invalidate the results. Under such circumstances the system may have a limited range of output power or require additional, expensive feedback control electronics to regulate the output of the light source.

The new ModuLab XM PhotoEchem incorporates high stability, high power LED's which offer excellent thermal stability while eliminating the need for feedback control loops.

Control and Measure up to 6 Decades of Light Intensity

The fast Si Photodetector has seven gain stages which provide excellent measurement resolution for very low level intensity studies. The addition of a 0.01 Neutral Density filter extends the range of the measurement possibilities to over 6 decades of intensity.

A two stage collimation and focusing optical arrangement ensures high power beams with > 0.1 Sun equivalent intensity and excellent homogeneity. This impressive performance is achieved without having to alter the optical arrangement thus ensuring repeatability of measurements.

Reference Detection to Eliminate Phase and Magnitude Errors at High Drive Frequencies

The reference mode for transfer function techniques for photoelectrochemical systems such as IMPS and IMVS was first developed by Prof Laurie Peter in the late 1980's. The ModuLab XM PhotoEchem bench incorporates this philosophy with the addition of a reference mode. A 50:50 Anti-Reflective Coated beam splitter directs an equal amount of light onto the sample and the reference detector. The response of the cell under test is directly compared with the response of the reference signal thus eliminating errors associated phase shift and changes in magnitude of light.

Not Just a PhotoElectrochemical System

The ModuLab XM PhotoEchem utilizes the powerful ModuLab Frequency Response Analyzer and Potentiostat technology. Existing systems can be upgraded to ModuLab XM PhotoEchem with an option card and optical bench.

A comprehensive suite of standard electrochemical techniques is included:

- Cyclic Voltammetry (Staircase and Linear Sweep)
- Potentiostatic Steps
- Normal and Differential Pulse Techniques
- Potentiostatic and Galvanostatic Impedance (Single Sine or Multi-Sine FFT)
- AC Voltammetry

The ability to control the optical bench for each of these techniques will allow researcher to develop more diagnostic techniques for DSSC's

Specifications

Potentiostat

Slots Taken	1
Cell Connections	2, 3 or 4 terminal
Instrument Connections	CE, WE, RE, lo
Floating Measurements	yes
Impedance Measurement Bandwidth	1 MHz (via FRA)
Maximum ADC sample rate	1 MS/s
Smooth Scan Generator	64 MS/s interpolated and filtered
Maximum Time Record	Unlimited
DC Scan Rate (potentiostatic)	1.6 MV/s to 1 µV/s
DC Scan Rate (galvanostatic)	60 kA/s to 200uA/s
Minimum Pulse Duration	1µs
IR compensation	yes
Counter Electrode	
Voltage Polarization Range	± 8 V (± 100 V)*
Current Polarization Range	± 300 mA (± 2 A)*
Maximum Compliance (Ce. vs LO)	± 8 V
Bandwidth (decade steps)	1 MHz to 10 Hz
Polarization V / I error (setting and range)	0.1% + 0.1%
Slew Rate	>10 V / µs
Reference Inputs (RE)	
Connections	Differential Input
Cable Shields	Driven / Ground
Maximum Voltage Measurements	± 8 V
Ranges	8 V to 3 mV
Accuracy (reading % + range% + offset)	0.1% + 0.05% + 100 µV
Maximum Resolution	1 µV
Input Impedance	>100 GΩ, < 28 pF
Input Bias Current	< 10 pA
Working Electrode (WE)	
Maximum Current	± 300 mA
Ranges	300 mA to 30 nA
Accuracy (reading % +range % + offset)	0.1% + 0.05% + 30 fA
Maximum Resolution	1.5 pA
Compliance Voltage Range (floating)	± 8 V
Auxilary Electrodes (A, B, C, D)	
Connections	4 (each differential)
Specification	Same as RE above
DC Measurement	Synchronized to RE
Impedance Measurement Bandwidth	1 MHz (via FRA)

* not compatible with Photoelectrochemical card

Optics

Wavelength Range	400 nm-700 nm
Intensity Range	6 decades (with ND filter)
Max Beam Divergence	4°
Max Beam Diameter / cell size	1 cm
IMPS / IMVS Transfer Function	Reference Photodetector
Calibration	NIST Traceable
LED Driver Max Current	2 A
Typical LED Stability at MAX power	< 2% drift after 24hrs
LED Driver Max Frequency (IMPS and IMVS)	100kHz

LED Options

LED Options (nm)	Max Power (mA)	Bandwidth (FWHM) (nm)
420	500	12
455	1000	18
470	1600	29
505	1000	30
530	1600	31
590	1600	14
625	1000	16
660	1200	25
Cold White	1000	n/a
Warm White	1000	n/a

Frequency Response Analyzer

Maximum Sample Rate	40 MS/s
Frequency Range (1 MHz and 300 kHz options)	10 µHz to 1 MHz or 10 µHz to 300kHz
Frequency Resolution	1 in 65,000,000
Frequency Error	± 100 ppm
Minimum Integration Time per measurement (single sine, FFT or Harmonic)	10 ms

Signal Output

Waveform	Single Sine, Multisine
Single Sine Sweep	Linear / Logarithmic
Multi-Sine	All Frequencies or Selected Frequencies

Analysis Channels

Accuracy (ratio)	± 0.1%, ± 0.1°
Anti-alias and digital filters	Automatic
Analysis Channels	RE, WE, Aux A/B/C/D
Analysis Modes	Single Sine, FFT, Harmonic
DC Bias Rejection	Automatic

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