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QUANTUM YIELD BERLIN

QYB Quantum Yield Berlin GmbH | Braunschweiger Str. 71 | D-12055 Berlin

Update Notes LuQY-Control v1.9.2

1) **Implied Voc (iVoc) changed to quasi-Fermi level splitting (QFLS)**
While the iVoc metric is typically used in Si solar cell research, we figured that most of our customers prefer to use the term quasi-Fermi level splitting. Thus all the iVoc predictions in V have been changed to QFLS predictions in eV. The absolute numbers are identical though, it is more a semantic change.

2) **Remote control of software**
The entire LuQY-Control software can now be controlled from external, user programmed code running on the measurement computer.

The following code snippet is an exemplary **Python code** to open a local TCP connection to the LuQY-Control software and record a PL measurement (a more detailed code example incl. adjusting integration time and recording the dark measurement can be found in the manual section 6.4.3):

```
import socket

# Connect to local TCP host via port 6341
sock = socket.create_connection(('localhost', 6341))

# Define function to send commands to LuQY-Control software and receive
response
def send_receive(command):
    # Send command terminated with CRLF
    sock.sendall(command.encode('utf-8'))
    # Readout response from software
    response = b""
    while not response.endswith(b"\r\n"):
        chunk = sock.recv(200000)  # reads up to 200000 bytes
        if not chunk:
            break
        response += chunk
        # user feedback the response string
        print(response.decode('utf-8').strip())
    # Return response to function caller
    return response.decode('utf-8').strip()

# Perform actions
try:
    # Activate Laser
    send_receive("Laser On\r\n")
    # Open shutter
    send_receive("Shutter Open\r\n")
    # Define the savefile path and name
    send_receive("SaveFile c:\\measurements\\example\\test.txt\r\n")
    # Record a measurement
    send_receive("RecordSpectra\r\n")

finally:
    # Close TCP connection
    sock.close()
```

A full command list and further information can be found in the updated manual section 6.4.

3) Measurement Settings section: revised and added functionalities incl. new sweep options.

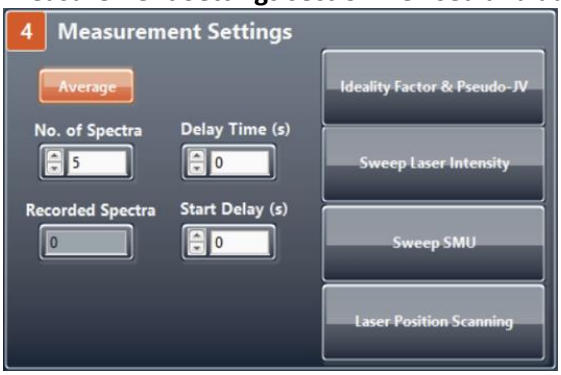

*Figure 1: new **'Measurement Settings'** section with an added "Start Delay" option and more sophisticated sweep functionalities as a sub window opened by buttons on the right.*

The new measurement settings section comes with a basic added function called **"Start Delay"**. This function allows to add a certain delay time, before the first spectrum of a measurement is recorded. It can e.g. be used to ensure a certain time of light stabilization in PL measurements before the spectrum are recorded.

Further, the buttons on the right open up sub-windows which allow to perform more sophisticated measurement sweeps such as laser intensity PL measurement sweeps or current density EL measurement sweeps

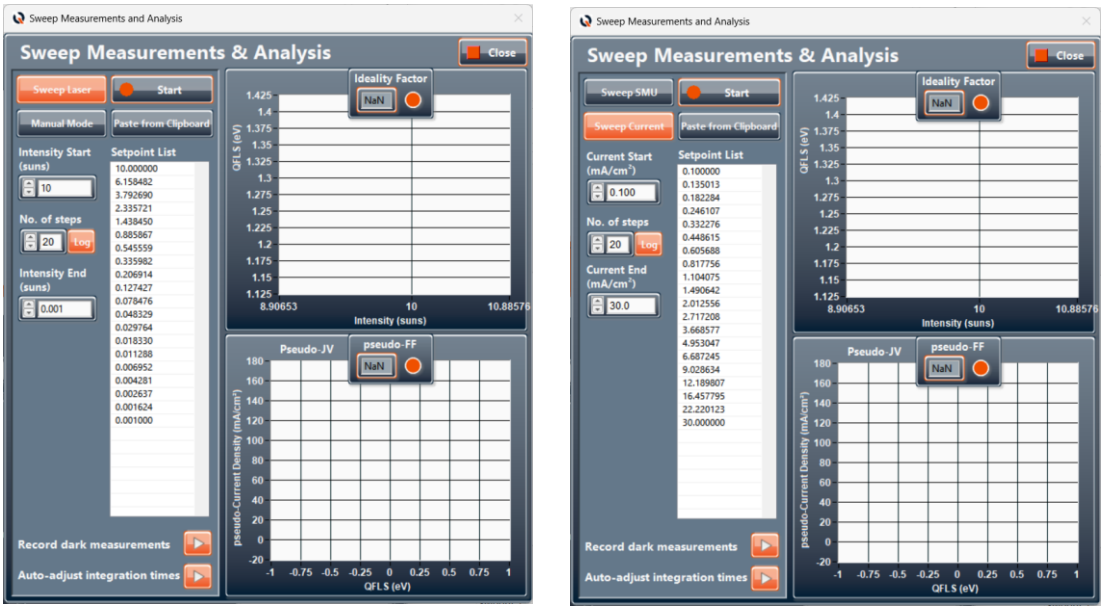

*Figure 2: new **'Measurement Sweep'** sub-window for laser intensity sweeps (left) and el. current density sweeps (right).*

You can now more clearly define the setpoints of your sweeps or paste them entirely user defined from clipboard.

Further, there is an automated PL measurement sweep function which **directly extracts the ideality factor and the pseudo-JV curve by a simple click.** Please watch the video from our website or have a look at the updated manual section 6.3.5 for all details.

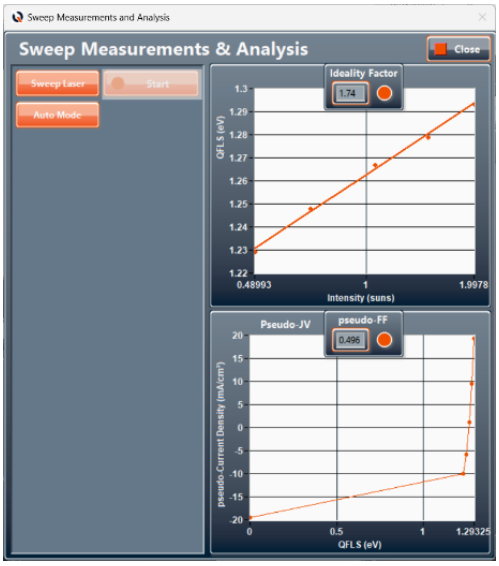

*Figure 3: new **automated measurement sweep with ideality factor and pseudo-JV extraction.***

4) Load and view previously recorded measurements to the results view graph

When **'Live View'** is turned off, the last measurement result is displayed. In this view mode, an additional **'Log'** button appears above the photon flux axis which allows to show the data on logarithmic scale.

*Figure 4: new **results view graph with option to load and view previously recorded measurements.***

Further a **'+ Load Spectra'** button allows to load previous measurements into the results view graph. After loading previously recorded measurement files, further buttons appear which allow to de-select all previous measurement graphs from displaying **('Un/Check All')** and to remove again all measurements from the graph which are de-selected **('- Unchecked'). Individual measurements can be de-/selected from the plot by clicking the measurement's checkbox in the graph legend.**

5) SMU: current density control mode added.

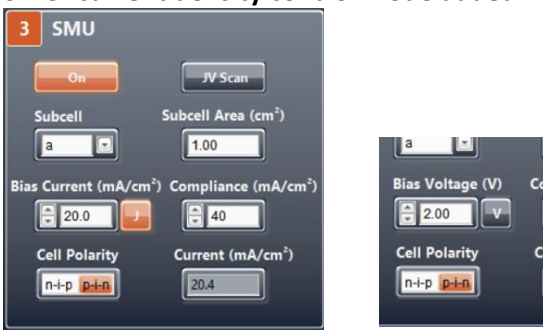

*Figure 5: revised section 3 **'SMU'** with added current density control mode left and traditional voltage control mode right. The modes can be changed by clicking the 'J' or 'V' buttons..*

You can switch between bias current density or bias voltage mode by clicking the J / V button. Enter your desired el. bias values, change the current limit compliance and cell polarity if required. Eventually, click the Off button to switch electrical biasing into the On mode. More details in revised manual section 6.3.4.

6) Load EQE: revised GUI

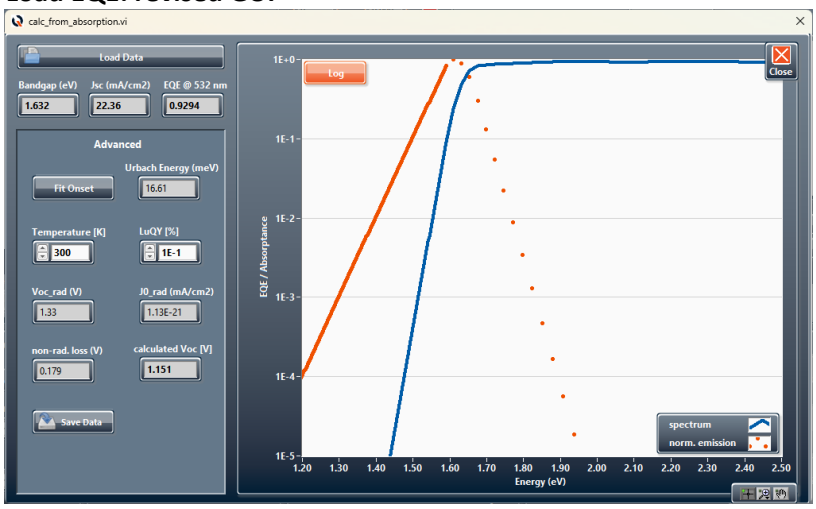

*Figure 6: **'Load EQE'** window with revised button arrangement.*

- Advanced: parameters are automatically calculated when Temperature or LuQY input fields are changed after "Fit Onset".
- Advanced: savefile was revised and now includes both the fitting results and the EQE/emission spectra. Exemplary savefile:

```
J0,rad (mA/cm²)      1.126E-21
Jsc (mA/cm²)         22.356
Voc,rad. (V)         1.330
LuQY(%)              0.100
Non-rad. loss (V)    0.179
Voc,calc. (V)        1.151
Urbach Energy (meV) 16.608
Temperature (K)      300.000
Band Gap (eV)        1.610


Energy (eV)   EQE_PV (no units)   Norm. emission (arb. units)
5.000E-1      2.922E-30           4.888E-12
5.022E-1      3.333E-30           5.168E-12
5.044E-1      3.801E-30           5.465E-12
…             …                   …
```

7) **Laser section: revised order of buttons and displays, spot sized can now be changed by single click.**

Figure 7: revised section 2 ***'Laser'*** *with changed button arrangement and new spot size slider.*

8) **SMU: JV scan added save JV function**

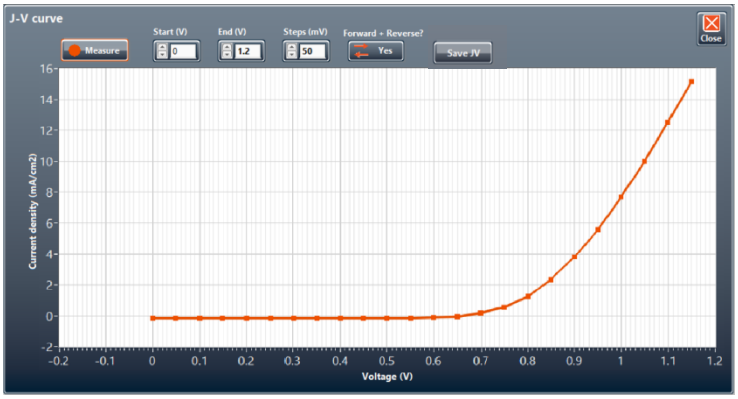

Figure 8: new ***'JV scan' window*** *with Save JV option.*

"Save JV" now allows to save the measured JV file. The file will be saved in the folder and filename defined on the main GUI window but will receive a "_JV" extension behind the filename.

9) Added functions in application settings

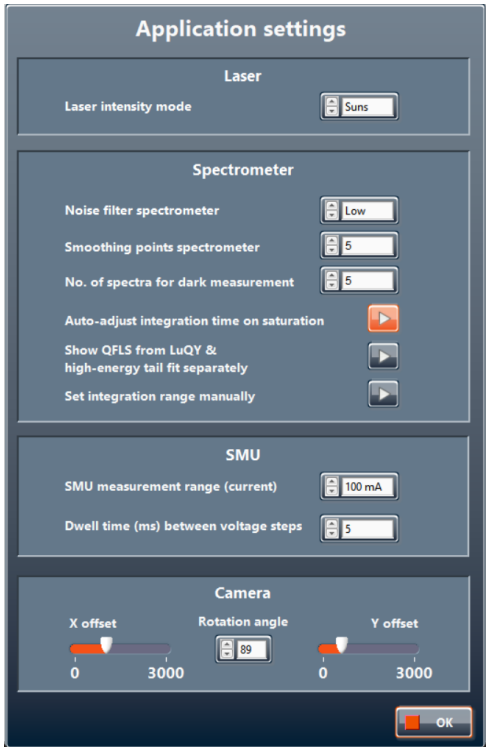

Figure 9: revised application settings window with new functions to show QFLS prediction from LuQY and high-energy tail fit method as well as to set the wavelength range for photon flux integration in LuQY calculation manually.

There is a new section 'Laser' in the application settings which allows you to change the Laser intensity mode which is by default given in suns-equivalents in the software and can be changed here to a direct mW/cm² power density control. In this mode, Section 2 – Laser in the main GUI will allow you to enter the setpoint Laser intensity directly in mW/cm².

While functions related to measurement sweeps (change integration time and record dark spectrum at each measurement setpoint) have been moved to the individual measurement sweep sub-windows, the Spectrometer part in the application settings has received two additions:

a) The user can now have QFLS predictions from LuQY and from high-energy tail fitting method displayed and saved in the savefiles
b) The wavelength range for integration in the LuQY calculation can now be set manually

For more information have a look at the manual section 6.3.7.

10) General bugfixes

Several bugfixes are included in this update which will not be discussed in detail here.