Light Beam Induced Current (LBIC) Mapping System of Photovoltaic Cells

User's Guide
Key features:

- Fully integrated automatic turn-key system: no optical alignment is necessary;
- Compact (20"×21"×26.5") and light weight (~20lbs);
- High measurement throughput (~0.1 second/point) for high speed, large-area solar cell inspection;
- Excellent spatial resolution (~65 µm in normal mode and 30 µm with F-theta lens) for micro-sized defect detection;
- Multiple laser excitation wavelengths available to inspect all commercial solar cells and devices under development.

Introduction

The energy conversion efficiency of a photovoltaic cell can be measured with the equation below:

\[ \eta = \frac{P_m}{A \times E_c} \times 100 \]

where \( \eta \) is the efficiency, \( P_m \) is the generated maximum output power, \( E_c \) is the irradiance of the normalized standard spectrum, and \( A \) is the surface area illuminated [1,2].

The equation shows the accuracy of the measurement is directly related to the area. Traditional ways of measurements always using a relatively large area, thus only the averaged performance of this area can be calculated. However, the solar cell is not always uniform within the area tested due to multiple reasons such as impurities or precipitates, which results in inaccurate evaluation of the solar cell [3].

Alphasense's light beam induced current(LBIC) mapping system provides a solution to accurately evaluate the photoresponse from individual points within any given area of a solar cell; A laser spot is moved in a point-by-point raster scan pattern, and the corresponding photocurrents are collected to reconstruct an intensity contour image. Consequently, device non-uniformity issues and fabrication defects can be revealed based on the photoresponse mapping.

Compared with existing commercial products for solar cell mapping [4], the merits of our product include the following aspects:

- Fully integrated and easy-to-use turn-key system. Data collection, analysis and display is fully automatic, and there is no need for complicated optical alignment;
- Compact and standalone system. The bench-top system has a small footprint, thus saving precious lab space;
- Low cost solution. Unlike existing products, in which
expensive (i.e. several thousand dollars per axis) translational stages with long travel length and fine step size are used, our product utilizes a relatively inexpensive high-speed galvanometer scanner to quickly sweep the laser across the solar cell surface. Additionally, an external lock-in amplifier is typically used in existing product to obtain good signal quality. In our solution, however, digital lock-in is implemented with the data acquisition circuitry, which further reduces the overall system cost;

- Reliable and stable under typical lab environment. Digital lock-in is used in our product to enhance the signal to noise ratio, and to eliminate any artifacts caused by environmental vibrations. Therefore, the system is reliable and stable under typical lab environment, and does not require an optical table for vibration isolation.

**Schematic diagram and Experimental setup**

Figure 1 illustrates the LBIC solar cell mapping system. The laser beam from the excitation laser source is directed onto the solar cell surface through optical components, including a reflecting mirror, a beam splitter and a galvanometer scanner. The galvanometer scanner is controlled by control electronics to sweep the laser spots in a raster scan pattern. A mechanical chopper is used in the beam path to modulate the excitation laser source. Since photocurrent is in pace with the laser excitation source, while noise is random in nature, subsequent digital lock-in amplification of the modulated photocurrent signal can help dramatically enhance the signal to noise ratio. Consequently, noises from various sources can be minimized to avoid artifacts in the reconstructed photoresponse map.

![Schematic diagram of the LBIC mapping system.](image)

Figure 1. Schematic diagram of the LBIC mapping system.

Figure 2 shows a picture of the LBIC product. The LED light on the front panel indicates the system status.
The power switch is used to turn on/off the system, and an emergency stop is used to reset the system in the case that the system malfunctioned.

USB connectors are used to communicate data and command between the LBIC system and a computer.

Figure 2. Product display.

The font sliding door is open from the side, allowing the user to position the solar cell sample within the sample compartment. To properly position the sample, one should make sure that the silver bus is placed right under the iron click and the back of the solar cell is in good contact with the aluminum plate.

Experimental section

Figure 3 (B) is a photoresponse map reconstructed from a defect-free silicon solar cell (9mm × 9mm) at 543.5 nm laser excitation with fine scan mode (110 μm/step). Except for the silver buses shown in light yellow, the rest of the area has a relatively uniform red color indicating high energy conversion efficiency. Additionally, the relatively uniform red color in Figure 3(B) indicated that the digital lock-in dramatically minimized noises and avoided artifacts in the reconstructed photoresponse map by enhancing the signal to noise ratio. Figure 3(C) is a photoresponse map reconstructed from a defective solar cell with the same inspection area. Compared with Figure 3(B), several yellow spots appeared in the reconstructed map, which corresponded to the defective areas.

The results clearly demonstrate that the LBIC mapping system of PV cells can effectively detect various defects present in solar cells, which are introduced either during the fabrication process or after field application.
Figure 3. (A) photo of a silicon solar cell (9mm × 9mm). Photoresponse map reconstructed from (B) a defect-free silicon solar cell (9mm × 9mm) and (C) a defective silicon solar cell. The excitation laser wavelength is 543.5nm, and the scanning step is 110 μm.

Software section

Figure 4 is a display of the software user interface. After "run" is clicked on the software, the menu on the top has three options: USB Connection, Preview, and Start scanning.

Figure 4. Software user interface.

After the user clicks "USB Connection", the LBIC system will scan through all the peripheral serial ports. Connection between the system and a computer will be established via a USB 2.0 interface. The user is then prompted to a preview window to set up the scanning parameters, including the length and width of scanning area, and the step size (Figure 5 (A)). The desired inspection area are subsequently previewed. Users can adjust those three parameters and observe the corresponding inspection area, until they are satisfied with the settings.

Figure 5. (A) Preview.
Raster scan of the specified inspection area will be initiated by clicking "Start scanning" on the top selection menu. Once the scanning is started, the green scanning status LED will be turned on. Photocurrent collected along the laser scanning path are displayed in both a 1D (i.e. data array) and 2D (intensity contour) format. Picture palettes with home, zooming and dragging functions are included in the 1D data display for the user to better examine data collected within area of interest (Figure 5(B)).

If for any reason, the USB connection were failed, or the scanning were stuck, the user can click the "emergency stop" button on the software interface to terminate the whole process. The system will be refreshed and ready for new set of commands.

References


