# NREL Invents a Superior Diagnostics Tool for Solar Cell Manufacturing

A solid-state optical system, invented by the National Renewable Energy Laboratory (NREL) and commercialized by Tau Science, measures solar cell quantum efficiency (QE) in less than a second, enabling a suite of new capabilities for solar cell manufacturers. QE measurements indicate how well a solar cell converts the various wavelengths of sunlight into electricity.

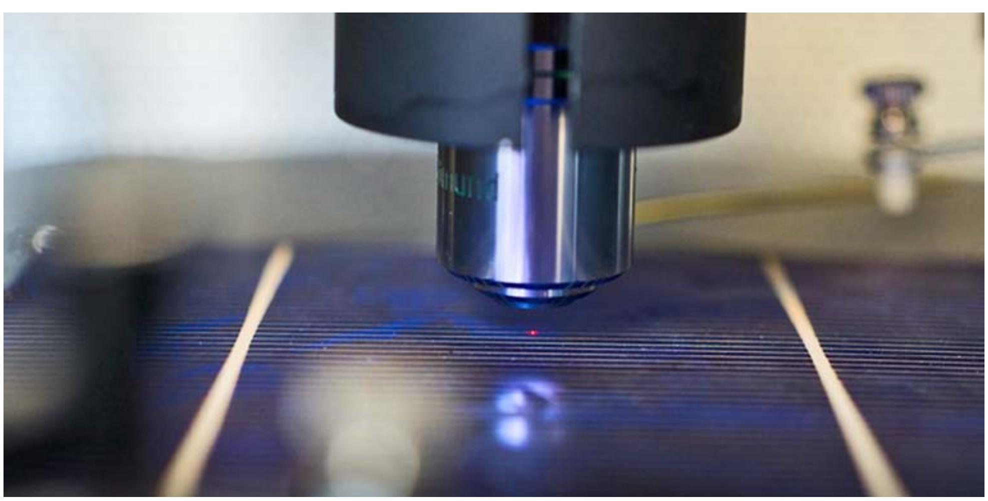
To ensure quality and optimize solar cell efficiency, solar cell manufacturers want to measure the QE of every cell they produce. When a cell does not perform in a certain wavelength range, that tells manufacturers to adjust their production tools to fix the problem. So measuring QE is a crucial diagnostic tool for solar cell performance.

The problem is, traditional methods for measuring QE on the production line have been too slow. One cell moves past a reference point in the line about every second, but a conventional QE measurement takes up to 20 minutes per cell. Because the line goes so much faster than the measuring process, only one in a batch of 10,000 or even 100,000 can be evaluated.

## The Parallel Processing Solution

NREL's technique, commercialized by Tau Science as the FlashQE™ system, uses a solid-state light source, synchronized electronics, and advanced mathematical analysis to parallel-process QE data in a tiny fraction of the time required by the current method.

The conventional approach has been a step-by-step process for each cell, measuring one QE data point at a time through a range of light wavelengths. The data are plotted on a graph to



*NREL's prototype QE measurement system uses pulsing lights to generate currents in a solar cell. Within the span of a second, the varying currents produced by the solar cell are translated into data that reveal the quantum efficiency and other characteristics of that cell. Tau Science licensed this NREL technology and commercialized it as the FlashQE system.* Photo by Dennis Schroeder, NREL PIX 18967

The Spectrum of Clean Energy Innovation

Fundamental Science
Market-Relevant Research
Systems Integration
Testing and Validation
Commercialization
Deployment

*Through deep technical expertise and an unmatched breadth of capabilities, NREL leads an integrated approach across the spectrum of renewable energy innovation. From scientific discovery to accelerating market deployment, NREL works in partnership with private industry to drive the transformation of our nation's energy systems.*

*This case study illustrates NREL's innovations in Market-Relevant Research through Commercialization.*

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produce a QE curve, which illustrates how well the cell produces electricity from light of various wavelengths. NREL scientists, however, have devised an ingenious new approach, in which parallel processing allows all of the QE data points to be measured simultaneously to produce a QE graph in 1 second—or more than 1,000 times faster than the industry's state-of-the-art technique.

An array of light-emitting diodes (LEDs) is at the heart of this method. Each different-colored LED generates a specific wavelength found in sunlight. The LEDs are controlled by a system of unique synchronized electronics so that, within the span of a second, all of the following happens:

- Several dozen different-colored LEDs blink on and off at varying frequencies above the solar cell, with each LED emitting light at a wavelength corresponding to a different portion of the solar cell's test spectrum.
- The light from each LED generates electrical current within the solar cell, rising and falling at the unique drive frequency of the associated LED.
- The current is collected from the solar cell and fed into a computer as a vast jumble of electrical signals.
- Using an algorithm to identify patterns in this jumble of signals, a mathematical filter simultaneously and instantly sorts out the currents generated from each LED and applies a calibration factor to the signal.
- The data are plotted into a QE curve, which reveals how well the cell generates electricity at specific wavelengths.

To summarize, this innovative design allows the light from all the LEDs to shine all at once on one cell. Thus, multiple QE measurements can be made concurrently, rather than one after another as in the conventional approach.

## A Leap Forward in Capabilities

The FlashQE system is not just an incremental improvement over current QE measurement options. Rather, its 1,000-fold increase in measurement speed is enabling numerous new capabilities for industry and laboratory researchers. For example, in addition to evaluating every solar cell, the system can:

- Monitor the quality of the entire manufacturing process. If there are unacceptable deviations, production can be quickly adjusted.
- Sort wafers by QE. Wafers with similar QE characteristics can be identified and "binned" together. Modules made from cells in the same bins lead to optimal performance.
- Map entire wafers. Three-dimensional mapping, mostly within a laboratory setting, can help identify performance characteristics and detect material problems within the cell.

In addition to these capabilities, the FlashQE system is less expensive than conventional systems, and has proven to be precise and stable.

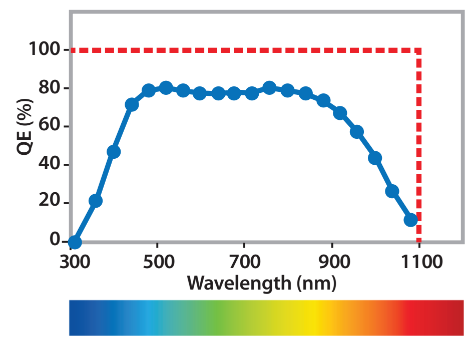
In recognition of FlashQE's great potential impact, R&D Magazine honored NREL and Tau Science with a 2011 R&D 100 Award, identifying it as one of the top 100 technological innovations of the year. The FlashQE system enables new capabilities needed by the solar industry—capabilities that can lead to better solar cells and modules, improved manufacturing production, and increased energy production. And this NREL technique, now available commercially, is almost certain to become the new industry standard for QE measurements.

## What does a quantum efficiency (QE) curve tell us?

The shape of a QE curve helps scientists and manufacturers to understand various characteristics of a solar cell—from how well it generates electricity from certain wavelengths of light, to which part of the cell needs improvement.

The graph below shows a basic QE plot (blue line) for a sample silicon solar cell. The vertical axis represents percent QE and the horizontal axis represents wavelength of light. The red line shows an ideal QE for a solar cell.

In this case, the curve is low in the far left-hand region because the cell has a lower response to blue light—that is, the cell does not use shorter-wavelength light very effectively to produce electrical current. The curve is low in the far right-hand region because it has a lower response to longer-wavelength red light. These deviations from the ideal indicate characteristics of the cell that need to be addressed—such as altering the material composition, the thickness of layers, or the quality of the top, middle, or bottom layers of the cell.

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