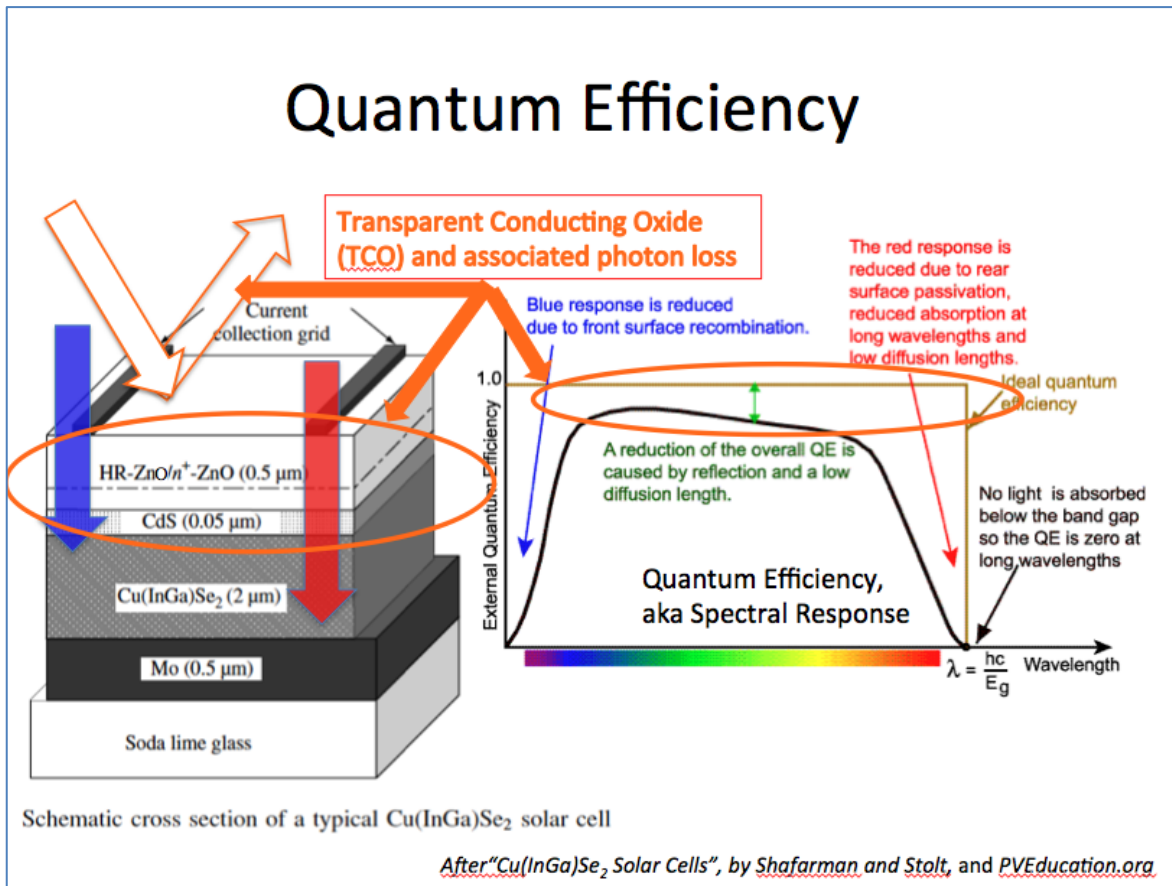


## Laboratory #5b Guide: External Quantum Efficiency Measurement

November 4, 2014

### Introduction

As we have discussed in lectures and in previous labs, the *Quantum Efficiency* (also known as the *Spectral Response*) is an important characteristic of any photovoltaic device. There are two versions of Quantum Efficiency (QE); External Quantum Efficiency (EQE) and Internal Quantum Efficiency (IQE). The latter is concerned only with the photons that are absorbed in the active region of the device, while the former considers all photons incident on the device. Clearly, it is much more straightforward to measure EQE. The EQE is determined as a function of wavelength, and is the ratio of incident photons to the number of electron-hole pairs that flow in the external circuit. The QE cannot exceed 1, and is generally measured under short circuit where the electric field within the device is large. However, QE measurements can be done at any bias voltage and can reveal information about recombination in the PV device.



At this point in the course, you should have extensive experience developing investigative methods to study the optical and electrical properties of PV materials and devices using the experimental set-ups, LabView-controlled instrumentation, and Igor Pro. In this lab, you will apply these capabilities to measure the EQE of two

different PV devices. Specifically, you will analyze the EQE of the Si photodiode and a CdTe solar cell. You will compare and contrast the EQE of the two different devices, and, using the measured EQE data, determine the short-circuit current density that would be expected if these devices were measured under an AM1.5G solar spectrum.

### ***Goals of Lab #6***

Your goals are to developing a deep understanding and sound expertise in measurement of the External Quantum Efficiency of photovoltaic cells. Your understanding should extend from the detailed operation of the LabView software, through to the instrumentation, the EQE measurement, and the impact of bandgap on expected current density under solar irradiation.

### Sample List

1. Si photodiode
2. CdTe solar cell

### ***Experimental Steps (Demonstrate understanding within your lab report)***

***It is strongly suggested that purpose of each step and the entire procedure be understood before experimental work is begun. Planning ahead can help save a lot of time.***

1. **Measure the incident light spectrum power density.** Set-up the optical system to yield a focused beam at the location where you intend to measure the EQE of the Si diode. Choose a suitable light intensity and slit width. Since EQE is defined as the ratio of photons/sec in versus current out, as a function of wavelength, consider the units you will need to have for the light spectrum data to be able to carryout this calculation. Also consider the methods you will need to use to achieve this. Keep in mind that the voltage output from the lock-in is something like the RMS voltage of the in phase component of the primary frequency of the measured waveform.
2. **Measure the current from the device** at or near short circuit when illuminated by the light source characterized above. The light intensity will be considerably less than in the previous lab, so consider how this measurement can be done with the available equipment. Besides directly reading the current with the Keithley, you may wish to employ a resistor across the output and choose to measure the voltage across it with the lock-in technique. How is this related to the short circuit current? The comments made in (1) with respect to the output voltage from the lock-in apply here as well.
3. **Develop the EQE plot for Si.** It may be useful to run through steps (1) and (2) incompletely to make sure you have enough light intensity from (1) to make a

good current measurement in (2). You may wish to apply reasonable smoothing to the data from (1) and/or (2), but be sure that the qualities are not substantially changed.

**4. Repeat 1-3 for CdTe**

**5. Lab report**

- a. Discuss experiment and qualitatively compare and contrast results for Si and CdTe.
- b. Determine the short circuit current density that would be expected if the Si and CdTe devices were illuminated by the AM1.5G spectrum.
- c. Report the expected short circuit current density if all photons in the AM1.5G spectrum could be converted to current, and report the results for the Si and CdTe devices as fraction of this total amount.
- d. Discuss (b) and (c) from the point of view maximizing the power conversion efficiency of a PV device exposed to our Sun's light.