Introduction:
The purpose of this project is to design and build a complete microwave reflectometer system to characterize the minority carrier lifetime and relative quantum efficiency (QE) of a silicon solar cell.

Many measurement techniques occur at the end of the fabrication process when physical contacts may be applied to the solar cell. Ideally, testing should be performed earlier so that defective cells can be removed before spending significant resources completing the fabrication process. This technique leverages a contactless microwave probe to characterize the cell’s performance prior to surface metallization by modulating an LED light source to change the microwave reflectance by generation of excess charge carriers3.

Microwave Reflectometer:

An IQ demodulation scheme was designed to capture both the magnitude and phase information encoded in the reflectance signal.

• Carrier signal cancellation improves the dynamic range of the system while leaving sideband information untouched.

• Inherently more selective than a crystal detector while providing a smaller form factor than previously used techniques2.

System Diagram:

LED Control System:
The light engine has a distributed control system consisting of several cards. The primary system control card manages communications with the host PC via USB and is responsible for loading LED configuration test vectors onto the switch control cards. Communication with switch control cards is accomplished by utilizing a static memory controller interface across the backplane communication bus, with the CPLDs programmed to act as memory to store incoming test vectors. The test vectors contain information on pulse duration, LED drive levels, number of cycles, and whether or not to modulate.

The benefit of this setup is that the switch control cards act as synchronous state machines driven by a single clock from the system control card, which allows for multiple LEDs to be modulated in unison across multiple cards.

Negative Index of Refraction Lens:

This lens enhances our microwave sensitivity by significantly increasing the spatial resolution in the far-field. Small spot sizes produced by the lens allow for far-field measurements of the solar cells without sacrificing SNR.

• Spot size: < 1cm²
• Effective gain: ~11dB
• Developed custom electroplating process
• Designed in SolidWorks²

• Focal length: ~ 4-7cm
• Optimal frequency: 10-12 GHz
• Fabricated with SLA 3D printer
• Low material cost

Results:
Project is currently in the system level integration phase of development. Initial testing of the measurement critical subsystems show full functionality. Preliminary data observed on the complete system show necessary signals required for digital signal processing.

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Primary References:

Measurement Electronics:
Custom low noise measurement electronics were designed to capture both the quantum efficiency and minority carrier lifetime data. Narrowband analog filters limit the bandwidth of the IQ signal in order to pull signals out of the noise floor for digital processing. Due to the unique architecture of the XMXS microcontroller chosen for this application, digital signal processing may occur on board prior to being transmitted over high speed USB to the host computer. Reference channels monitor the incident photon power for QE curve normalization.

• Single supply 5.5-9V
• Inputs protected up to 40V
• High speed USB data rate
• Alternate 8th order bandpass filter for long integration of extremely small signals
• Dual channel simultaneous 1MSps ADC
• Up to two additional 1MSps multiplexed sampling ADCs for reference signals
• Adjustable high gain instrumentation amplifiers