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Quantifying Electroluminescence Image Data for Multijunction Solar Cells

Summary: This study explores developing characterization methods for multijunction solar cells using electroluminescence.

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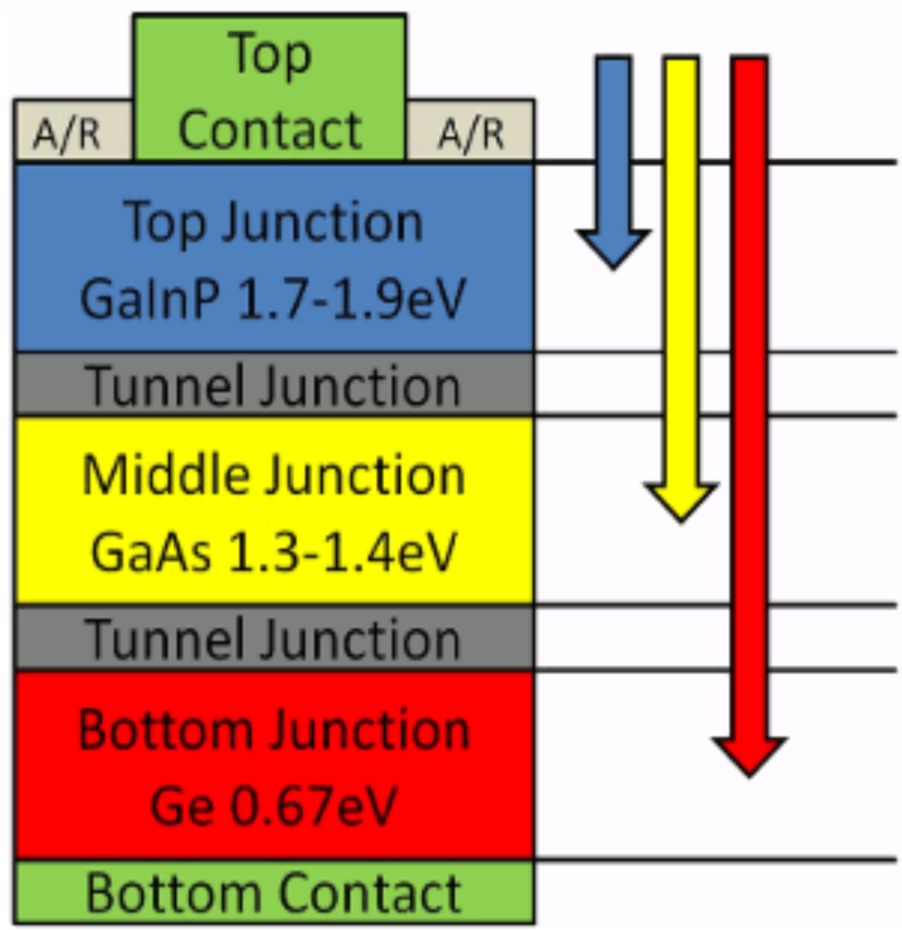
What is a Triple Junction Solar Cell?

- Comprised of three P-N junctions of different material
- Each junction absorbs a different wavelength of light
- Higher bandgap material located at the top of the cell
- Increases efficiency of the solar cell



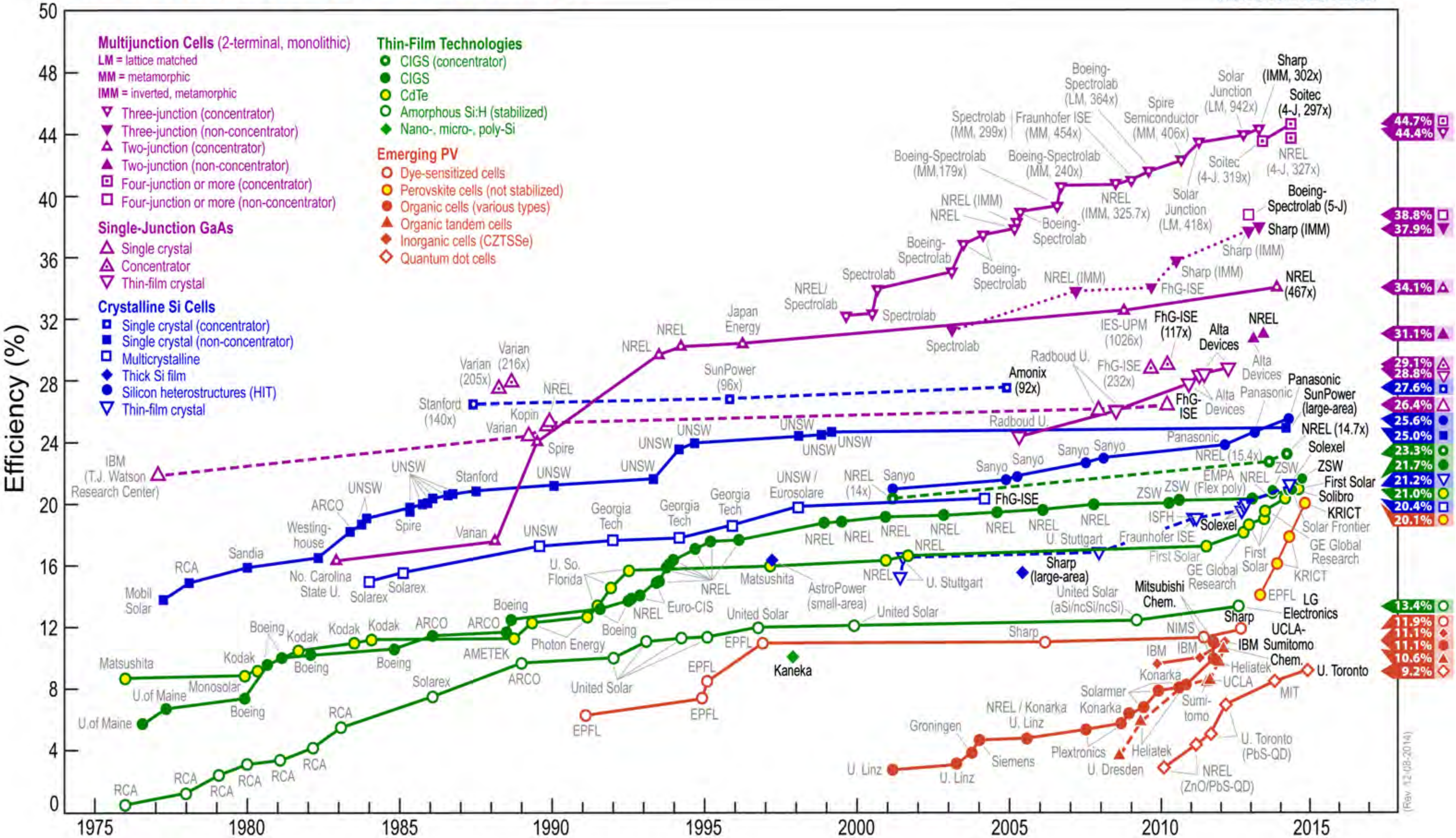
Weisse, J. (2010, November 28). Concentrated Solar Photovoltaics. Retrieved October 4, 2018, from http://large.stanford.edu/courses/2010/ph240/weisse2/

Advantages of Multi-Junction Solar Cells?

- Maximizes electrical energy per unit surface area
- Highest efficiency among solar cells
- Used for extraterrestrial applications
- Increases payload space
- Reduces launch costs


Loff, S. (2015, July 22). CubeSats Overview. Retrieved October 14, 2018, from https://www.nasa.gov/mission_pages/cubesats/overview

Efficiency of various solar photovoltaic technologies



NREL. (2014). Best Research Cell Efficiencies [Digital image]. Retrieved October 20, 2018, from https://3c1703fe8d.site.internapcdn.net/newman/gfx/news/hires/2014/nreldemonstr.jpg

Challenges and Limitation of Triple Junction Solar Cells?

- High cost
- Radiation damage while in space
- Few methods exist to test and characterize individual junctions within the cell

Research Motivation

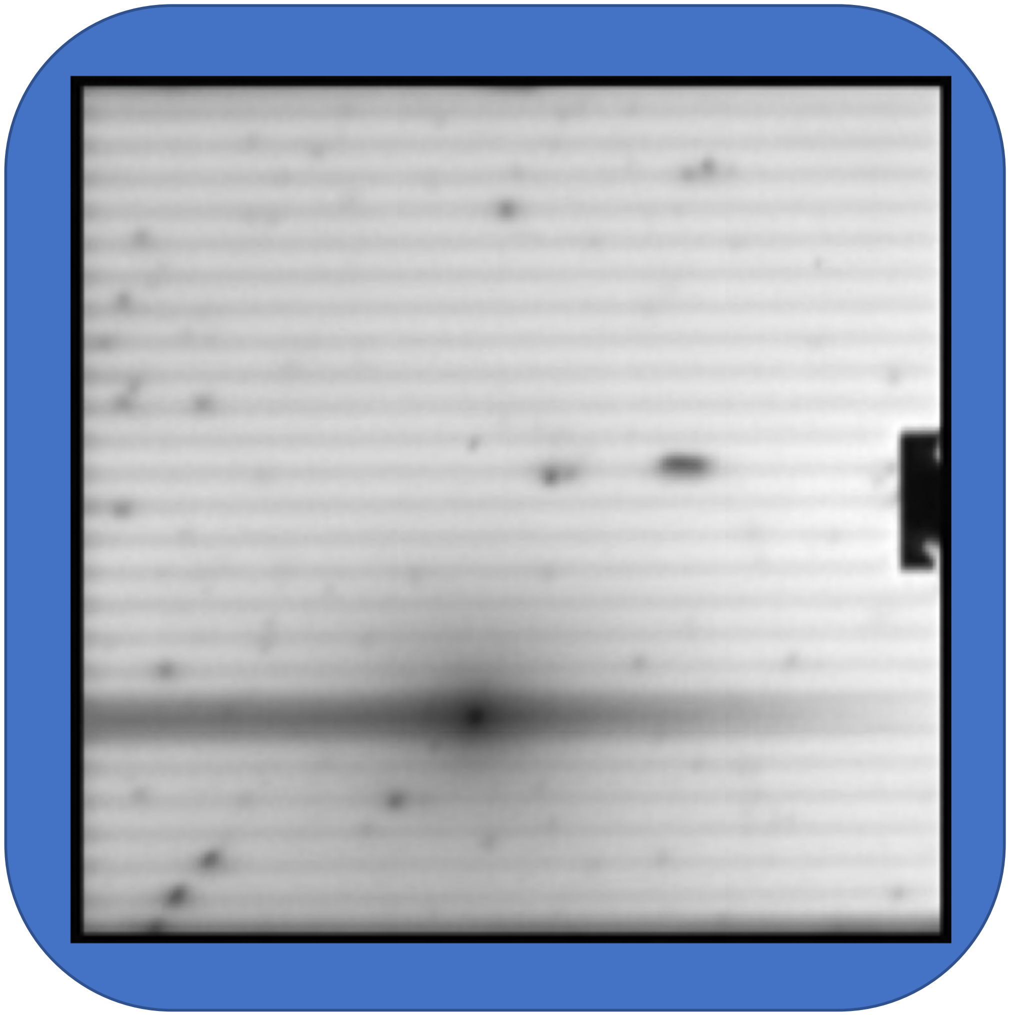
Electroluminescence (EL) imaging is generally used to gather qualitative data for photovoltaic cells, in an effort to quickly identify defective regions. In recent studies, a relationship was discovered between maximum intensity and operation voltage within single junction cells. This relation allowed dark IV curves and voltage maps to be generated from these EL images. This work inspired the idea to attempt to generate dark IV curves and voltage maps for individual junctions in multijunction solar cells using electroluminescence.

Research Methods

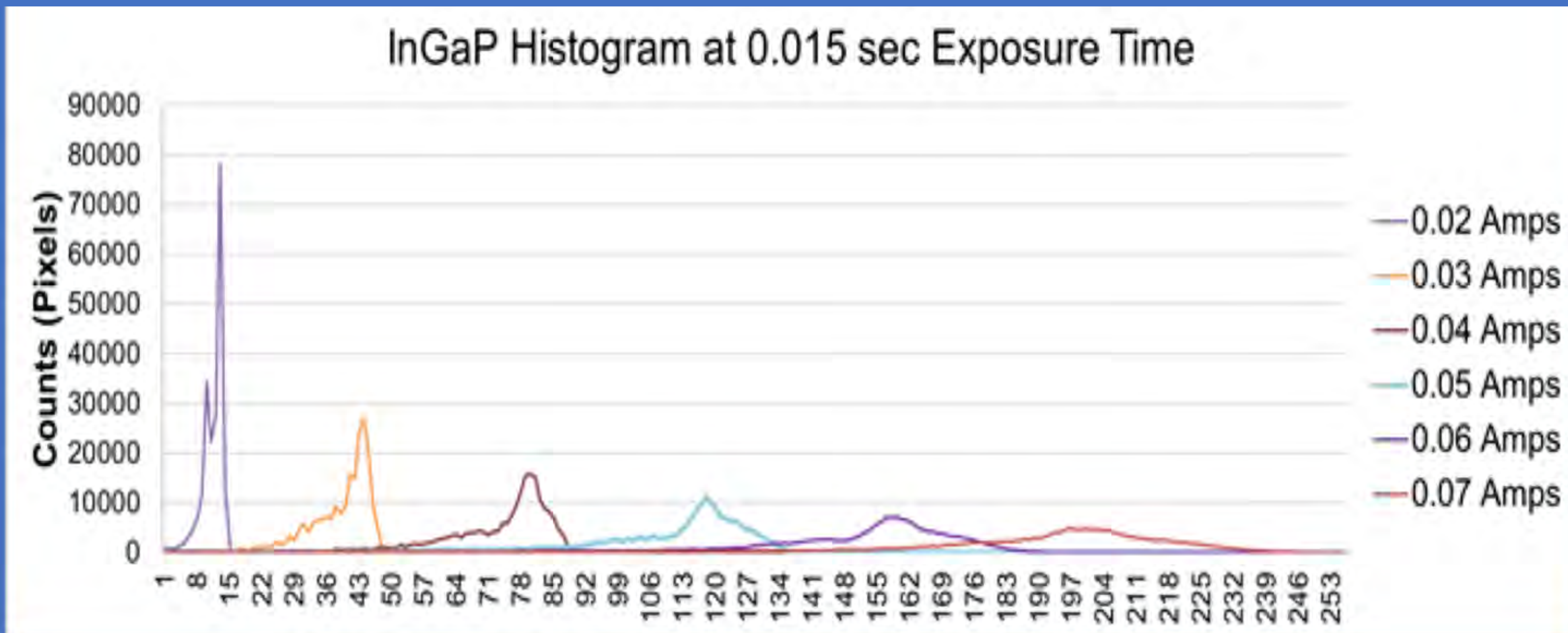
- A photovoltaic cell will emit photons that correlate to the material's band gap when a current is applied.
- A silicon charged coupled device (CCD) camera with filters was used to capture pictures of the cells.
- Exposure time was adjusted to obtain clearer images
- Background noise was subtracted to clean up the data
- Histograms were constructed using ImageJ software to determine the cell's max intensity.
- Operating Voltage (Vop) determined using equation

$$V_{op} = V_T \cdot ln\left(\frac{\phi(x_{max})}{C}\right)$$

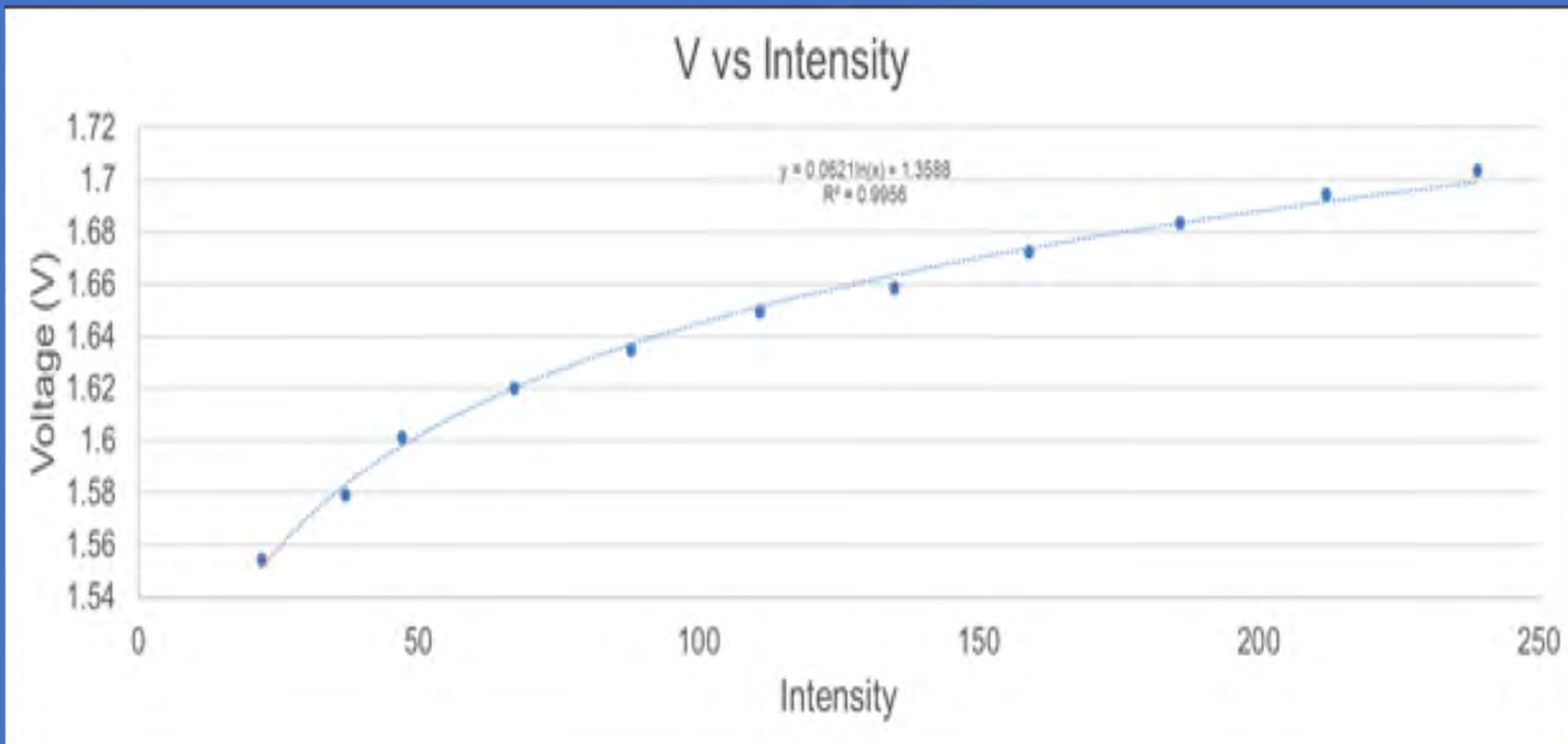
InGaP solar multi-junction cell with a forward current bias of 0.07 amps applied.



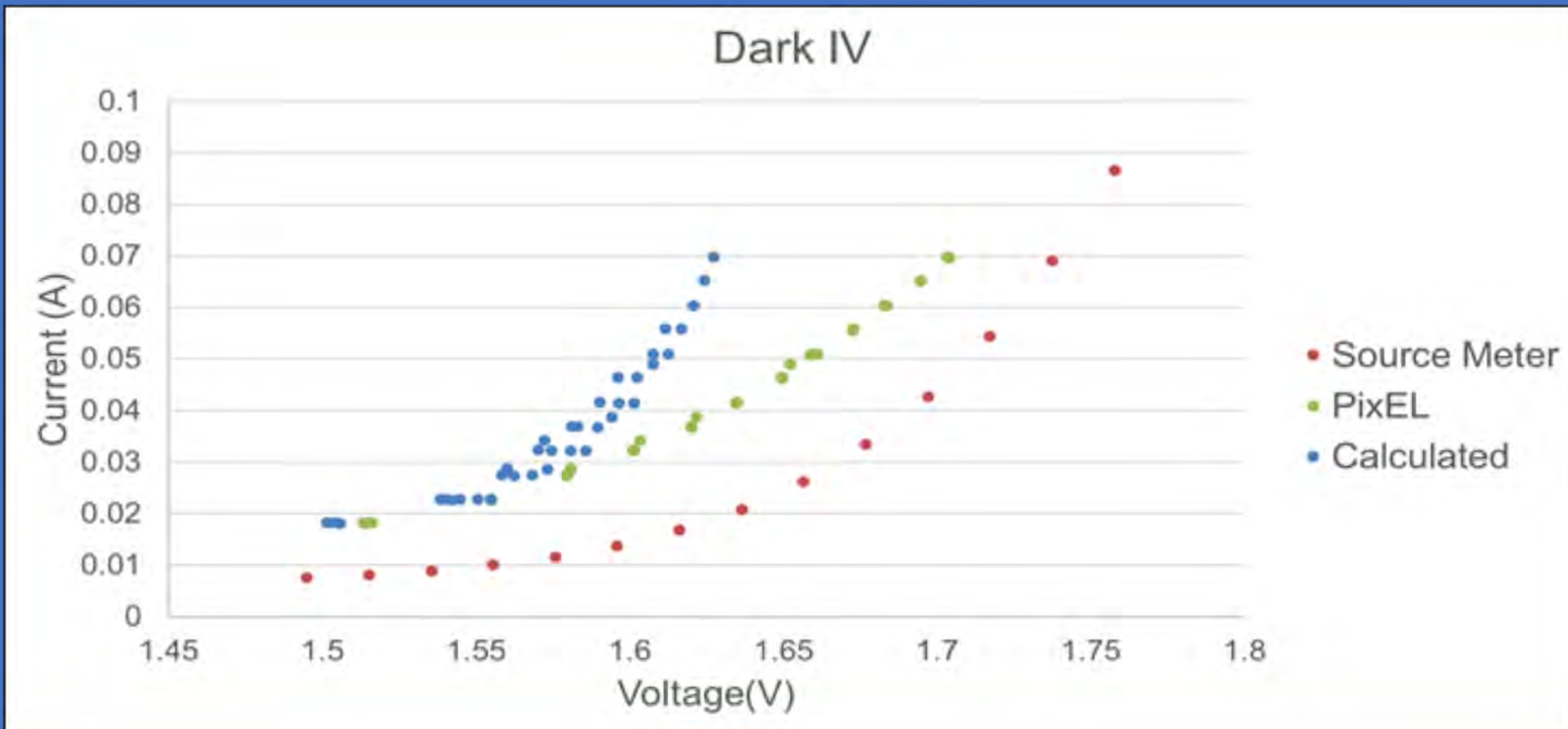
Histogram at various current biases for the InGaP cell at a 0.015 second exposure time.



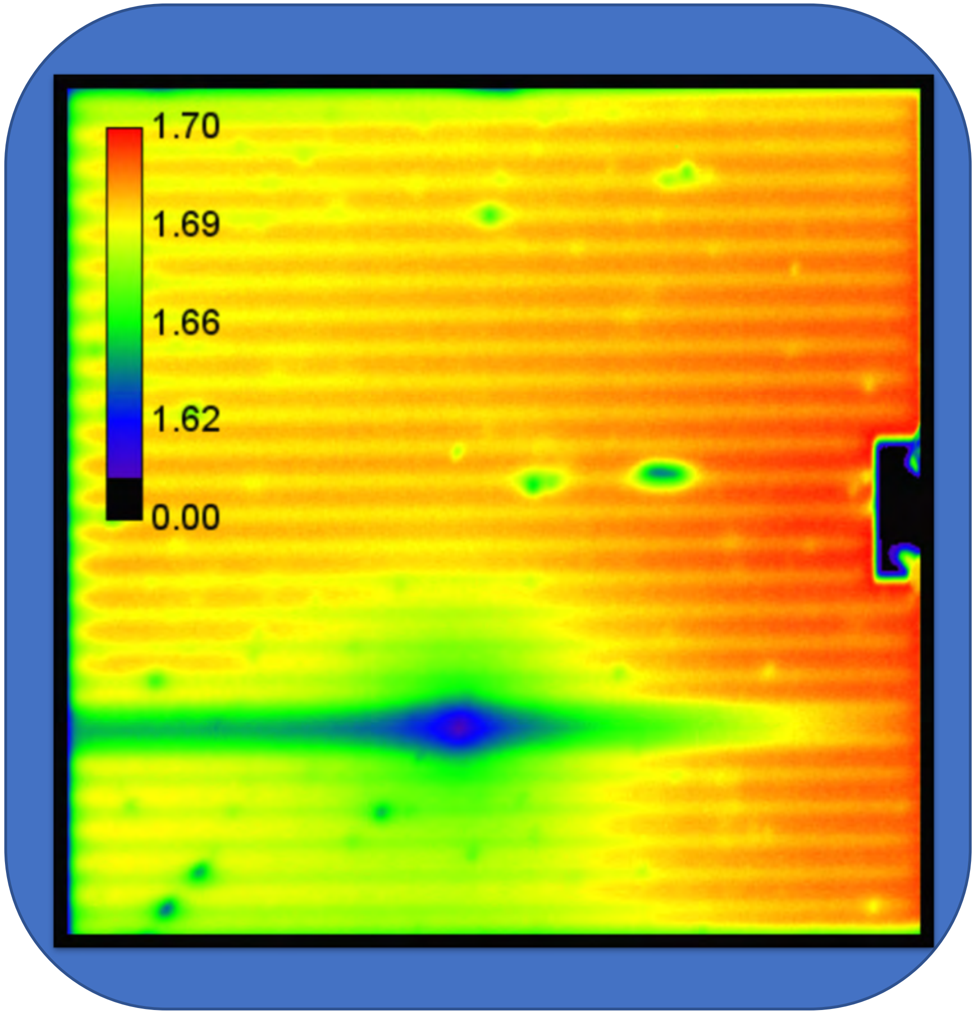
Relationship between the voltage measured by the Electroluminescence system and the max intensity determined by the image processing program, ImageJ.



Dark IV curves from a source meter, PixEL, and calculated data for an InGaP solar cell. The difference between PixEl and source meter data is due to contact resistance.



Using the relationship between voltage and max intensity, we can construct a voltage map using ImageJ software.



Local Calibration Factor

- Used to calculate Vop
- Related to material and optical properties
- Cell material and exposure time
- Need an initial voltage

$$C = \frac{\phi(x_{\max})}{\exp\left(\frac{v_{\mathrm{mod}}}{v_T}\right)}$$

  - ϕ = Intensity
  - v_{mod} = Voltage of cell
  - v_T = Thermal voltage

Experimental Results

Using the data obtained from ImageJ, and calculated Vop, voltage maps and dark current-voltage (dark IV) curves are created.

- Related voltage to max intensity to calibrate the voltage map.
- Created voltage map using ImageJ
- Graphed dark IV measured from a source meter and the EL machine (PixEL) along with dark IV calculated.

Next Steps?

The work done in this study will be a foundation for AFRL's work on this topic.

Future research would include obtaining a large sample of *C* values from isotypes for the junction of interest, average them, and use that value to obtain Vop for the junction.

I hope to continue working with the lab to complete this research.

What I learned from the experience

- Lab etiquette
- How to convey complex ideas to fellow scientists
- Qualifications and responsibilities for working in a national laboratory
- Advancements in the space and defense industry
- Networking strategies

Acknowledgements

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