Multi-Quantum Well (MQW) GaAs/AlGaAs Solar Cell

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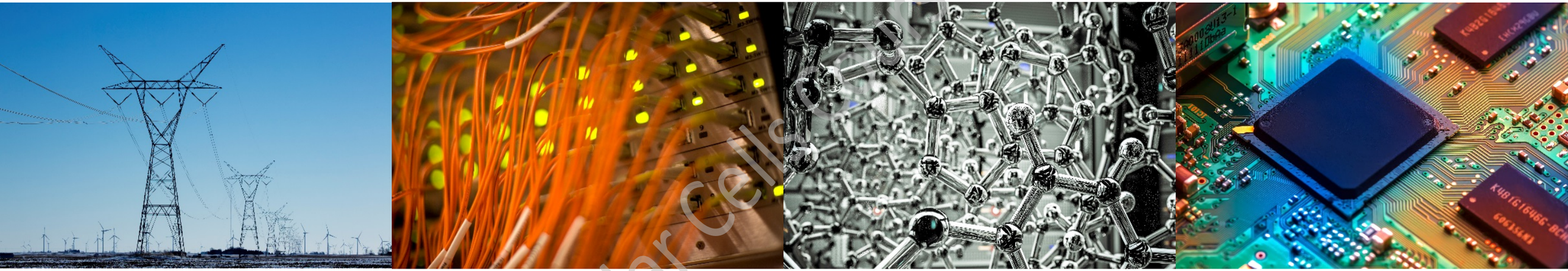
ECE 443 Final Project – Spring 2021



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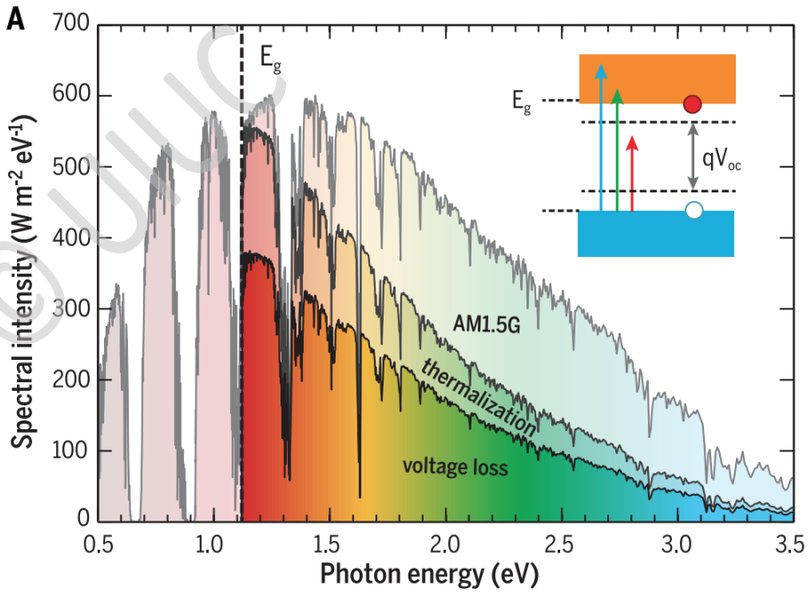
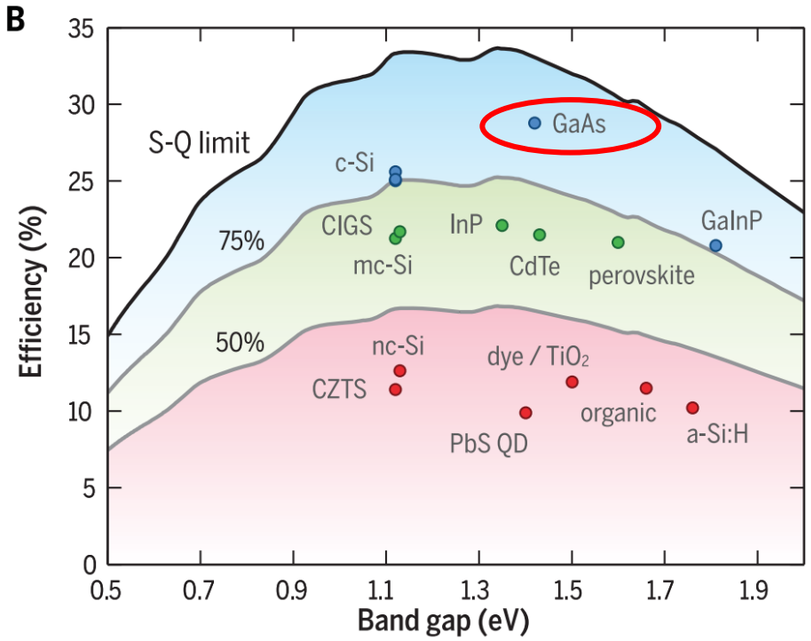
Problem & Motivation

- Shockley-Queisser limit: ~33.7%
- Goal: increase the range of photon wavelengths a solar cell can absorb
  - Multi-junction solar cells
  - Multi-quantum well (MQW) structures
- Best single junction solar cell: GaAs
  - Interest in QWs from GaAs and related alloys (e.g., AlGaAs, InGaAs, GaAsP, etc.)

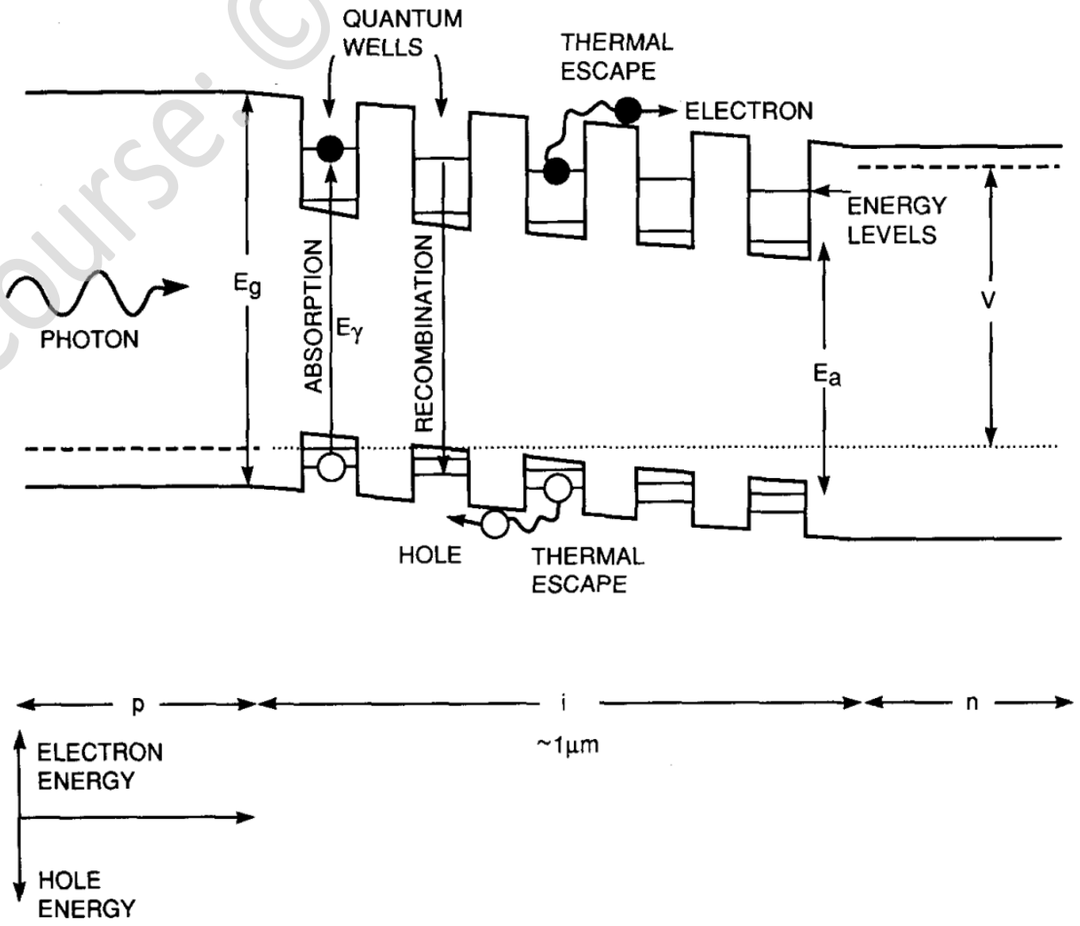




A. Polman, M. Knight, E. C. Garnett, B. Ehrler, and W. C. Sinke, "Photovoltaic materials: Present efficiencies and future challenges," *Science (80-.).*, vol. 352, no. 6283, 2016, doi: 10.1126/science.aad4424.

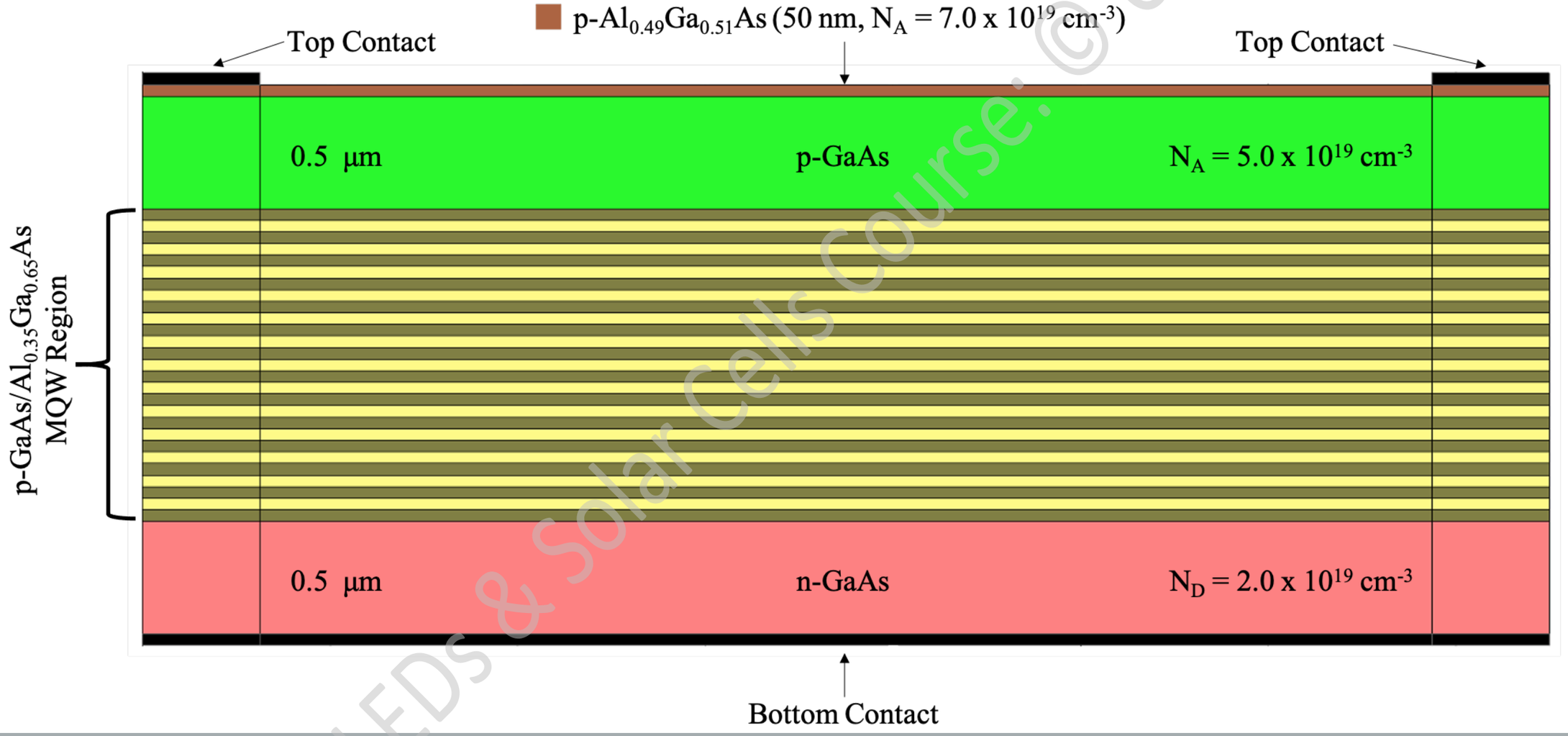
Multi-Quantum Well (MQW) Solar Cells

- Staggered quantum wells in place of intrinsic layer
- Photons with $E < E_g$ can be absorbed by quantum wells
- $I_{ph} \uparrow$ but $V_{OC} \downarrow$
- Side processes
  - Thermal escape
  - Quantum tunneling



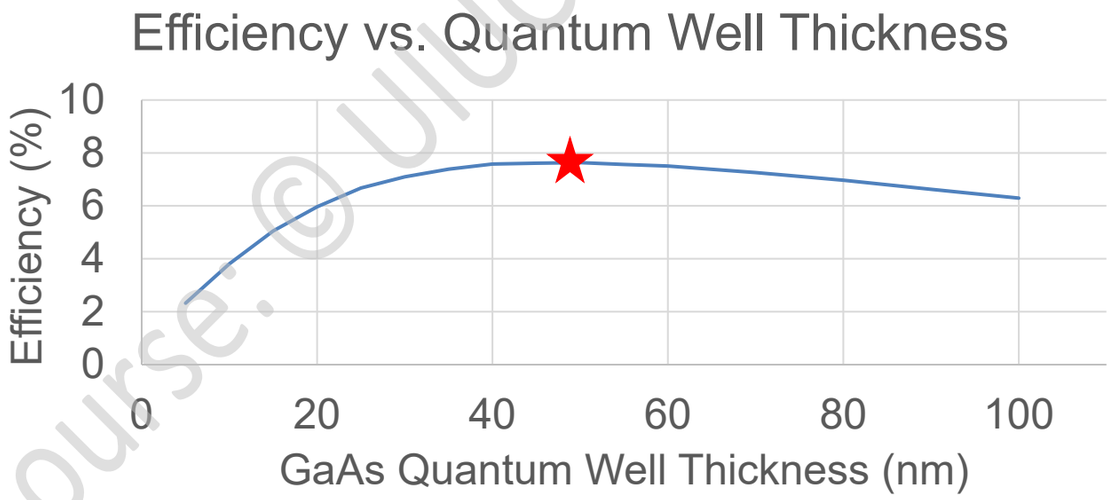
K. Barnham, J. Barnes, J. Nelson, M. Paxman, T. Foxon, and J. Roberts, "Quantum-Well Solar Cells," *MRS Bull.*, no. OCTOBER 1993, pp. 51–55, 1993.

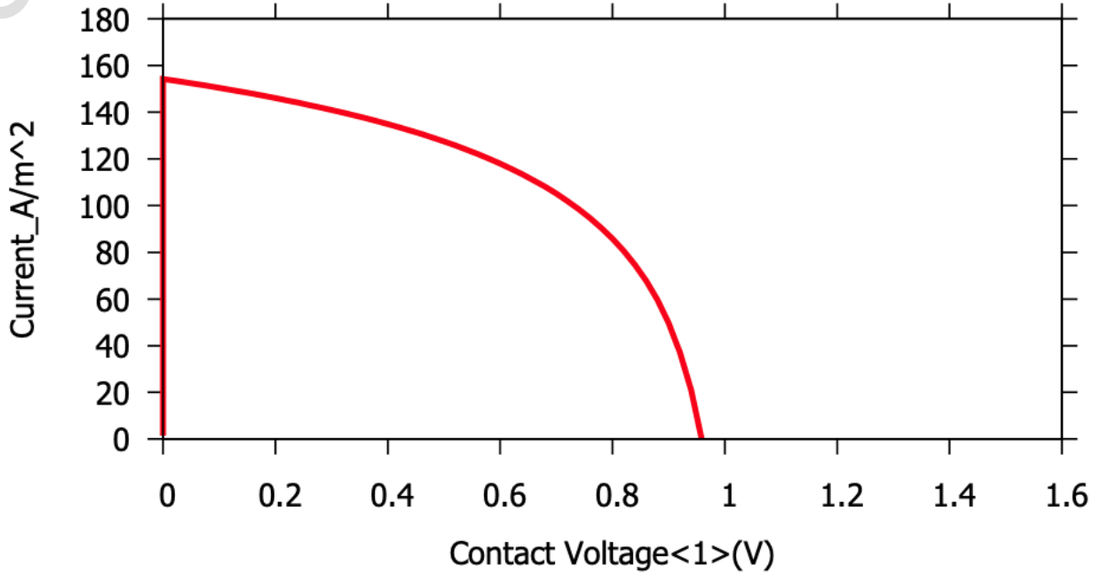
MQW GaAs/AlGaAs Device Structure



Quantum Well Thickness

- 13 QW, 1 nm $Al_{0.35}Ga_{0.65}As$ barrier layers
- Best efficiency: 50 nm GaAs QW layers
  - V_{OC} = 0.959 V
  - J_{SC} = 0.155 mA/cm^2
  - FF = 49.6%
  - AM1.5 Efficiency = 7.636%

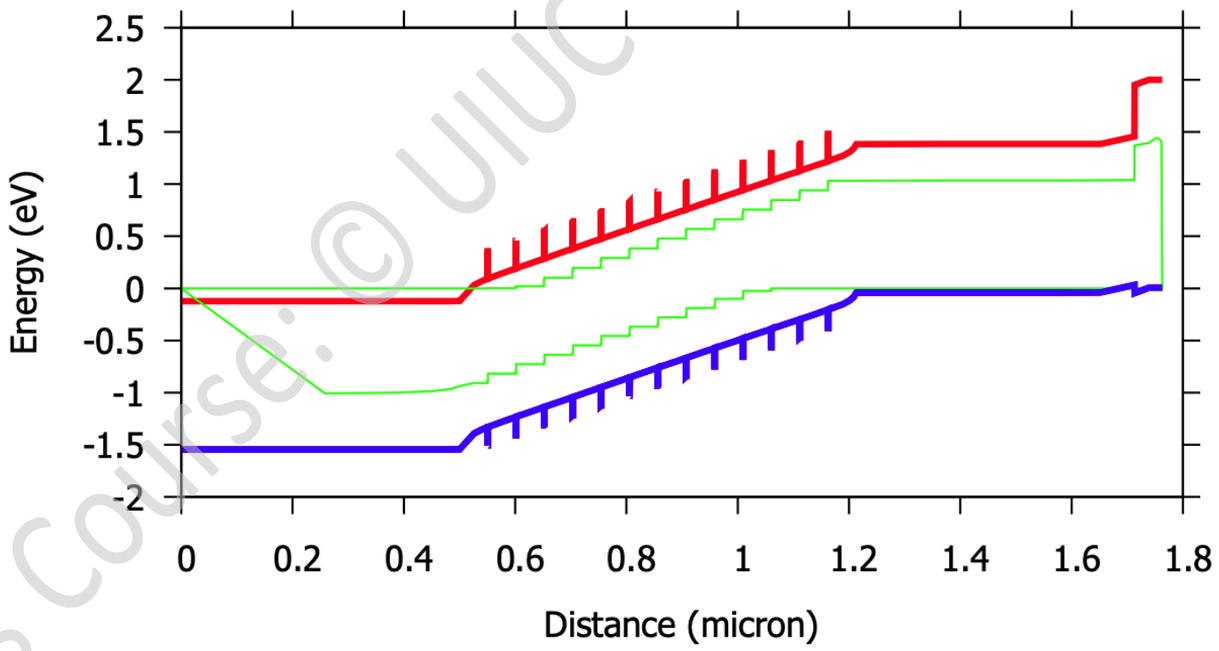


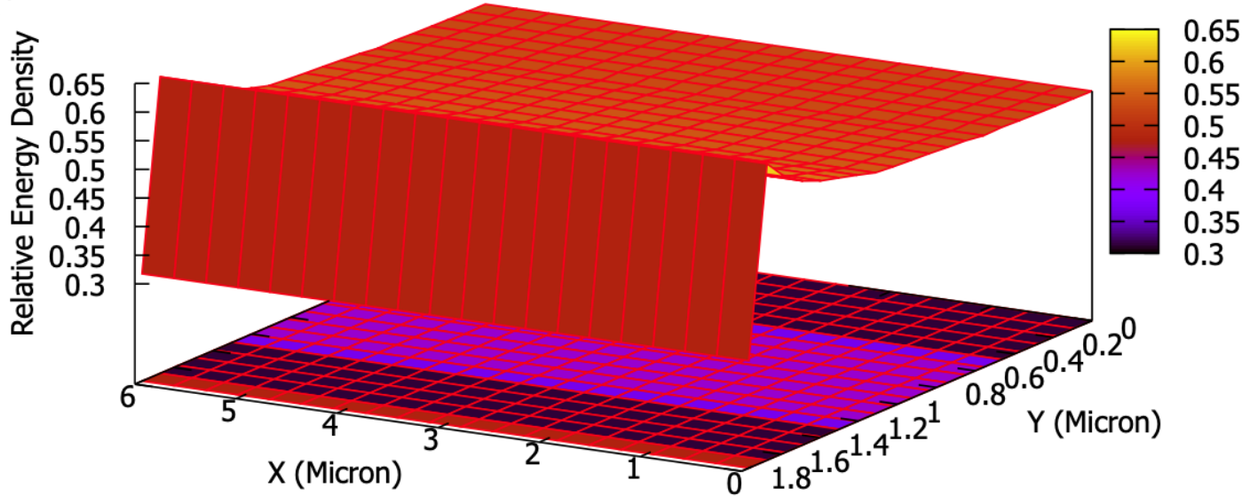


Simulation Results

- 13 distinct QWs
- Most energy conversion is occurring at the junction

- Best GaAs cell: 28.8%
- Theoretical Limit: ~32%
- This MQW Design: 7.64%





Conclusion

- MQW solar cells are possible but have many challenges
  - Trade-off between barrier and QW thicknesses
  - Combatting decreased V_{OC} due to QWs
- Future considerations
  - Many degrees of freedom: # of QWs, barrier composition, etc.
  - Non-uniform QW arrangements
  - Combine with other improvements
    - Back surface field (BSF) layer
    - Anti-reflective coatings

Thank you!

Questions?