The Future of Photovoltaics

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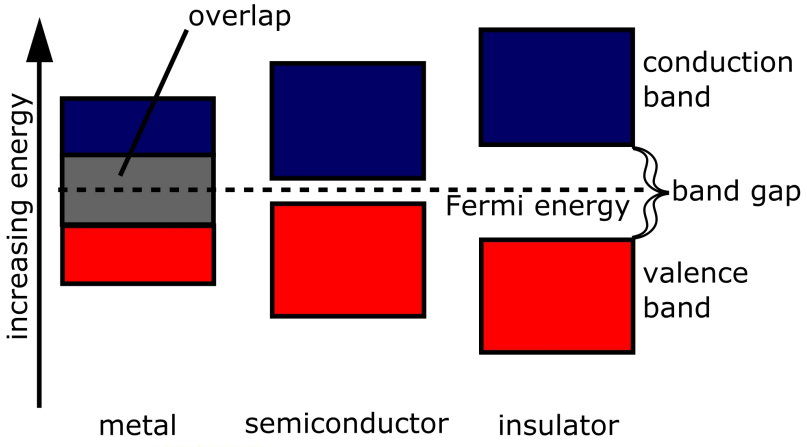
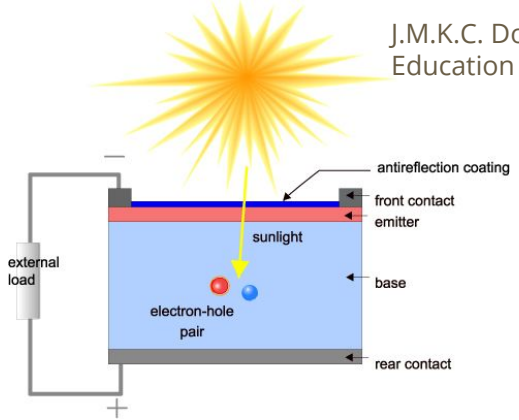
Introduction

Review

- Photosensitive Diode
- Semiconductors most often used
- Band gap theory
- Forbidden region
- Carriers
- Completing the circuit



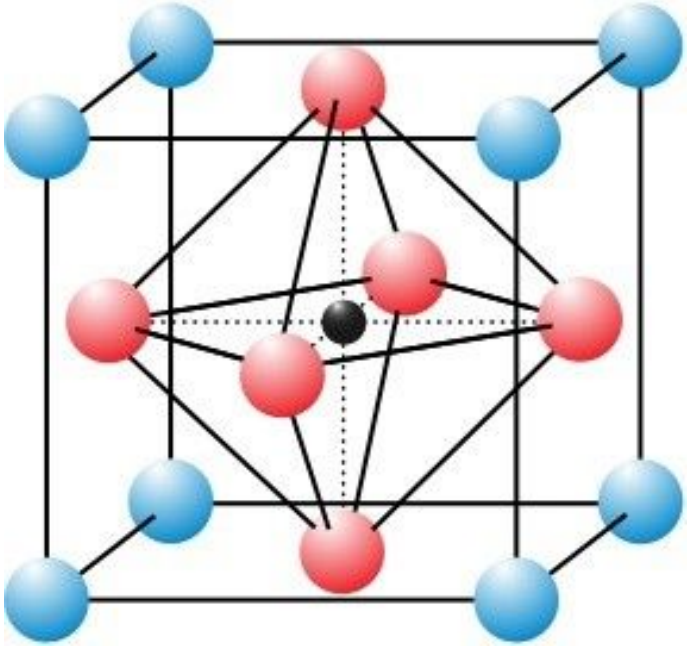
J.M.K.C. Donev et al. (2015). Energy Education - Band gap [Online].



https://www.pveducation.org

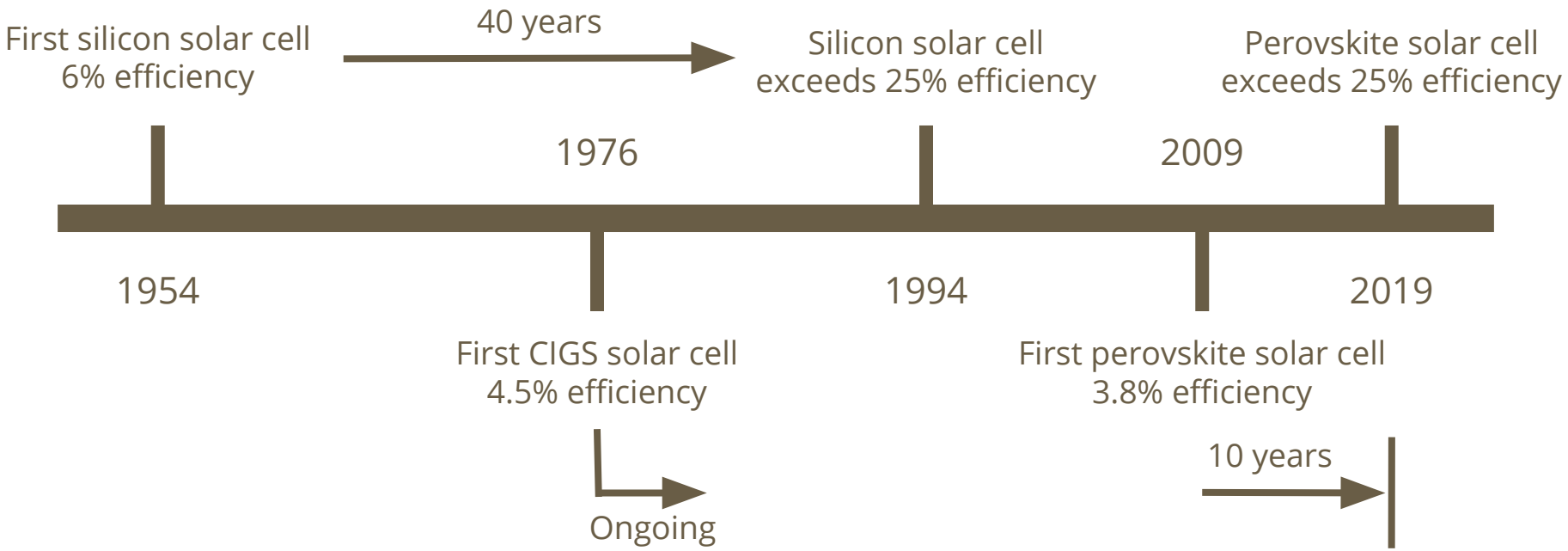
Perovskites

- Material with same lattice structure as Titanium Oxide (TiO_2)
- Cheap to produce
- Not energy intensive to make
- Interactions with humidity
- Future applications



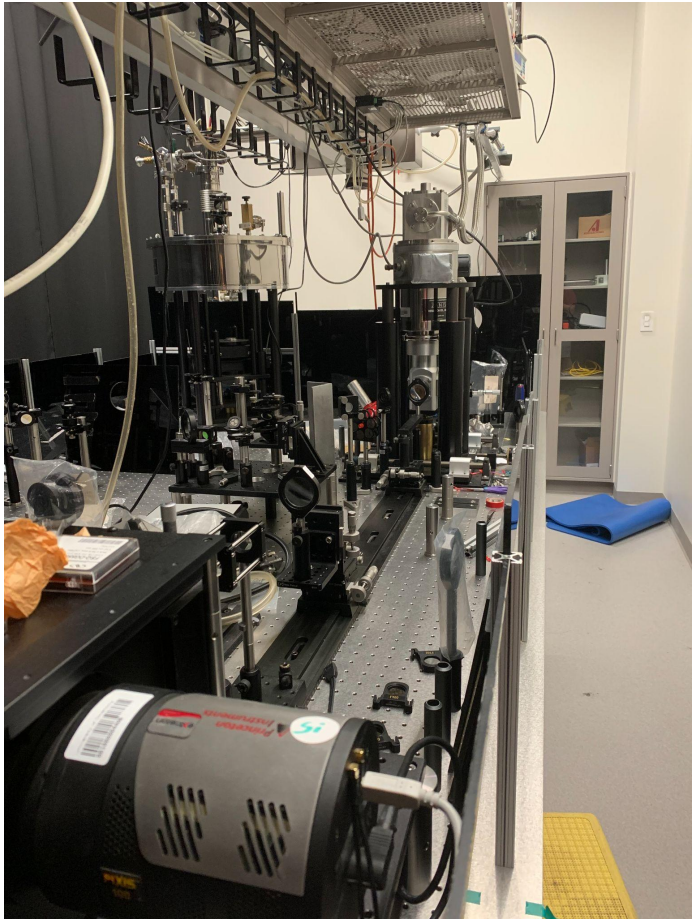
https://www.cei.washington.edu/education/science-of-solar/perovskite-solar-cell/

Timeline - Why Perovskites?



Overarching Goal

- Determining a temperature dependence on perovskites
- Limited work has been done by other groups
- Studying a triple cation perovskite



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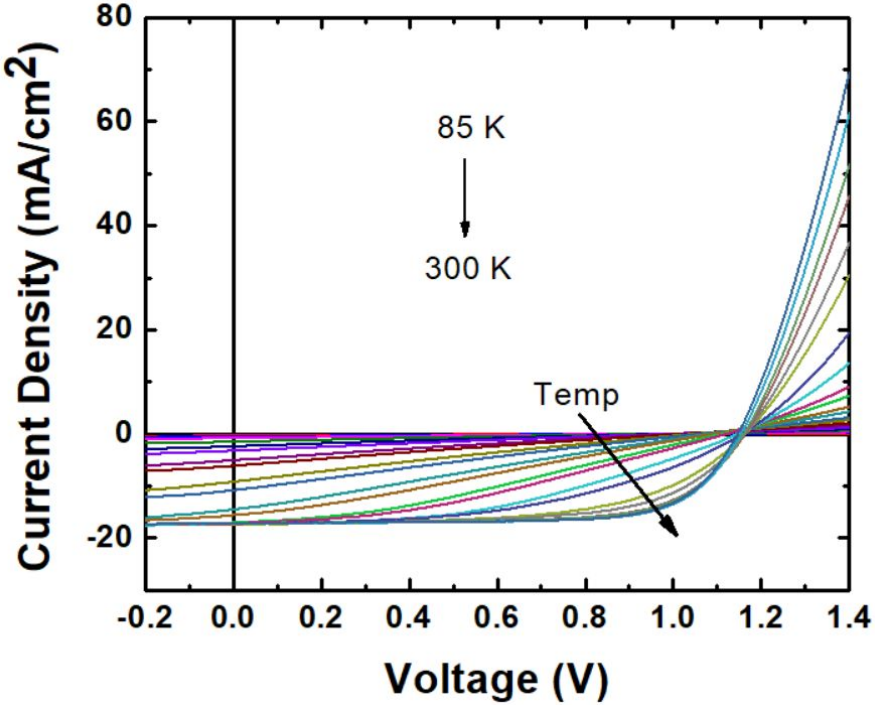
Experimental Results and Data Analysis

Current Density vs Voltage

- Solar simulator shines onto sample
- Fill factor
- Evidence of low temperature barrier for carrier extraction
- Temperature increase reduces barrier gradually



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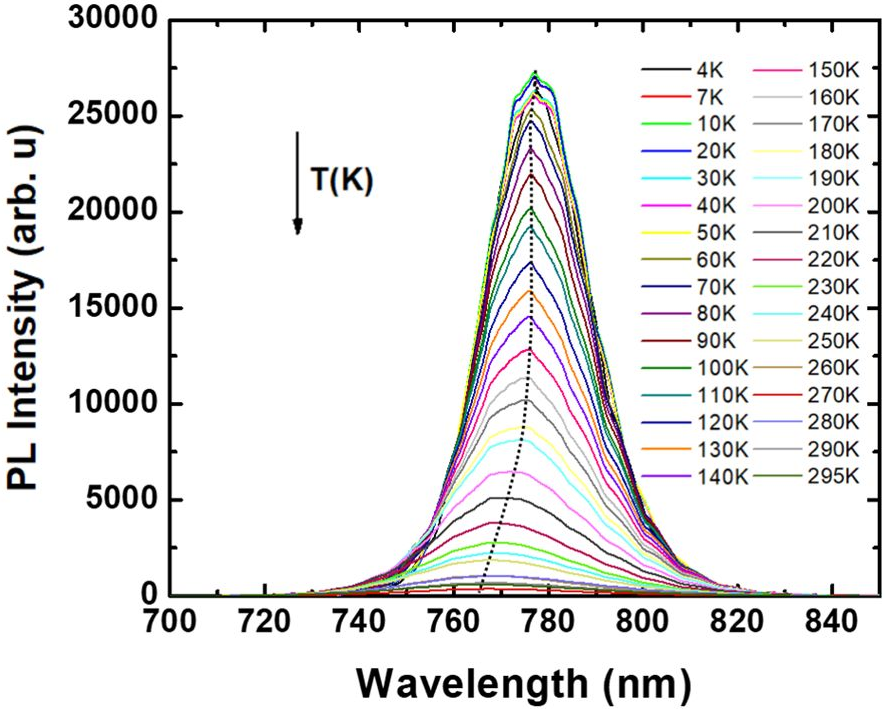
Photoluminescence

- Fourier smoothing applied
- Incident laser light for excitation
- Measuring emission of photons
- Gives insight into band gap



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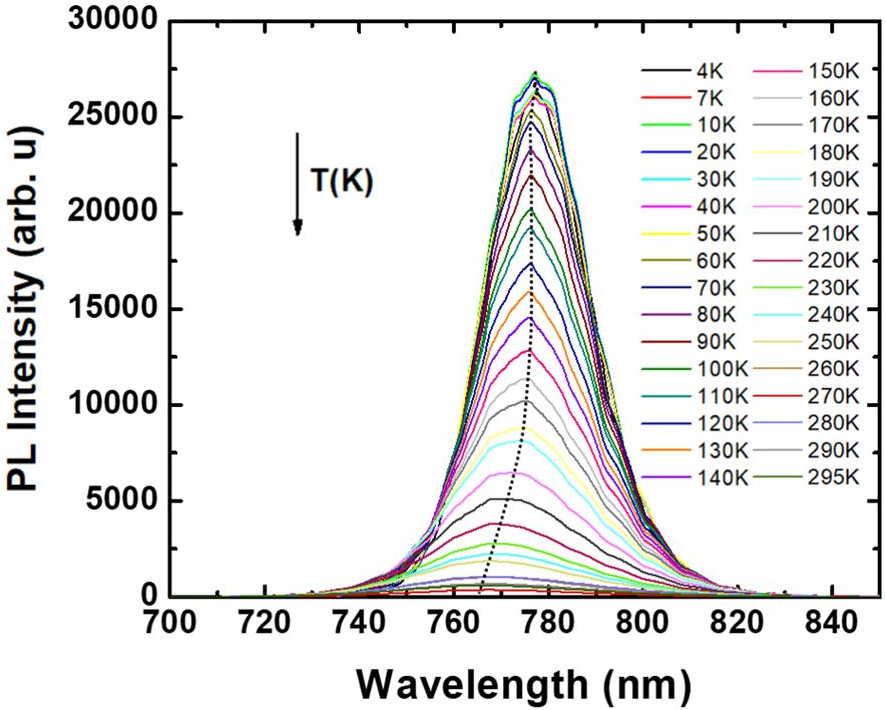
Photoluminescence

- Significance of the curve's peak
- Blue shift in the band gap
- Temperature increases band gap in this system
- Not like traditional photovoltaics



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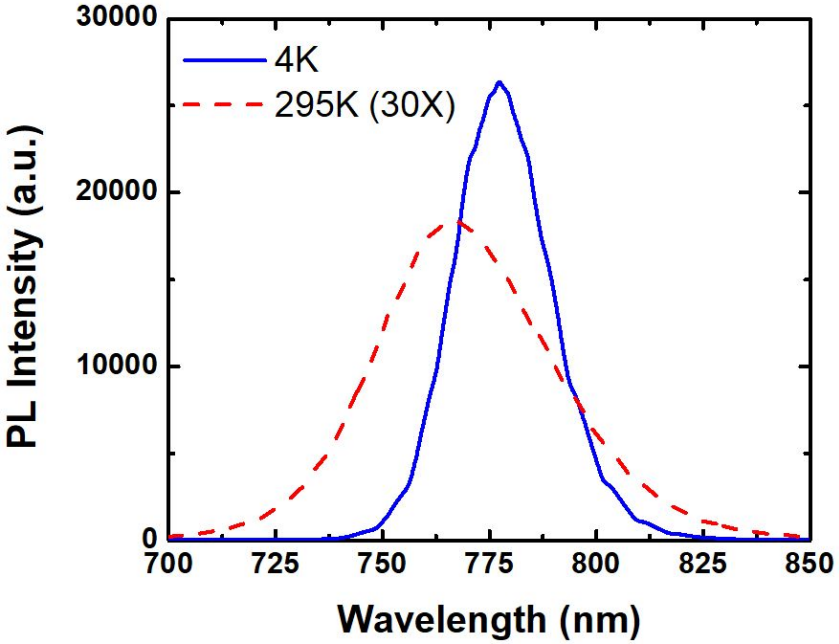
Photoluminescence

- Massive decrease in PL intensity
- Clear evidence of band gap change
- Nonradiative recombination dominates as Temperature increases
- Thermalization and phonon interactions



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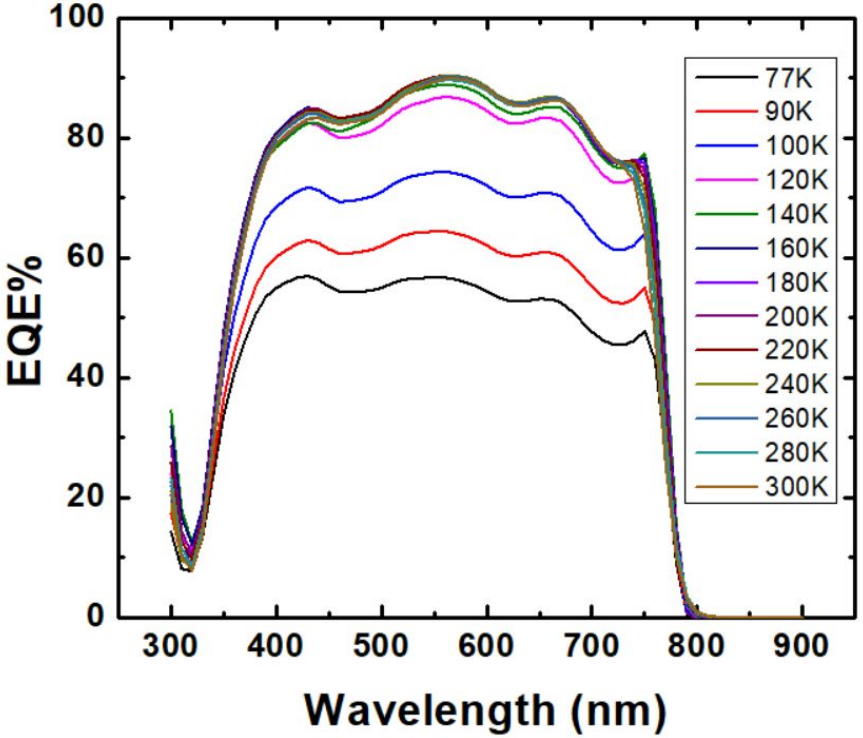
External Quantum Efficiency (EQE)

- Ratio of carriers generated to incident photons
- Can also be used to analyze band gap
- Measure of absorption
- Clear evidence of excitons reflected in EQE



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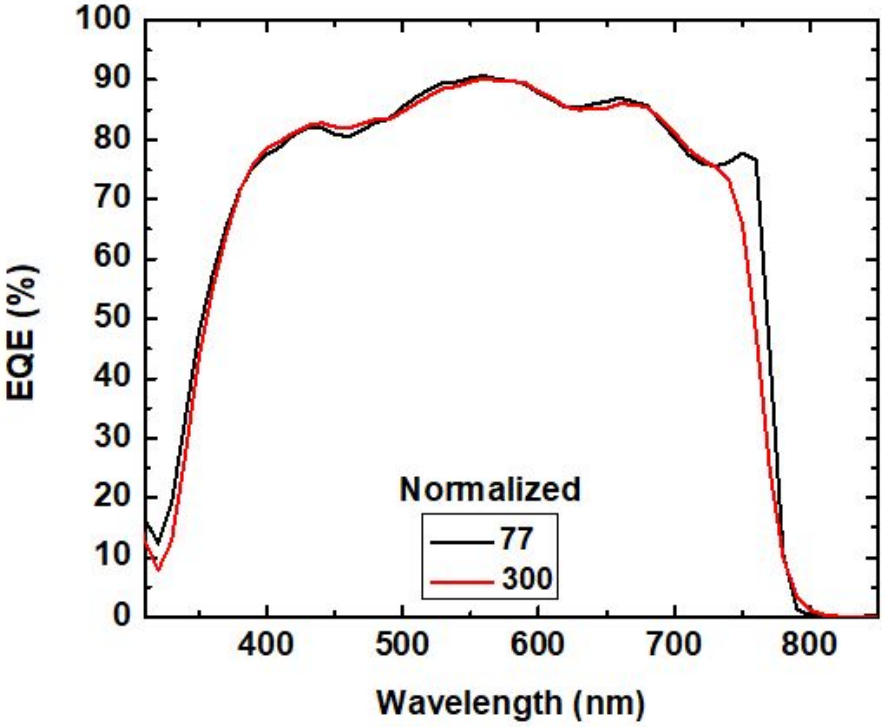
Excitons - What are they?

- Electron-Hole pair bounded
- Electron in conduction band
- Hole in valence band
- Coulombic force
- Influence of thermal excitation



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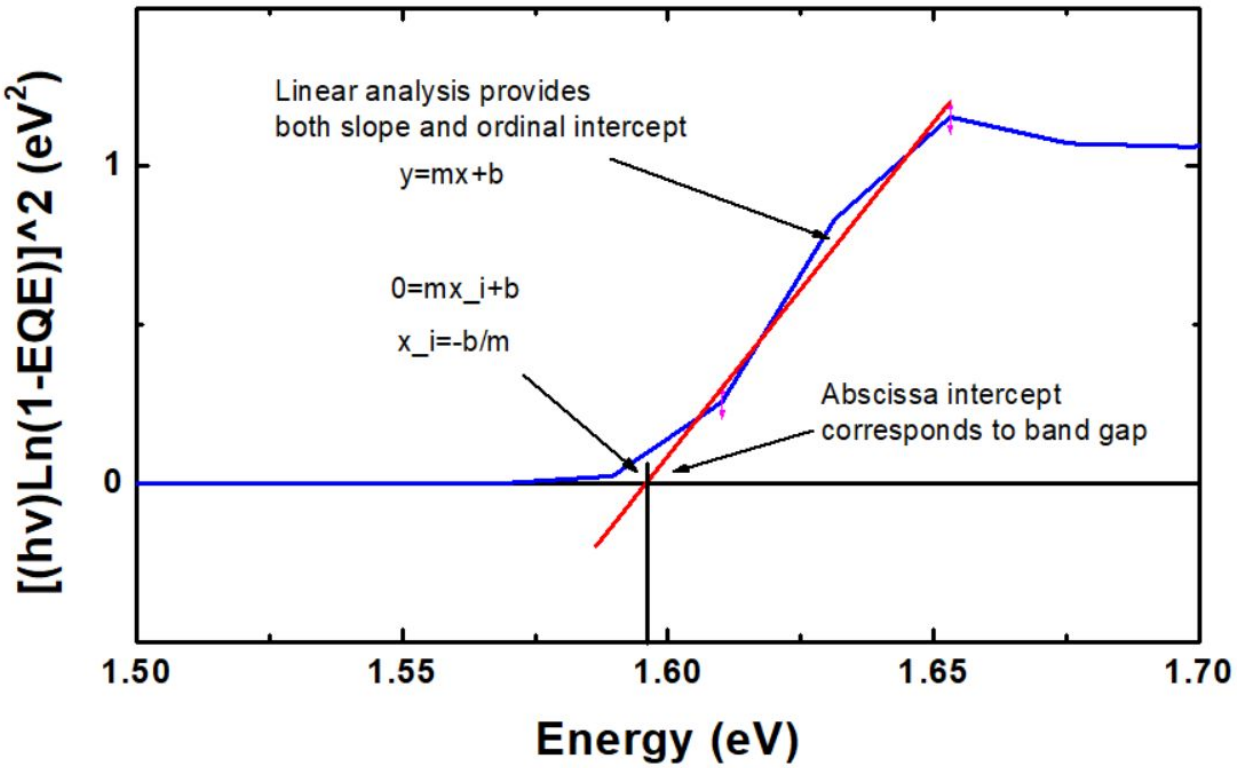
Tauc Plots

- Look at small linear region
- The line of best fit
- The band gap
- Changes with temperature



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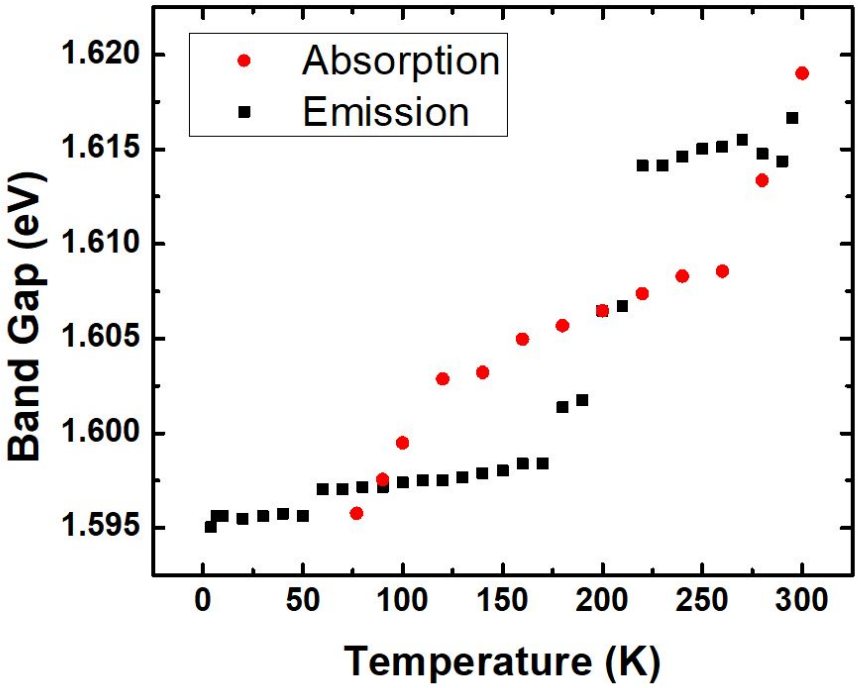
Stokes Shifting

- Apparent differences in results
- Emissions show band gap to experience sudden increase
- 170K to 210K is range of interest
- Phonon activation begins to occur within the lattice
- Possible exciton dissociation at ≥160K contributing to difference



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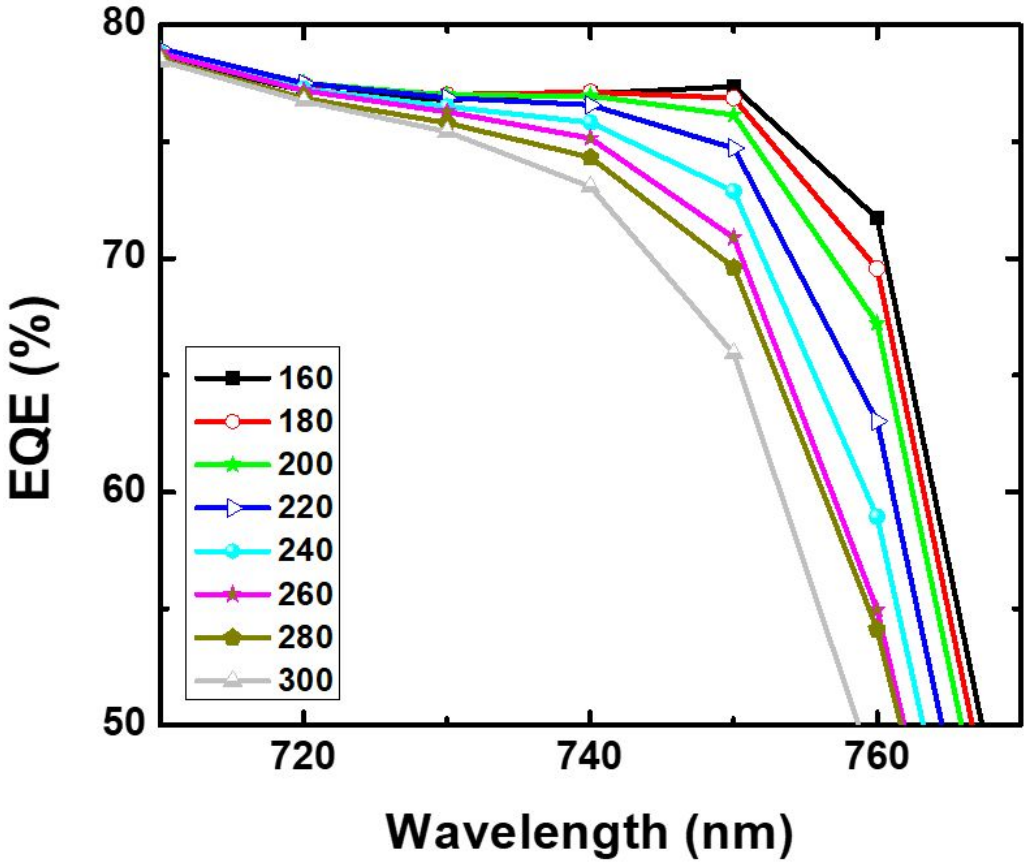
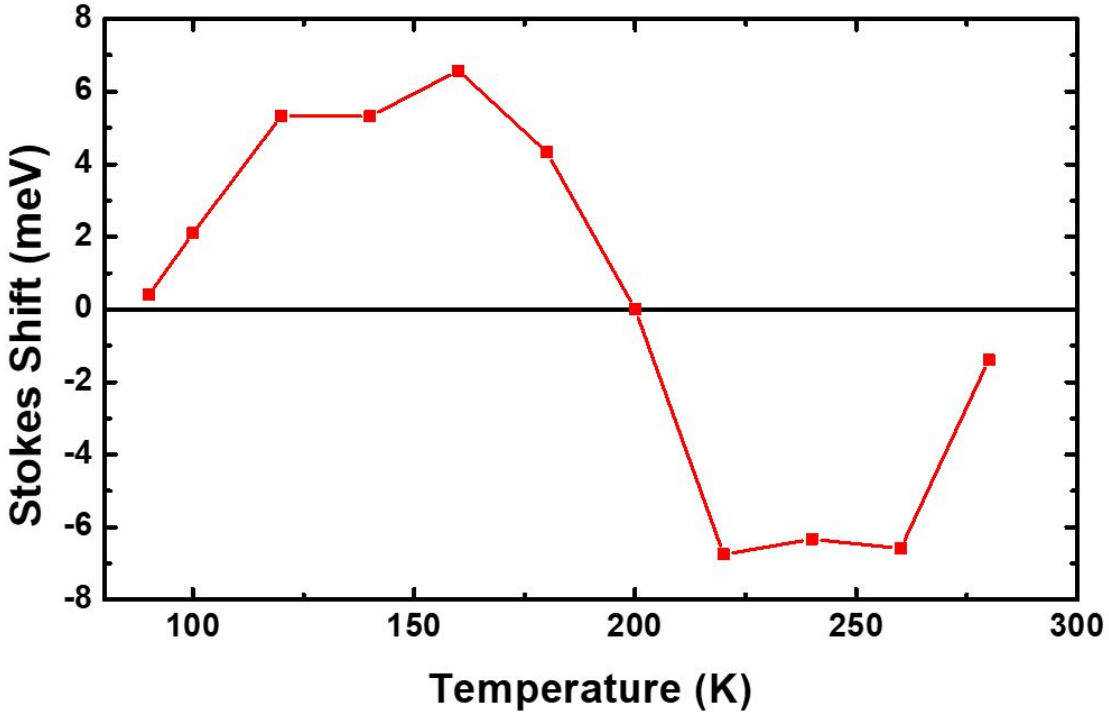

80
70
60
50
EQE (%)
720
740
760
Wavelength (nm)
160
180
200
220
240
260
280
300

Stokes Shifting

$$\Delta S = E_{Absorbed} - E_{Emitted}$$

- Difference in peaks of absorption and emission
- Band gap difference
- 200K is the critical point
- *ΔS>0* : vibrational states
- *ΔS<0* : thermal phonon dissipation within the lattice gives energy



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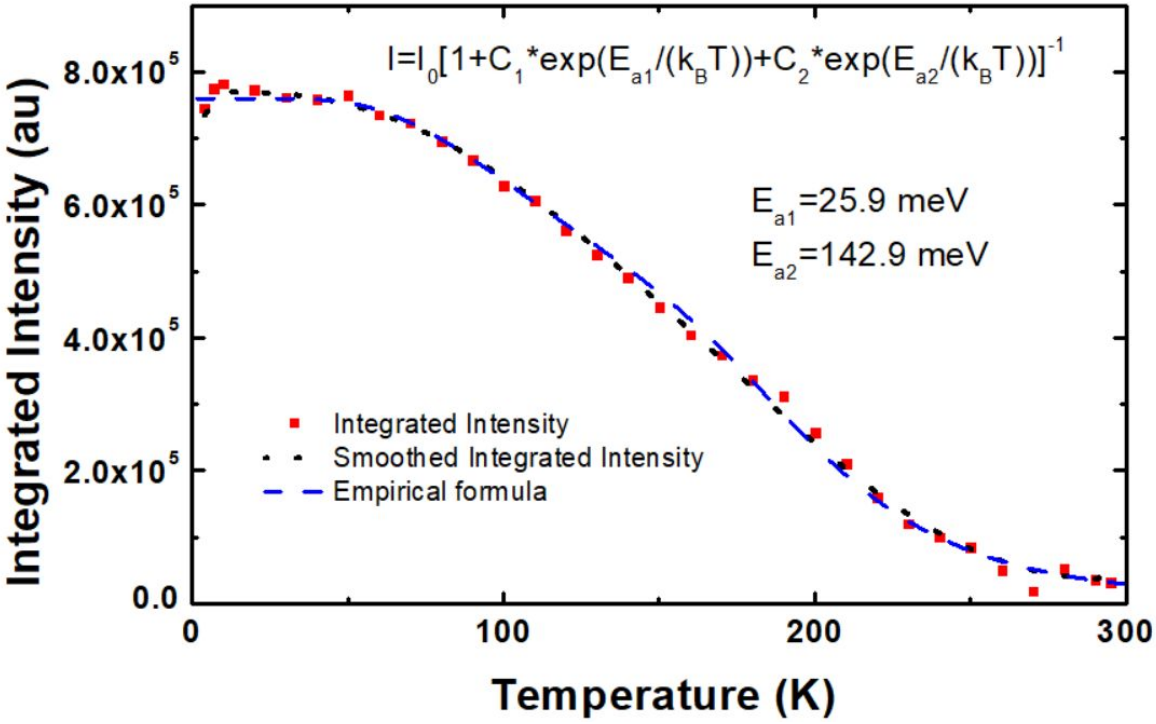
Integrated Intensity

- Measure of area under PL Curves
- Obtain information on excitons
- Binding energy of exciton
- Strong electron confinement



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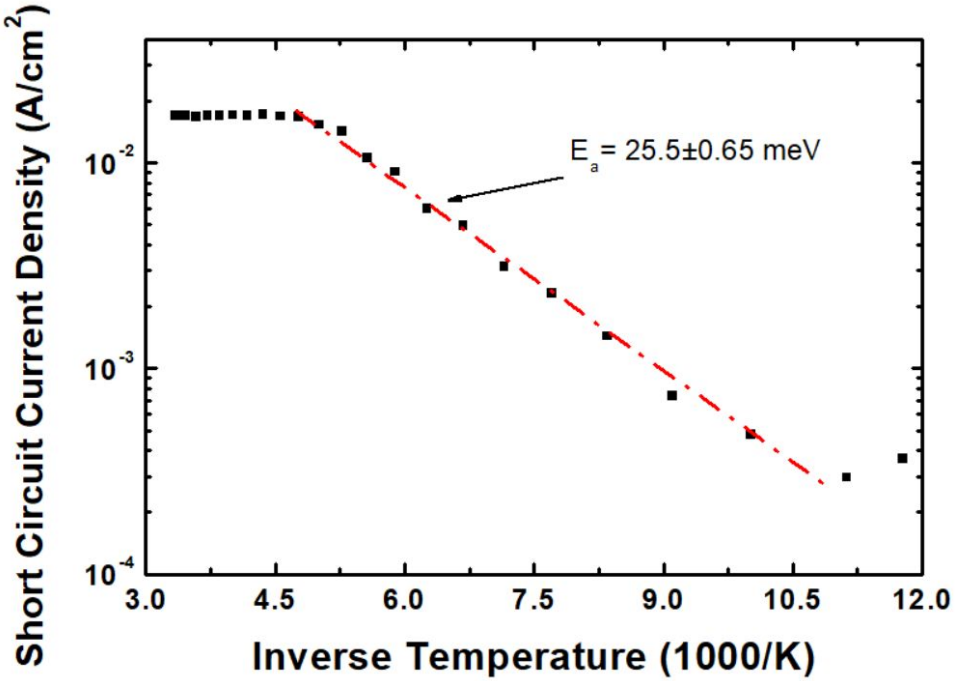
Arrhenius Plotting for Exciton Binding Energy

- Abscissa is inverse scale
- Slope used to calculate binding energy
- Agrees with previous technique's result



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Summary

- Perovskites production
- Motivations for research
- Better understanding of temperature dependence
- Various techniques and properties to study
- Excitonic behavior in perovskites

Citations

- Cesium-containing triple cation perovskite solar cells: improved stability, reproducibility and high efficiency - Energy & Environmental Science (RSC Publishing)
- Temperature-dependent photoluminescence in light-emitting diodes | Scientific Reports
- Quantum Efficiency | PVEducation
- Investigation of InAs/GaAs1−xSbx quantum dots for applications in intermediate band solar cells - ScienceDirect
- Phys. Rev. B 75, 115337 (2007) - Exciton dissociation and hole escape in the thermal photoluminescence quenching of $(\mathrm{Ga}_\mathrm{In})(\mathrm{N}_\mathrm{As})$ quantum wells
- Excitons - an overview | ScienceDirect Topics
- Stokes shift
- Stokes Shift, Fluorescence Spectroscopy | Edinburgh Instruments
- Analysis of Record Photovoltaic Efficiencies from 1954 to 2009
- Emerging Solar Technologies: Perovskite Solar Cell
- Research Direction toward Scalable, Stable, and High Efficiency Perovskite Solar Cells - Park - 2020 - Advanced Energy Materials - Wiley Online Library
- Research on Copper Indium Gallium Selenide (CIGS) Thin-Film Solar Cells

Questions