# Low Temperature Cathodoluminescence in Disordered $SiO_2$

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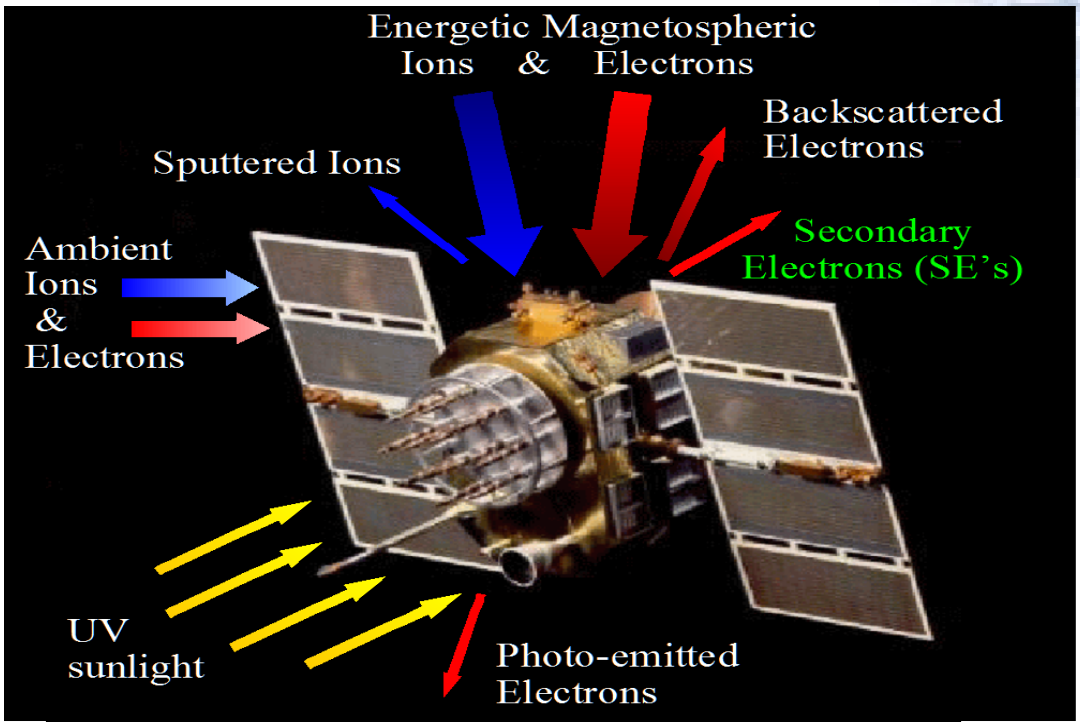
DEPARTMENT OF PHYSICS

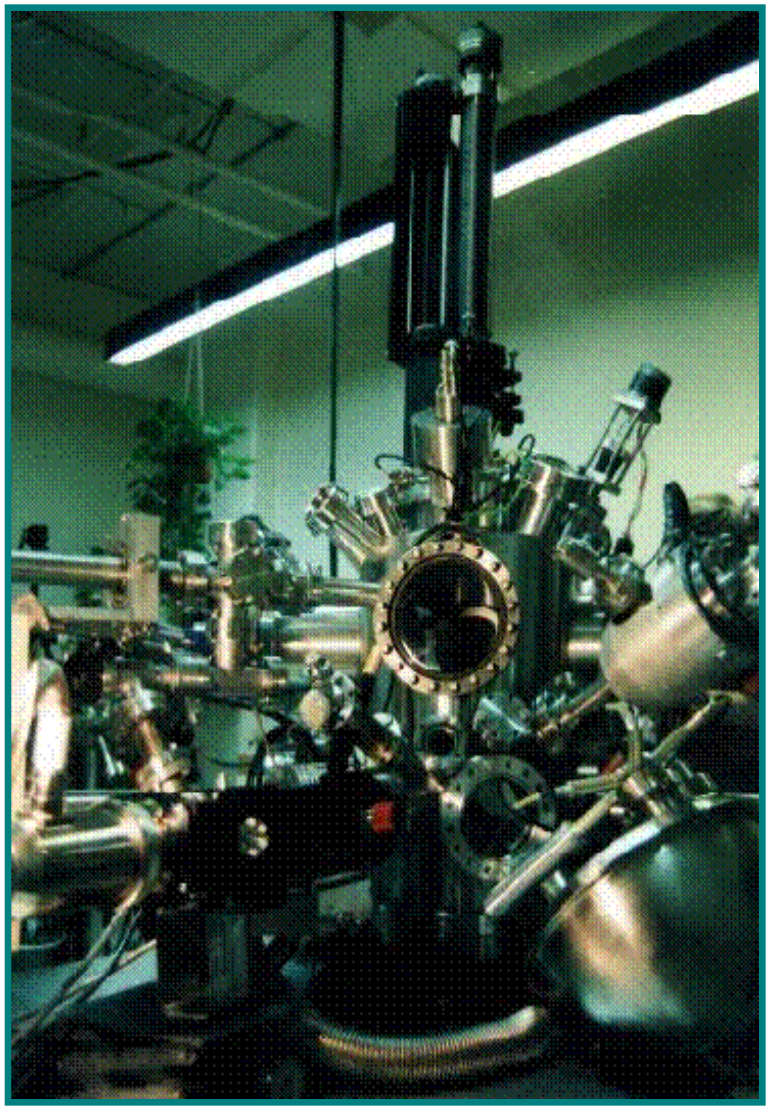
# Motivation

- Space based observatory optical instrumentation

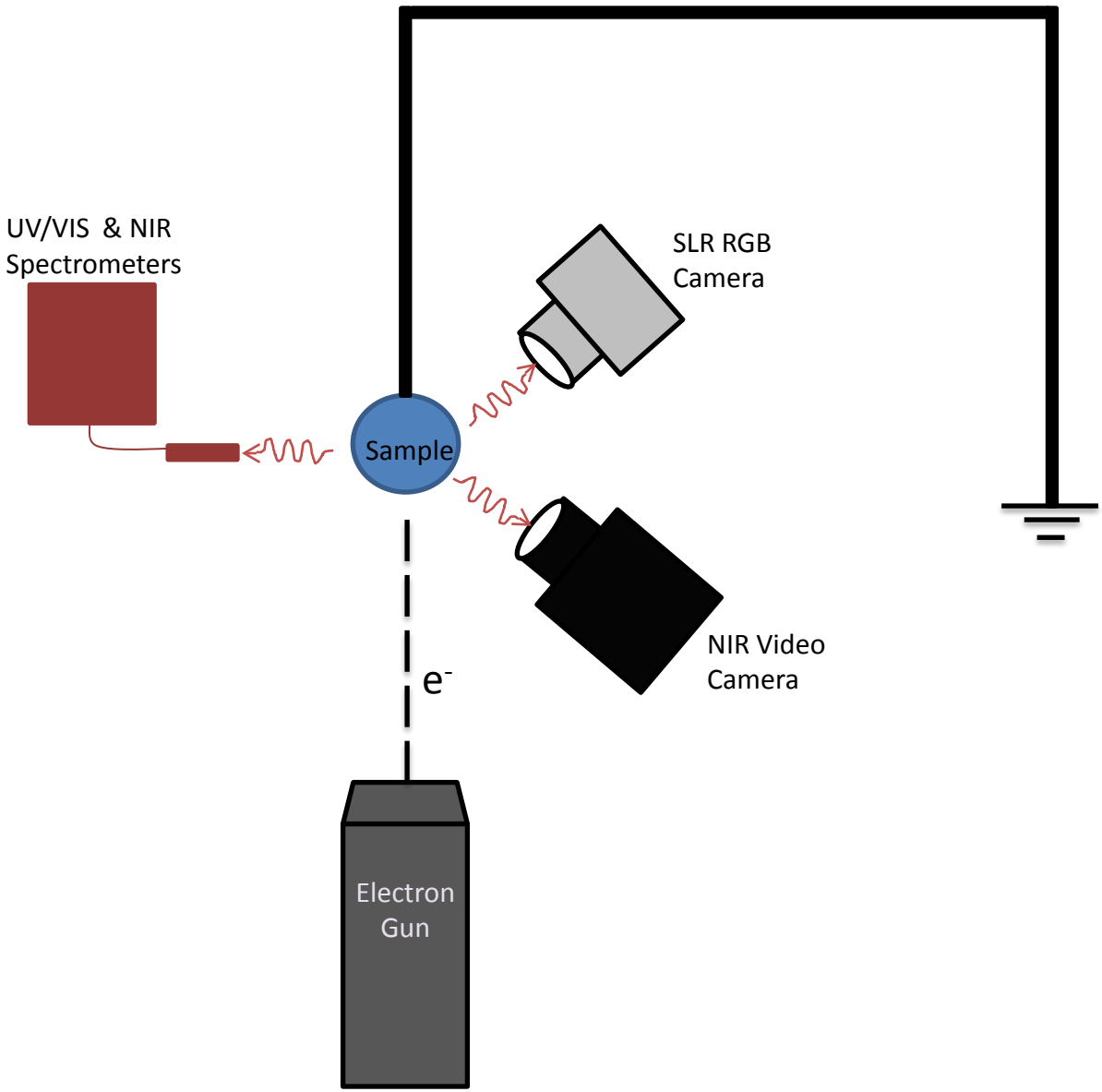



- Harsh space environment

# Experimental Set-Up



# Experimental Set-Up

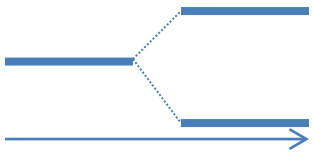


# THEORY

# Band Theory of Solids

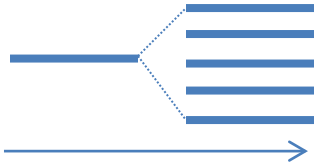
As individual atoms are brought closer together, their individual energy levels split and mix with those of their surrounding atoms. The number of energy levels is equal to the number of atoms.

2 atoms



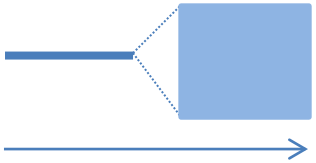
Decreasing internuclear distance

5 atoms

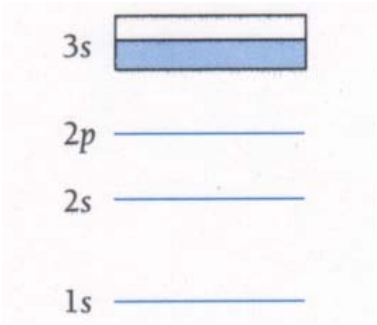


Decreasing internuclear distance

Many atoms

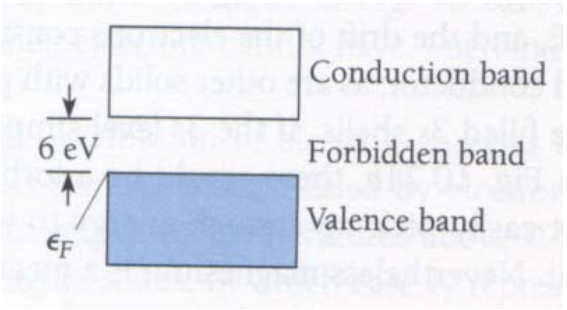


Decreasing internuclear distance



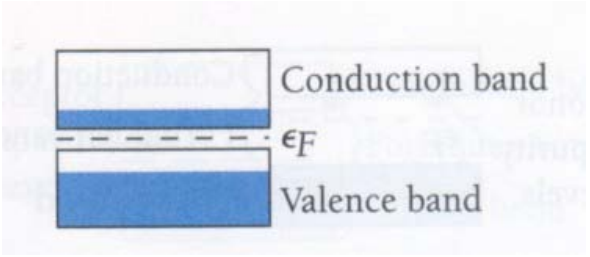

**Conductor**

**Partially filled bands**




**Insulator**

**Completely filled bands**

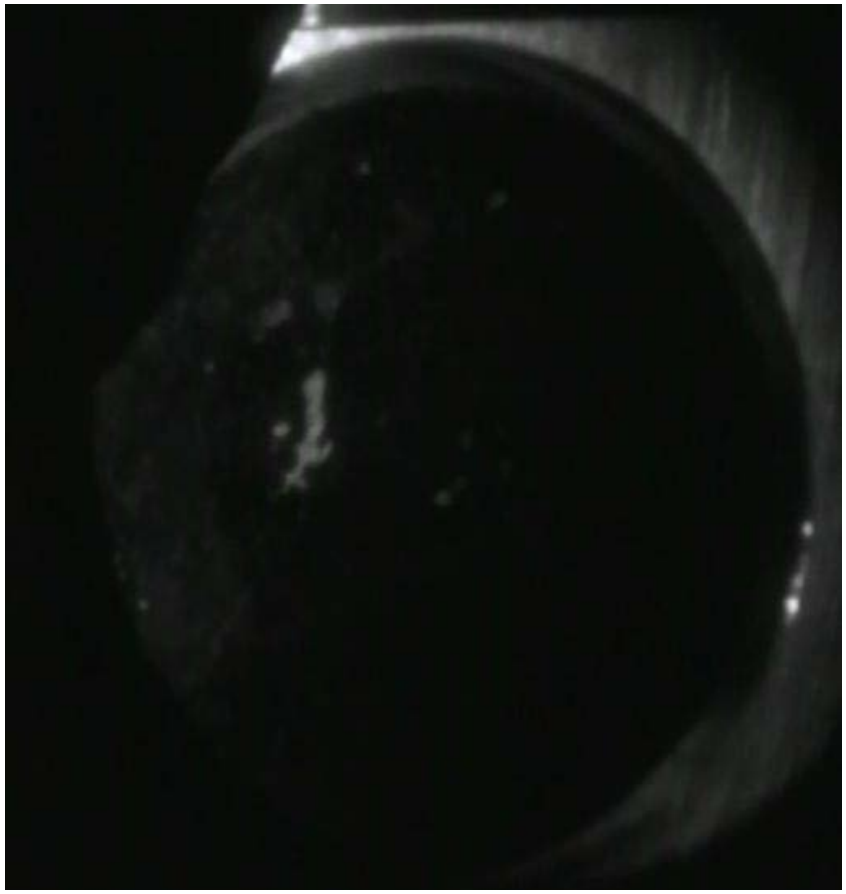



**Semiconductor**

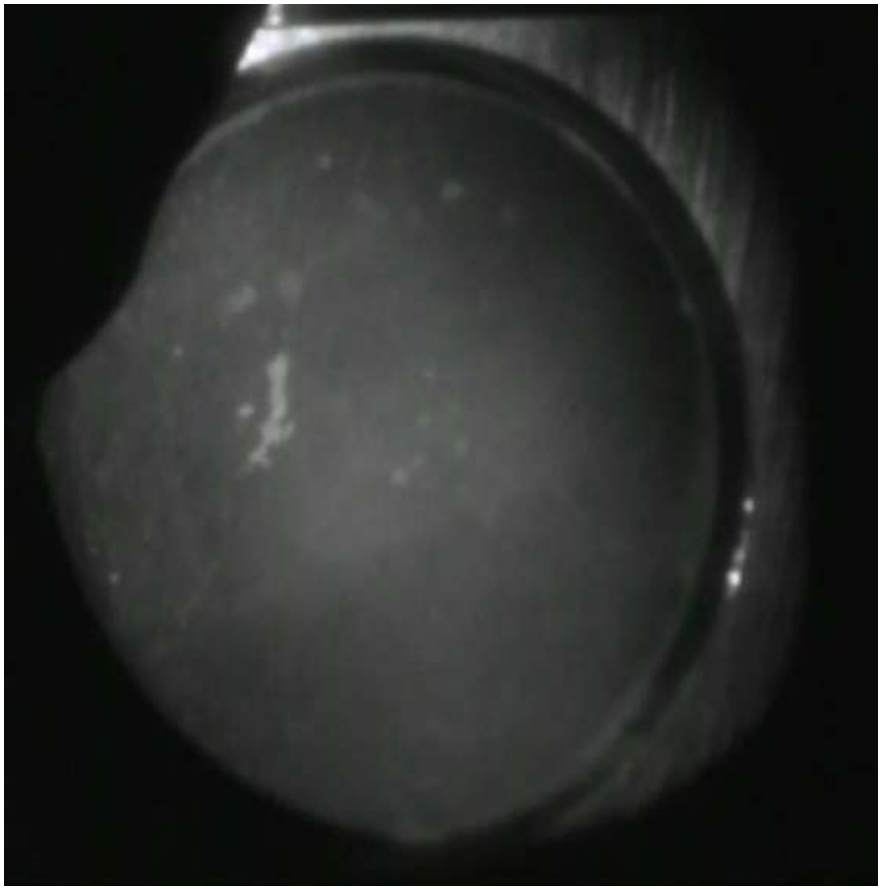
**Insulators at finite T**

# RESULTS

# Cathodoluminescence of thin film $SiO_2$ layer on mirror surface

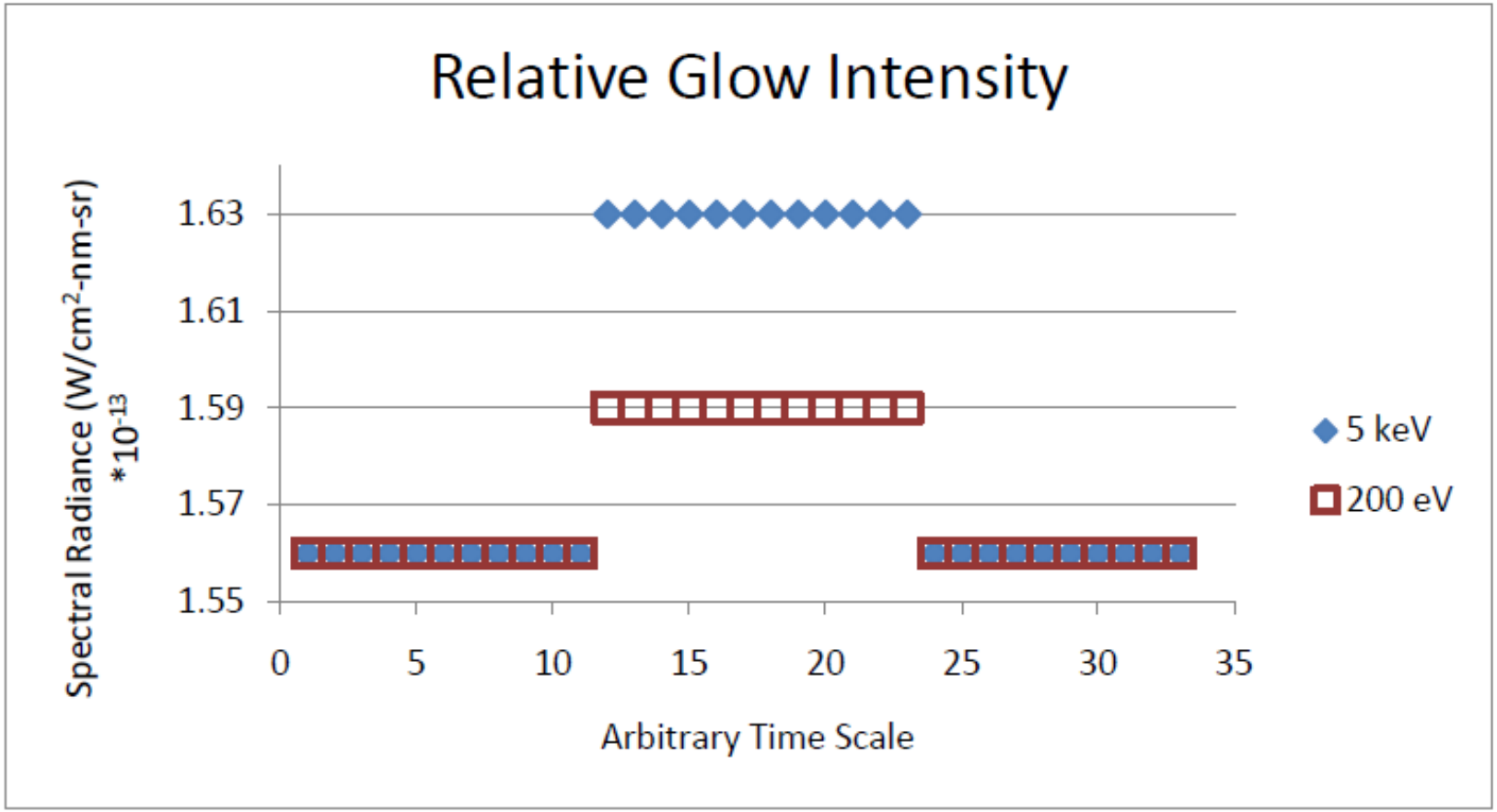


Beam off

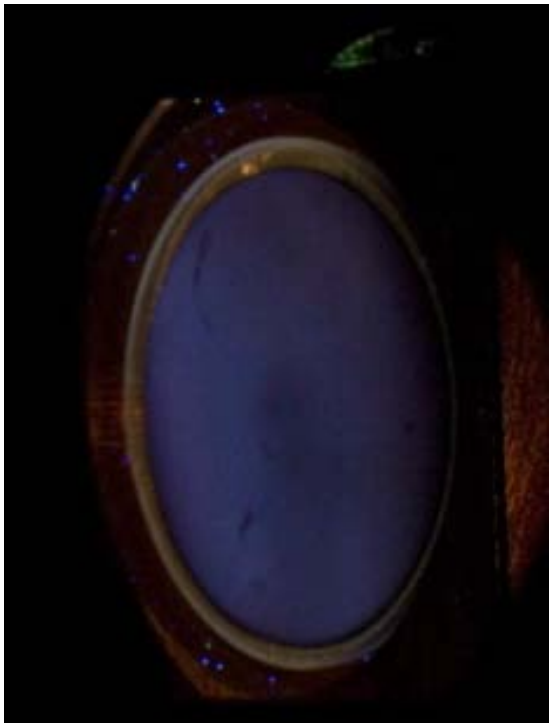


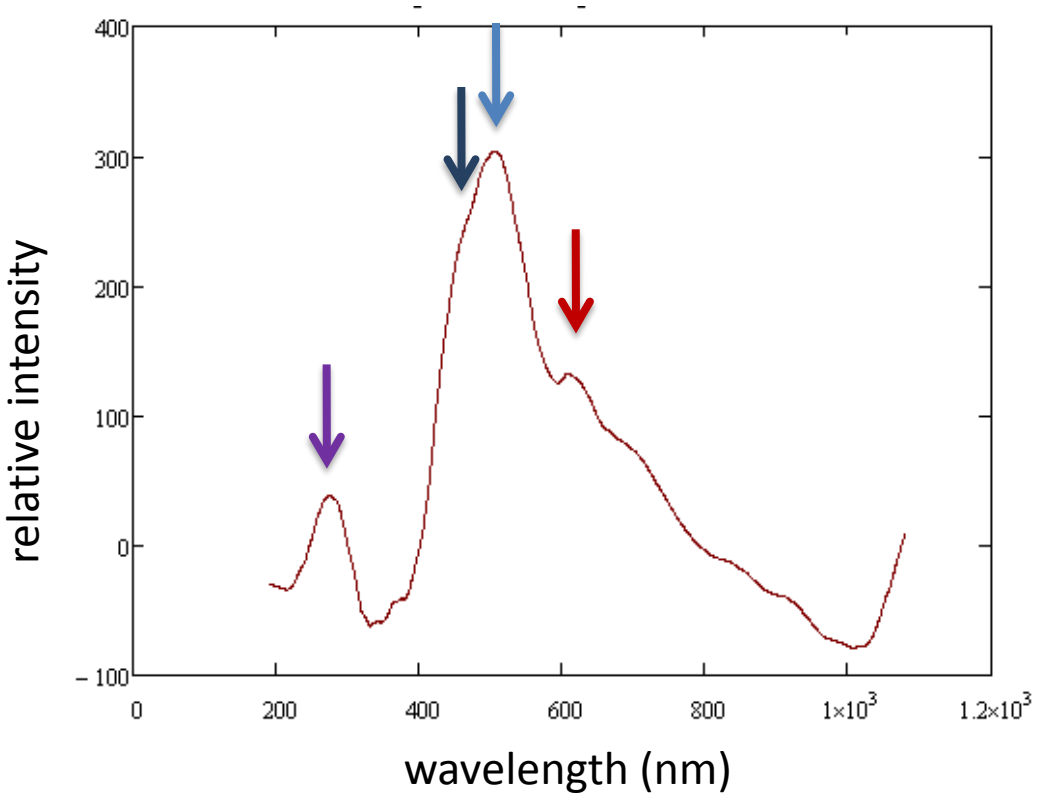
Beam on

# Effect of Beam Energy

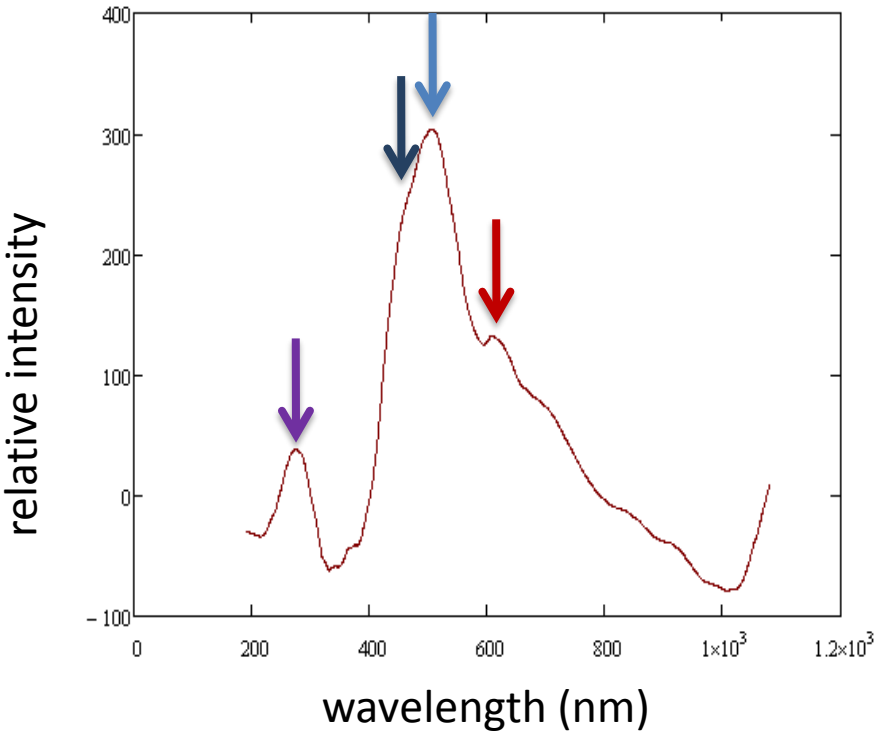


# Multi-Photon Luminescence

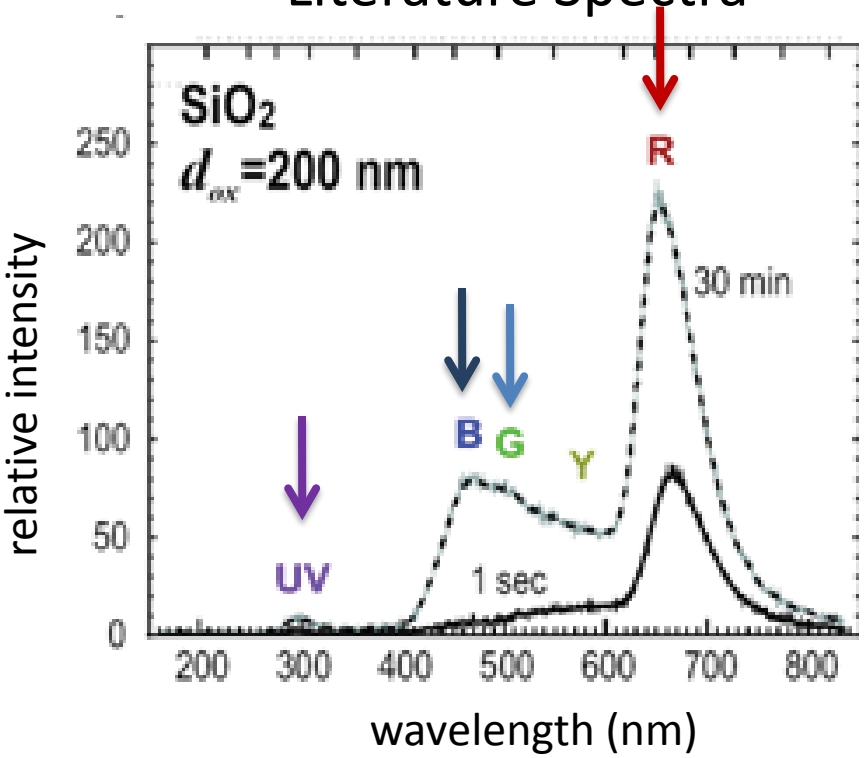




## Experimental Spectra



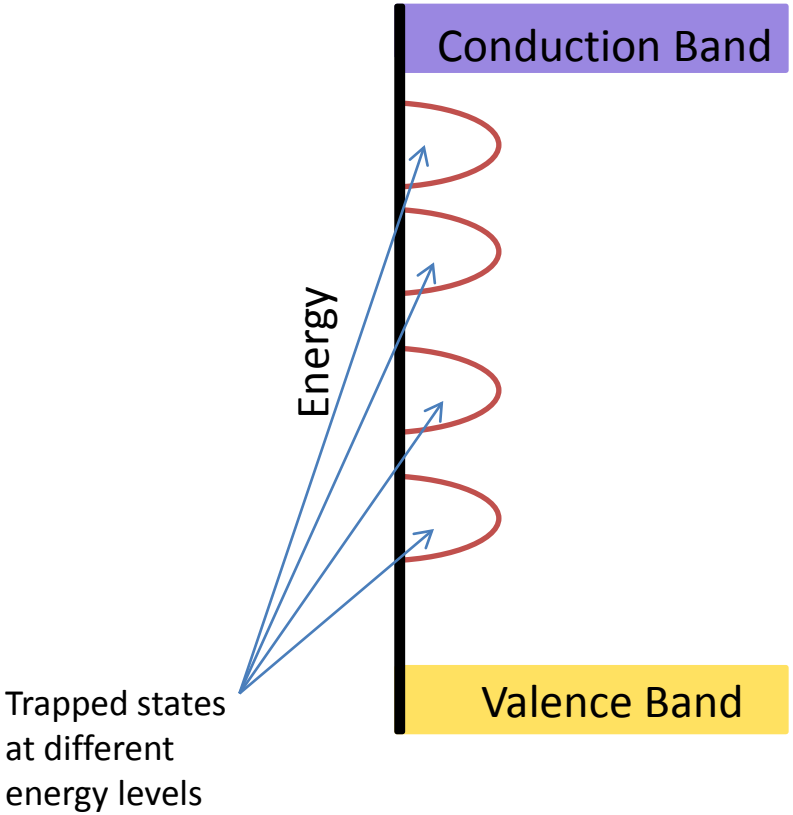

## Literature Spectra




Though relative intensities differ, the peaks occur at the same wavelength bands.

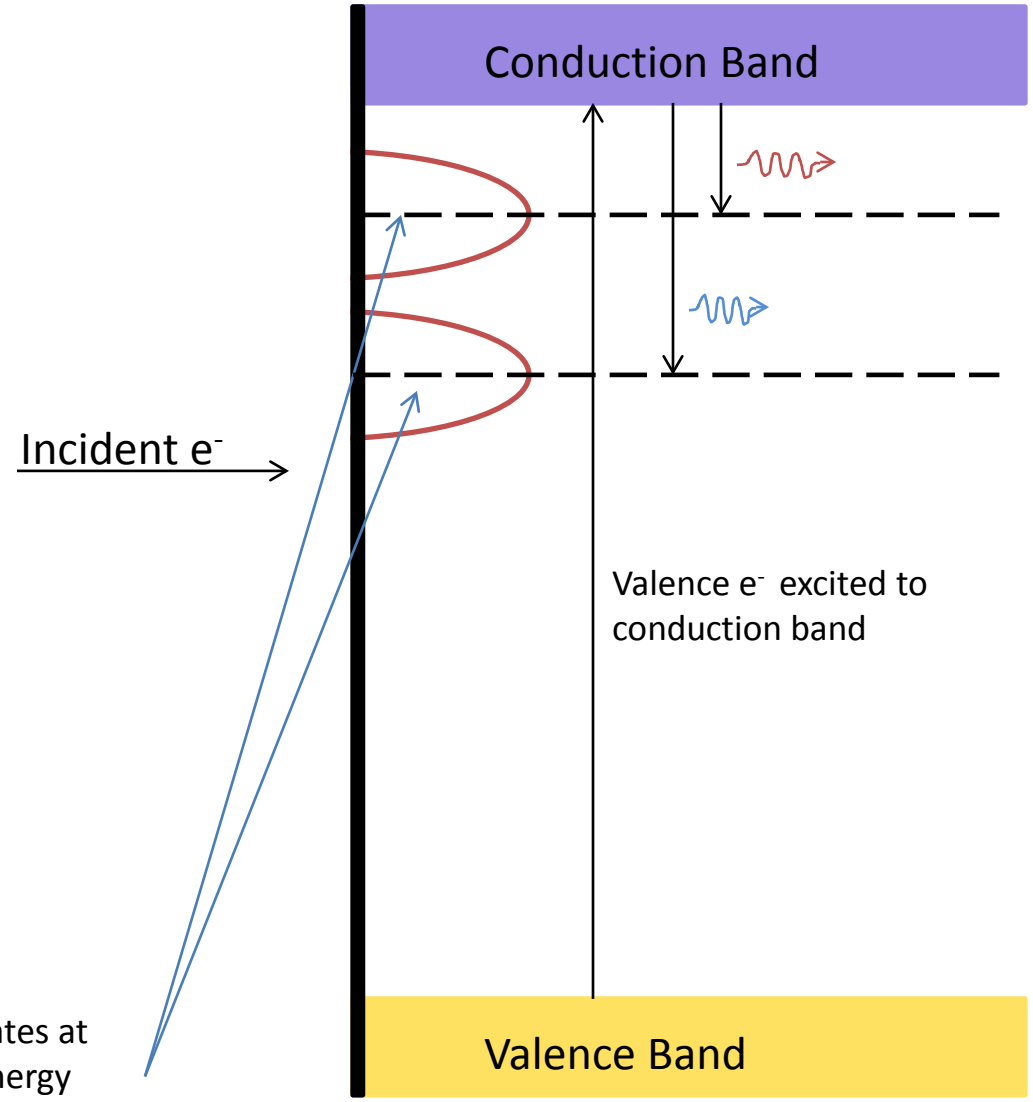
# MODEL

# Trapped States and Chromophores




- Trapped states occur with the presence of defects
- Defects can manifest themselves as chromophores, the light emitting part of a molecular structure
- Cathodoluminescence can identify these defects

# Excitation and Relaxation

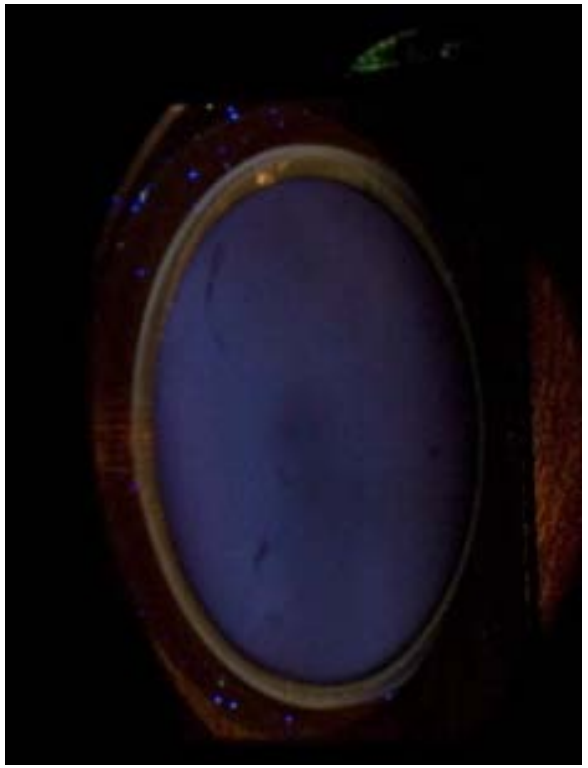


# RESULTS

# Temperature Dependent Luminescence

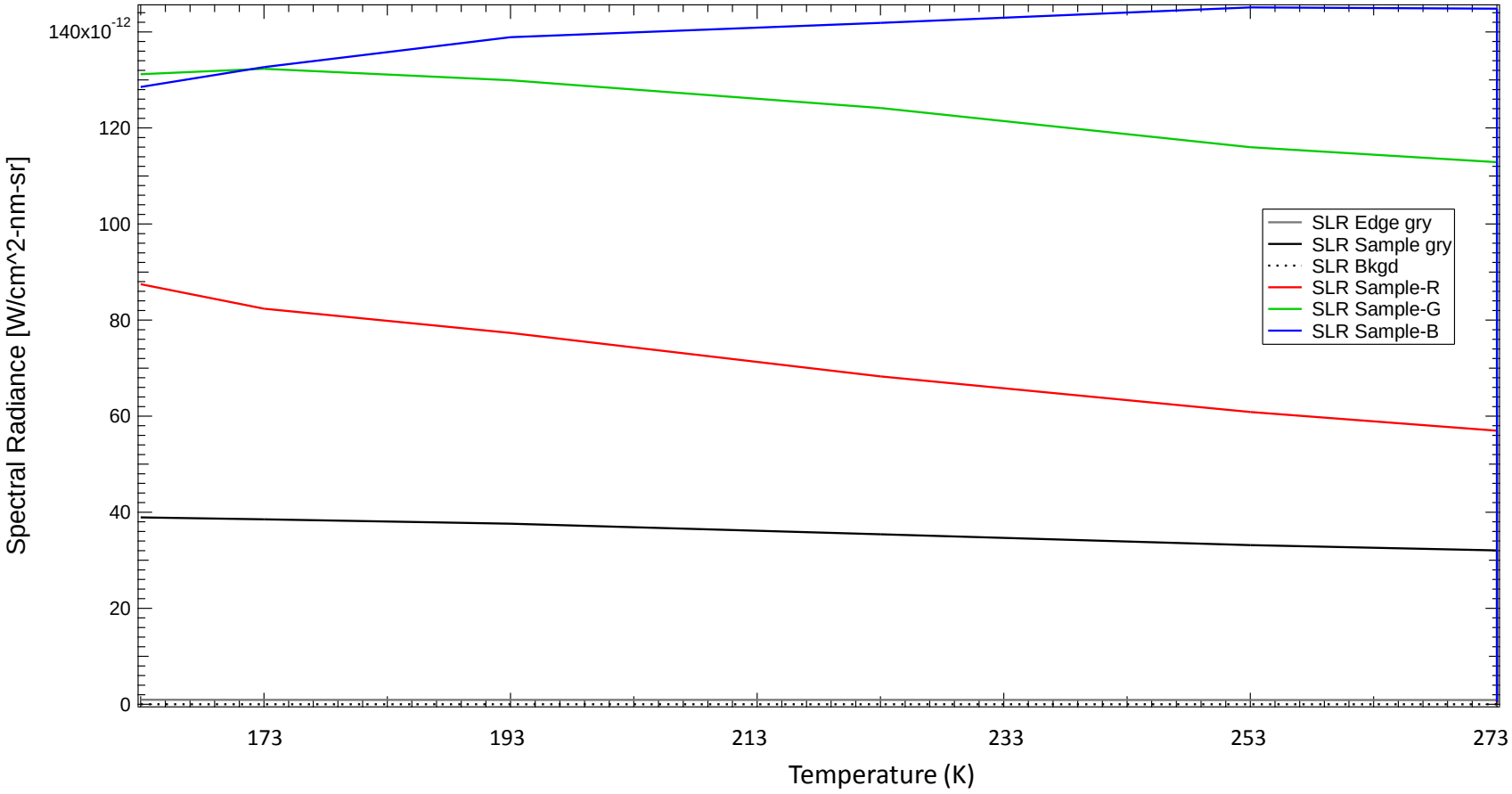
163 K

193 K

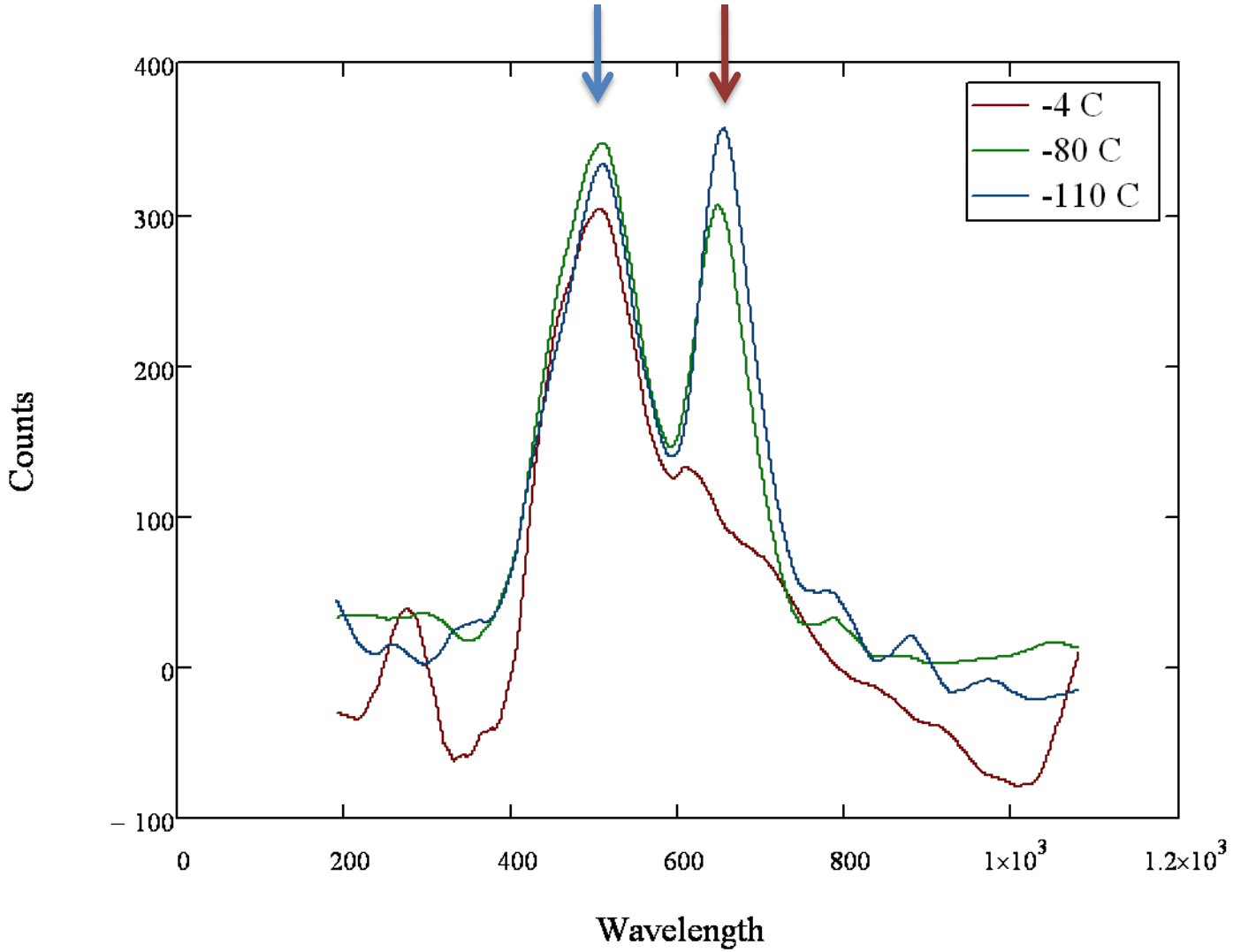


269 K

# SLR Spectral Radiance vs Temperature

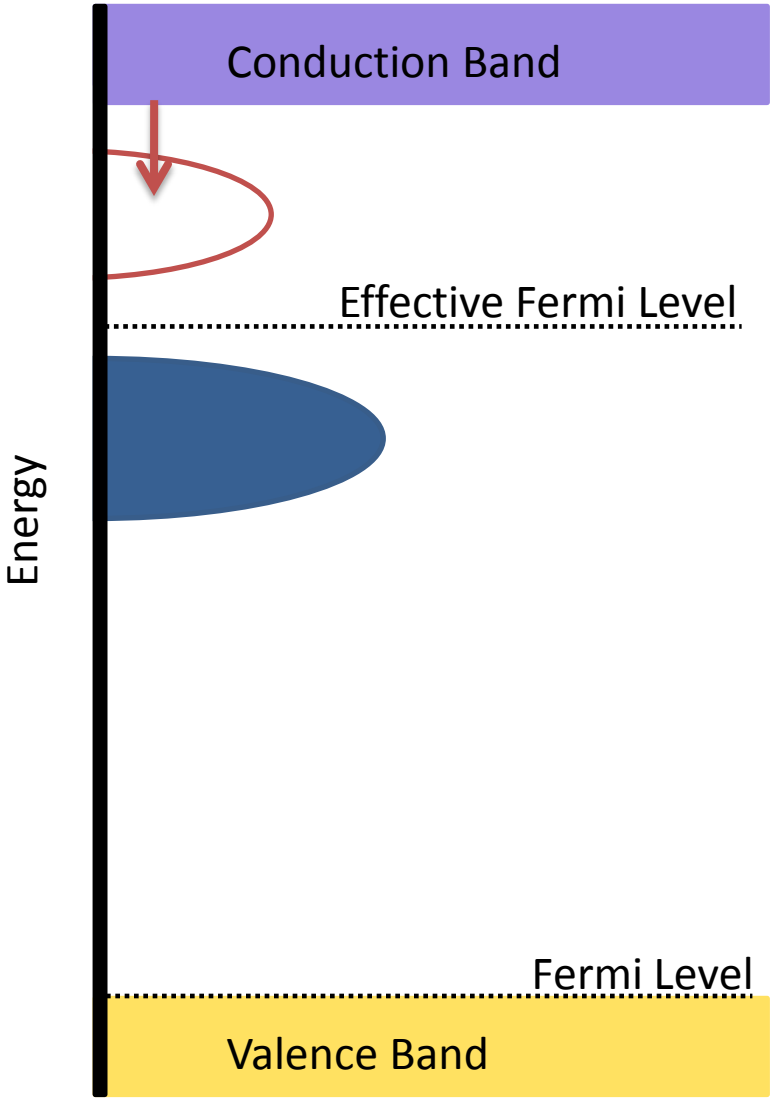


# Temperature Dependent UV-Vis Spectra

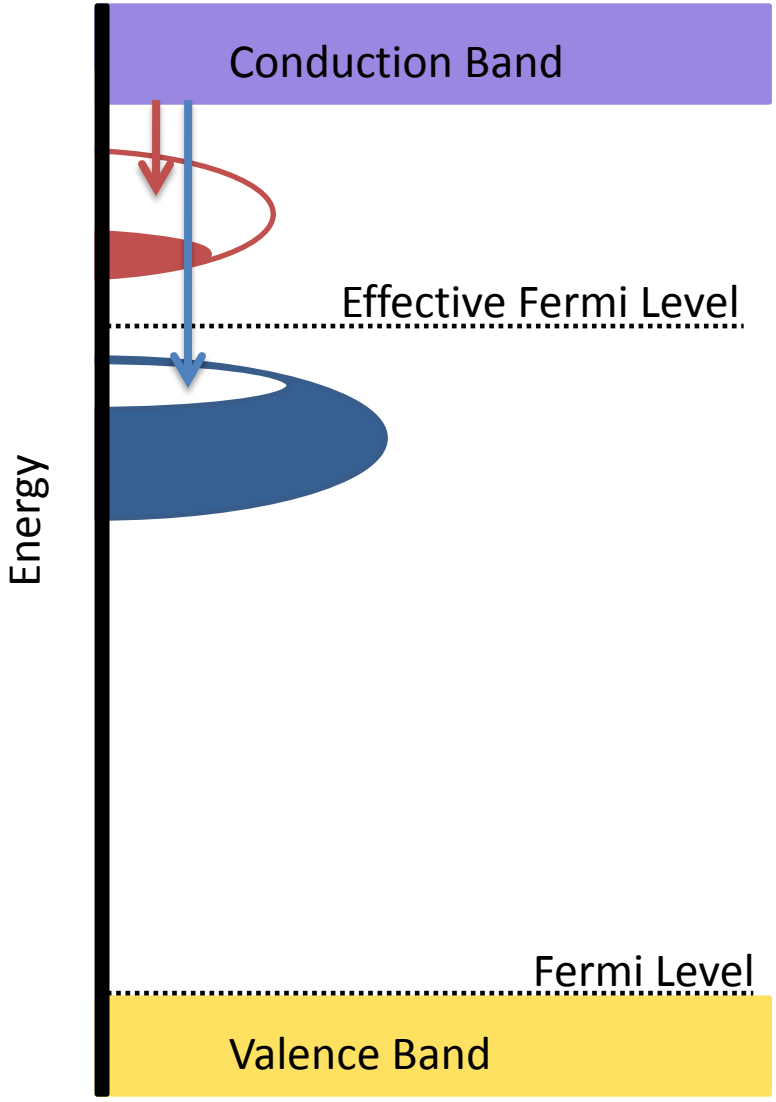


# MODEL

# T = 0


Conduction Band
Effective Fermi Level
Energy
Fermi Level
Valence Band

# Low T


Conduction Band
Effective Fermi Level
Energy
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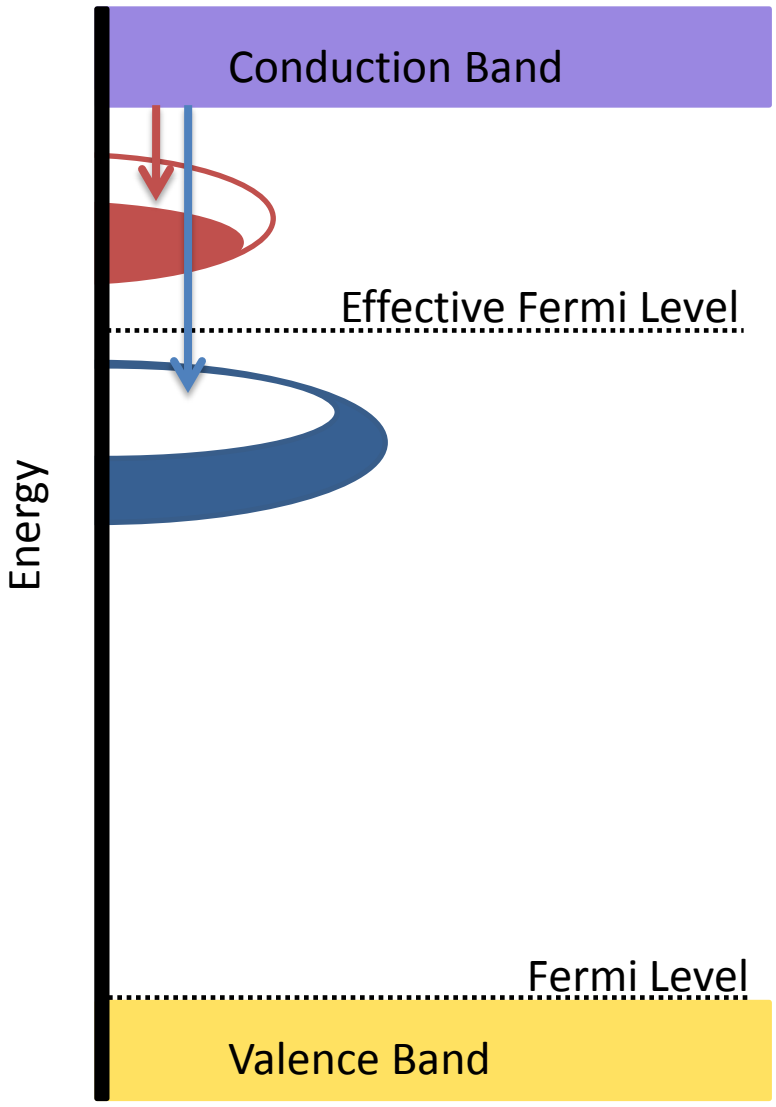
Valence Band

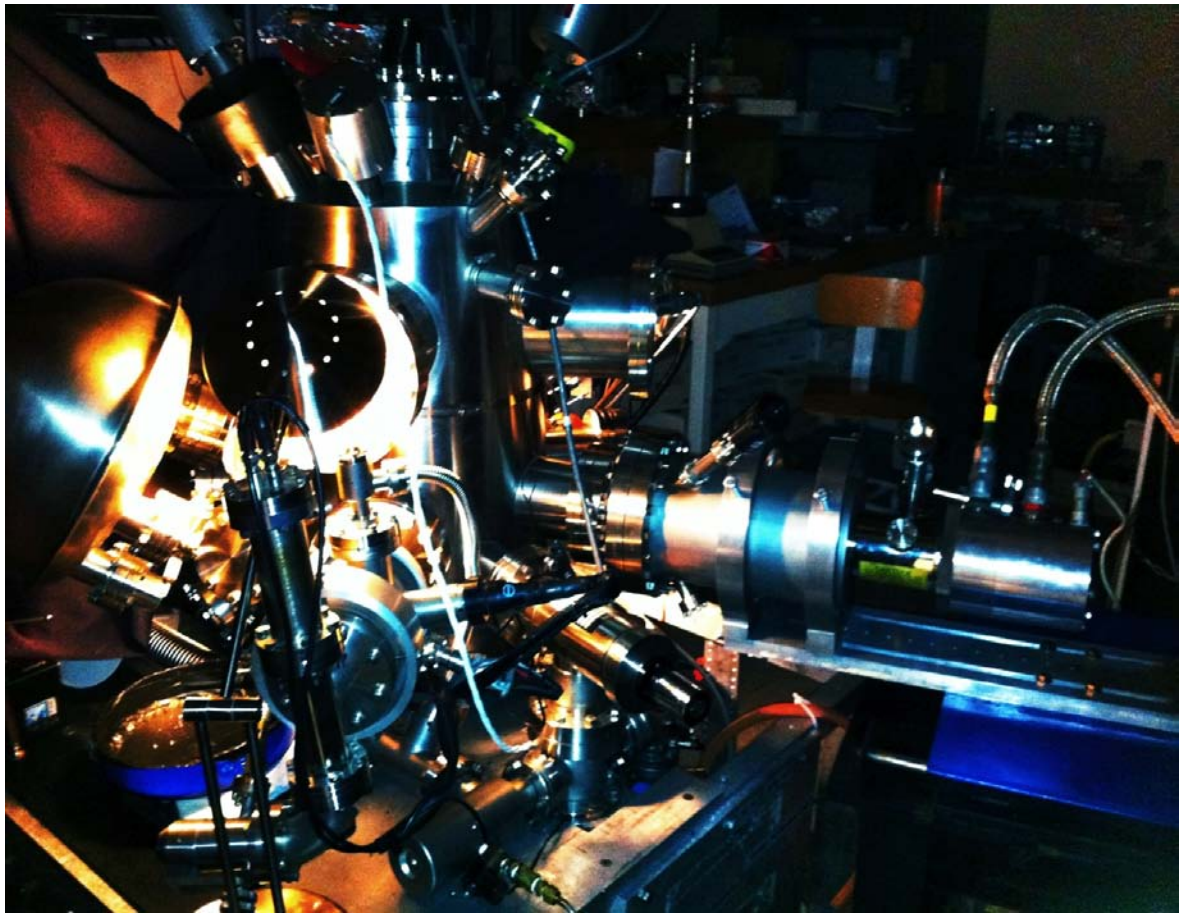
# High T


Conduction Band
Effective Fermi Level
Energy
Fermi Level
Valence Band

# Conclusions

- Our model, thus far, is qualitatively consistent with experimental results

- Future work:
  - Cool sample to 40 K
  - Extend model



# Acknowledgments

•Funding from NASA Goddard Space Flight Center

•Utah State University Material Physics Group

# References

1. Salh, R, et. al., *Cathodoluminescence of $SiO_x$ under-stoichiometric silica layers.* Phys. Stat. Sol. PACS **203,** April 2006.

2. Beiser, Arthur, *Concepts of Modern Physics*, Ed 6, McGraw Hill, 2003, pp 354-360.

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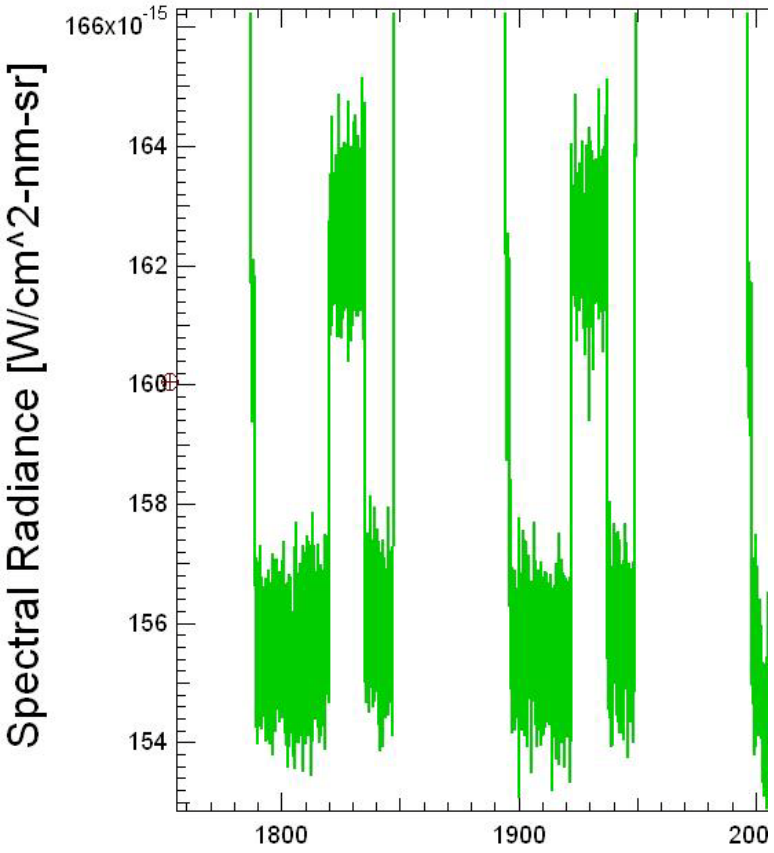
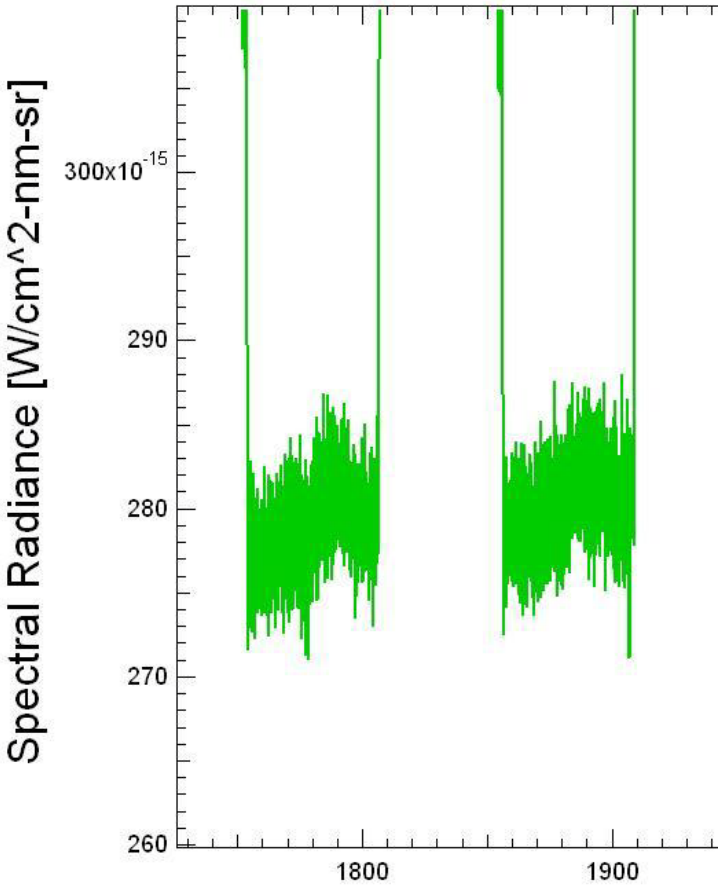
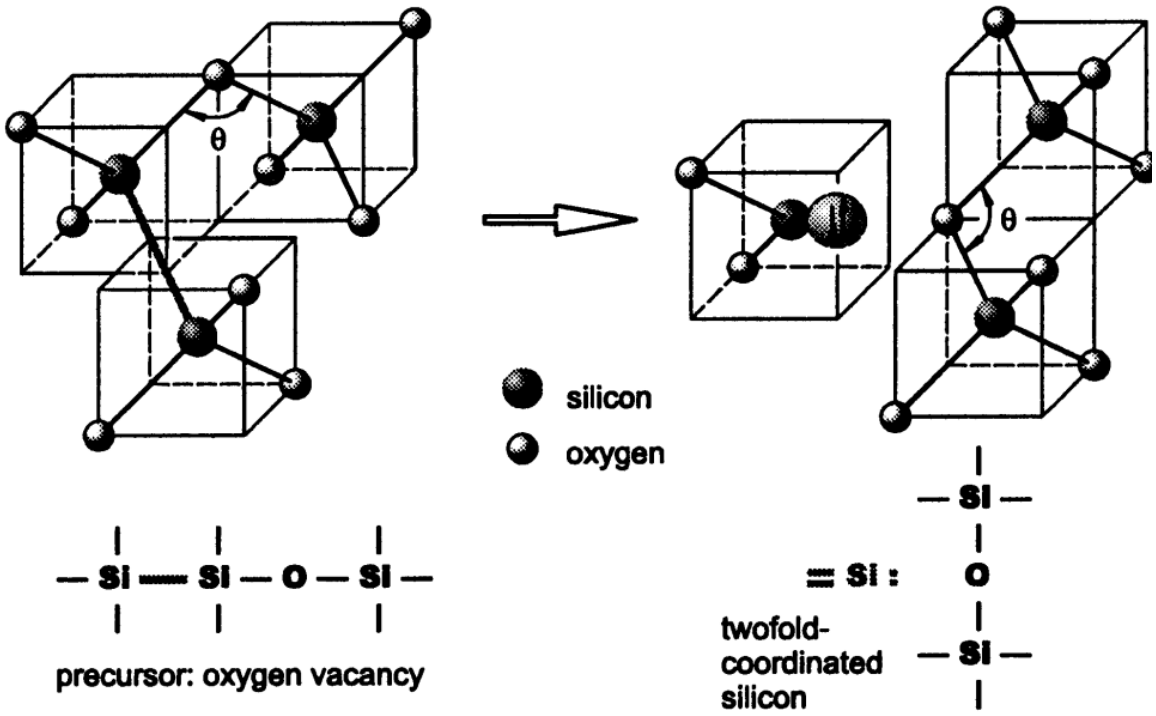


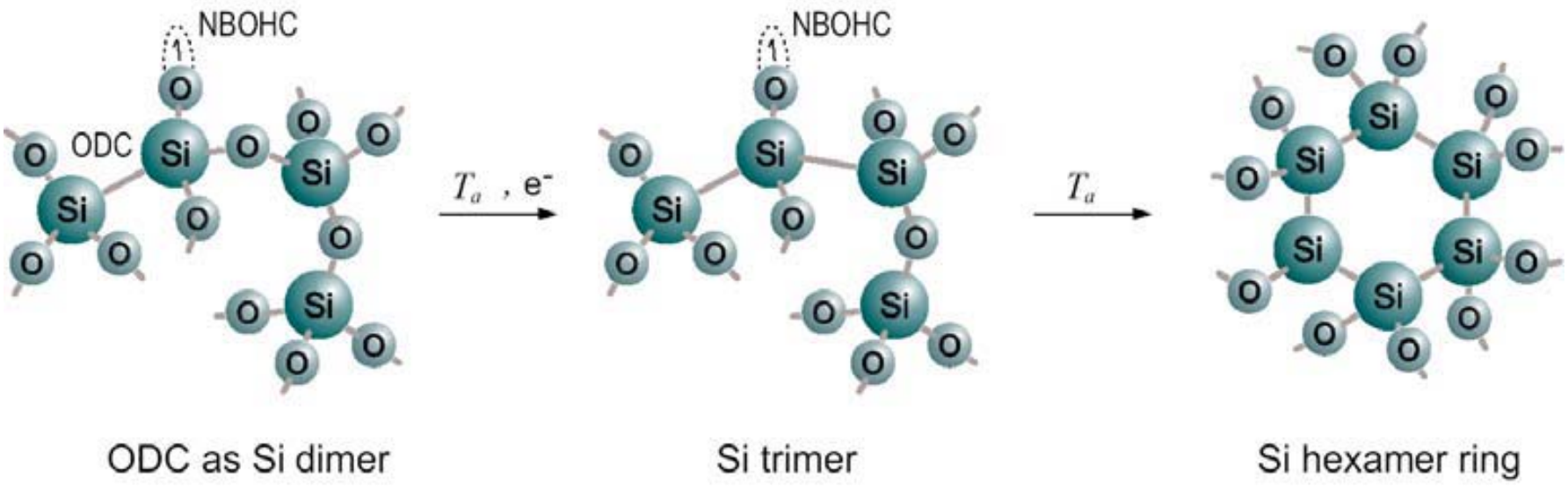



# Chromophores




An oxygen vacancy in the structure on the left is a precursor for the chromophore on the right, a twofold-coordinated silicon defect.

# Chromophores




A nonbridging oxygen hole center (NBOHC) and oxygen deficiency center (ODC) can be transformed into a Si trimer or ring through annealing and/or electron beam irradiation.