# ECE 447/547 (Semiconductor Devices)
## *Southern Illinois University Carbondale*

## *Project #1: Design and Analysis of Nanoscale Light Emitters Exploiting Quantum Confinement Effect*

## *Introduction*:

Nanocrystals (NCs) *confine* charge carriers (electrons and/or holes) within a nanoscale region. Due to quantum mechanical effects, the energy of these carriers is *quantized* as can be derived from the solution of the Schrodinger equation. This is called an eigenvalue problem where, besides energy eigenvalues, one also obtains the wavefunctions that describe the probability of finding the carriers in real space. As was discussed in the class, these nanostructures are potential candidates for generating non-classical light with greater efficiency.

## *Design Problem:*

Use the *nanoSSL* simulator on nanoHUB (https://nanohub.org/tools/nanossl) to "design" an *ultraviolet light emitter having a wavelength of 350 nm* using a *Box Shaped GaN Nanocrystal* as the active material.

**Hint**: On the *Device Structure* phase of the simulator, keep $L_x = L_y = 10$ nm and vary $L_z$ from 1 to 6 nm. From the output drop-down menu, choose *Energy States* and you will get the *bandgap,* $E_G$. Plot $E_G$ against $L_z$. Using Planck's equation, $E_G = hf = hc/\lambda$, obtain the $E_G$ (and then the $L_z$) needed for this particular emission wavelength. Note that for this stage you do not need to use the "Light Source" tab in the simulator; simply skip and hit the "Simulate" button.

## *Analysis:*

1) *Why* does the bandgap vary with $L_z$?
2) Express $E_G$ as a function of dimension $L_z$ (you may obtain a mathematical equation from a spreadsheet polynomial fitting). From this equation, comment on the sensitivity of the emitter w.r.t. $L_z$. For sensitivity, you may consider obtaining an expression for $\frac{dE_G}{dL_z}$.
3) For your particular design (that is, with the extracted value for $L_z$) re-simulate the device. This time, go to the "Light Source" tab and consider *sweeping* the angle "phi" from 0 to 360 degree.
4) From the drop-down menu, obtain images for 3-D wavefunctions. Comment on the shape of the *ground state* and the *first excited state* wavefunctions. Which wavefunction assumes the shape of a *p* orbital (remember, quantum dot or nanocrystals behave as artificial atoms!)?
5) From the drop-down menu, obtain an image for "Absorption" profile. Comment of the *broadening* aspect of the optical absorption. Why does broadening happen?
6) From the "Integrated Absorption" graph discuss how absorption is correlated to the shape of the *ground state* and the *first excited state* wavefunctions.

## ***Report*:**

Follow the *IEEE* style (https://www.ieee.org/conferences/publishing/templates.html) and write on the following aspects:

- *Abstract (a brief statement on what you plan to do in this project)*
- *Introduction (Why this project and related device is important)*
- *Design Method (i.e. the simulator used and a reference to it)*
- *Discussions on Design and Analysis*
- *Here, while describing your design and analysis, attach necessary graphs, snapshots of the simulator pages, and/or codes (if used).*
- *Conclusion*
- *Here, in short state what you have learnt from this project*
- *References (as needed)*