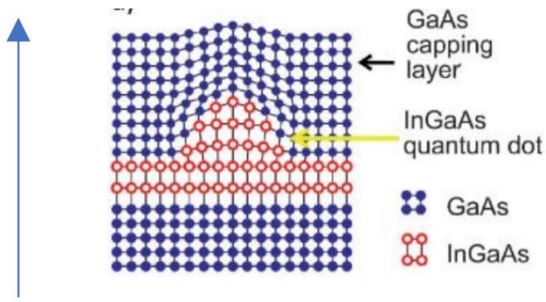
Problem 1

Typical quantum dots used for spin manipulation has strong confinement of excitons along the growth direction that can be modelled as an infinitely deep potential box. The symmetry of the in-plane confinement allows for qualitative description via a two-dimensional harmonic oscillator. Consider for example InGaAs/GaAs quantum dot shown below of size 30-40 nm wide and a height of 5 nm along the growth direction.



- Find the wave function of the excitons and its energy eigenvalues.
- The application of light with frequency ω creates excitons if it satisfies the spin selection rule. Let us consider the excitation light is right circularly polarized, what conditions leads to the creation of bright and dark excitons? Can you write the state of the system using spin states? Remind that electrons in the conduction band has s-like symmetry and heavy holes in the valence band have p-like symmetry.

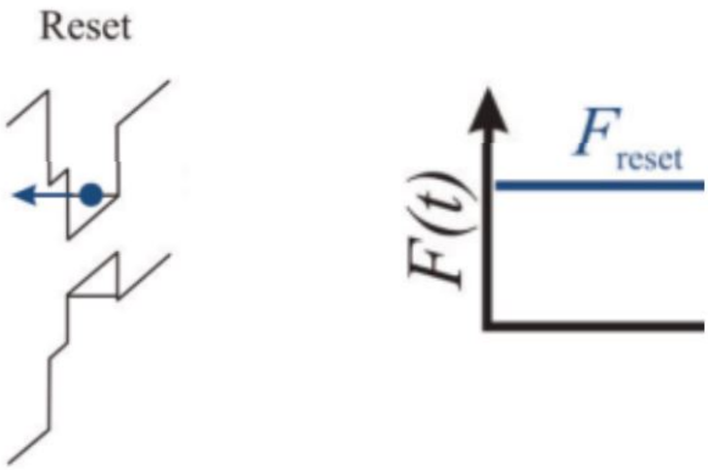
Problem 2

Consider two dots (quantum dot molecule) that are only separated by a thin barrier, e.g., 3 nm of GaAs between InGaAs dots, and the interactions between states of the individual dots significantly depend on their relative energy detuning resulting in the formation of a coupled system. Show that this effect leads to an avoided crossing behavior, 'anticrossing', as two interacting states are tuned in and out of resonance.

Problem 3

One of the techniques used for optical manipulation and read out of spins in quantum dots (e.g., InGaAs embedded in a GaAs photodiode structure) is to use operations that involve the application of electric field and lasers in the following order:
reset. . . >charging. . . .>Storgae. . . ..> spin-to-charge conversion. . . .>readout.

1. Can you show the energy diagram and discuss the operation to create, manipulate and read the spin state of an electron?
2. During the reset process discharging of the quantum dots is needed as shown below using appropriate electric field F to create spin up or down state. What do you do if you want to create spin up state by optical excitation? What polarization of light should be used? Discuss the techniques that will allow you to read the spin state after some storage time.



3. Interaction with the external environment may flip the spin state discussed in (2). How do you know if the spin is flipped?