

Questions and answers for Module 6

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1 Questions

1. How can one-particle states be perceived in a semiconductor quantum dot?
2. Write the energy-dispersions in a semiconductor quantum dot.
3. How does a forbidden-energy level transition become an allowed transition in the case of an optical near field ?
4. What is the major difference between the excited states for an optical far field and an optical near field ?
5. When does unidirectional excitation energy transfer take place in a semiconductor quantum dot ?

2 Answers

1. A semiconductor quantum dot has many electrons associated with it. Thus one can view a semiconductor quantum dot as a many-particle problem. But by determining a ground state and excited states of one-particle problem and also by determining a ground state of many-particle problem by filling particles one by one into lowest energy levels that are not already occupied, one can consider the problem as pertaining to those of one particle states.

2.

$$\begin{aligned} E_c &= E_g + \frac{\hbar^2 k^2}{2m_c} \\ &= E_g + \frac{\hbar^2}{2m_c} \left\{ \left(\frac{n_x \pi}{L_x} \right)^2 + \left(\frac{n_y \pi}{L_y} \right)^2 + \left(\frac{n_z \pi}{L_z} \right)^2 \right\} \end{aligned}$$

and

$$E_v = \frac{\hbar^2}{2m_v} \left\{ \left(\frac{n_x \pi}{L_x} \right)^2 + \left(\frac{n_y \pi}{L_y} \right)^2 + \left(\frac{n_z \pi}{L_z} \right)^2 \right\}$$

3. For transitions to be allowed, all of (n_x, n_y, n_z) should be odd. The transitions become forbidden if either of (n_x, n_y, n_z) becomes even. This results in the spatial modulation of the center of mass motion for a semiconductor quantum dot with the even or odd properties of the envelope function being mixed in the near-field case. This results in the violation of the forbidden conditions. Thus due to optical near field, forbidden-energy level transitions become allowed energy level transitions.
4. In far-field case, the two semiconductor quantum dots cannot be distinguished spatially owing to the diffraction limit. Hence in the far-field case, the excitation of two quantum dots can lead only to a symmetric state. But in the optical near-field case, as one can go beyond the diffraction limit, one can obtain either one or both of the symmetric or anti-symmetric states. Thus the symmetric state can be perceived as a bright state while the anti-symmetric state can be perceived as a dark state. Thus using an optical near field, a specific semiconductor quantum dot can be excited locally.
5. Unidirectional excitation energy transfer is guaranteed in a semiconductor quantum dot only when a fast relaxation process occurs soon after the excitation energy transfer.