

Simple and Multi-layered Quantum dot in various structures

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Abstract: Quantum dots have interesting optical properties. They absorb incoming light of one color and emit out light of a completely different color. This research paper discloses eigen states of a simple and multilayer quantum dot in various structures for cuboid, cylinder, dome, cone, and pyramid, and its three-dimensional wave function, energy states, light and dark transitions (X-polarized), light and dark transitions (Y-polarized), light and dark transitions (Z-polarized), light and dark transitions ($\phi = 0$ and $\theta = 45$), absorption ($\phi = 0$ and $\theta = 45$), absorption sweep of angle θ , and integrated absorption are plotted and the observations of high peak values are noted and documented.

Keywords: quantum dot, quantum mechanics, simple quantum dot, multilayer quantum

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0 Introduction

Semiconductors have a valence band that is filled with electrons and an empty conduction band separated by a band gap (energy gap). For an electron to be energized into the conduction band, it has to intake energy that is higher than the band gap. When a semiconductor is struck by a photon with energy higher than the band gap energy, an electron is energized into the conduction band leaving behind a hole of opposite charge in the valence band. An electron and its hole are drawn toward one another by coulomb forces, and together they form an exciton. The distance between the electron in the conduction band and its hole in the valence band is called

the Bohr radius. The diameter of a quantum dot is in the same order as its exciton Bohr radius, which spatially limits the exciton and leads to the quantum confinement effect. This effect quantizes the energy levels of valence and conduction band within the quantum dot with energy values directly related to the quantum dot's size. The unique optical properties of quantum dot are attributed to this quantum confinement effect, which is the origin of the name of quantum dots^[1].

In an old-fashioned solar cell that convert sun's rays into electricity; the process involves photons of sunlight excite the electrons out of a semiconductor and making useful electric power, but the efficiency of the process is very low. Quantum dots produce more electrons (or holes) for each photon that strikes them, theoretically offering a boost in efficiency of maybe 10% over conventional semiconductors. Charge-coupled devices and complementary metal oxide semiconductor sensors, which are the image detecting chips for digital cameras and webcams, work in a related way to solar cells, by transmuted incoming light into patterns of electrical signals; efficient quantum dots could be used to make tiny and more efficient image sensors for applications where conventional devices are too big and awkward^[2].

1 Simple Quantum Dot in a Cuboid

1.1 Quantum dot in a cuboid structure

A simulation for quantum dot in a cuboid was performed and its three-dimension function at different energy levels, energy states, light and dark transitions for X, Y, Z, ϕ , θ , absorptions, absorption sweep of angle θ and integrated absorptions are plotted and observations are noted^[3, 4].

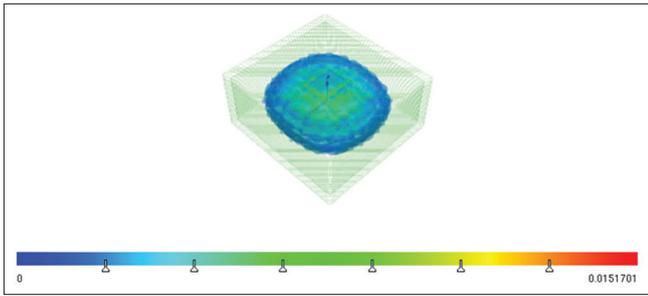


Figure 1. Three-dimensional wave function of simple quantum dot in the cuboid structure at energy level 1

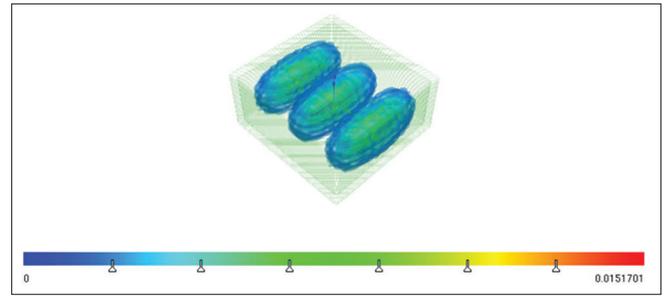


Figure 5. Three-dimensional wave function of simple quantum dot in the cuboid structure at energy level 5

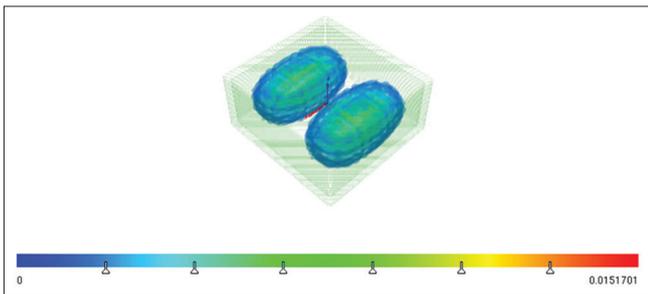


Figure 2. Three-dimensional wave function of simple quantum dot in cuboid structure at energy level 2

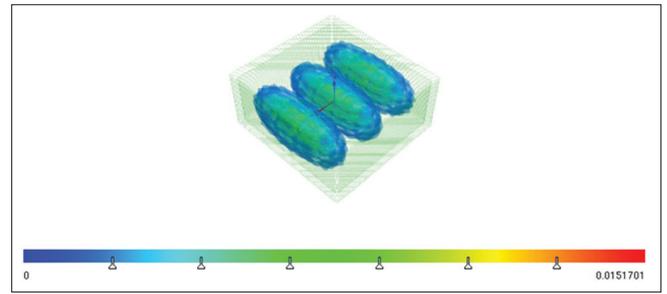


Figure 6. Three-dimensional wave function of simple quantum dot in the cuboid structure at energy level 6

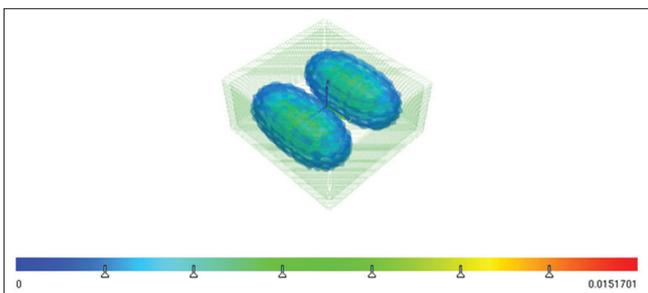


Figure 3. Three-dimensional wave function of simple quantum dot in the cuboid structure at energy level 3

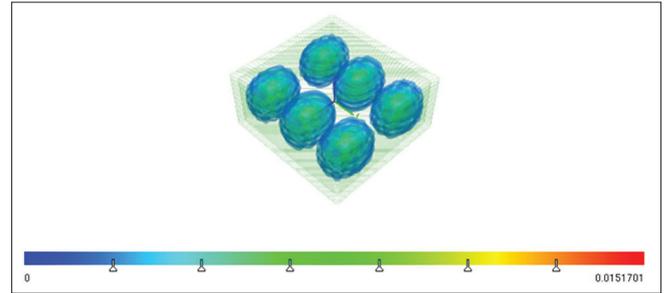


Figure 7. Three-dimensional wave function of simple quantum dot in the cuboid structure at energy level 7

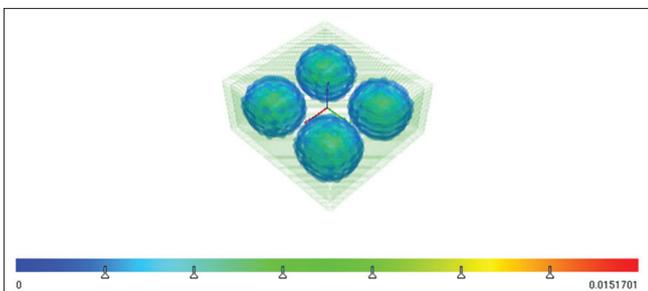


Figure 4. Three-dimensional wave function of simple quantum dot in the cuboid structure at energy level 4

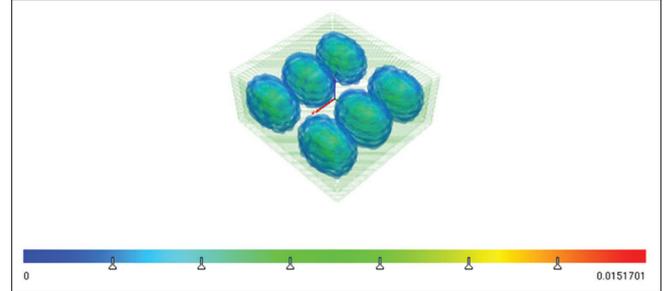


Figure 8. Three-dimensional wave function of simple quantum dot in the cuboid structure at energy level 8

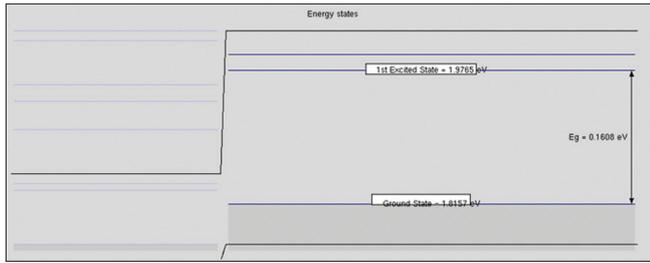


Figure 9. Energy states of the quantum dot in a cuboid structure

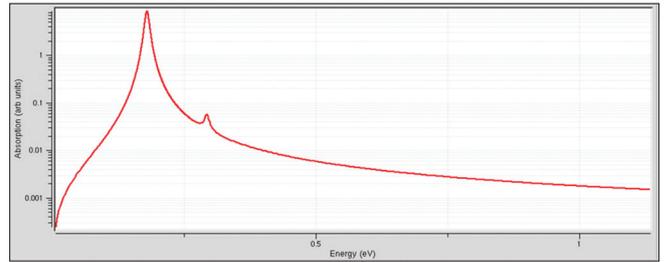


Figure 14. Absorption ($\phi=0$ and $\theta=45$) of simple quantum dot

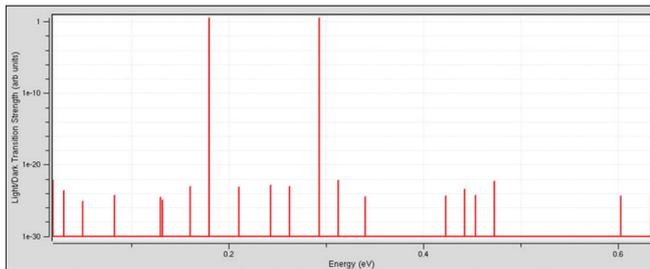


Figure 10. Light and dark transitions (X-polarized) of simple quantum dot

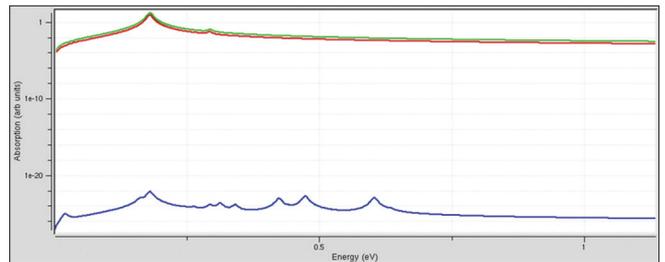


Figure 15. Absorption sweep of angle θ of simple quantum dot

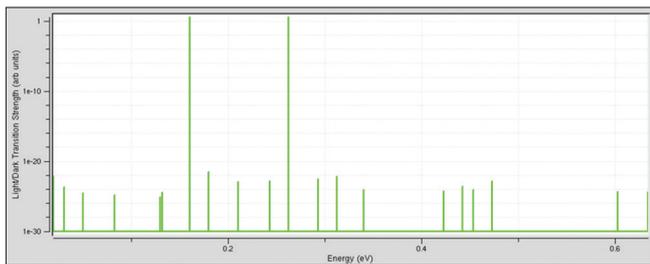


Figure 11. Light and dark transitions (Y-polarized) of simple quantum dot

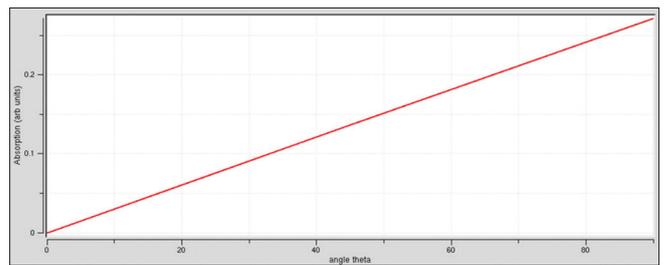


Figure 16. Integrated absorption of simple quantum dot

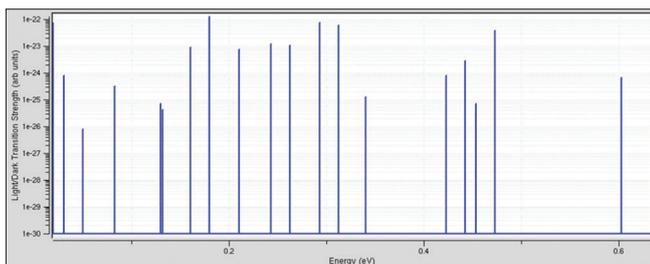


Figure 12. Light and dark transitions (Z-polarized) of simple quantum dot

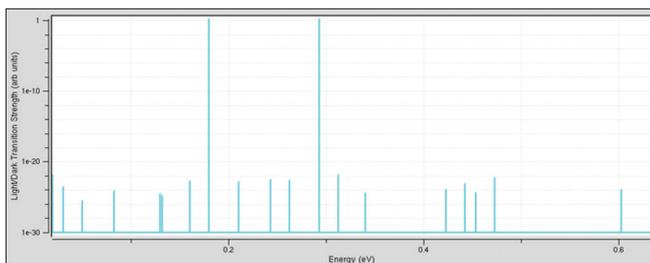


Figure 13. Light and dark transitions ($\phi=0$ and $\theta=45$) of simple quantum dot

1.2 Observations

1. Quantum dot performance changes for every new energy level.
2. There is a change in phase for the quantum dot for every new energy level.
3. High peak for light and dark transitions (X-polarized) is 2.99603arb units at 0.179953 eV and 3.49376arb at 0.293125 eV.
4. High peak for light and dark transitions (Y-polarized) is 3.35876arb units at 0.16077 eV and 3.91693arb units at 0.262532 eV.
5. High peak for light and dark transitions (Z-polarized) is 1.2976e-22arb units at 0.179953 eV.
6. High peak for angle polarized is 1.49802arb units at 0.179953 eV and 1.74688arb units at 0.293125 eV.
7. High peak for absorption for a simple quantum dot in cuboid at $\phi=0$ and $\theta=45$ is noted and is 8.59762arb units at 0.18011 eV.

2. Simple Quantum Dot in a Cylinder

2.1. Quantum dot in a cylinder structure

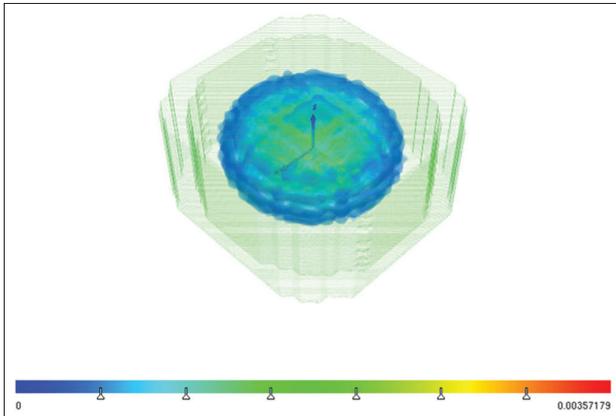


Figure 17. Three-dimensional wave function of simple quantum dot in cylinder structure at energy level 1

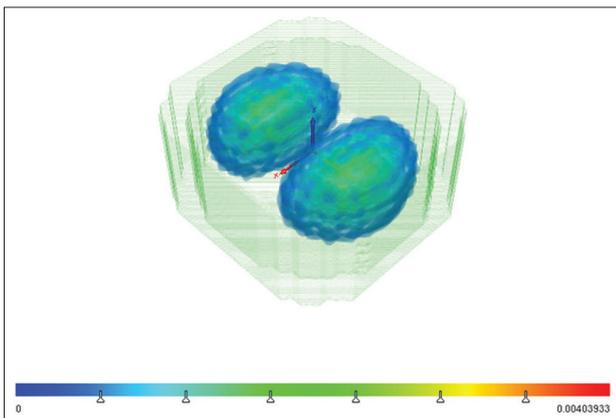


Figure 18. Three-dimensional wave function of simple quantum dot in cylinder structure at energy level 2

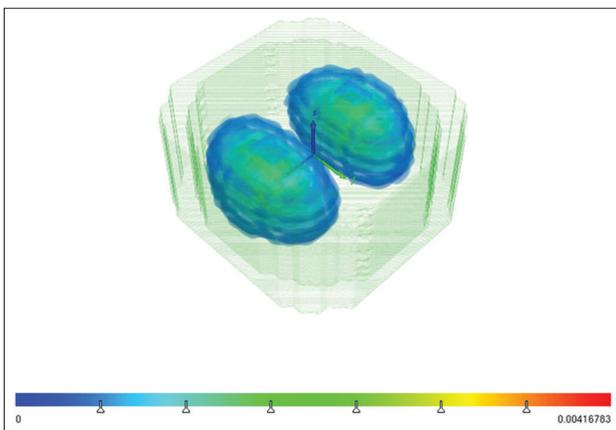


Figure 19. Three-dimensional wave function of simple quantum dot in cylinder structure at energy level 3

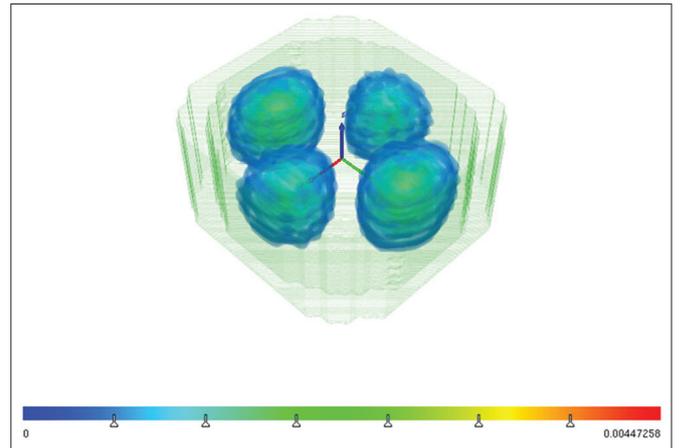


Figure 20. Three-dimensional wave function of simple quantum dot in cylinder structure at energy level 4

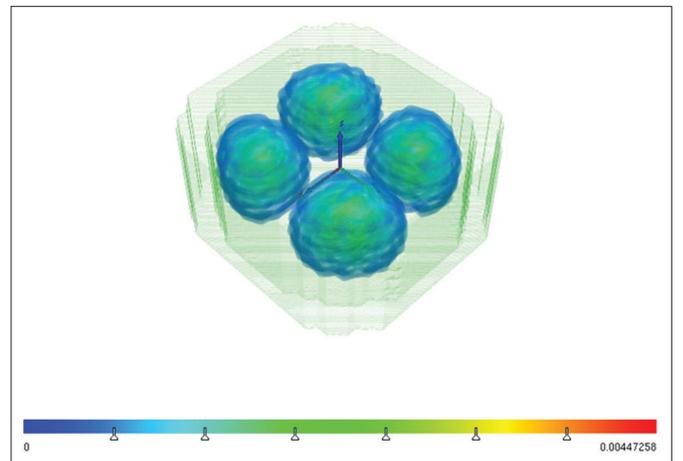


Figure 21. Three-dimensional wave function of simple quantum dot in cylinder structure at energy level 5

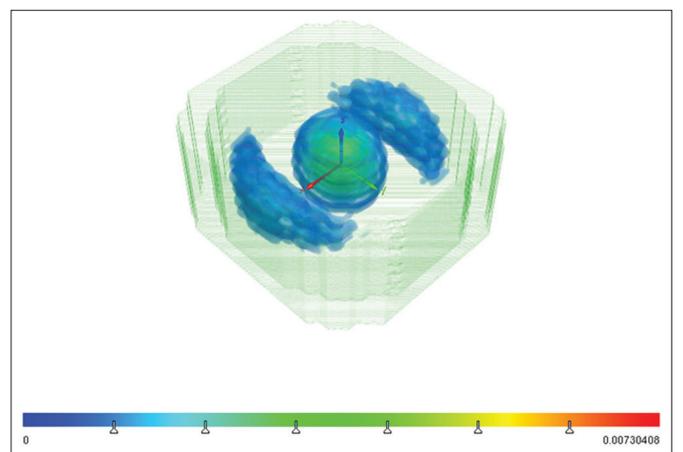


Figure 22. Three-dimensional wave function of simple quantum dot in cylinder structure at energy level 6

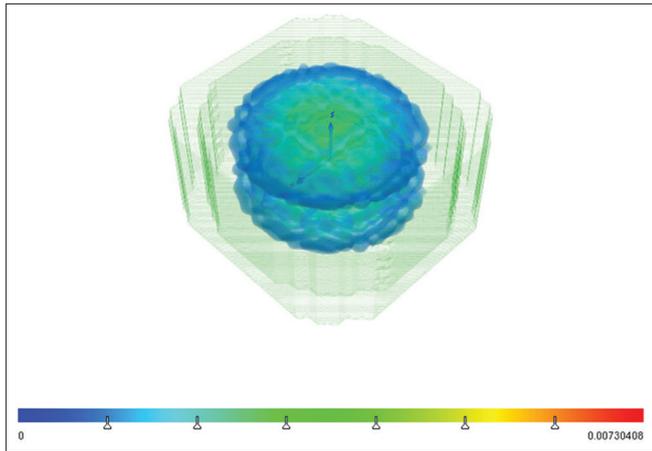


Figure 23. Three-dimensional wave function of simple quantum dot in cylinder structure at energy level 7

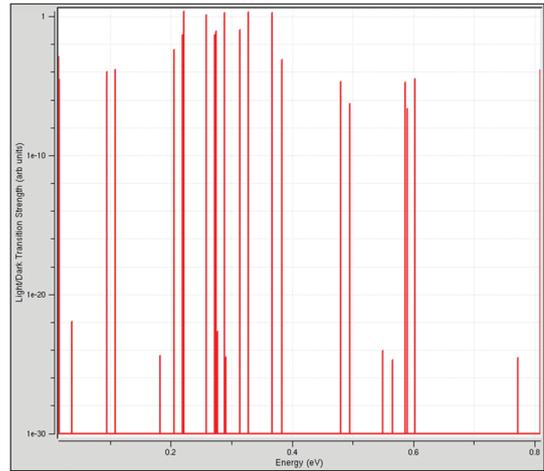


Figure 26. Light and dark transitions (X-polarized) of simple quantum dot in a cylinder structure

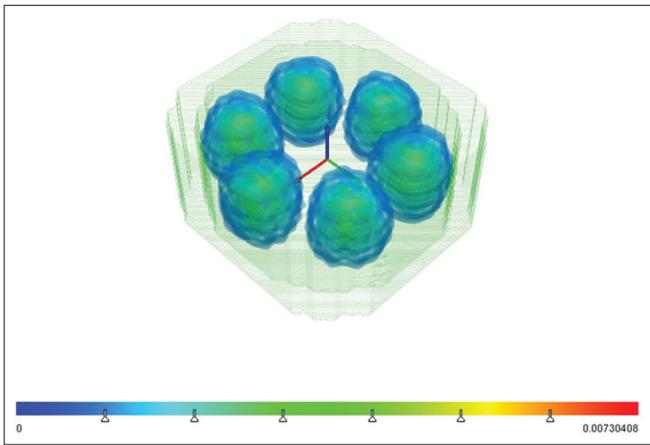


Figure 24. Three-dimensional wave function of simple quantum dot in a cylinder structure at energy level 8

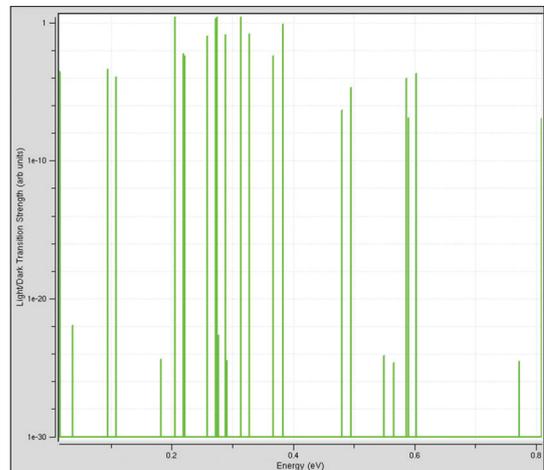


Figure 27. Light and dark transitions (Y-polarized) of simple quantum dot in a cylinder structure

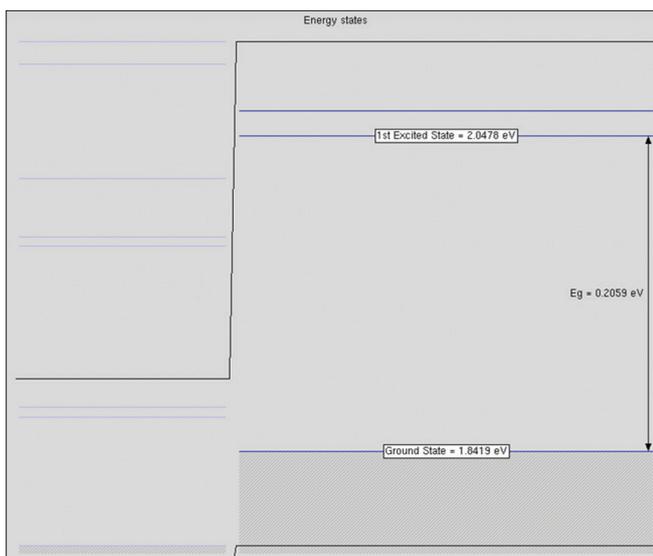


Figure 25. Energy states of the quantum dot in a cylinder structure

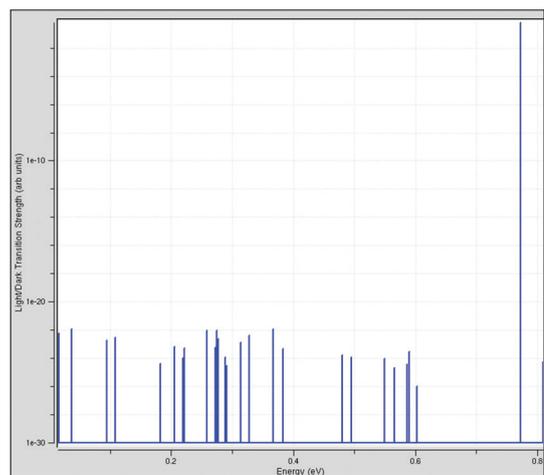


Figure 28. Light and dark transitions (Z-polarized) of simple quantum dot in a cylinder structure

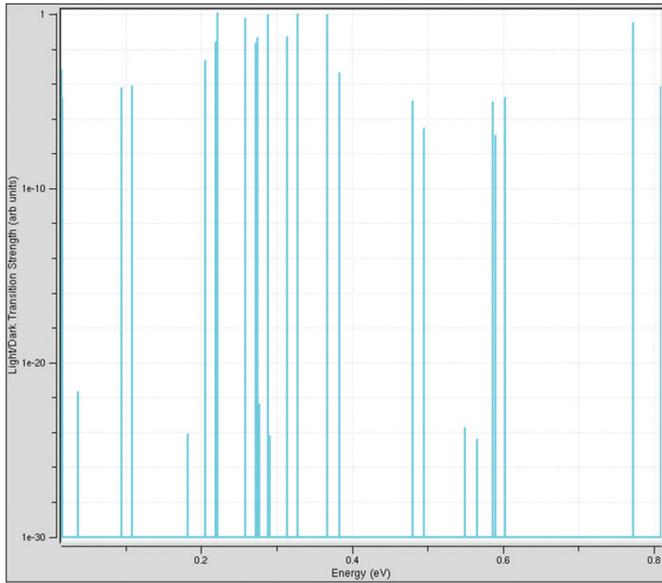


Figure 29. Light and dark transitions ($\phi=0$ and $\theta=45$) of simple quantum dot in a cylinder structure

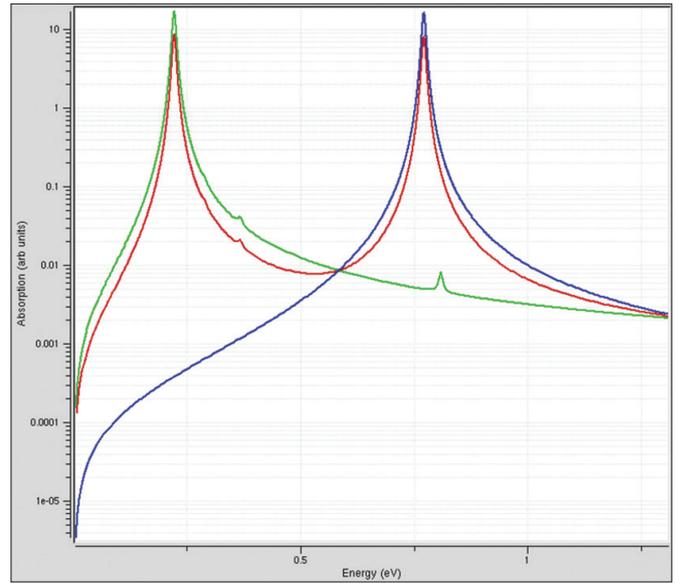


Figure 31. Absorption sweep of angle θ of simple quantum dot in a cylinder structure

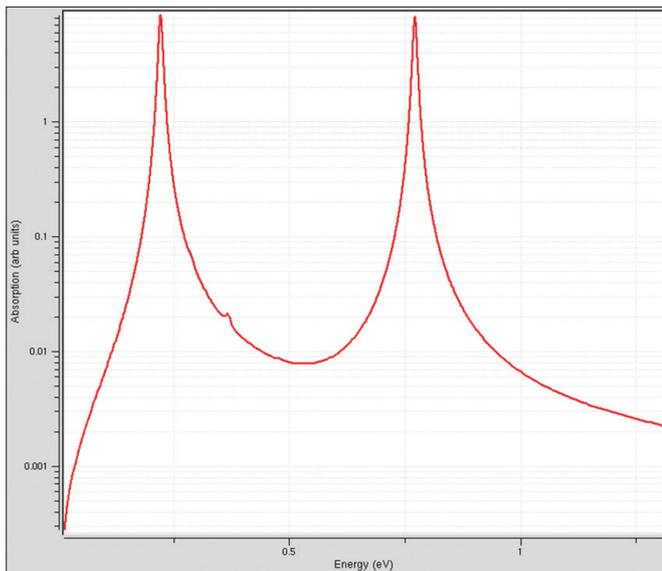


Figure 30. Absorption ($\phi=0$ and $\theta=45$) of simple quantum dot in a cylinder structure

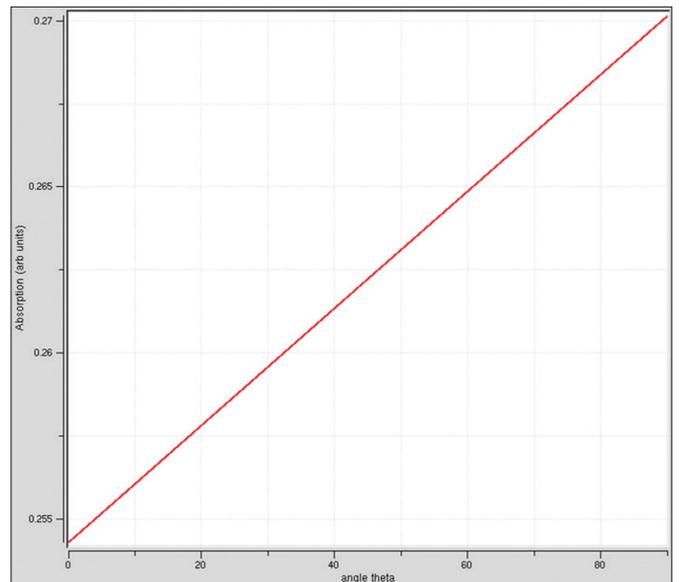


Figure 32. Integrated absorption of simple quantum dot in a cylinder structure

2.2 Observations

1. There is a change in phase for the quantum dot for every new energy level in cylinder structure.
2. High peak for light and dark transitions (X-polarized) for cylinder structure is 2.41865arb units at 0.222159 eV.
3. High peak for light and dark transitions (Y-polarized) is 2.62045arb units at 0.20584 eV.

4. High peak for light and dark transitions (Z-polarized) is 0.662821arb units at 0.771813 eV.
5. High peak for angle polarized is 1.20933arb units at 0.222159 eV.
6. High peak for absorption for a simple quantum dot in cylinder at $\phi=0$ and $\theta=45$ is 8.54902arb units at 0.222135 eV.

3 Simple quantum dot in a dome

3.1 Quantum dot in a dome structure

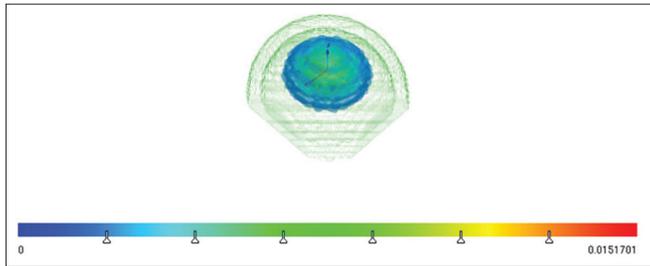


Figure 33. Three-dimensional wave function of simple quantum dot in a dome structure at energy level 1

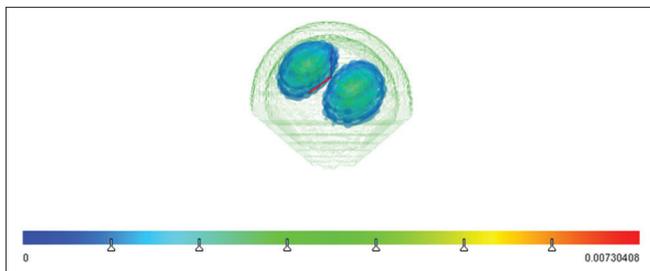


Figure 34. Three-dimensional wave function of simple quantum dot in a dome structure at energy level 2

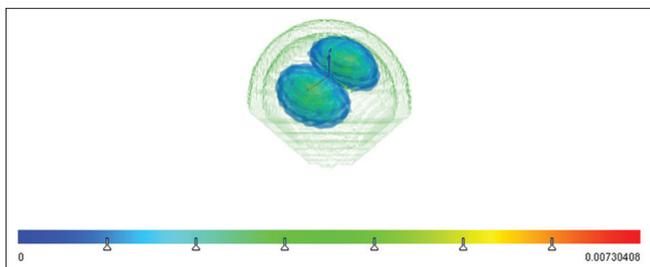


Figure 35. Three-dimensional wave function of simple quantum dot in a dome structure at energy level 3

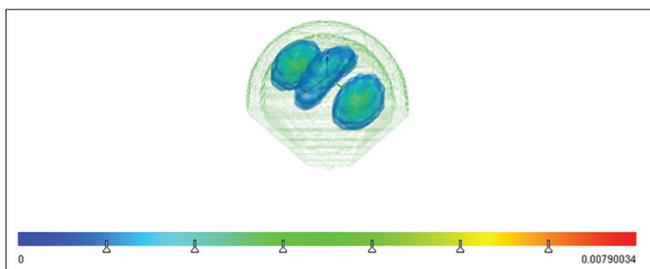


Figure 36. Three-dimensional wave function of simple quantum dot in a dome structure at energy level 4

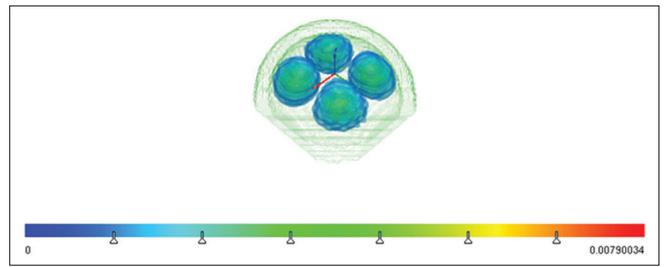


Figure 37. Three-dimensional wave function of simple quantum dot in a dome structure at energy level 5

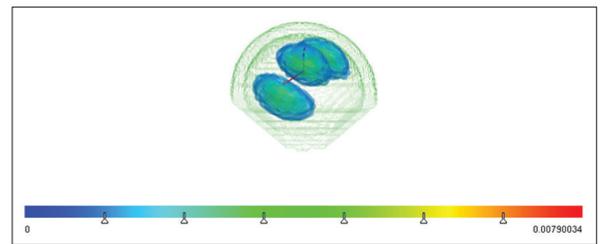


Figure 38. Three-dimensional wave function of simple quantum dot in a dome structure at energy level 6

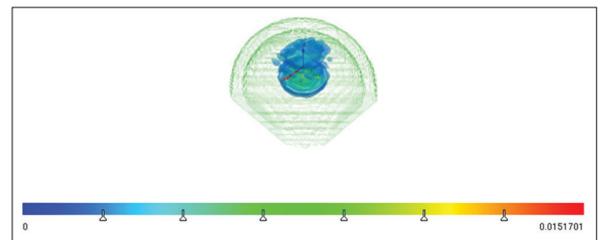


Figure 39. Three-dimensional wave function of simple quantum dot in a dome structure at energy level 7

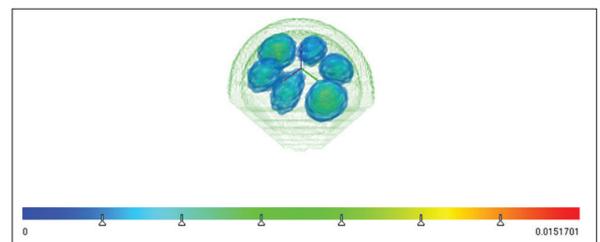


Figure 40. Three-dimensional wave function of simple quantum dot in a dome structure at energy level 8

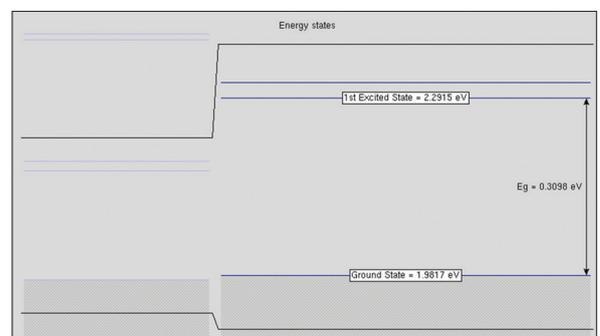


Figure 41. Energy states of the quantum dot in a dome structure

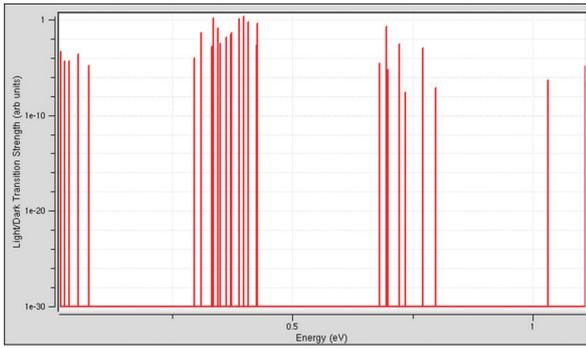


Figure 42. Light and dark transitions (X-polarized) of simple quantum dot in a dome structure

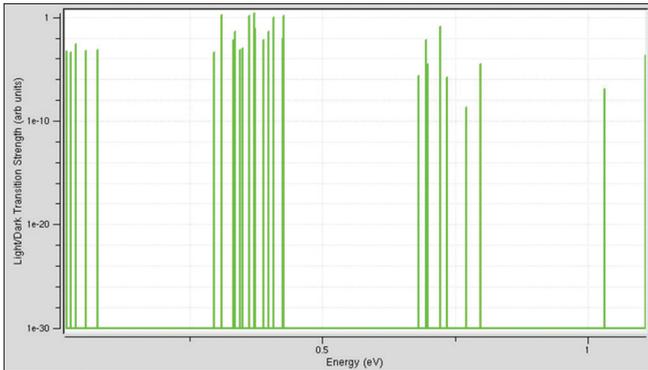


Figure 43. Light and dark transitions (Y-polarized) of simple quantum dot in a dome structure

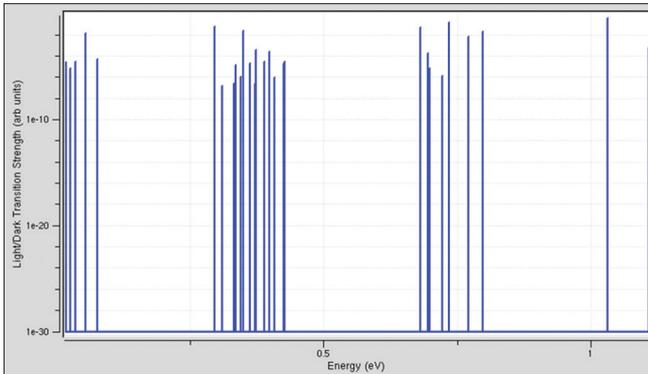


Figure 44. Light and dark transitions (Z-polarized) of simple quantum dot in a dome structure

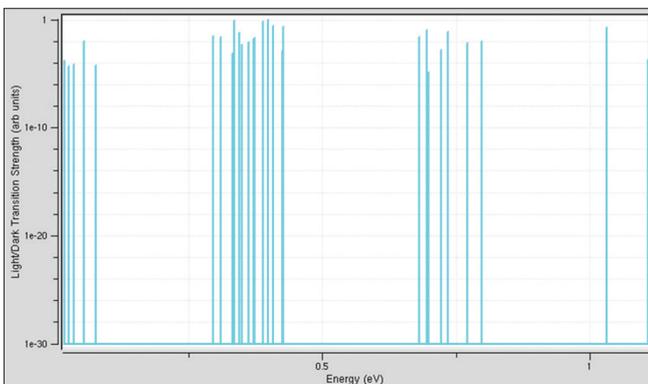


Figure 45. Light and dark transitions ($\phi=0$ and $\theta=45$) of simple quantum dot in a dome structure

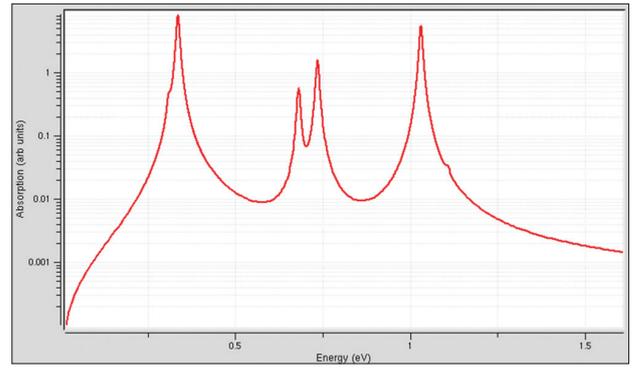


Figure 46. Absorption ($\phi=0$ and $\theta=45$) of simple quantum dot in a dome structure

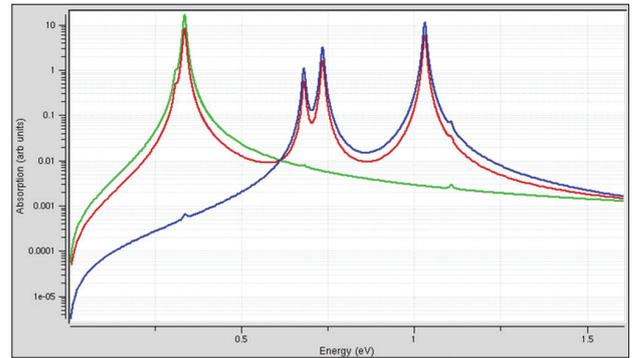


Figure 47. Absorption sweep of angle theta of simple quantum dot in a dome structure

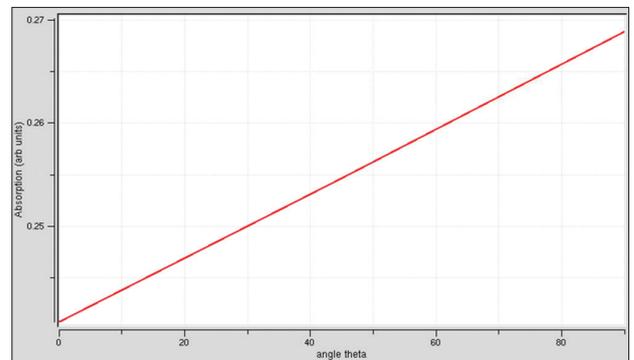


Figure 48. Integrated absorption of simple quantum dot in a dome structure

3.2 Observations

1. There is a change in phase for the quantum dot for every new energy level in dome structure.
2. High peak for light and dark transitions (X-polarized) for dome structure is 2.02499arb units at 0.398796 eV.
3. High peak for light and dark transitions (Y-polarized) is 2.47299arb units at 0.371067 eV.
4. High peak for light and dark transitions (Z-polarized) is 0.341172arb units at 1.03079 eV.

5. High peak for angle polarized is 0.989747arb units at 0.398796 eV.
6. High peak for absorption for a simple quantum dot in dome at $\phi=0$ and $\theta=45$ is 8.28773arb units at 0.335893 eV.

4 Simple quantum dot in a cone

4.1 Quantum dot in a cone structure

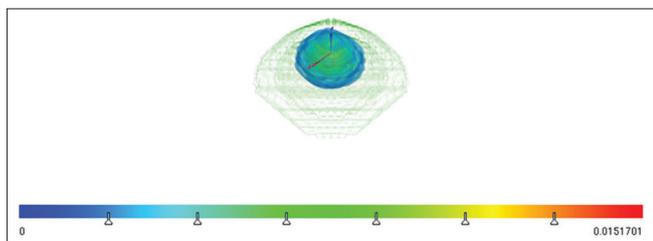


Figure 49. Three-dimensional wave function of simple quantum dot in a cone structure at energy level 1

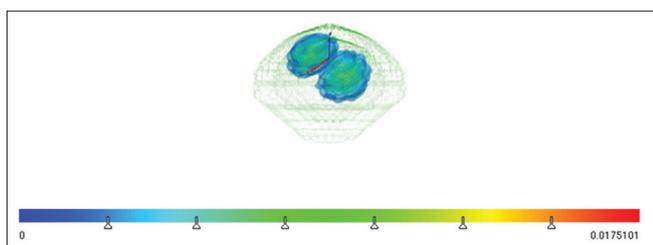


Figure 50. Three-dimensional wave function of simple quantum dot in a cone structure at energy level 2

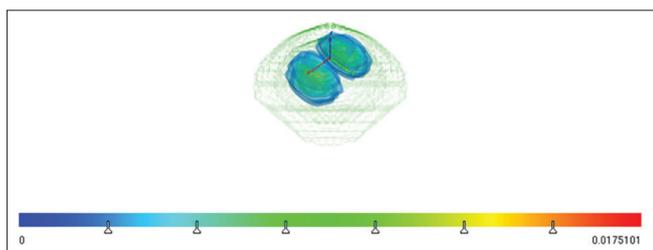


Figure 51. Three-dimensional wave function of simple quantum dot in a cone structure at energy level 3

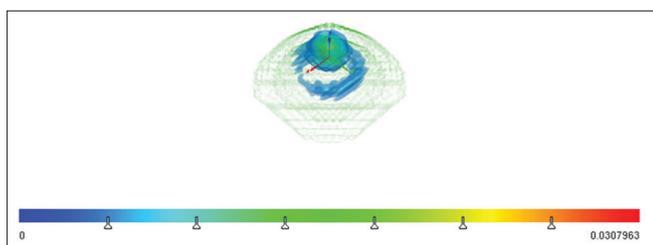


Figure 52. Three-dimensional wave function of simple quantum dot in a cone structure at energy level 4

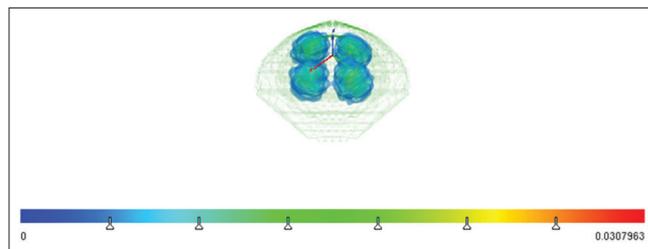


Figure 53. Three-dimensional wave function of simple quantum dot in a cone structure at energy level 5

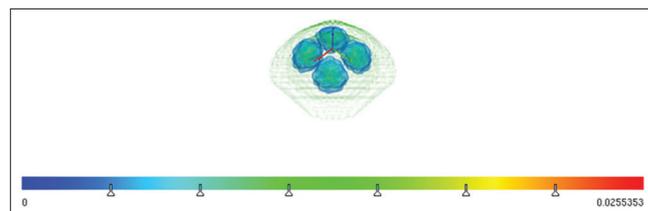


Figure 54. Three-dimensional wave function of simple quantum dot in a cone structure at energy level 6

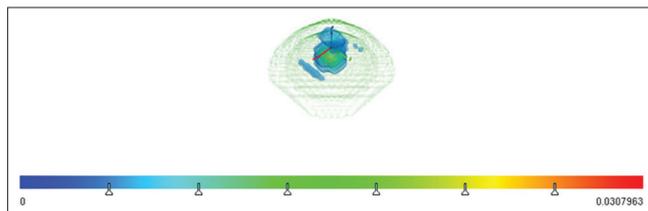


Figure 55. Three-dimensional wave function of simple quantum dot in a cone structure at energy level 7

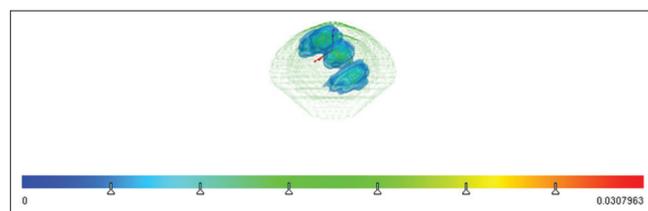


Figure 56. Three-dimensional wave function of simple quantum dot in a cone structure at energy level 8

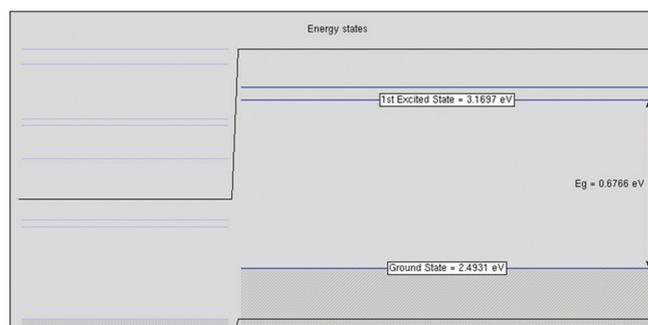


Figure 57. Energy states of the quantum dot in a cone structure

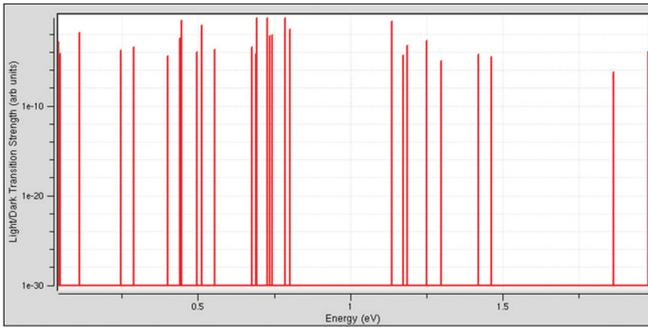


Figure 58. Light and dark transitions (X-polarized) of simple quantum dot in a cone structure

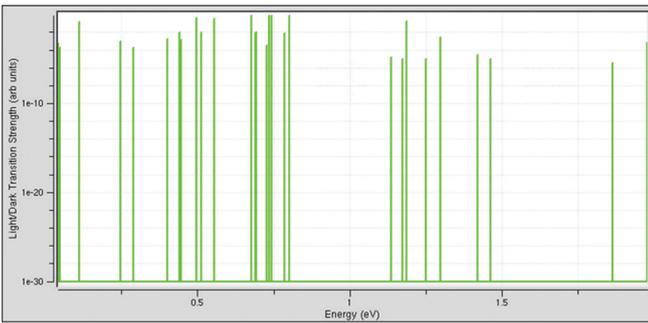


Figure 59. Light and dark transitions (Y-polarized) of simple quantum dot in a cone structure

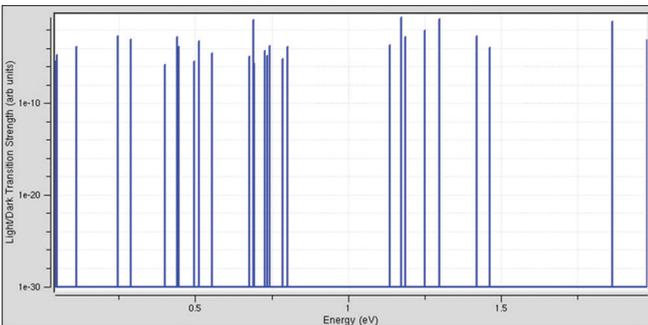


Figure 60. Light and dark transitions (Z-polarized) of simple quantum dot in a cone structure

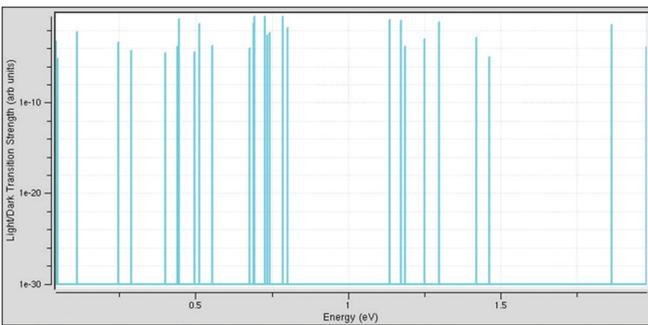


Figure 61. Light and dark transitions ($\phi=0$ and $\theta=45$) of simple quantum dot in a cone structure

4.2 Observations

1. There is change in phase for the quantum dot for every new energy level in cone structure.

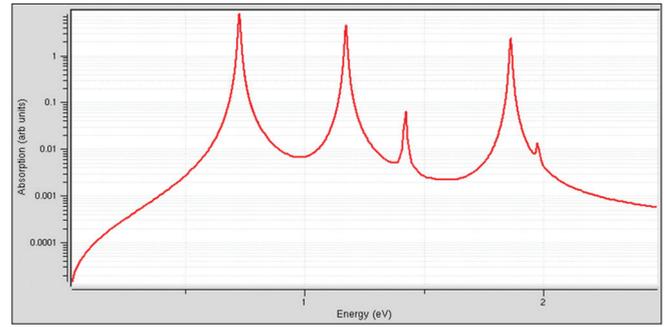


Figure 62. Absorption ($\phi=0$ and $\theta=45$) of simple quantum dot in a cone structure

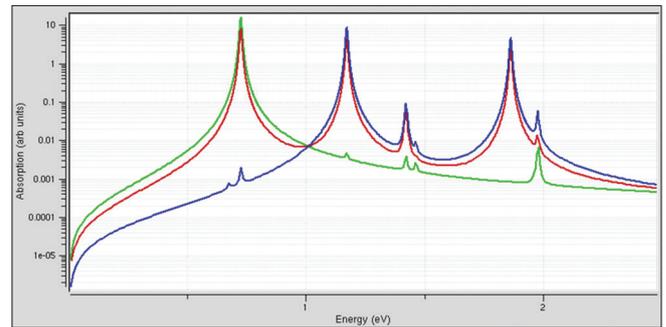


Figure 63. Absorption sweep of angle θ of simple quantum dot in a cone structure

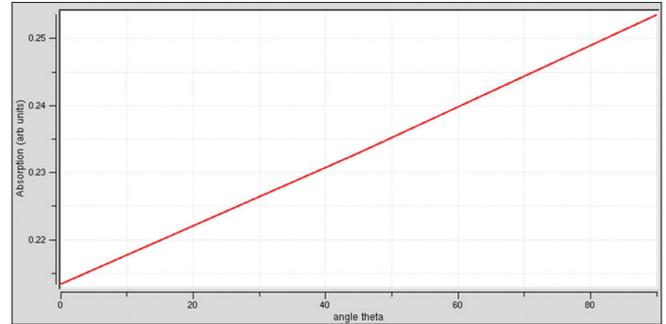


Figure 64. Integrated absorption of simple quantum dot in a cone structure

2. High peak for light and dark transitions (X-polarized) for cone structure is 0.698433arb units at 0.726253 eV.
3. High peak for light and dark transitions (Y-polarized) is 0.761935arb units at 0.676602 eV, 0.696281arb units at 0.735605 eV, 0.711759arb units at 0.743543 eV, and 0.777877arb units at 0.803006 eV.
4. High peak for light and dark transitions (Z-polarized) is 0.235857arb units at 1.17251 eV.
5. High peak for angle polarized is 0.34316arb units at 0.726253 eV.

6. High peak for absorption for a simple quantum dot in cone at $\phi=0$ and $\theta=45$ is 7.93162arb units at 0.726195 eV.

5 Simple quantum dot in a pyramid

5.1 Quantum dot in a pyramid structure

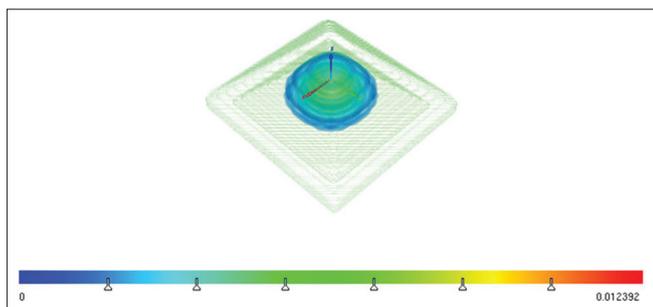


Figure 65. Three-dimensional wave function of simple quantum dot in a pyramid structure at energy level 1

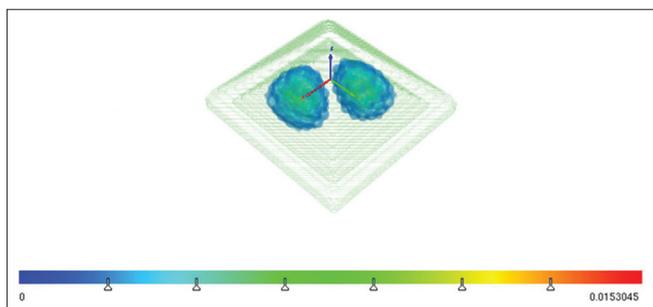


Figure 66. Three-dimensional wave function of simple quantum dot in a pyramid structure at energy level 2

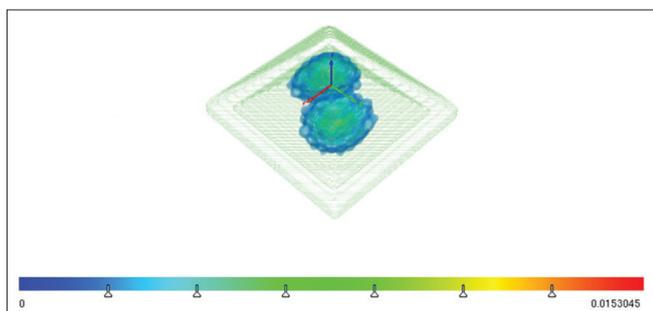


Figure 67. Three-dimensional wave function of simple quantum dot in a pyramid structure at energy level 3

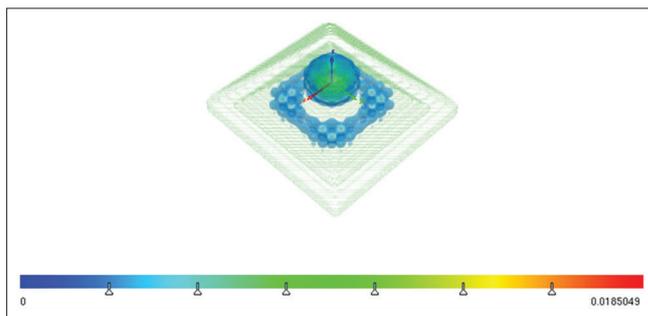


Figure 68. Three-dimensional wave function of simple quantum dot in a pyramid structure at energy level 4

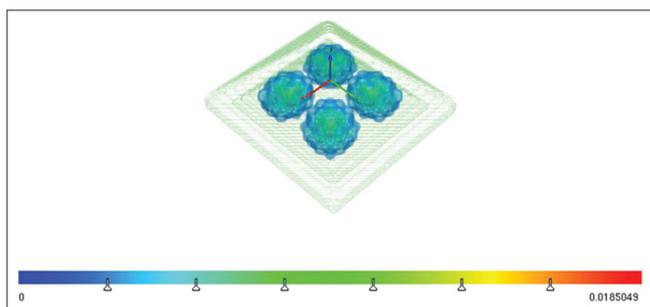


Figure 69. Three-dimensional wave function of simple quantum dot in a pyramid structure at energy level 5

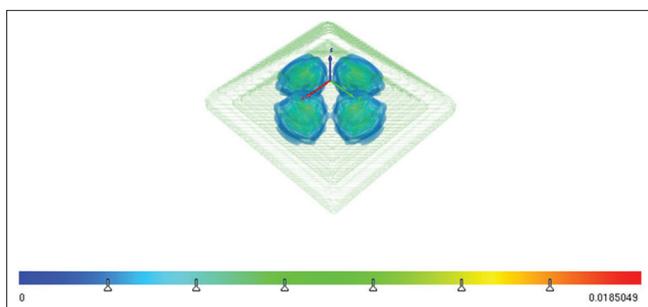


Figure 70. Three-dimensional wave function of simple quantum dot in a pyramid structure at energy level 6

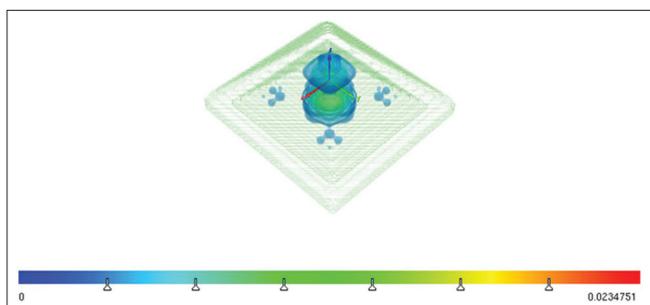


Figure 71. Three-dimensional wave function of simple quantum dot in a pyramid structure at energy level 7

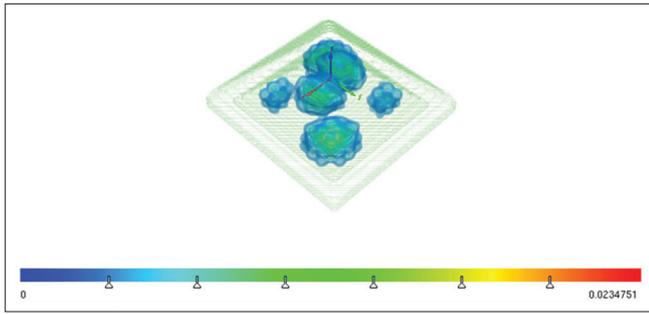


Figure 72. Three-dimensional wave function of simple quantum dot in a pyramid structure at energy level 8

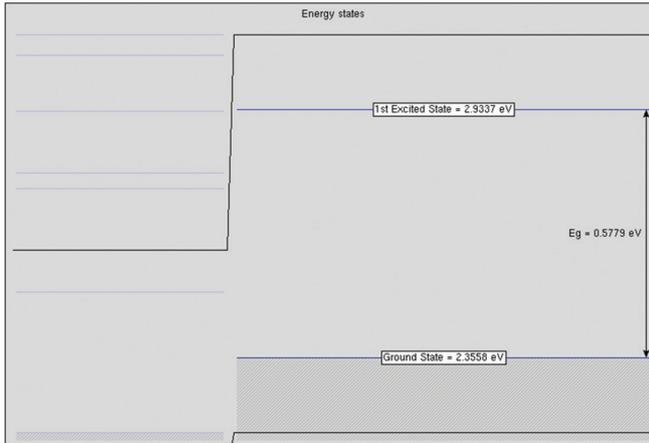


Figure 73. Energy states of the quantum dot in a pyramid structure

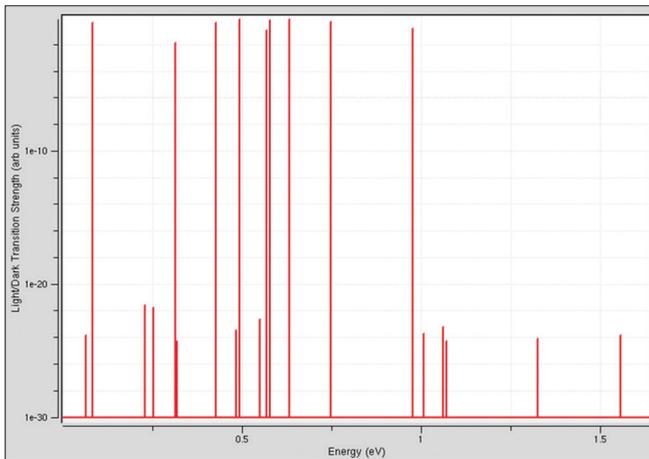


Figure 74. Light and dark transitions (X-polarized) of simple quantum dot in a pyramid structure

5.2 Observations

1. There is a change in phase for the quantum dot for every new energy level in pyramid structure.
2. High peak for light and dark transitions (X-polarized) for pyramid structure is 0.771552arb units at 0.493703 eV and 0.816251arb units at 0.633605 eV.
3. High peak for light and dark transitions (Y-polarized) is 0.975603arb units at 0.568064 eV.

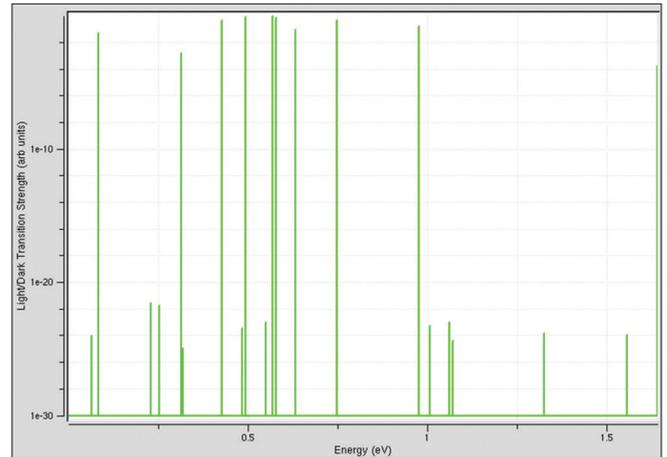


Figure 75. Light and dark transitions (Y-polarized) of simple quantum dot in a pyramid structure

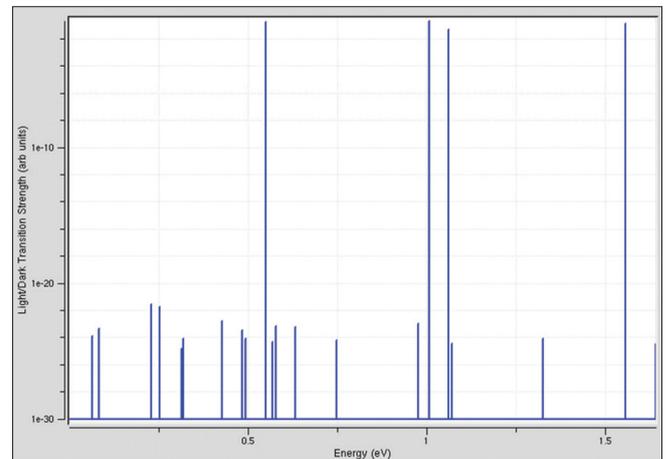


Figure 76. Light and dark transitions (Z-polarized) of simple quantum dot in a pyramid structure

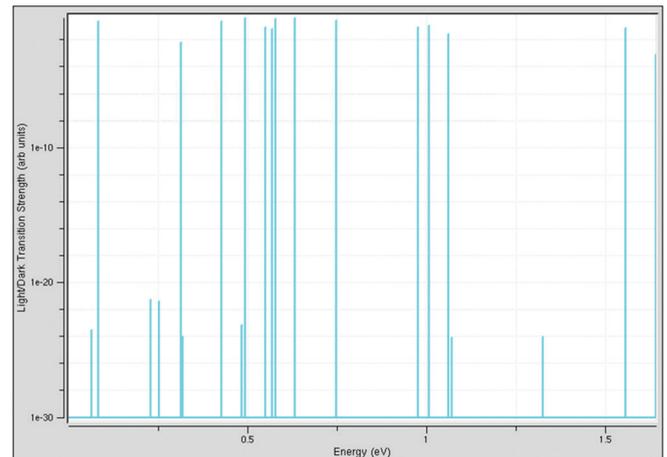


Figure 77. Light and dark transitions ($\phi=0$ and $\theta=45$) of simple quantum dot in a pyramid structure

4. High peak for light and dark transitions (Z-polarized) is 0.211412arb units at 1.00614 eV.
5. High peak for angle polarized is 0.385776arb units at 0.493703 eV and 0.408126arb units at 0.633605 eV.

6. High peak for absorption for a simple quantum dot in pyramid at $\phi = 0$ and $\theta = 45$ is 8.22245arb units at 0.578084 eV.

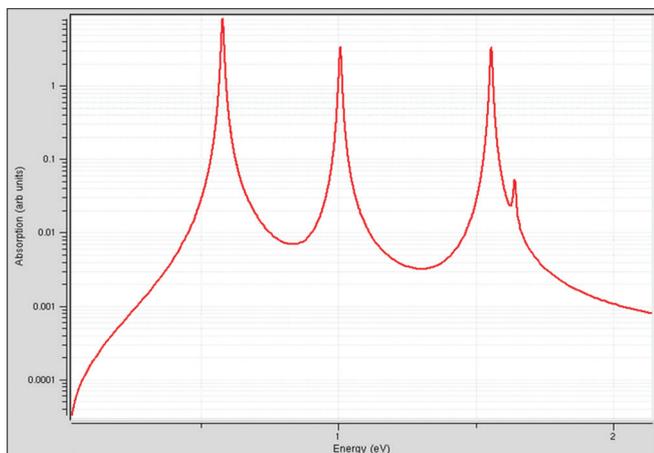


Figure 78. Absorption ($\phi=0$ and $\theta=45$) of simple quantum dot in a pyramid structure

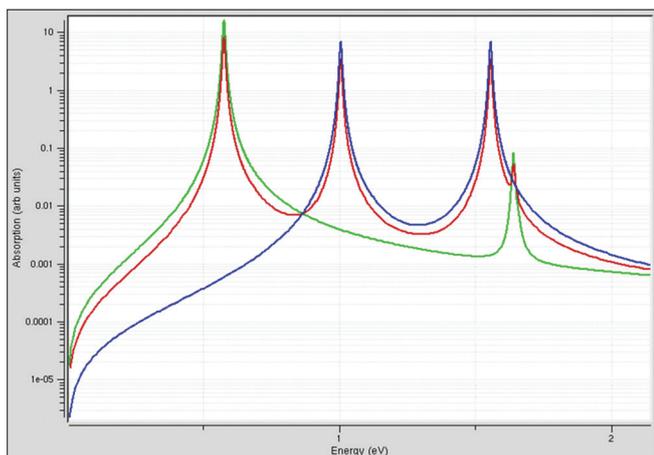


Figure 79. Absorption sweep of angle θ of simple quantum dot in a pyramid structure

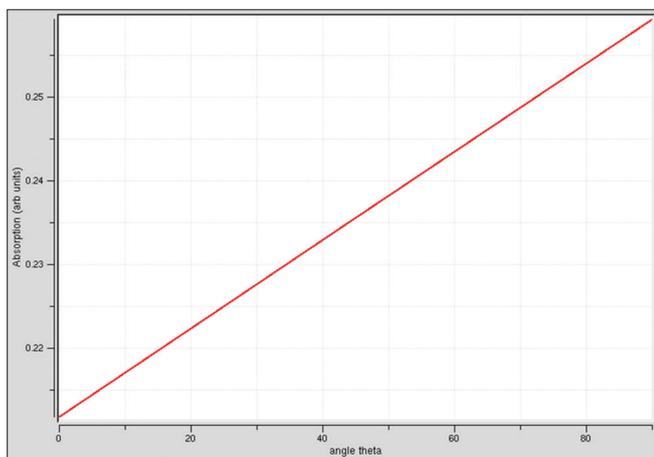


Figure 80. Integrated absorption of simple quantum dot in a pyramid structure

6 Multilayer quantum dot in a cuboid

6.1 Multilayer quantum dot in a cuboid structure

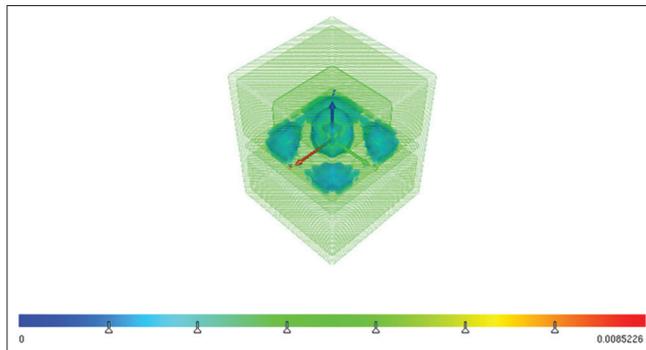


Figure 81. Three-dimensional wave function of multilayer quantum dot in a cuboid structure at energy level 1

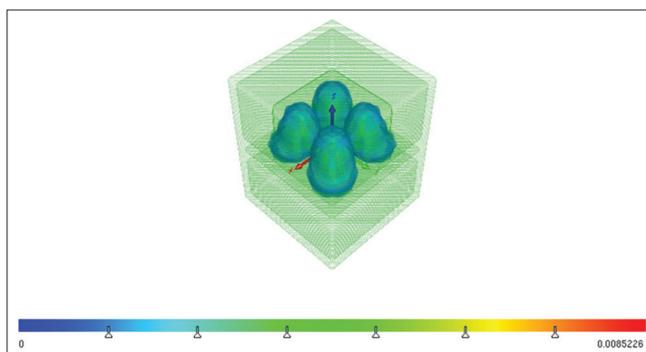


Figure 82. Three-dimensional wave function of multilayer quantum dot in a cuboid structure at energy level 2

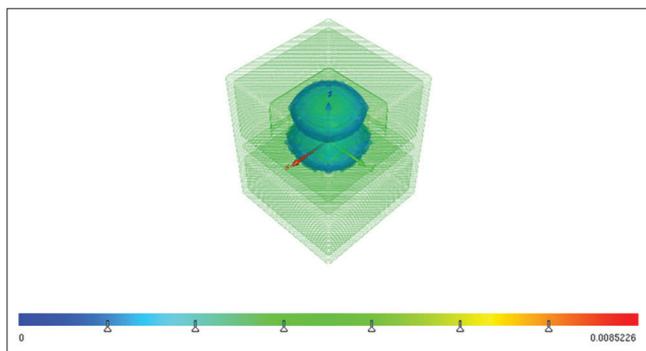


Figure 83. Three-dimensional wave function of multilayer quantum dot in a cuboid structure at energy level 3

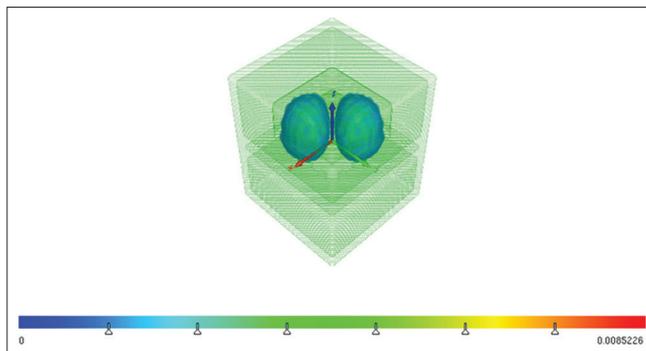


Figure 84. Three-dimensional wave function of multilayer quantum dot in a cuboid structure at energy level 4

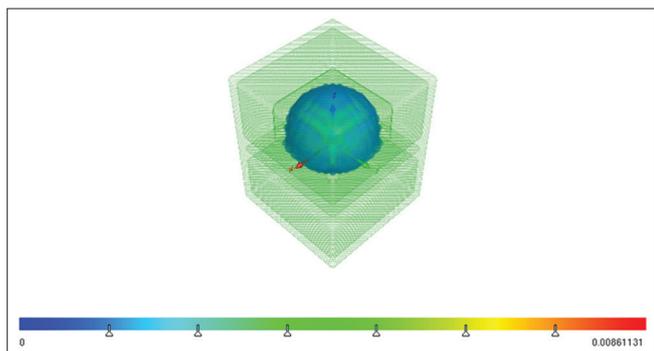


Figure 85. Three-dimensional wave function of multilayer quantum dot in a cuboid structure at energy level 5

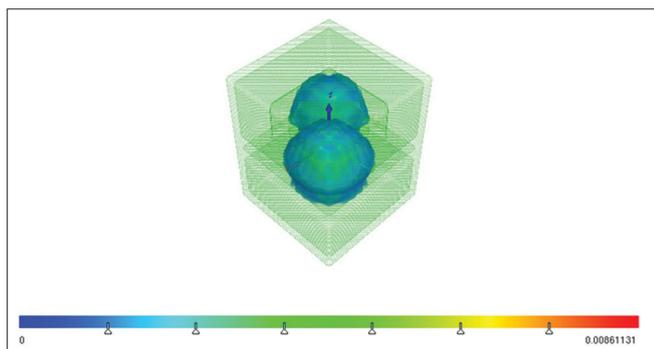


Figure 86. Three-dimensional wave function of multilayer quantum dot in a cuboid structure at energy level 6

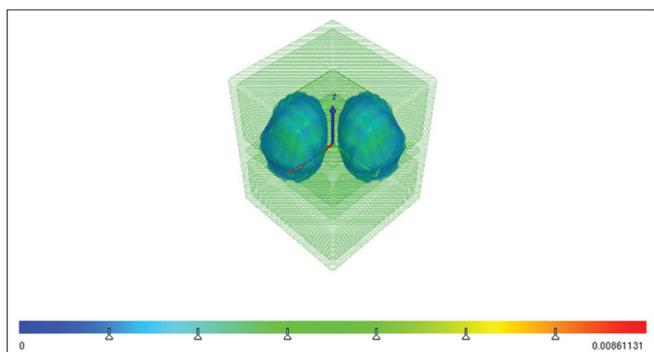


Figure 87. Three-dimensional wave function of multilayer quantum dot in a cuboid structure at energy level 7

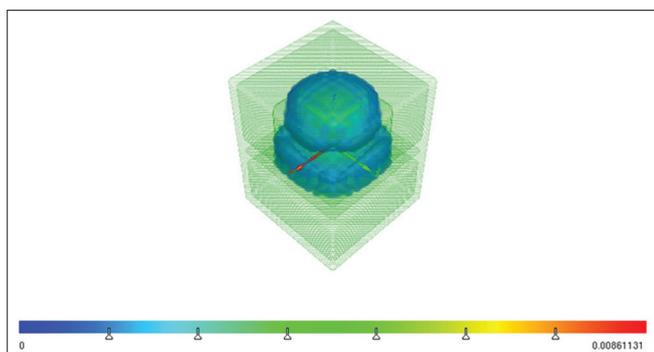


Figure 88. Three-dimensional wave function of multilayer quantum dot in a cuboid structure at energy level 8

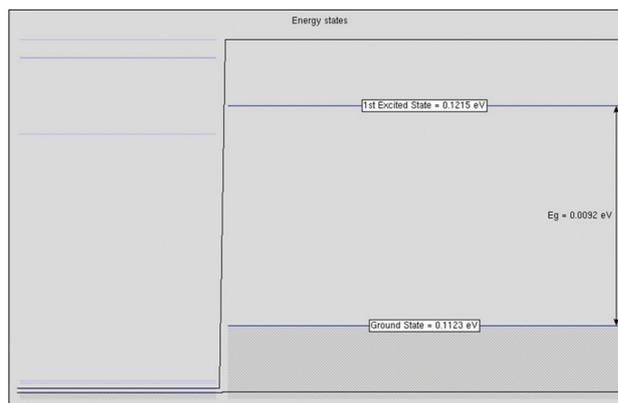


Figure 89. Energy states of the multilayer quantum dot in a cuboid structure

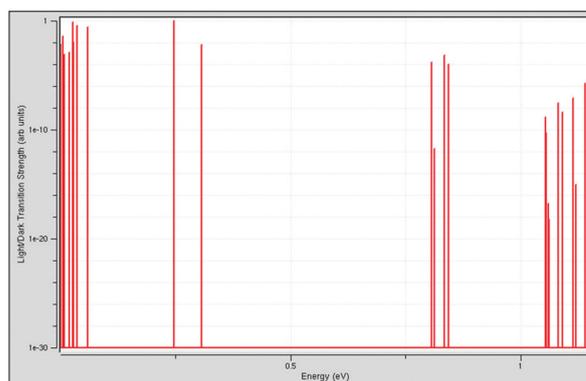


Figure 90. Light and dark transitions (X-polarized) of multilayer quantum dot in a cuboid structure

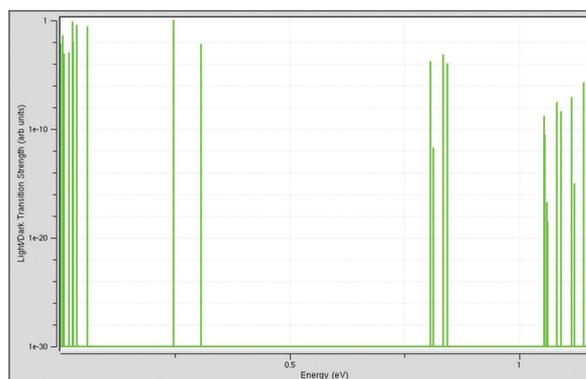


Figure 91. Light and dark transitions (Y-polarized) of multilayer quantum dot in a cuboid structure

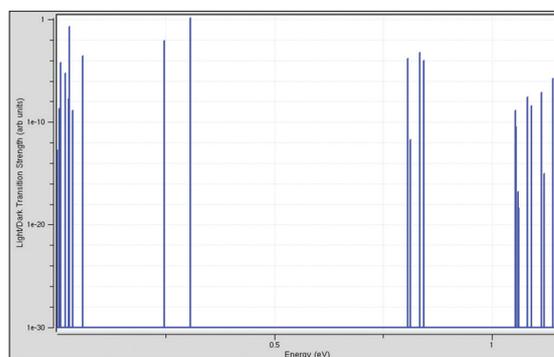


Figure 92. Light and dark transitions (Z-polarized) of multilayer quantum dot in a cuboid structure

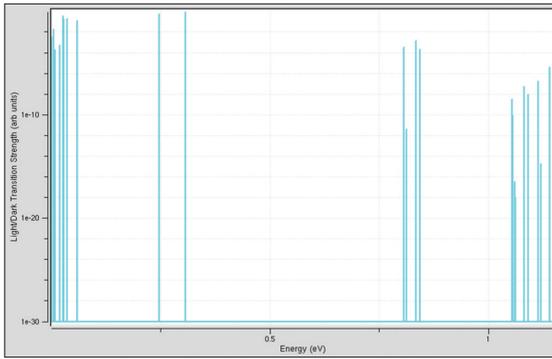


Figure 93. Light and dark transitions ($\phi=0$ and $\theta=45$) of multilayer quantum dot in a cuboid structure

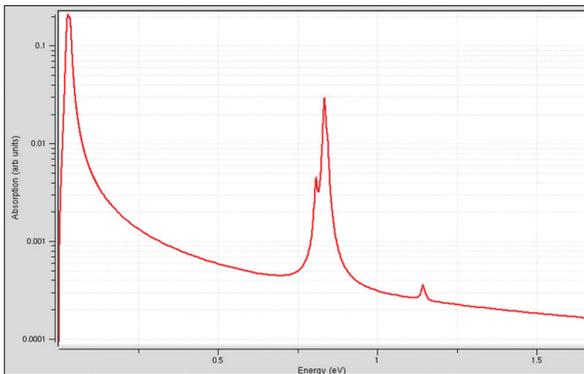


Figure 94. Absorption ($\phi=0$ and $\theta=45$) of multilayer quantum dot in a cuboid structure

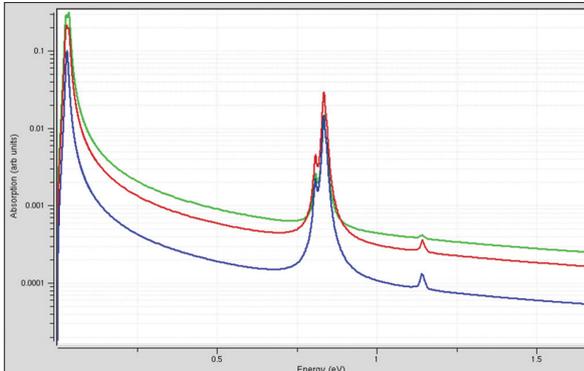


Figure 95. Absorption sweep of angle theta of multilayer quantum dot in a cuboid structure

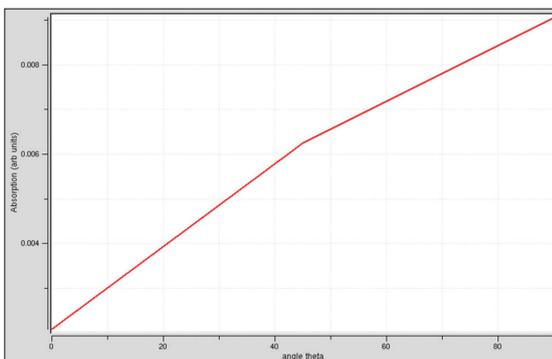


Figure 96. Integrated absorption of multilayer quantum dot in a cuboid structure

6.2 Observations

1. There is a change in phase for the quantum dot for every new energy level in cuboid structure.
2. High peak for light and dark transitions (X-polarized) for cuboid structure is 1.0181arb units at 0.247654 eV.
3. High peak for light and dark transitions (Y-polarized) is 1.0181arb units at 0.247654 eV.
4. High peak for light and dark transitions (Z-polarized) is 1.49642arb units at 0.306864 eV.
5. High peak for angle polarized is 0.844652arb units at 0.306864 eV.
6. High peak for absorption for a multilayer quantum dot in dome at $\phi=0$ and $\theta=45$ is 0.210958arb units at 0.02916eV.

7 Multilayer quantum dot in a cylinder

7.1 Multilayer quantum dot in a cylinder structure

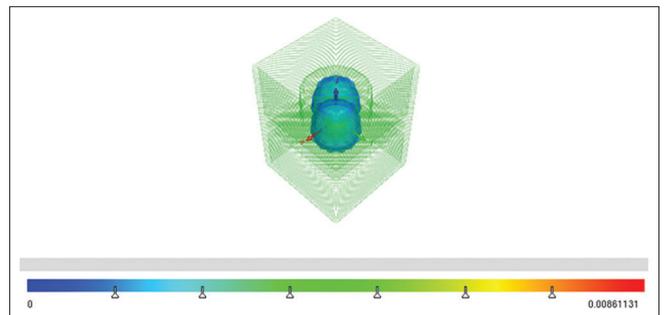


Figure 97. Three-dimensional wave function of multilayer quantum dot in a cylinder structure at energy level 1

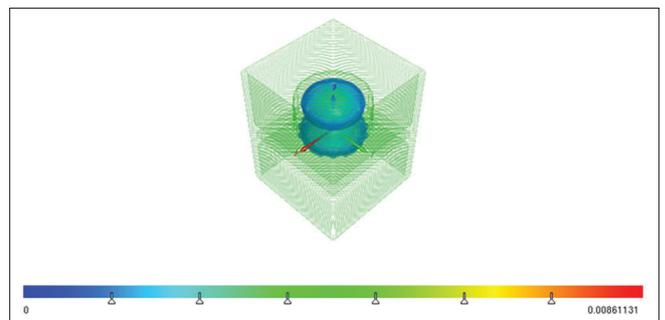


Figure 98. Three-dimensional wave function of multilayer quantum dot in a cylinder structure at energy level 2

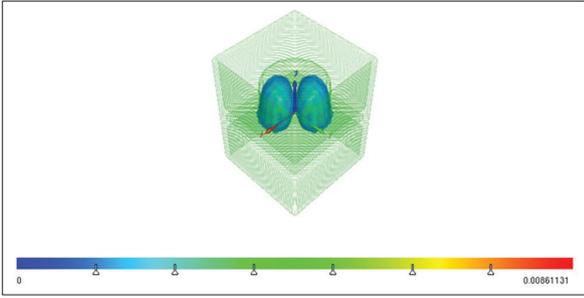


Figure 99. Three-dimensional wave function of multilayer quantum dot in a cylinder structure at energy level 3

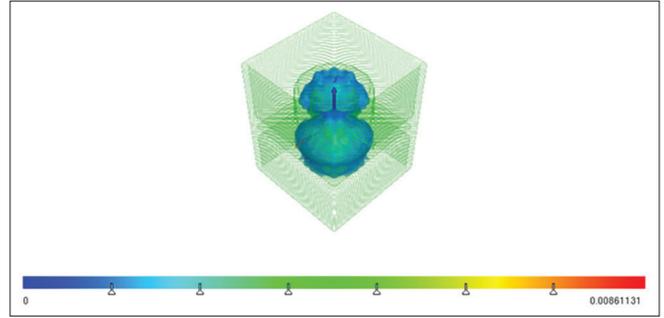


Figure 103. Three-dimensional wave function of multilayer quantum dot in a cylinder structure at energy level 7

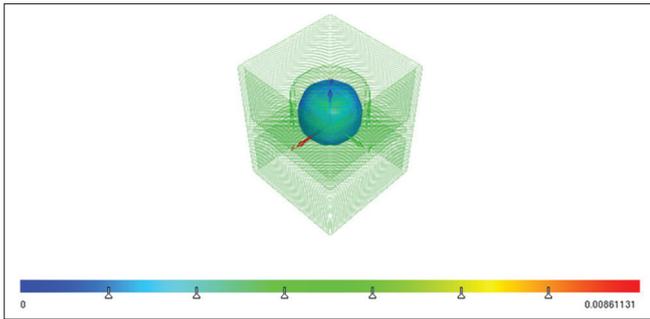


Figure 100. Three-dimensional wave function of multilayer quantum dot in a cylinder structure at energy level 4

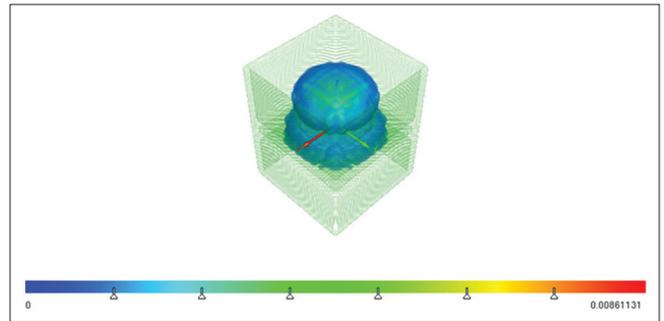


Figure 104. Three-dimensional wave function of multilayer quantum dot in a cylinder structure at energy level 8

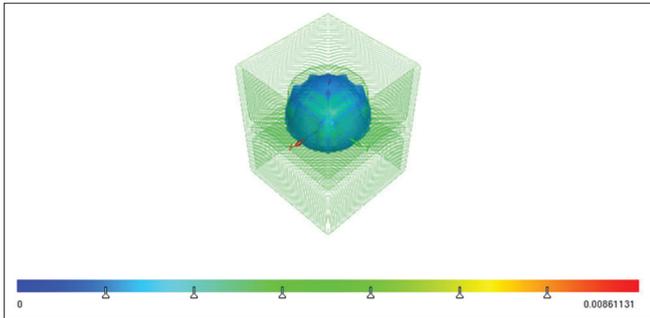


Figure 101. Three-dimensional wave function of multilayer quantum dot in a cylinder structure at energy level 5

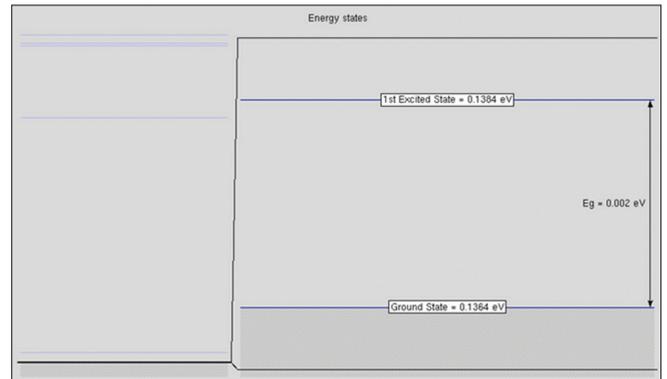


Figure 105. Energy states of the multilayer quantum dot in a cylinder structure

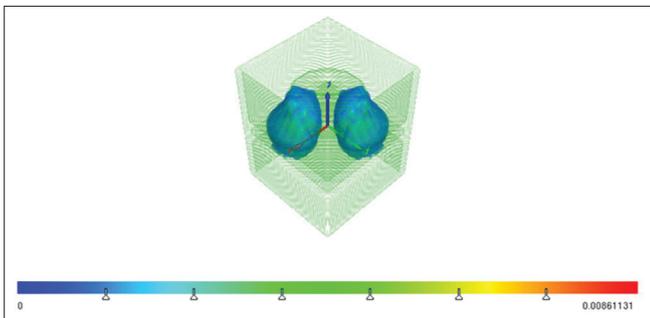


Figure 102. Three-dimensional wave function of multilayer quantum dot in a cylinder structure at energy level 6

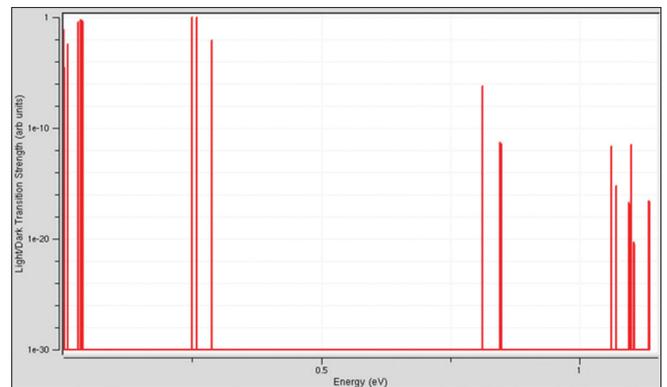


Figure 106. Light and dark transitions (X-polarized) of multilayer quantum dot in a cylinder structure

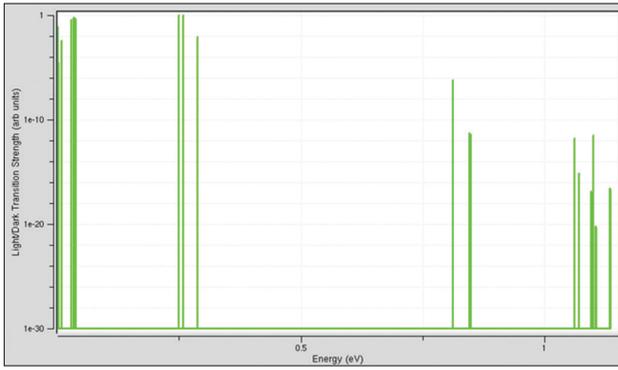


Figure 107. Light and dark transitions (Y-polarized) of multilayer quantum dot in a cylinder structure

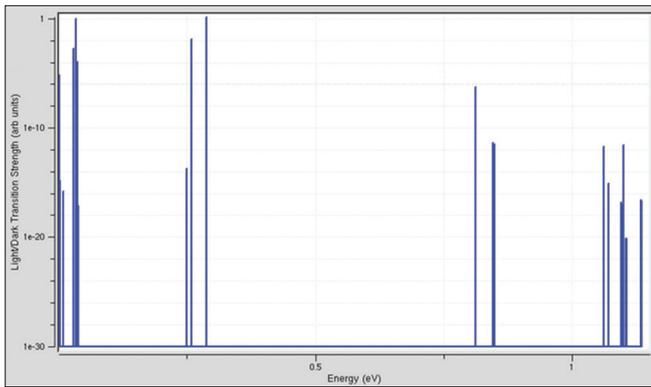


Figure 108. Light and dark transitions (Z-polarized) of multilayer quantum dot in a cylinder structure

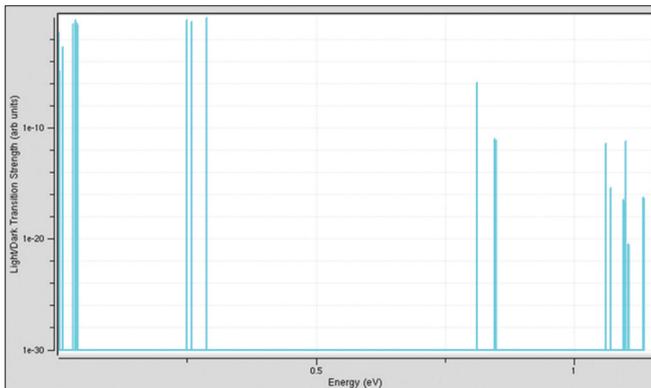


Figure 109. Light and dark transitions ($\phi=0$ and $\theta=45$) of multilayer quantum dot in a cylinder structure

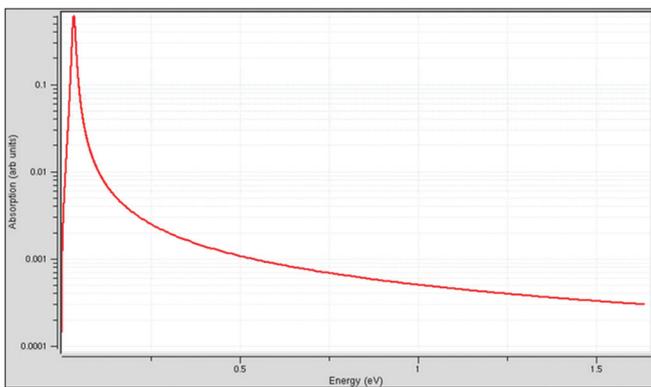


Figure 110. Absorption ($\phi=0$ and $\theta=45$) of multilayer quantum dot in a cylinder structure

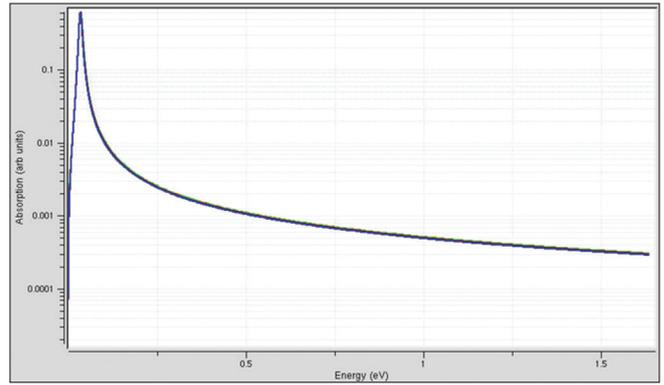


Figure 111. Absorption sweep of angle θ of multilayer quantum dot in a cylinder structure

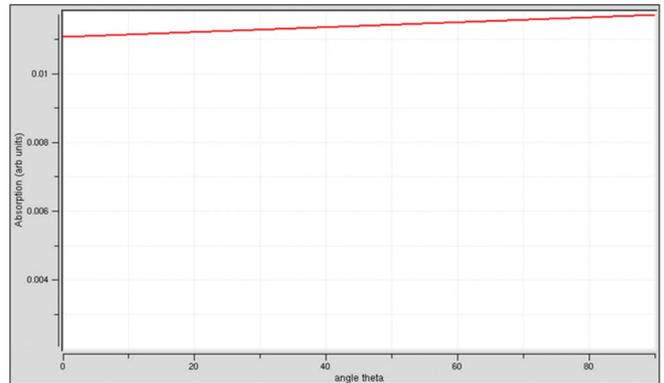


Figure 112. Integrated absorption of multilayer quantum dot in a cylinder structure

Table 1. Simulation notes for simple quantum dot in a cuboid

Simulation specifications	Value
First excited state	1.9765 eV
Ground state	1.8157 eV
E_g	0.1608 eV

7.2 Observations

1. There is a change in phase for the quantum dot for every new energy level in cylinder structure.
2. High peak for light and dark transitions (X-polarized) for cylinder structure is 0.953922arb units at 0.249595 eV and 0.889337arb units at 0.258712 eV.
3. High peak for light and dark transitions (Y-polarized) is 0.953922arb units at 0.249595 eV and 0.889337arb units at 0.258712 eV.
4. High peak for light and dark transitions (Z-polarized) is 1.48711arb units at 0.287963 eV.
5. High peak for angle polarized is 0.8571arb units at 0.287963 eV.
6. High peak for absorption for a multilayer quantum dot in dome at $\phi=0$ and $\theta=45$ is 0.618992arb units at 0.034687 eV.

8 Multilayer quantum dot in a dome

8.1 Multilayer quantum dot in a dome structure

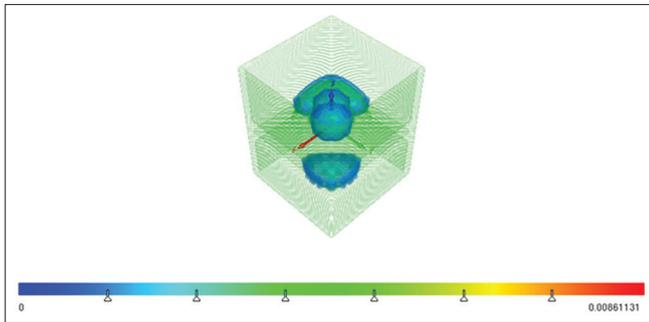


Figure 113. Three-dimensional wave function of multilayer quantum dot in a dome structure at energy level 1

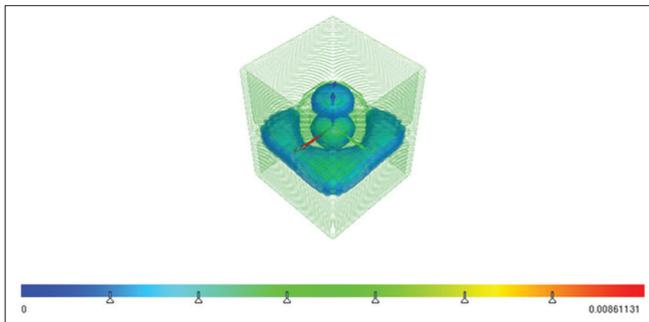


Figure 114. Three-dimensional wave function of multilayer quantum dot in a dome structure at energy level 2

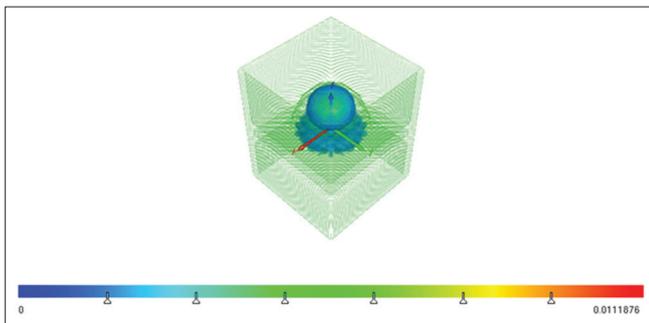


Figure 115. Three-dimensional wave function of multilayer quantum dot in a dome structure at energy level 3

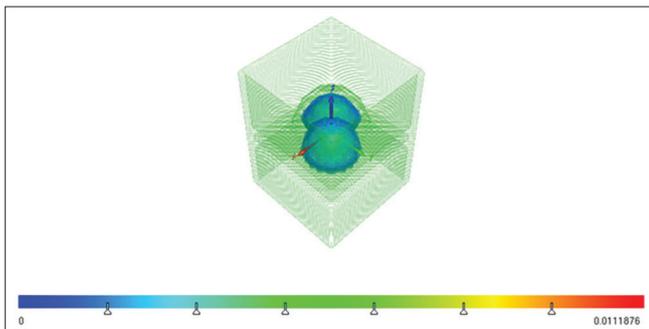


Figure 116. Three-dimensional wave function of multilayer quantum dot in a dome structure at energy level 4

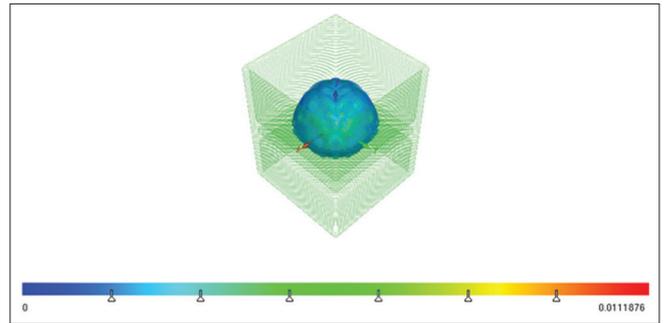


Figure 117. Three-dimensional wave function of multilayer quantum dot in a dome structure at energy level 5

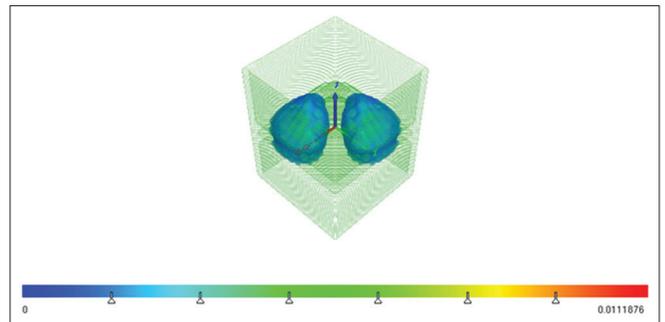


Figure 118. Three-dimensional wave function of multilayer quantum dot in a dome structure at energy level 6

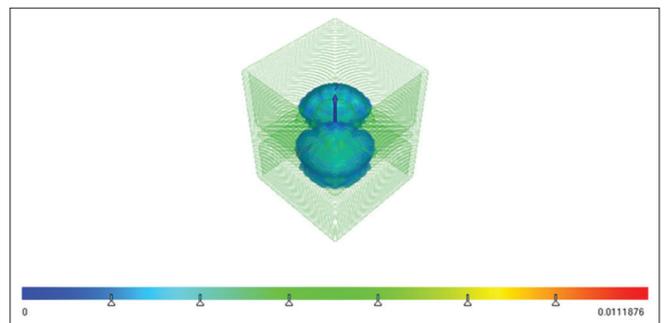


Figure 119. Three-dimensional wave function of multilayer quantum dot in a dome structure at energy level 7

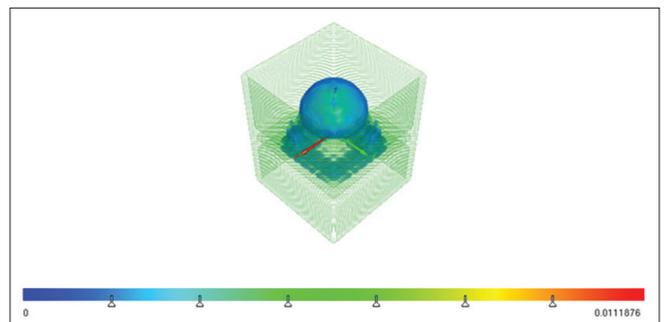


Figure 120. Three-dimensional wave function of multilayer quantum dot in a dome structure at energy level 8

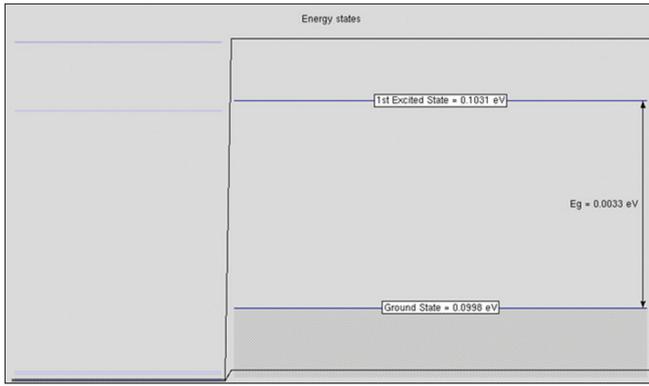


Figure 121. Energy states of the multilayer quantum dot in a dome structure

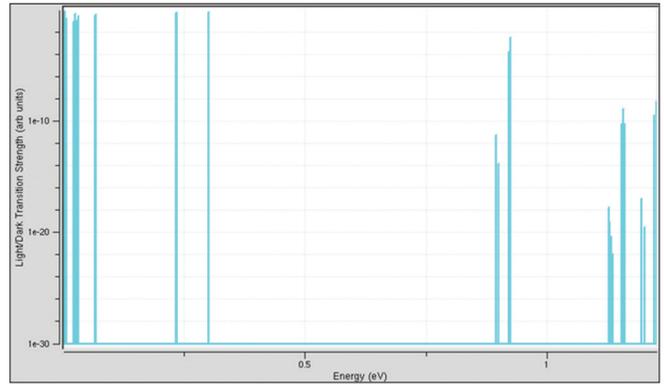


Figure 125. Light and dark transitions ($\phi=0$ and $\theta=45$) of multilayer quantum dot in a dome structure

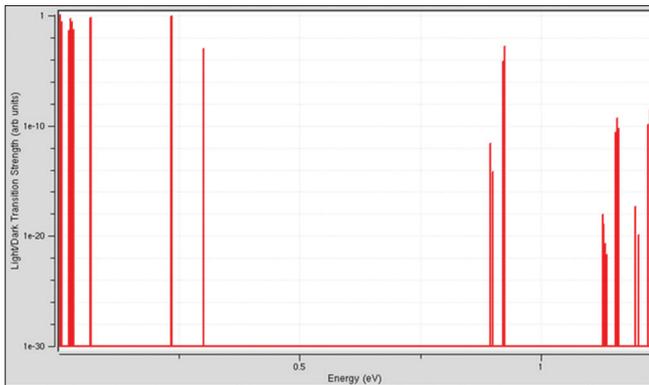


Figure 122. Light and dark transitions (X-polarized) of multilayer quantum dot in a dome structure

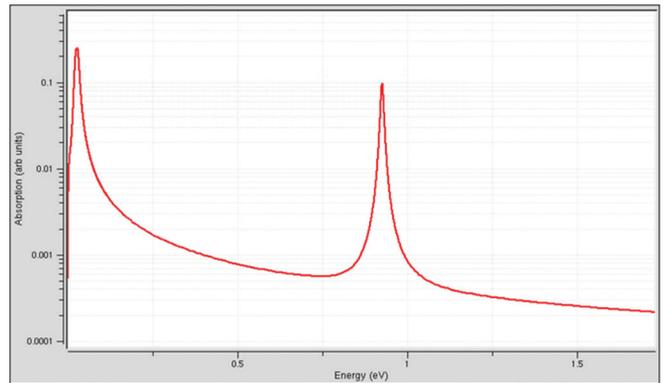


Figure 126. Absorption ($\phi=0$ and $\theta=45$) of multilayer quantum dot in a dome structure

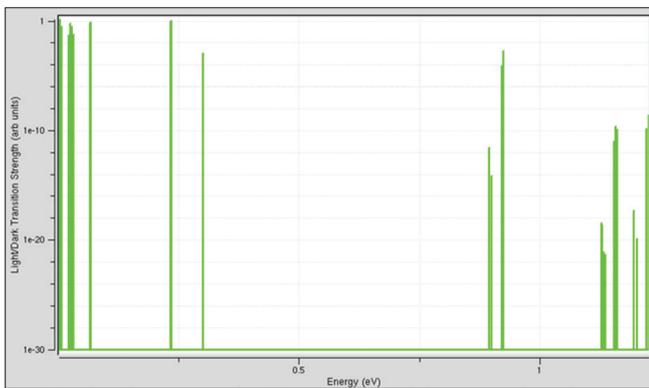


Figure 123. Light and dark transitions (Y-polarized) of multilayer quantum dot in a dome structure

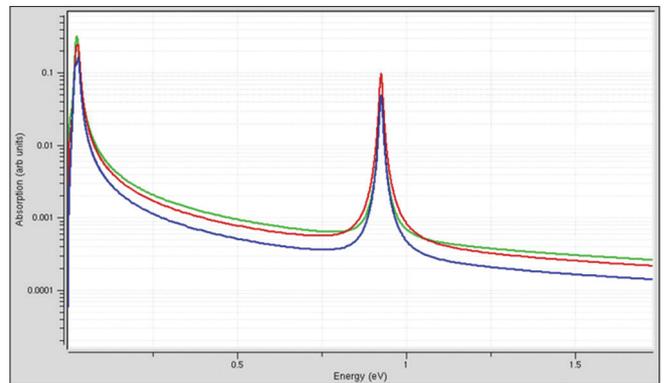


Figure 127. Absorption sweep of angle θ of multilayer quantum dot in a dome structure

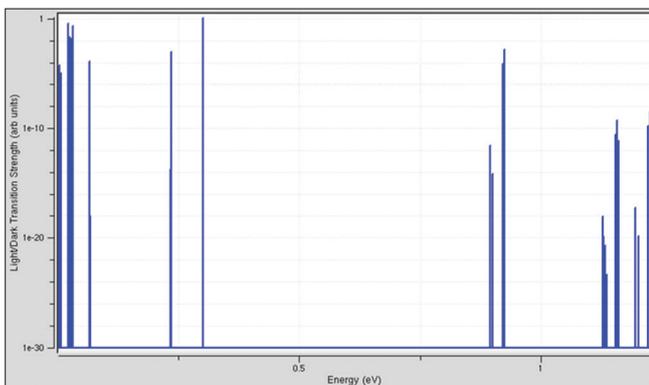


Figure 124. Light and dark transitions (Z-polarized) of multilayer quantum dot in a dome structure

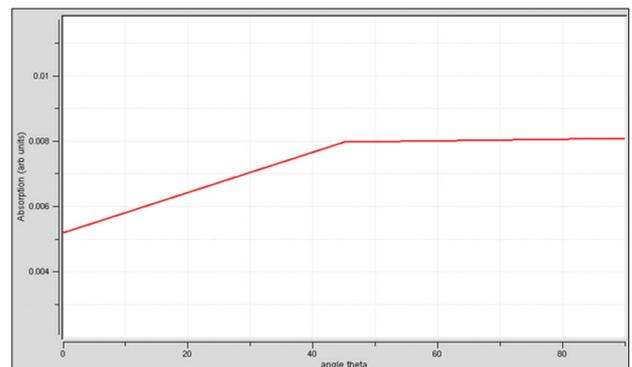


Figure 128. Integrated absorption of multilayer quantum dot in a dome structure

8.2 Observations

1. There is a change in phase for the quantum dot for every new energy level in dome structure.
2. High peak for light and dark transitions (X-polarized) for dome structure is 1.37282arb units at 0.00331042 eV.
3. High peak for light and dark transitions (Y-polarized) is 1.39984arb units at 0.00331042 eV.
4. High peak for light and dark transitions (Z-polarized) is 1.11801arb units at 0.301033 eV.
5. High peak for angle polarized is 0.695004arb units at 0.00331042 eV.
6. High peak for absorption for a multilayer quantum dot in dome at $\phi=0$ and $\theta=45$ is 0.249arb units at 0.0281758 eV.

9 Multilayer quantum dot in a cone

9.1 Multilayer quantum dot in a cone structure

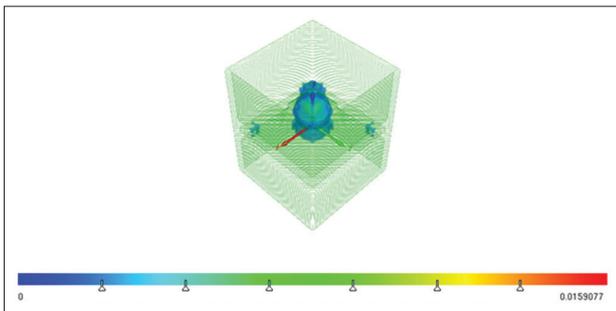


Figure 129. Three-dimensional wave function of multilayer quantum dot in a cone structure at energy level 1

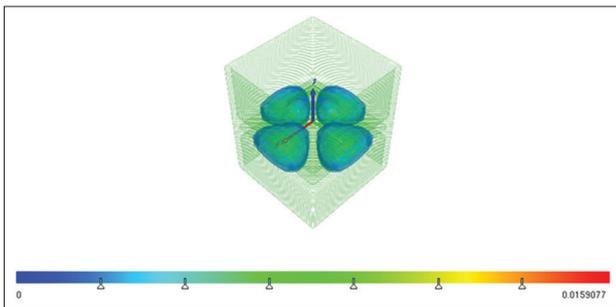


Figure 130. Three-dimensional wave function of multilayer quantum dot in a cone structure at energy level 2

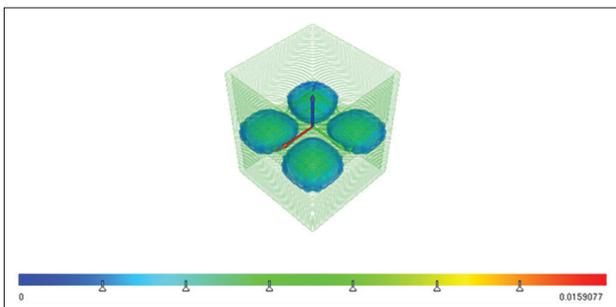


Figure 131. Three-dimensional wave function of multilayer quantum dot in a cone structure at energy level 3

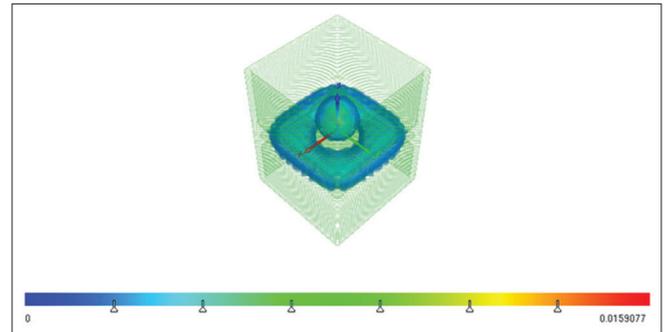


Figure 132. Three-dimensional wave function of multilayer quantum dot in a cone structure at energy level 4

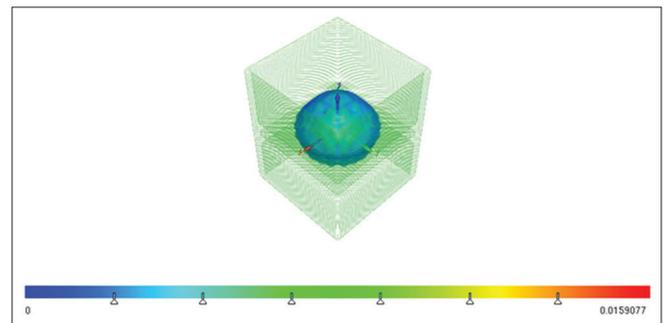


Figure 133. Three-dimensional wave function of multilayer quantum dot in a cone structure at energy level 5

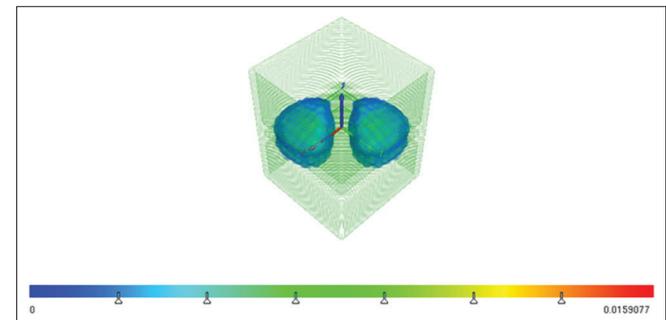


Figure 134. Three-dimensional wave function of multilayer quantum dot in a cone structure at energy level 6

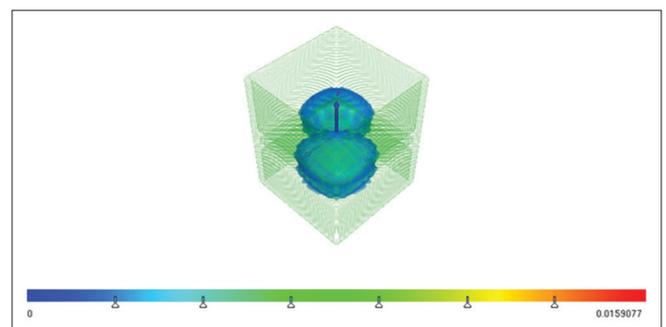


Figure 135. Three-dimensional wave function of multilayer quantum dot in a cone structure at energy level 7

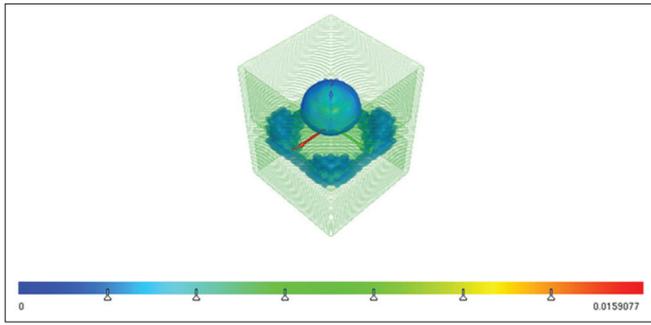


Figure 136. Three-dimensional wave function of multilayer quantum dot in a cone structure at energy level 8

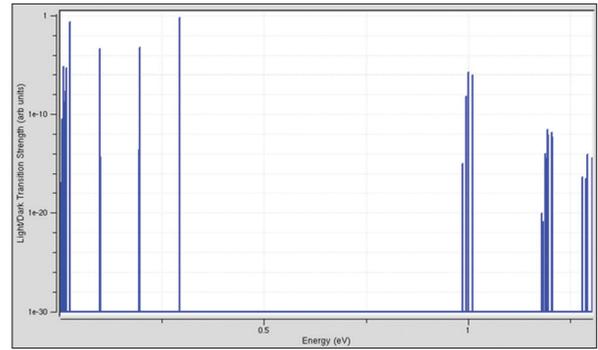


Figure 140. Light and dark transitions (Z-polarized) of multilayer quantum dot in a cone structure

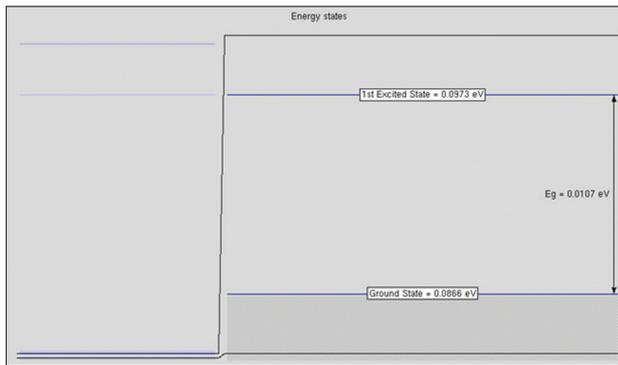


Figure 137. Energy states of the multilayer quantum dot in a cone structure

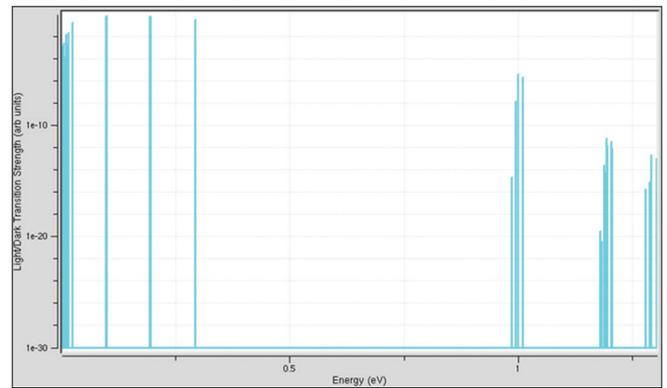


Figure 141. Light and dark transitions ($\phi = 0$ and $\theta = 45$) of multilayer quantum dot in a cone structure

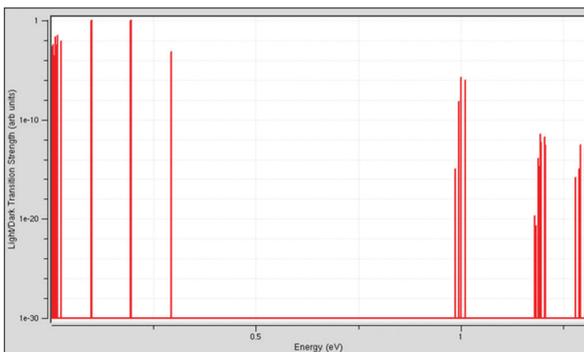


Figure 138. Light and dark transitions (X-polarized) of multilayer quantum dot in a cone structure

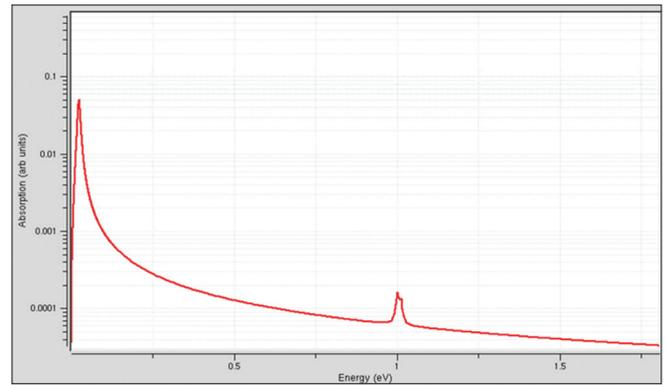


Figure 142. Absorption ($\phi=0$ and $\theta=45$) of multilayer quantum dot in a cone structure

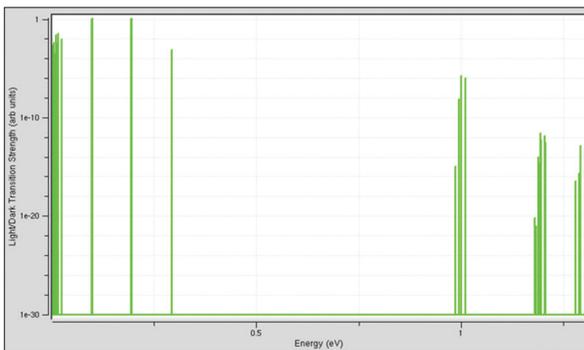


Figure 139. Light and dark transitions (Y-polarized) of multilayer quantum dot in a cone structure

Table 2. Simulation structure nomenclature for simple quantum dot in a cuboid

Simulation specifications	Value
Number of states	8
Shape	Cuboid
X dimensions	10 nm
Y dimensions	10.5 nm
Z dimensions	5 nm
Lattice constant	0.565 nm
Effective mass	0.067
Energy gap	1.43 eV

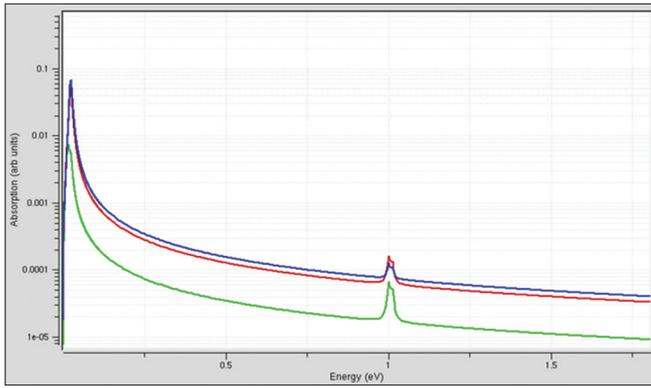


Figure 143. Absorption sweep of angle theta of multilayer quantum dot in a cone structure

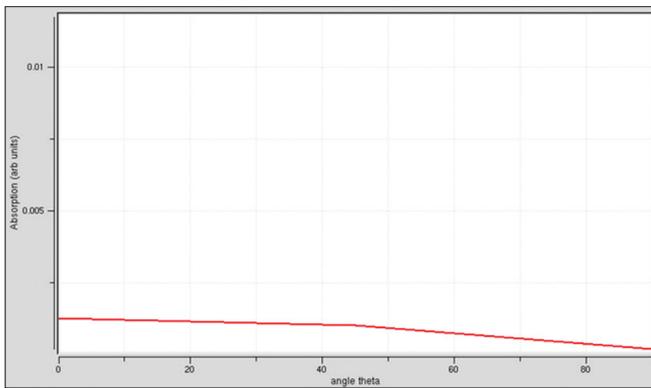


Figure 144. Integrated absorption of multilayer quantum dot in a cone structure

9.2 Observations

1. There is a change in phase for the quantum dot for every new energy level in dome structure.
2. High peak for light and dark transitions (X-polarized) for cone structure is 1.0791arb units at 0.0991437 eV and 1.06416arb units at 0.196069 eV.
3. High peak for light and dark transitions (Y-polarized) is 1.0791arb units at 0.0991437 eV and 1.06416arb units at 0.196069 eV.
4. High peak for light and dark transitions (Z-polarized) is 0.56055arb units at 0.292765 eV.
5. High peak for angle polarized is 0.539548arb units at 0.0991437 eV and 0.506595arb units at 0.196069 eV.
6. High peak for absorption for a multilayer quantum dot in cone at $\phi=0$ and $\theta=45$ is 0.0504693arb units at 0.0239637 eV.

10 Multilayer quantum dot in a pyramid

10.1 Multilayer quantum dot in a pyramid structure

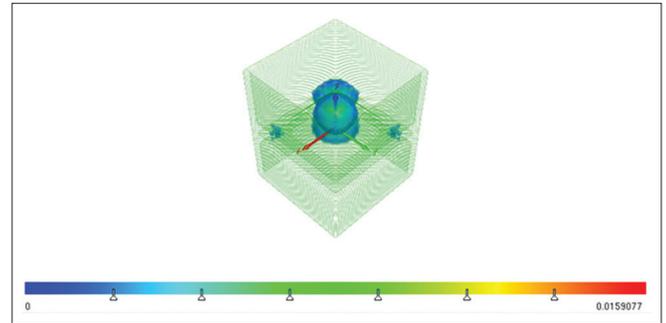


Figure 145. Three-dimensional wave function of multilayer quantum dot in a pyramid structure at energy level 1

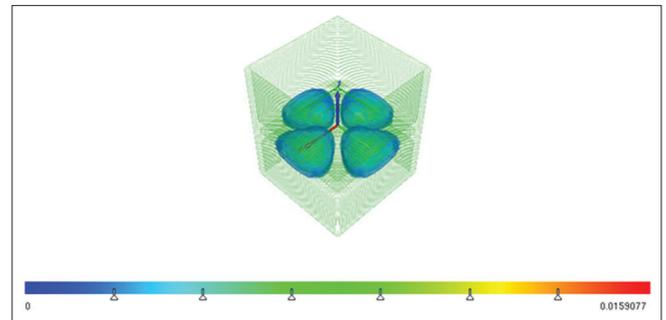


Figure 146. Three-dimensional wave function of multilayer quantum dot in a pyramid structure at energy level 2

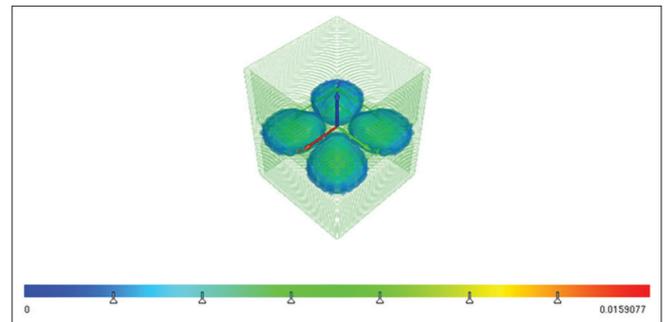


Figure 147. Three-dimensional wave function of multilayer quantum dot in a pyramid structure at energy level 3

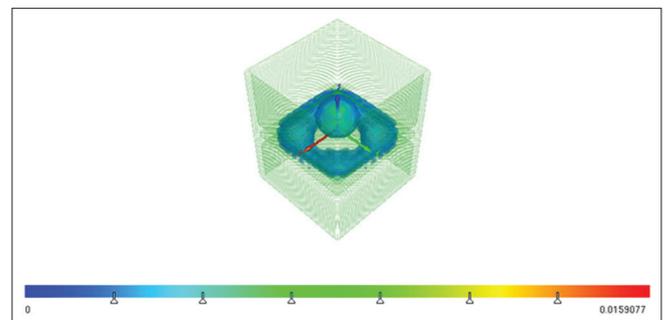


Figure 148. Three-dimensional wave function of multilayer quantum dot in a pyramid structure at energy level 4

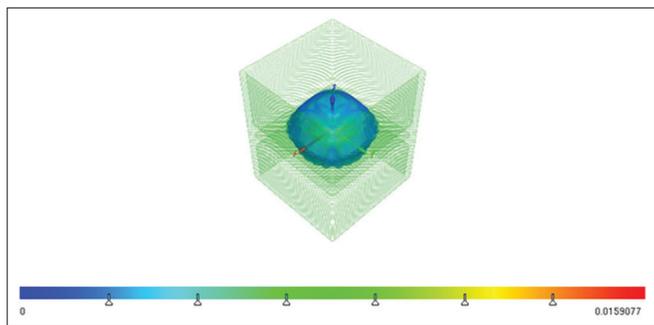


Figure 149. Three-dimensional wave function of multilayer quantum dot in a pyramid structure at energy level 5

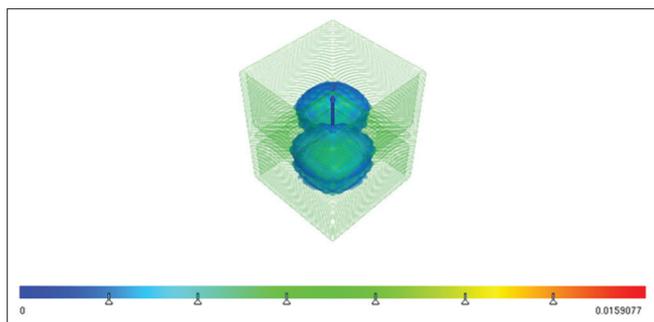


Figure 150. Three-dimensional wave function of multilayer quantum dot in a pyramid structure at energy level 6

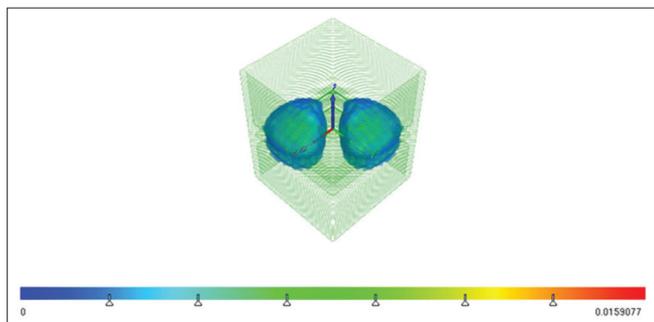


Figure 151. Three-dimensional wave function of multilayer quantum dot in a pyramid structure at energy level 7

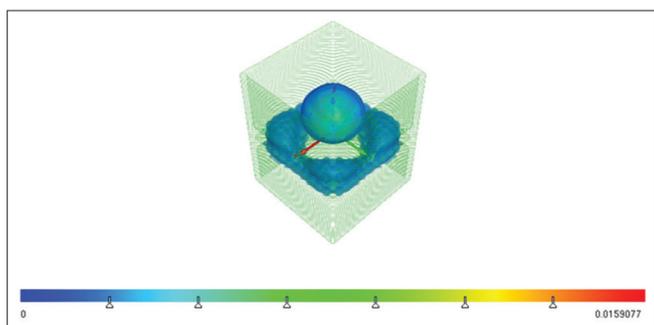


Figure 152. Three-dimensional wave function of multilayer quantum dot in a pyramid structure at energy level 8

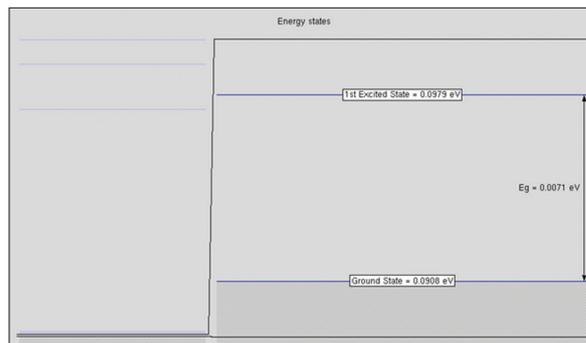


Figure 153. Energy states of the multilayer quantum dot in a pyramid structure

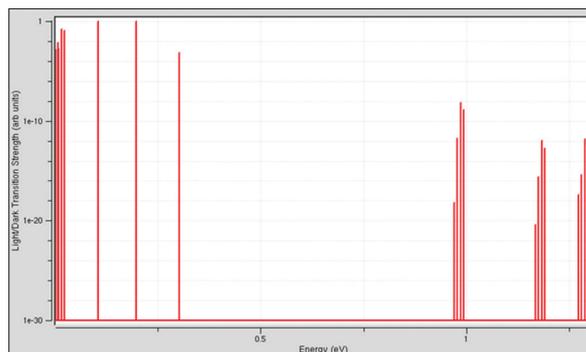


Figure 154. Light and dark transitions (X-polarized) of multilayer quantum dot in a pyramid structure

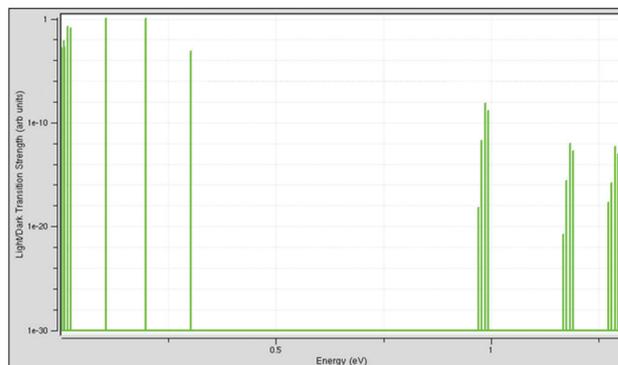


Figure 155. Light and dark transitions (Y-polarized) of multilayer quantum dot in a pyramid structure

Table 3. Simulation optics nomenclature for simple quantum dot in a cuboid

Light polarization/sweep	Value
Angle theta	45°
Angle phi	0°
Absolute fermi level	No
Electron fermi level	0 eV
Temperature	300 K
State broadening	0.01
Sweep parameter	Angle theta in units of “degree”
Energy gap	1.43eV
Minimum	0
Maximum	90
Number of points	3

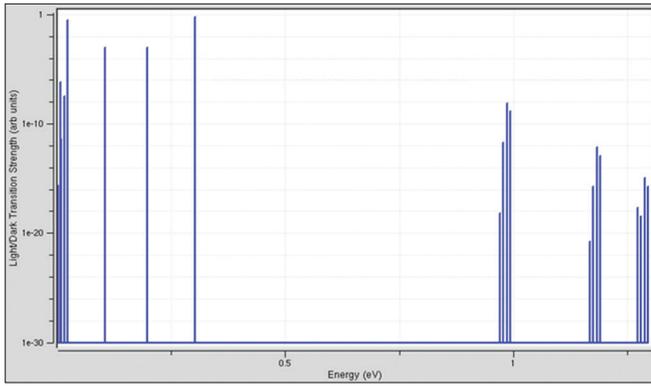


Figure 156. Light and dark transitions (Z-polarized) of multilayer quantum dot in a pyramid structure

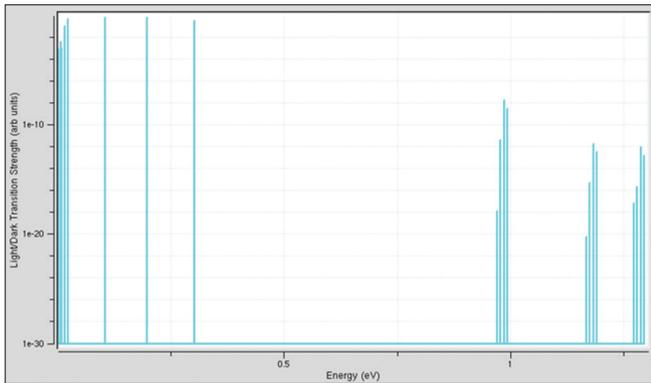


Figure 157. Light and dark transitions ($\phi=0$ and $\theta=45$) of multilayer quantum dot in a pyramid structure

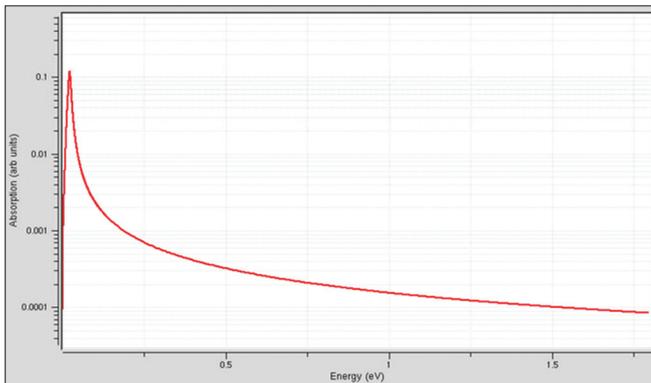


Figure 158. Absorption ($\phi=0$ and $\theta=45$) of multilayer quantum dot in a pyramid structure

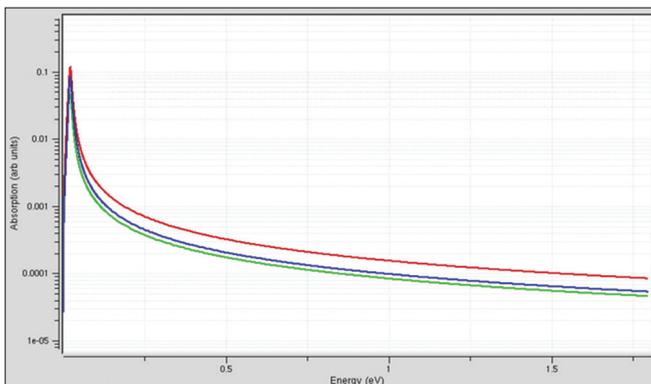


Figure 159. Absorption sweep of angle theta of multilayer quantum dot in a pyramid structure

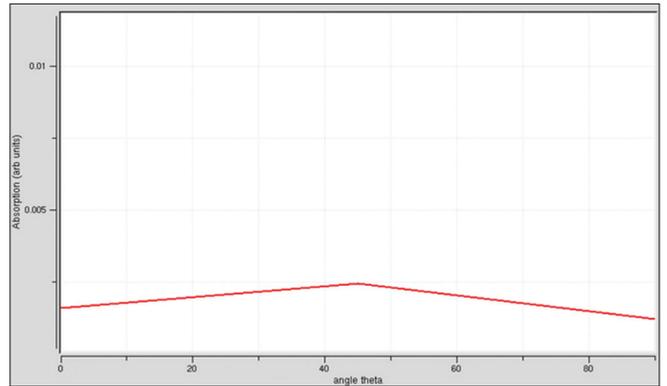


Figure 160. Integrated absorption of multilayer quantum dot in a pyramid structure

Table 4. Simulation notes for simple quantum dot in a cylinder

Simulation specifications	Value
First excited state	2.0478 eV
Ground state	1.8419 eV
Eg	0.2059 eV

Table 5. Simulation structure nomenclature for simple quantum dot in a cylinder

Simulation specifications	Value
Number of States	8
Shape	Cylinder
X dimensions	10 nm
Y dimensions	10.5 nm
Z dimensions	5 nm
Lattice constant	0.565 nm
Effective mass	0.067
Energy gap	1.43 eV

Table 6. Simulation optics nomenclature for simple quantum dot in a cylinder

Light polarization/Sweep	Value
Angle theta	45°
Angle phi	0°
Absolute fermi level	No
Electron fermi level	0 eV
Temperature	300 K
State broadening	0.01
Sweep parameter	Angle theta in units of “degree”
Minimum	0
Maximum	90
Number of points	3

Table 7. Simulation notes for simple quantum dot in a dome

Simulation specifications	Values
First excited state	2.2915 eV
Ground state	1.9817 eV
Eg	0.3098 eV

Table 8. Simulation structure nomenclature for simple quantum dot in a dome

Simulation specifications	Value
Number of states	8
Shape	Dome
X dimensions	10 nm
Y dimensions	10.5 nm
Z dimensions	5 nm
Lattice constant	0.565 nm
Effective mass	0.067
Energy gap	1.43 eV

Table 9. Simulation optics nomenclature for simple quantum dot in a dome

Light polarization/sweep	Value
Angle theta	45°
Angle phi	0°
Absolute fermi level	No
Electron fermi level	0eV
Temperature	300K
State broadening	0.01
Sweep parameter	Angle theta in units of “degree”
Minimum	0
Maximum	90
Number of points	3

Table 10. Simulation notes for simple quantum dot in a cone

Simulation specifications	Value
First excited state	3.1697 eV
Ground state	2.4931 eV
Eg	0.6766 eV

10.2 Observations

1. There is a change in phase for the quantum dot for every new energy level in dome structure.
2. High peak for light and dark transitions (X-polarized) for pyramid structure is 1.09688arb units at 0.197138 eV.

Table 11. Simulation structure nomenclature for simple quantum dot in a cone

Simulation specifications	Value
Number of states	8
Shape	Cone
X dimensions	10 nm
Y dimensions	10.5 nm
Z dimensions	5 nm
Lattice constant	0.565 nm
Effective mass	0.067
Energy gap	1.43 eV

Table 12. Simulation optics nomenclature for simple quantum dot in a cone

Light Polarization/Sweep	Value
Angle theta	45°
Angle Phi	0°
Absolute fermi level	No
Electron fermi level	0eV
Temperature	300K
State broadening	0.01
Sweep parameter	Angle theta in units of “degree”
Minimum	0
Maximum	90
Number of points	3

Table 13. Simulation notes for simple quantum dot in a pyramid

Simulation specifications	Value
First excited state	2.9337 eV
Ground state	2.3558 eV
Eg	0.5779 eV

Table 14. Simulation structure nomenclature for simple quantum dot in a pyramid

Simulation specifications	Value
Number of states	8
Shape	Pyramid
X dimensions	10 nm
Y dimensions	10.5 nm
Z dimensions	5 nm
Lattice constant	0.565 nm
Effective mass	0.067
Energy gap	1.43 eV

3. High peak for light and dark transitions (Y-polarized) is 1.09502arb units at 0.197513 eV.

Table 15. Simulation optics nomenclature for simple quantum dot in a pyramid

Light Polarization/Sweep	Value
Angle theta	45°
Angle phi	0°
Absolute fermi level	No
Electron fermi level	0 eV
Temperature	300 K
State broadening	0.01
Sweep parameter	Angle theta in units of “degree”
Minimum	0
Maximum	90
Number of points	3

Table 16. Simulation notes for multilayer quantum dot in a cuboid

Simulation specifications	Value
First excited state	0.1215 eV
Ground state	0.1123 eV
Eg	0.0092 eV

Table 17. Simulation structure nomenclature for multilayer quantum dot in a cuboid

Simulation Specifications	Value
Number of conduction band states	4
Number of valence band states	4
Tight binding basis	Two band effective mass model
Materials	GaAs - InAs - GaAs
Shape	Cuboid
Device X dimension	10 nm
Device Y dimension	10 nm
Z dimension (substrate)	5 nm
Z dimension (wetting layer)	1 nm
X dimension (quantum dot)	5 nm
Y dimension (quantum dot)	5 nm
Z dimension (quantum dot)	3 nm

Table 18. Simulation optics nomenclature for multilayer quantum dot in a cuboid

Light polarization/sweep	Value
Angle theta	45°
Angle phi	0°
Absolute fermi level	No
Electron fermi level	0 eV
Temperature	300 K
State broadening	0.01
Sweep parameter	Angle theta in units of “degree”
Minimum	0
Maximum	90
Number of points	3

Table 19. Simulation notes for multi-layer quantum dot in a cylinder

Simulation specifications	Value
1 st excited state	0.1384 eV
Ground state	0.1364 eV
Eg	0.002 eV

Table 20. Simulation structure nomenclature for multilayer quantum dot in a cylinder

Simulation Specifications	Value
Number of conduction band states	4
Number of valence Band states	4
Tight binding basis	Two band effective mass model
Materials	GaAs - InAs - GaAs
Shape	Cylinder
Device X dimension (structure)	10 nm
Device Y dimension (structure)	10 nm
Z dimension (substrate)	5 nm
Z dimension (wetting layer)	1 nm
X dimension (quantum dot)	5 nm
Y dimension (quantum dot)	5 nm
Z dimension (quantum dot)	3 nm

Table 21. Simulation optics nomenclature for multilayer quantum dot in a cylinder

Light polarization/sweep	Value
Angle theta	45°
Angle phi	0°
Absolute fermi level	No
Electron fermi level	0 eV
Temperature	300 K
State broadening	0.01
Sweep parameter	Angle theta in units of “degree”
Minimum	0
Maximum	90
Number of points	3

Table 22. Simulation notes for multilayer quantum dot in a dome

Simulation specifications	Value
First excited state	0.1031 eV
Ground state	0.0998 eV
Eg	0.0033 eV

Table 23. Simulation structure nomenclature for multilayer quantum dot in a dome

Simulation specifications	Value
Number of conduction band states	4
Number of Valence band states	4
Tight binding basis	Two band effective mass model
Materials	GaAs - InAs - GaAs
Shape	Dome
Device X dimension (structure)	10 nm
Device Y dimension (structure)	10 nm
Z dimension (substrate)	5 nm
Z dimension (wetting layer)	1 nm
X dimension (quantum dot)	5 nm
Y dimension (quantum dot)	5 nm
Z dimension (quantum dot)	3 nm

Table 24. Simulation optics nomenclature for multilayer quantum dot in a dome

Light polarization/sweep	Value
Angle theta	45°
Angle phi	0°
Absolute fermi level	No
Electron fermi level	0 eV
Temperature	300 K
State broadening	0.01
Sweep parameter	Angle theta in units of “degree”
Minimum	0
Maximum	90
Number of points	3

Table 25. Simulation notes for multilayer quantum dot in a cone

Simulation specifications	Value
First excited state	0.0973 eV
Ground state	0.0866 eV
Eg	0.0107 eV

- High peak for light and dark transitions (Z-polarized) is 0.595948arb units at 0.302183 eV.
- High peak for angle polarized is 0.531612arb units at 0.105045 eV and 0.516888arb units at 0.197138 eV.
- High peak for absorption for a multilayer quantum dot in pyramid at phi = 0 and theta = 45 is 0.118838arb units at 0.0224354 eV.

Table 26. Simulation structure nomenclature for multilayer quantum dot in a cone

Simulation specifications	Value
Number of conduction band states	4
Number of valence band states	4
Tight binding basis	Two band effective mass model
Materials	GaAs - InAs - GaAs
Shape	Cone
Device X dimension (structure)	10 nm
Device Y dimension (structure)	10 nm
Z dimension (substrate)	5 nm
Z dimension (wetting layer)	1 nm
Bottom radius of dot	2.5 nm
Top radius of dot	0 nm
Z dimension (quantum dot)	3 nm

Table 27. Simulation optics nomenclature for multilayer quantum dot in a cone

Light polarization/sweep	Value
Angle theta	45°
Angle phi	0°
Absolute fermi level	No
Electron fermi level	0 eV
Temperature	300 K
State broadening	0.01
Sweep parameter	Angle theta in units of “degree”
Minimum	0
Maximum	90
Number of points	3

Table 28. Simulation notes for multilayer quantum dot in a pyramid

Simulation specifications	Value
First excited state	0.0979 eV
Ground state	0.0908 eV
Eg	0.0071 eV

11 Results

What is claimed in this research article are as follows:

- Simple quantum dot in various structures is performed for cuboid, cylinder, dome, cone, and pyramid.
- Multilayer quantum dot in various structures is performed for cuboid, cylinder, dome, cone, and pyramid.
- Phase of the simple and multilayer quantum dot changes for every new energy level for cuboid, cylinder, dome, cone, and pyramid.

Table 29. Simulation structure nomenclature for multilayer quantum dot in a pyramid

Simulation Specifications	Value
Number of conduction band states	4
Number of valence band states	4
Tight binding basis	Two band effective mass model
Materials	GaAs - InAs - GaAs
Shape	Pyramid
Device X dimension (structure)	10 nm
Device Y dimension (structure)	10 nm
Z dimension (substrate)	5 nm
Z dimension (wetting layer)	1 nm
X dimension (quantum dot)	5 nm
Y dimension (quantum dot)	5 nm
Z dimension (quantum dot)	3 nm
Z dimension (capping layer)	6 nm

Table 30. Simulation optics nomenclature for multilayer quantum dot in a pyramid

Light polarization/sweep	Value
Angle theta	45°
Angle phi	0°
Absolute fermi level	No
Electron fermi level	0 eV
Temperature	300 K
State broadening	0.01
Sweep parameter	Angle theta in units of “degree”
Minimum	0
Maximum	90
Number of points	3

4. Graphs such as 3D functions for eight different energy levels, energy states, light and dark transitions (X-polarized), light and dark transitions (Y-polarized), light and dark transitions (Z-polarized), light and dark transitions (phi = 0 and

theta = 45), absorptions (phi = 0 and theta = 45), absorptions sweep of angle theta, and integrated absorptions are plotted for simple and multilayer quantum dot for cuboid, cylinder, dome, cone, and pyramid.

5. Observations for high peak for light and dark transitions (X-polarized), high peak for light and dark transitions (Y-polarized), high peak for light and dark transitions (Z-polarized), high peak for angle polarized, and high peak for absorption are noted and documented in the observations for simple and multilayer quantum dot.

12 Discussion

In this research article, all the values are taken as default values which are documented in Tables 1-30. Results, quantum dot structure, graph, voltages, etc., vary for the change in the values.

13 Acknowledgment

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