REFERENCES

[1] B. G. Steerman and S. Banerjee. Solid state electronic devices. New Jersey: Prentice Hall, 2002.

[2] J. Singh. Electronic and optical properties of semiconductor structure. Cambridge: Cambridge University Press, 2007.

[3] R. S. Muller. Device electronics for integrated circuits. New York: John Wiley & Sons, 2002.

[4] M. Quirk and J. Serda. Semiconductor manufacturing technology. New Jersey: Prentice Hall, 2000.

[5] J. E. Ayers. Heteropitaxy of semiconductors: theory, growth, and characterization. New York: CRC Press, 2007.

[6] Intel corporation. Architecture & silicon technology. [Online]. Available from: http://www.intel.com/technology/architecture-silicon/ [2009, December 15]

[7] N. Koguchi, S. Takahashi, and T. Chikyow. New MBE growth method for InSb quantum well boxes. J. Crystal Growth 111 (1991): 688.

[8] D. Leonard, M. Krishnamurthy, C.M. Reaves, S.P. Denbaars, and P.M. Petroff. Appl. Phys. Lett. 63 (1993): 3203.

[9] R. Nötzel, J. Temmyo, and T. Tamamura.Self-organized growth strained InGaAs quantum disk. Nature 369 (1994): 131.

[10] R. Kelsall, I. W. Hamley, and M. Geohegan. Nanoscale science and technology. New York: John Wiley & Sons, 2005.

[11] W. R. Fahrner. Nanotechnology and nanoelectronics: materials devices, measurement techniques. Berlin: Springer, 2004.

[12] A. L. Babrabasi. Self-assembled island formation in heteroepitaxial growth. Appl. Phys Lett. 70 (1997): 2565.

[13] M. D. Ventra, S. Evoy, and J. R. Heflin. Introduction to nanoscale science and technology. Berlin: Springer, 2004.

[14] S. Vengasandra, M. Lynch, J. Xu, and E.Henderson. Micro fluidic ultra-microscale deposition and patterning of quantum dots. Nanotechnology 16 (2005): 2052.

[15] R. Turton. The quantum dot: a journey into the future of microelectronics. Oxford: Oxford University Press, 1996.

[16] P. A. Ling. Quantum dots: new research. New York: Nova Science, 2006.

[17] Wikipedia. Quantum_dot [Online]. 2004. Available from http://en.wikipedia.org /wiki/Quantum_dot [2009, December 15]

[18] H. F. Hameka. Quantum mechanics: a conceptual approach. New York: John Wiley & Sons, 2004.

[19] D. Reuter, et al. Hole and electron wave functions in self-assembled InAs quantum dots: a comparison. Physica Status Solidi B 243 (2006): 3942.

[20] F. Rinaldi. Basics of molecular beam epitaxy (MBE). Annual Report 2002, Opto-electronics Department, University of Ulm, Germany.

[21] S. Adachi. Physical properties of III-V semiconductor compounds: InP, InAs, GaAs, GaP, InGaAs, and InGaAsP. New York: John Wiley & Sons, 1992.

[22] S. Anantathanasarn et al. Wavelength controlled InAs/InP quantum dots for telecom laser applications. Microelectronics Journal 37 (2006), 1461.

[23] K. F. Brennan. The physics of semiconductors: with applications to optoelectronic devices . Cambridge: Cambridge University Press, 1999.

[24] S. Prasad, H. Schumacher ,and A. Gopinath. High-speed electronics and opto-electronics: devices and circuits. Cambridge: Cambridge University Press, 2009.

[25] H. Li and K. Iga. Vertical-cavity surface-emitting laser devices. Berlin: Springer, 2002.

[26] A. Rogach. Semiconductor nanocrystal quantum dots: synthesis, assembly, spectroscopy and applications. Berlin: Springer, 2008.

[27] S. U. Hong, et al. Self-alignment of self-assembled InAs quantum dots. J. Crystal Growth 286 (2006): 18.

[28] P. W. Li, et al. Fabrication of a germanium quantum-dot single-electron transistor with large Coulomb-blockade oscillations at room temperature. Appl. Phys. Lett. 85 (2004): 1532.

[29] H. Heidemeyer, S. Kiravittaya, N. Y. Jinphillip, and O. G. Schmit. Closely stacked InAs/GaAs quantum dots grown at low growth rate. Appl. Phys. Lett. 80 (2002): 1544.

[30] G. Jin, J. L. Liu, S. G. Thomas, Y. H. Luo, and K. L. Wang. Controlled arrangement of self-organized Ge islands on patterned Si (001) substrates. Appl. Phys. Lett. 75 (1997): 2752.

[31] H. Lee, J. A. Johnson, J. S. Speck, Y. H. Luo, and K. L. Wang. Controlled ordering and positioning of InAs self-assembled QDs. Journal of Vacuum Science & Technology B 18 (2000): 2193.

[32] B. Xu, et al. Controlled growth of III-V compound semiconductor nanostructures and their application in quantum-devices. Materials Science Forum 475 (2005): 1783.

[33] N. N. Ledentsov, et al. Three-dimensional arrays of self-ordered quantum dots for laser applications. Microelectronics Journal 28 (1997): 915.

[34] S. Kiravittaya, M. Benyoucef, R. Zapf-Gottwick, A. Rastelli, and O. G. Schmidt. Ordered GaAs quantum dot arrays on GaAs(001): Single photon emission and fine structure splitting. Appl. Phys. Lett. 89 (2006): 233102.

[35] M. Grundmann. The physics of semiconductors: an introduction including devices and nanophysics. Berlin: Springer, 2006.

[36] R. Prasanth. Electroabsorption and electrorefraction in InAs/GaAs and InAs/InP quantum dots. J. Appl. Phys. 99 (2006): 054501.

[37] J. Finley, M. Sabathil, P. Vogl, and G. Abstreiter. Quantum-confined Stark shifts of charged exciton complexes in quantum dots. Phys. Rev. B. 70 (2004): 201308.

[38] O. Stier. Electronic and optical properties of strained quantum dots and wire. Berlin: Verlag, 2000.

[39] M. Guo. Quantum wells. Journal of Chemistry 571 (2005): 11.

[40] X. Leyronas and M. Combescot. Quantum wells, wires and dots with finite barrier: analytical expressions of the bound states. Solid State Communications 119 (2001): 631.

[41] T. Chakraborty. Quantum dots: a survey of the properties of artificial atoms. Amsterdam: Elsevier Science, 1999.

[42] K. Nakamura and K. Nakamura. Quantum chaos and quantum dots : mesoscopic physics and nanotechnology. Oxford: Oxford University Press, 2004.

[43] G. Grosso. Solid state physics. California: Academic Press, 2000.

[44] R. V. N Melnik and K. N. Zotsenko. Finite element analysis of coupled electronic states in quantum dot nanostructures. Modeling and Simulation in Materials Science and Engineering 12 (2004): 465.

[45] G. T. Einevoll and L. J. Sham. Boundary condition for envelop functions at interface between dissimilar materials. Phys. Rev. B. 49 (1994): 10533.

[46] C. Pryor. Geometry and material parameter dependence of InAs/GaAs quantum dot electronic structure. Phys. Rev. B. 60 (1999): 2869.

[47] P. Harrison. Quantum wells, wires and dots: theoretical and computational physics of semiconductor nanostructures. New York: John Wiley & Sons, 2005.

[48] P. Y. Yu, and M. Cardona. Fundamentals of semiconductors: physics and materials properties. Berlin: Springer-Verlag, 1999.

[49] C. Kittel. Introduction to solid state physics. 7 th ed. New York: John Wiley & Sons, 1996.

[50] Wikipedia. Thermal de Broglie wavelength [Online]. 2004. Available from http://en.wikipedia.org/wiki/Thermal_de_Broglie_wavelength [2009, December 16]

[51] D. Bimberg, M. Grundmann, and N. N. Ledenstov. Quantum dot heterostructures. New York: John Wiley & Sons, 1999.

[52] NanOp. Metal-organic vapour phase deposition of quantum dots [Online]. 1998. Available from http://www.nanop.de/animationen/mocvd_en.htm [2009, December 16]

[53] M.Sugawara. Theoretical bases of the optical properties of semiconductor quantum nanostructures. In M. Sugawara (ed.), Semiconductors and Semimetals vol.60: Self-Assembled InGaAs/GaAs Quantum Dots. pp.1-116. San Diego: Academic Press, 1999.

[54] Y. Arakawa, and H.Sakaki. Multidimensional quantum well laser and temperature dependence of its threshold current. Appl. Phys. Lett. 40 (1982): 939.

[55] M. Asada, Y. Miyamoto, and Y. Suematsu. Gain and the threshold of three-dimensional quantum-box lasers. IEEE Journal of Quantum Electronics QE-22 (1986): 1915.

[56] Z. I. Alferov. the double heterostructure concept and its applications. Nobel Lecture. Reviews of Modern Physics 73 (2001): 767.

[57] M. A. Parker. Solid state and quantum theory for optoelectronics. New York: CRC Press, 2009.

[58] C. P. Poole, Jr and F. J. Owen. Introduction to nanotechnology. New Jersey: John Wiley & Sons, 2003.

[59] P. N. Prasad. Nanophotonics. New Jersey: John Wiley & Sons, 2004.

[60] C. Pryor. Eight-band calculations of strained InAs/GaAs quantum dots compared with one-, four-, and six-band approximations. Phys. Rev. B. 57 (1998): 7190.

[61] O. Stier, M. Grundmann, and D. Bimberg. Electronic and optical properties of strained quantum dots modeled by 8-band k.p theory. Phys. Rev. B. 59 (1999): 5688.

[62] L. W. Wang, J. Kim, and A. Zunger. Electronic structures for [110]-faceted self-assembled pyramidal InAs/GaAs quantum dots. Phys. Rev. B. 59 (1999): 5678.

[63] S. L. Chuang. Physics of optoelectronic devices. New York: John Wiley & Sons, 1995.

[64] E. Biolatti, I. D'Amico, P. Zanardi, and F. Rossi. Electro-optical properties of semi-conductor quantum dots: Application to quantum information processing. Phys. Rev. B. 65 (2002): 075306.

[65] V. Poenariu. Influence of lateral electric field in InAs-quantum dots. Doctoral dissertation, Department of Natural Science Faculty of Physics and Astronomy Ruhr University Bochum, 2005.

[66] C. Cohen-Tannoudji, B. Diu, and F. Laloö. Quantum mechanics. New York: John Wiley & Sons, 1977.

[67] M. Reimann and M. Manninen. Electronic structure of quantum dots. Reviews of Modern Physics 74 (2002): 1283.

[68] A. Wojs, P. Hawrylak, S. Fafard, and L. Jacak. Electronic structure and magneto-optics of self-assembled quantum dots. Phys. Rev. B. 54 (1996): 5604.

[69] Y. Marzin and G. Bastard. Calculation of the energy-levels in InAs/GaAs. quantum dots. Solid State Communications 92 (1994): 437.

[70] M. Grundmann, O. Stier, and D. Bimberg. InAs/GaAs pyramidal quantum dots: strain distribution, optical phonons, and electronic structure. Phys. Rev. B. 52 (1995): 11969.

[71] T. Mura. Micromechanics of defects in solids. Berlin: Springer, 1987.

[72] J. Y. Tsao. Materials fundamentals of molecular beam epitaxy. Boston: Academic Press, 1992.

[73] J. Oshinowo, M. Nishioka, S. Ishida, and Y. Arakawa, Highly uniform InGaAs/GaAs quantum dots (approximately 15 nm) by metalorganic chemical vapor deposition. Appl. Phys. Lett. 65 1994): 1425.

[74] J.A. Lott, et al. Room temperature continuous wave InAs-InGaAs quantum dot VCSEL on GaAs substrates emitting at 1.3 um. IEEE Annual Meeting Conference Proceedings 1, pp.304-305, 2000.

[75] M. Yamada, et al. Low-threshold operation of 1.3-um GaAsSb quantum-well lasers Directly Grown on GaAs Substrates. IEEE Photonics Technology Letters 12 (2000): 774.

[76] E. L. Ivchenko. Optical spectroscopy of semiconductor nanostructures. Middlesex: Alpha Science International, 2005.

[77] R. Winkler. Spin-orbit coupling effects in two-dimensional electron and hole systems. Berlin: Springer, 2003.

[78] E. Räsänen, et al. Electronic structure of rectangular quantum dots. Phys. Rev. B. 67 (2003): 235307.

[79] E. Räsänen, A. Harju, M. J. Puska, and R. M. Nieminen. Rectangular quantum dots in high magnetic fields. Phys. Rev. B. 69 (2004): 165309.

[80] M. Xiao. Plasmon changes in rectangular quantum dots under one-, two- and three-dimensional quantum-confinement. Optik - International Journal for Light and Electron Optics 112 (2001): 537.

[81] M. Scully and M. S. Zubairy, Quantum optics. Cambridge: Cambridge University Press, 1997.

[82] S. Nagaraja and J. P. Leburton. Electronic properties and many-body effects in quantum dots. Journal of Physics: Condensed Matter 11 (1999): 5953.

[83] A. Esser, R. Zimmermann, and E. Runge. Theory of trion spectra in semiconductor nanostructures. Physica Status Solidi B 227 (2001): 297.

[84] A. Zora, C. Simserides, and G. P. Triberis. Theory of spontaneous emission of quantum dots in the linear regime. Journal of Physics: Condensed Matter 19 (2007): 406210.

[85] S.W. Koch, T. Meier, W. Hoyer, M. Kira. Theory of the optical properties of semi-conductor nanostructures. Physica E 14 (2002): 45.

[86] C. Simserides , A. Zora A and G. Triberis. Near-field magnetoabsorption of quantum dots. Phys. Rev. B. 73 (2006): 155313.

[87] F. Rossi. Coherent phenomena in semiconductors. Semicond. Sci. Technol. 13 (1998): 147.

[88] W. Quade and E. Schöll. Quantum theory of impact ionization in coherent high-field semiconductor transport. Phys. Rev. B. 50 (1994): 7398.

[89] T. Kuhn and F. Rossi. Monte Carlo simulation of ultrafast processes in photoexcited semiconductors: coherent and incoherent dynamics. Phys. Rev. B. 46 (1992): 7496.

[90] G. D. Mahan. Many-particle physics. New York: Plenum, 1981.

[91] O. Mauritz, G. Goldoni, and E. Molinari. Local optical spectroscopy of semiconductor nanostructures in the linear regime. Phys. Rev. B. 62 (1999): 8204.

[92] M. Kira, F. Jahnke, W. Hoyer, and S. W. Koch. Quantum theory of spontaneous emission and coherent effects in semiconductor microstructures. Progress in Quantum Electronics 23 (1999): 189.

[93] K. Matsuda, T. Saiki, H. Saito, and K. Nishi. Room-temperature photoluminescence spectroscopy of self-assembled In0.5Ga0.5As single quantum dots by using highly sensitive near-field scanning optical microscope. Appl. Phys. Lett. 76 (2000): 73.

[94] M. Wimmer, S. V. Nair, and J. Shumway. Biexciton recombination rates in self-assembled quantum dots. Phys. Rev. B. 73 (2006): 165305.

[95] G. C. La Rocca and M. Cardona. Light-Hole non-parabolicity in the single band approximation. Physica Status Solidi B 167 (1991): 115.

[96] E. H. Li. Material parameters of InGaAsP and InAlGaAs systems for use in quantum well structures at low and room temperatures. Physica E 5 (2000): 215.

[97] C. G. Darwin. Proc. Camb. Phil. Soc. 27 (1930): 86.

[98] K. Leossona, D. Birkedalb, I. Magnusdottirb, W. Langbeinc and J.M. Hvam. Homogeneous linewidth of self-assembled III–V quantum dots observed in single-dot photoluminescence. Physica E 17 (2003): 1.

[99] K. Matsuda K, et al. Homogeneous linewidth broadening in a In0.5Ga0.5As/GaAs single quantum dot at room temperature investigated using a highly sensitive near-field scanning optical microscope. Phys. Rev. B. 63 (2001): 121304.

[100] A. V. Uskov, A. P. Jauho, B. Tromborg, J. Mork, and R. Lang. Dephasing Times in Quantum dots due to elastic LO phonon-carrier ollisions. Phys. Rev. Lett. 85 (2000): 1506.

[101] J. R. Arthur. Molecular beam epitaxy. Surface Science 500 (2002): 189.

[102] Department of material science & engineering, University of Texas at Dallas. Molecular beam epitaxy [Online]. 2008. Available from http://mse.utdallas.edu/images/facilities/newmachine.jpg [2009, December 28]

[103] Institute of Semiconductor and Solid State Physics, Johannes Kepler University. Molecular beam epitaxy [Online]. Available from http://www.hlphys.jku.at/groupsites/iv-vi/facilities/iv-vi_MBE.jpg [2009, December 28]

[104] Institute of Physics AS CR. Molecular beam epitaxy [Online]. 2008. Available from http://www.fzu.cz/departments/surfaces/mbe/soubory/mbe/mbe_method.htm [2009, December 28]

[105] A. Ichimiya and P. I. Cohen. Reflection high-energy electron diffraction. Cambridge: Cambridge University Press, 2004.

[106] P. Samori. STM and AFM studies on (bio) molecular systems: travelling the nanoworld. Berlin: Springer, 2008.

[107] M. Gaft, R. Reisfeld, and G. Panczer. Modern Luminescence Spectroscopy of Minerals and Materials. Berlin: Springer (2005).

[108] Wikipedia. Mono layer [Online]. 2003. Available from http://en.wikipedia.org/wiki/Monolayer [2009, December 30]

[109] University of Cambridge. Epitaxial growth modes [Online]. 2006. Available from http://www-sp.phy.cam.ac.uk/research/images/HASgrowthcurves.png [2009, December 30]

[110] M. A. Herman, and H. Sitter. Molecular beam epitaxy: fundamentals and current status. Berlin: Springer (1989).

[111] Wikipedia. Wetting layer [Online]. 2005. Available from http://en.wikipedia.org /wiki/Wetting_layer [2009, December 30]

[112] N. P. Kobayashi, T. R. Ramachandran, P. Chen, and A. Madhukar. In situ, atomic force microscope studies of the evolution of InAs three-dimensional islands on GaAs (001). Phys. Lett. 68 (1996): 3299.

[113] E. P. O' Reilly. Valence band engineering in strained-layer structures. Semiconductors Science and Technology 4 (1989): 121.

[114] Walter Schottky Institut. Aligned QD structure [Online]. Available from http://www.wsi.tum.de/Portals/0/media/e24/fontcuberta/ceo-dots-chain.jpg [2010, January 4]

[115] S. Suraprapapich, S. Thainoi, S. Kanjanachuchai, and S. Panyakeow. Ordered quantum dot formation on engineered template by molecular beam epitaxy. Microelectronic Engineering 78 (2005): 349.

[116] C. Chiewpanich , C. Wissawinthanon, and S. Panyakeow, Comparison between two techniques for the growth of self-assembled laterally-aligned quantum dots: the superlattice template and the InGaAs induction layer. The 32th Thailand's National Electrical Engineering Conference Proceedings, Vol.II, pp.915-918, October 2009.

[117] K. M. Kim, et al. Artificial array of InAs quantum dots on a strain-engineered superlattice. Physica E 24 (2004): 148.

[118] F. Hiwatashi and K. Yamaguchi. Selective growth of self-organizing InAs quantum dots on strained InGaAs surfaces. Applied Surface Science (1998): 737.

[119] Wikipedia. Wetting layer [Online]. 2004. Available from http://en.wikipedia.org/ wiki/Stark_effect [2010, January 6]

[120] I. B. Akca, Electro-optic and electro-absorption characterization of InAs quantum dot waveguides. Opt. Exp. 16 (2008): 3439.

[121] K. P. Ho. Phase-modulated optical communication systems. Berlin: Springer, 2005.

[122] K. Wakita. Semiconductor optical modulators. Berlin: Springer, 1997.

[123] D. Dragoman and M. Dragoman. Advanced optoelectronic devices. Berlin: Springer, 1998.

[124] H. Haug and S. W. Koch. Quantum theory of the optical and electronic properties of semiconductors. Toh Tuck Link: World Scientific, 2009.

[125] Institute of technical physics, University of Erlangen. Electroabsorption [Online]. Available from http://www.tp1.physik.uni-erlangen.de/research/spin/pics/fke.gif [2010, January 8]

[126] P. Bhattacharya. Semiconductor optoelectronic devices. New Jersey: Prentice-Hall, 1996.

[127] D. A. B. Miller, et al. Band-edge electroabsorption in quantum well structures: the quantum-confined Stark effect. Phys. Rev. Lett. 53 (1984): 2173.

[128] D. A. B. Miller, et al. Electric field dependence of optical absorption near the band gap of quantum well structures. Phys. Rev. B. 32 (1985): 1043.

[129] S. Schmitt-Rink, D. S. Chcrnla, and D. A. B. Miller. Linear and nonlinear optical properties of semiconductor quantum wells. Ado. Phys. 38 (1989): 89.

[130] University of Glasgow. Silicon photonics [Online]. Available from http://userweb. elec.gla.ac.uk/d/dpaul/siphotonics.html [2010, January 11]

[131] S. V. Gaponenko. Optical properties of semiconductor nanocrystals. Cambridge: Cambridge University Press, 1999.

[132] D. Cotter, H. P. Girdlestone, and K. Moulding. Size-dependent electroabsorptive properties of semiconductor microcrystallites in glass. Appl. Phys. Lett. 58 (1991): 1455.

[133] D. M. Kuo and Y. C. Chang. Electron tunneling rate in quantum dots under a uniform electric field. Phys. Rev. B. 61 (2000): 11051.

[134] M. Sabathil, et al. Theory of vertical and lateral Stark shifts of excitons in quantum dots. Physica Status Solidi C 4 (2003): 1181.

[135] M. Larsson, P. O. Holtz, A. Elfving, G. V. Hansson, and W. X. Ni. Reversed quantum-confined Stark effect and an asymmetric band alignment observed for type-II Si/Ge quantum dots. Phys. Rev. B. 77 (2005): 113301.

[136] I. V. Ignatiev and I. E. Kozin. Phonon resonances in photoluminescence spectra of self-assembled quantum dots in an electric field. Phys. Rev. B. 63 (2001): 075316.

[137] W. Sheng and J. P. Leburton. Anomalous quantum-confined Stark effects in stacked InAsGaAs self-assembled quantum dots. Phys. Rev. Lett. 88 (2002): 167401.

[138] Y. Ebiko, et al. Island size scaling in InAs/GaAs self-assembled quantum dots. . Phys. Rev. Lett. 80 (1998): 2650.

[139] D. L. Huffaker, G. Park, Z. Zou, O. B. Shchekin, and D. G. Deppe. 1.3 μm room-temperature GaAs-based quantum-dot laser. Appl. Phys. Lett. 73 (1998): 2564.

[140] A. Patanè, et al. Piezoelectric effects in In0.5Ga0.5As self-assembled quantum dots grown on (311)B GaAs substrates. Appl. Phys. Lett. 77 (2000): 2979.

[141] A. Lemaître, A. D. Ashmore, J. J. Finley, D. J. Mowbray, and M. S. Skolnick. Enhanced phonon-assisted absorption in single InAs/GaAs quantum dots. Phys. Rev. B. 63 (2001): 161309.

[142] J. Wang. A perturbation theory for calculating strain distributions in heterogeneous and anisotropic quantum dot structures. J. Appl. Phys. 100 (2006): 053520.

[143] C. Heyn and A. Bolz. Temperature regimes of strain induced InAs quantum dot formation. Quantum Dots : Fundamentals, Applications, and Frontiers 2005: 103.

[144] C. Obermuller, et al. Mechanical nanomanipulation of single strain-induced semi-conductor quantum dots. Appl. Phys. Lett. 75 (1999): 358.

[145] I. A. Ovidko and A. G. Sheinerman. Defects in square 2D arrays of strained quantum dots. Rev. Adv. Mater. Sci. 4 (2003): 163.

[146] G. W. Wen, J. Y. Lin, and H. X. Jiang. Quantum-confined Stark effects in semiconductor quantum dots. Phys. Rev. B. 52 (1995): 5913.

[147] Y. Z. Hu, M. Lindberg, and S. W. Koch. Theory of optically excited intrinsic semiconductor quantum dots. Phys. Rev. B. 42. 1713 (1990).

[148] D. A. Varshalovich, A. N. Moskalev, and V. K. Khersonskii. Quantum theory of angular momentum. Toh Tuck Link: World Scientific, 1988.

[149] Nomura and T. Kobayashi. Clearly resolved exciton peaks in CdS_xSe_{1-x} microcrystallites by modulation spectroscopy. Solid State Communications 73 (1990): 425.

[150] A. S. Dissanayake, J. Y. Lin, and H. X. Jiang. Quantum-confined Stark effects in $CdS_{1-x}Se_x$ quantum dots. Phys. Rev. B. 51 (1995): 5457.

[151] M. A. Cusack, P. R. Briddon, and M. Jaros. Electronic structure of InAs/GaAs self-assembled quantum dots. Phys. Rev. B. 54 (1996): 2300.

[152] S. S. Li and J. B. Xia. Quantum-confined Stark effects of InAs/GaAs self-assembled quantum dot. J. Appl. Phys. 88 (2000): 7171.

[153] M. G. Burt. The justification for applying the effective-mass approximation to microstructures. Journal of Physics: Condensed Matter 4 (1992): 6651.

[154] B. A. Foreman. Exact effective-mass theory for heterostructures. Phys. Rev. B. 52 (1995): 12241.

[155] L. Bornstein. Numerical data and functional relationships in science and technology. Berlin: Springer-Verlag, 1982.

[156] P. W. Fry, et al. Photocurrent spectroscopy of InAs/GaAs self-assembled quantum dots: observation of a permanent dipole moment. Physica E 7 (2000): 408.

[157] P. W. Fry, et al. Quantum confined Stark effect and permanent dipole moment of InAs–GaAs self-assembled quantum dots. Physica Status Solidi A 178 (2000): 269.

[158] A. Barenco, D. Deutsch, and A. Ekert. Conditional quantum dynamics and logic gates. Phys. Rev. Lett. 74 (1995): 4083.

[159] G. P. Berman and G. D. Doolen. Solid-state quantum computation - a new direction for nanotechnology. Superlattices Microstruct. 27 (2000): 89.

[160] P. Jin, et al. Quantum-confined Stark effect and built-in dipole moment in self-assembled InAs/GaAs quantum dots. Appl. Phys. Lett. 85 (2004): 2791.

[161] J. A. Barker and E. P. O'Reilly. Theoretical analysis of electron-hole alignment in InAs-GaAs quantum dots. Phys. Rev. B. 61 (2000): 13840.

[162] W. Sheng and J. P. Leburton. Electron-hole alignment in InAs/GaAs self-assembled quantum dots: Effects of chemical composition and dot shape. Phys. Rev. B. 63 (2001): 161301.

[163] P. W. Fry, et al. Inverted electron-hole alignment in InAs-GaAs self-assembled quantum dots. Phys. Rev. Lett. 84 (1999): 733.

[164] Z. Chen, E. Ta. Kim, and A. Madhukar. Intraband-transition-induced dipoles in self-assembled InAs/GaAs (001) quantum dots. Appl. Phys. Lett. 80 (2002): 2770.

[165] F. Findeis, M. Baier, E. Beham, A. Zrenner, and G. Abstreiter. Photocurrent and photoluminescence of a single self-assembled quantum dot in electric fields. Appl. Phys. Lett. 78 (2001): 2958.

[166] S. Raymond, et al. Asymmetric Stark shift in $Al_xIn_{1-x}As/Al_yGa_{1-y}As$ self-assembled dots. Phys. Rev. B. 58 (1998): 13415.

[167] A. Passaseo, et al. Comparison of radiative and structural properties of 1.3 μm $In_xGa_{1-x}As$ quantum-dot laser structures grown by metalorganic chemical vapor deposition and molecular-beam epitaxy: effect on the lasing properties. Appl. Phys. Lett. 82 (2003): 3632.

[168] H. Shen and M. Dutta. Franz–Keldysh oscillations in modulation spectroscopy. J. Appl. Phys. 78 (1995): 2151.

[169] P. Jin, et al. Effect of InAs quantum dots on the Fermi level pinning of undoped-n^+ type GaAs surface studied by contactless electroreflectance. J. Appl. Phys. 93 (2003): 4169.

[170] J. W. Garland. Use of electroreflectance to characterize materials with a view to predict device performance. Solid State Physics (1996).

[171] N. N. Ledentsov, et al. Direct formation of vertically coupled quantum dots in Stranski-Krastanow growth. Phys. Rev. B. 54 (1996): 8743.

[172] Z. Jiang, D. Suqing, and X. G. Zhao. Dynamical localization of a square quantum dot molecule under magnetic and electric fields. Phys. Lett. A. 333 (2004): 132.

[173] C. E. Creffield and G. Platero. Dynamical control of correlated states in a square quantum dot. Phys. Rev. B. 66 (2002): 235303.

[174] H. Y. Ramirez, A. S. Camacho, and L. C. Lew Yan Voon. DC electric field effects on the electron dynamics in double rectangular quantum dots. Brazilian Journal of Physics 36 (2006): 869.

[175] C. Brosseau. Fundamentals of polarized light: a statistical optics approach. New York: John Wiley & Sons, 1998.

[176] J. N. Damask. Polarization optics in telecommunications. Berlin: Springer-Verlag, 2009.

[177] S. O. Kasap. Optoelectronics and photonics: principles and practices. New Jersey: Prentice Hall, 2001.

[178] Y. Nabetani, T. Ishikawa, S. Noda, and A. Sasaki. Initial growth stage and optical properties of a three-dimensional InAs structure on GaAs. J. Appl. Phys. 76 (1994): 347.

[179] Z. Zhuang, S. W. Suh, Y. J. Kim, and J. S. Patel. Defect in the circular-circularly rubbed liquid crystal cell with off-center alignment. Appl. Phys. Lett. 76 (2000): 3005.

[180] S. Sanguinetti, et al. Optical anisotropy in arrow-shaped InAs quantum dots. Phys. Rev. B. 57 (1997): 6815.

[181] H. Saito, K. Nishi, S. Sugou, and Y. Sugimoto. Controlling polarization of quantum-dot surface-emitting lasers by using structurally anisotropic self-assembled quantum dots. Appl. Phys. Lett. 71 (1997): 590.

[182] M. W. Shute, C. S. Brown, and J. Jarzynski. On calculating the degree of linear polarization: a Mueller matrix approach. Photonics Technology Letters 9, (1997): 949.

[183] Encyclopedia of laser physics and technology. Polarization of Laser Emission [Online]. Available from http://www.rp-photonics.com/polarization_of_laser_emission .html [2010, January 20]

[184] D. Penninckx and B. Nicolas. Definition, meaning, and measurement of the polarization extinction ratio of fiber-based devices. Applied Optics IP 44 (2005): 7773.

[185] E. F. Schubert. Light-emitting diodes. Cambridge: Cambridge University Press, 2006.

[186] T. Nakaoka, S. Kako, S. Ishida, M. Nishioka, and Y. Arakawa. Optical anisotropy of self-assembled InGaAs quantum dots embedded in wall-shaped and air-bridge structures. Appl. Phys. Lett. 81 (2002): 3954.

[187] S. Noda, T. Abe, and M. Tamura. Mode assignment of excited states in self-assembled InAs/GaAs quantum dots. Phys. Rev. B. 58 (1998): 7181.

[188] W. Sheng. Origins of optical anisotropy in artificial atoms. Appl. Phys. Lett. 89 (2006): 173219.

[189] S. J. Sun and Y. C. Chang. Modeling self-assembled quantum dots by the effective bond-orbital method. Phys. Rev. B. 62 (2000): 13631.

[190] W. Sheng and P. Hawrylak. Atomistic theory of electronic and optical properties of InAs/InP self-assembled quantum dots on patterned substrates. Phys. Rev. B. 72 (2005): 035326.

[191] W. Sheng. Linear polarization in the emission spectra of multiexciton states in InAs/GaAs self-assembled quantum dots. Physica E 40 (2008): 1894.

[192] W. Sheng, S. J. Cheng, and P. Hawrylak. Multiband theory of multi-exciton complexes in self-assembled quantum dots. Phys. Rev. B. 71 (2005): 035316.

[193] E. G. Tsitsishvili. Optical anisotropy in nonspherical quantum dots. Appl. Phys. A 66 (1998): 189.

[194] P. Borri and W. Langbein. Dephasing processes and carrier dynamics in (In,Ga)As quantum dots. Springer 90 (2003): 237.

[195] J. Humlicek, et al. Polarization anisotropy of photoluminescence from multilayer InAs/GaAs quantum dots. Physica E 13 (2002): 229.

[196] E.W. Bogaart, et al. Polarization anisotropy in self-assembled quantum dots within transient absorption bleaching. STW SAFE on semiconductor advances for future electronics (2004): 682.

[197] H. Gotoh, H. Kamada, T. Saitoh, H. Ando, and J. Temmyo. Electric-field-induced anisotropy of excitonic optical properties in semiconductor quantum dots. J. Appl. Phys. 94 (2003): 342.

[198] O. Benson, C. Santori, M. Pelton, and Y. Yamamoto. Regulated and entangled photons from a single quantum dot. Phys. Rev. Lett. 84 (2000): 2513.

[199] C. Santori, D. Fattal, M. Pelton, G. S. Solomon, and Y. Yamamoto. Polarization-correlated photon pairs from a single quantum dot. Phys. Rev. B. 66 (2002): 045308.

[200] H. Gotoh, H. Ando, and H. Kanbe. Excitonic optical properties in semiconductor thin quantum boxes of intermediate regime between zero and two dimensions. Appl. Phys. Lett. 68 (1996): 2132.

[201] H. Gotoh and H. Ando. Excitonic quantum confinement effects and exciton electro-absorption in semiconductor thin quantum boxes. J. Appl. Phys. 82 (1997): 1667.

[202] H. Gotoh, H. Kamada, H. Ando, and J. Temmyo. Lateral electric-field effects on excitonic photoemissions in InGaAs quantum disks. Appl. Phys. Lett. 76 (2000): 867.

[203] S. Ramanathan. Polarization studies of coupled quantum dots. Master's Thesis, Department of Physics and Astronomy Natural Science Faculty of the College of Arts and Sciences Ohio University, 2007.

[204] N. Chit Swe, S. Suraprapapich, C. Wissawinthanon, and S. Panyakeow. Effect of the electric field on the linear polarization property of binary quantum dots.

Proceedings of the 2nd IEEE International Conference on Nano/Micro Engineered and Molecular Systems, pp.1137-1140. Bangkok, 2007.

[205] E. A. Stinaff. Optical signatures of coupled quantum dots. Science 311 (2006): 636.

[206] V. A. Burdov. Two-electron states in a double quantum dot in a constant electric field. Physics of the Solid State 43 (2001): 1152.

[207] N. Chit. Swe. Optical Polarization Property of Laterally Aligned Quantum Dots. Doctoral dissertation, Department of Electrical Engineering Faculty of Engineering Chulalongkorn University, 2007.

[208] S. Suraprapapich, S. Thainoi, S. Kanjanachuchai, and S. Panyakeow. Self-assembled InAs lateral quantum dot molecules growth on (001) GaAs by thin-capping-and-regrowth MBE technique. Journal of Solid State Phenomena 121-123 (2007): 395.

[209] J. F. Chen and J. S. Wang. Electron emission properties of relaxation-induced traps in InAs/GaAs quantum dots and the effect of electronic band structure. J. Appl. Phys. 102 (2007): 043705.

[210] R. F. Pierret. Semiconductor Fundamentals. New York: Addison-Wesley, 1989.

[211] G. A. Narvaez, G. Bester, and A. Zunger. Dependence of the electronic structure of self-assembled (In,Ga)As/GaAs quantum dots on height and composition. J. Appl. Phys. 98 (2005): 043708.

[212] S. P. Wang, et al. Direct measurement of composition of buried quantum dots using aberration-corrected scanning transmission electron microscopy. Appl. Phys. Lett. 89 (2006): 072111.

[213] M. A. Migliorato, A. G. Cullis, M. Fearn, and J. H. Jefferson. Atomistic simulation of strain relaxation in $In_xGa_{1-x}As$/GaAs quantum dots with nonuniform composition. Phys. Rev. B. 65 (2002): 115316.

[214] B. Jing Butt, and Salman. Finite difference analysis of confined states in quantum-Dot system with an efficient mesh strategy. Journal of Computational and Theoretical Nanoscience 7 (2010): 1955.

[215] A. Taflove and S. C. Hagness. Computational electrodynamics: the finite-difference time-domain method. Boston: Artech House, 2005.

[216] Wikipedia. Round-off error [Online]. 2004. Available from http://en.wikipedia.org/wiki/Round-off_error [2010, February 1]

[217] R. Colombelli, V. Piazza, A. Badolato, M. Lazzarino, and F. Beltram. Conduction-band offset of single InAs monolayers on GaAs. Appl. Phys. Lett. 76 (2000): 1146.

[218] N. Bouarisss and H. Aourag. Effective masses of electrons and heavy holes in InAs, InSb, GaSb, GaAs and some of their ternary compounds. Infrared Physics & Technology 40 (1999): 343.

[219] S. S. Li, J. B. Xia, Z. L. Yuan, and Z. Y. Xu. Effective-mass theory for InAs/GaAs strained coupled quantum dots. Phys. Rev. B. 54 (1996): 11575.

[220] MathWorks. Avoiding Out of Memory Errors [Online]. Available from http://www.mathworks.com/support/tech-notes/1100/1107.html [2010, February 5]

[221] MathWorks. Sprase [Online]. Available from http://www.mathworks.com/help/techdoc/ref/sparse.html [2010, February 5]

[222] MathWorks. Eigs [Online]. Available from http://www.mathworks.com/help/techdoc/ref/eigs.html [2010, February 5]

[223] V. Apalkov. Quantum dot infrared photodetectors: interdot coupling. J. Appl. Phys. 100 (2006): 076101.

[224] Technical University of Denmark. Semiconductor quantum dots [Online]. 2007. Available from http://www.dtu.dk/upload/subsites/quantumphotonics/lodahl/olesen-et-al-fagprojekt.pdf [2009, March 3]

[225] University of Houston Cullen college of engineering . Solution of Laplace's Equation by Finite Differences [Online]. 2008. Available from http://www.egr.uh.edu/courses/ece/ECE2317/SectionWilliams/Misc/syllabusOLD.pdf [2009, February 1]

[226] Ioffee institute. GaAs [Online]. 2005. Available from http://www.ioffe.ru/SVA/NSM/Semicond/GaAs/basic.html [2010, February 7]

[227] Ioffee institute. InAs [Online]. 2005. Available from http://www.ioffe.ru/SVA/NSM/Semicond/InAs/basic.html [2010, February 7]

[228] D. K. Cheng. Field and wave electromagnetic. New York: Addison-Wesley, 1989.

[229] J. H. Mathews and K. K. Fink. Numerical methods using Matlab. New Jersey: Prentice Hall, 2004.

[230] Devexpress. Manhattan bar chart [Online]. Available from http://documentation.devexpress.com/#XtraCharts/CustomDocument2962 [2010, July 3]

[231] Z. M. Wang, K. Holmes, Yu. I. Mazur, and G. J. Salamo. Fabrication of (In,Ga)As quantum-dot chains on GaAs(100). Appl. Phys. Lett. 84 (2004): 1931.

[232] C. Y. Ngo, et al. Characteristics of 1.3 μm InAs/InGaAs/GaAs quantum dot electro-absorption modulator. Appl. Phys. Lett. 94 (2009): 143108.

[233] K. Hirakawa. High-sensitivity modulation-doped quantum dot infrared photo-detectors. Microelectronic Engineering 63 (2002): 185.

[234] G. H. Bernstein. Quantum-dot cellular automata: computing by filed polarization. IEEE Design Automation Conference Proceedings, pp.268-273. USA, June 2003.

Appendices

Appendix A: Matlab® Program

An Example of the M-file Script Routines Used to Calculate the Electron and the Hole Wavefunctions for Multiple Quantum Dots by Solving the Schrödinger Equation Using the Different Effective Masses Approach

The whole calculation program is separated into four files:

1. **PD_ALIGNED_QDs.m** -- the main routine used to calculate polarization degree of aligned QDs
2. **Call-ELECTRICFIELD.m** -- the subroutine called to define the two-dimensional electric field system
3. **Call-ALIGNED_QDs.m** -- the subroutine called to define the region of InAs and GaAs
4. **ALIGNED_QDs_eigenergy.m** -- the subroutine called to calculate the eigen-energies and eigen-functions of aligned QDs

List of the routines:

PD_ALIGNED_QDs.m

```
clc
clear
close all
clear all

  x0 = 0; xf=200;       % starting and end points of x axis (in units of nanometers)
  y0 = 0; yf=200;       % starting and end points of y axis (in units of nanometers)
  Mx =100;              % Number of sample points in x axis (in units of nanometers)
  My =100;
  n  = XX;              % size of quantum dot in x-direction
% to get the real dimension should multiply by 2)
  A  = XX;              % size of QDs in Y direction
  d  = XX;              % spacing between one QDs and another
% to get the real dimension, should calculated (d-1)x 2)
% XX stands for parameter, corresponding to QDs (by input value)

  dotaddleft  = XX;     % additional dots on left hand side
  dotaddright = XX;     % additional dots on right hand side
  numdots = dotaddleft+dotaddright; % total number of QDs, corresponding to
% numdots=dotaddleft+dotaddright
```

```
  N  = 50;                    %mid point of the mesh
  dx = (xf - x0)/Mx;
  dy = (yf - y0)/My;
   x = (-xf/2:xf/Mx:xf/2);    %position of sample points in x axis
   y = (-yf/2:yf/Mx:yf/2)';   %position of sample points in y axis

% NUMERICAL CALCULATION of the Schroedinger equation implemented by using Finite
% Difference Method
% Developed by Chonlakorn Chiewpanich (modified corresponding to Nan Nan Thidar Chit
% Swe's original program)
% The maximum mesh size for the two-dimensional Schroedinger equation is 100*100.
% One mesh is equivalent to 2 nm.
% Changing the mesh points is available by modifying N, Mx, My, xf, and yf,
corresponding to the condition of N = Mx = My = (xf/2) = (yf/2)

%--------------------------------------------------------------------
%--------------------------------------------------------------------

% Calculate the electron wavefunction
 disp( '%This program shows the wavefunctions obtained by solving the Schroedinger')
 disp('equation for ALIGNED quantum dots. The size of the dot is fixed at XX nm.')
 disp ('%')
 disp( '%Calculating the electron wavefunction')
 disp ('%')
 disp(' %The value of the band offset V1 is XX eV.')
 disp ('%')
 disp('%The length in the x direction and the y direction each is XX nm.')
 disp ('%')
 disp('%The number of the mesh points in the x and x directions is XX each.')
 disp ('%')
 disp(' %This program calculates based on the interdot spacing between QDs.')
 disp ('%')
 disp('Distance between QDs: 2d'  );
 disp ('%')
 d=input ('d=');
 num_sol=input ('%number of solutions:      ');
 disp ('%')
 m1=input ('%mass of electron in GaAs:      ');
 m2=input('%mass of electron in InAs:      ');
 disp ('%')
 disp ('%')
 Vp=input ('%band offset (eV):      ');

[phi,te,d,num_sol,V1,V]=ALIGNED_QDs_eigenergy(d,num_sol,Mx,My,Vp,m1,m2);

 figure(1);

 mesh(x,y,V1)
  xlabel('Distance (nm)')
  ylabel('Distance (nm)')
  zlabel('Potential energy, (eV)')
```

```
   K= reshape(phi(:,1),Mx-1,My-1);
   Phielectron=zeros(Mx+1,My+1);
   Phielectron(2:Mx,2:end-1)=K(1:end,1:end);
    Xlabel ('X-Distance (nm)'),
    ylabel ('Y-Distance (nm)')'
    zlabel ('Wavefunction');
    title  ('Electron wavefunction of the QDs')
    figure(2);
    mesh(x,y,Phielectron)

   %--------------------------------------------------------------------
   %--------------------------------------------------------------------

% Calculate the hole wavefunction
m1=input ('%mass of hole in GaAs:      ');
m2=input('%mass of hole in  InAs:      ');
[phi,te,d,num_sol,V,V1]=ALIGNED_QDs_eigenergy(d,num_sol,Mx,My,Vp,m1,m2);

    figure(3);
    mesh(x,y,V)
    xlabel('Distance (nm)')
    ylabel('Distance (nm)')
    zlabel('Potential energy, (eV)')

L= reshape(phi(:,1),Mx-1,My-1);
   Phihole=zeros(Mx+1,My+1);
   Phihole(2:Mx,2:end-1)=L(1:end,1:end);

   figure(4);
   mesh(x,y,Phihole);
   xlabel('X-Distance (nm)'),
   ylabel('Y-Distance (nm)')'
   zlabel('Wavefunction');
   title('Figure (4) : Hole wavefunction of the QDs')

  %--------------------------------------------------------------------
  %--------------------------------------------------------------------

% Calculate the overlap integral (for aligned QDs)
% An example of coupling regions in case of six QDs
%
%                N-(3*d/2)-2*n   N-(3*d/2)-n          |              N+(3*d/2)+n  N+(3*d/2)+2*n
%     _ _ _ _ _ _      _ _ _ _ _ _     _ _ _ _ _ _    |   _ _ _ _ _ _     _ _ _ _ _ _     _ _ _ _ _ _
%    |          | a(1)|    a(2)   | a(3)|     a(4)   | a(5)|    a(6)   | a(7)|    a(8)   | a(9)|          |  |
%    |          |     |          |     |          |  |  |  |          |     |          |     |          |  |
% - -|- - - - - -| - - |- - - - - -| - - |- - - - - -|- - -|- - - - - -| - - |- - - - - -| - - |- - - - - -| -|A
%    |<----n---->|<-d->|          |     |          |  |N |  |          |     |          |     |          |  |
%    |_ _ _ _ _ _|     |_ _ _ _ _ _|     |_ _ _ _ _ _|  |  |_ _ _ _ _ _|     |_ _ _ _ _ _|     |_ _ _ _ _ _|  |
%                                                    |
%N-(5*d/2)-3*n N-(5*d/2)-2*n          N-(d/2)-n  N-(d/2)| N+(d/2)  N+(d/2)+n          N+(5*d/2)+2*n N+(3*d/2)+3*
```

```
    Phi   = Phihole.*Phielectron;        % e-h overlapping
    Phiee= Phielectron.*Phielectron;     % e-e overlapping
    Phihh= Phihole.*Phihole;             % h-h overlapping

% Central overlap
Centralee=sum(sum(Phiee(N-A/2:N+A/2,(N-d/2+1):(N+d/2+1))));

Centralhh=sum(sum(Phihh(N-A/2:N+A/2,(N-d/2+1):(N+d/2+1))));

Centraleh=sum(sum(Phi(N-A/2:N+A/2,(N-d/2+1):(N+d/2+1))));

sumCentral=Centralee+Centralhh-2*Centraleh;

if NU == 1    %half number of total QDs. Note that for Bi-QDs, the program is operating
% only this logic

Area=(A*d);

Overlapped=sumCentral/Area

else

for i=1:NU-1  %In case of number of QDs is greater than

%Left overlap
Leftee(i)=sum(sum(Phiee(N-n/2:N+n/2,((N-((2*i+1)*d/2)-(2*i-1)*n+1)):((N-(2*i-1)*d/2)-
(2*i-1)*n+1))));

Lefthh(i)=sum(sum(Phihh(N-n/2:N+n/2,((N-((2*i+1)*d/2)-(2*i-1)*n+1)):((N-(2*i-1)*d/2)-
(2*i-1)*n+1))));

Lefteh(i)=sum(sum(Phi(N-n/2:N+n/2,((N-((2*i+1)*d/2)-(2*i-1)*n+1)):((N-(2*i-1)*d/2)-
(2*i-1)*n+1))));

%Right overlap
Rightee(i)=sum(sum(Phiee(N-n/2:N+n/2,((N+((2*i-1)*d/2)+(i*n)+1)):((N+(2*i+1)*d/2)
+(i*n)+1))));

Righthh(i)=sum(sum(Phihh(N-n/2:N+n/2,((N+((2*i-1)*d/2)+(i*n)+1)):((N+(2*i+1)*d/2)
+(i*n)+1))));

Righteh(i)=sum(sum(Phi(N-n/2:N+n/2,((N+((2*i-1)*d/2)+(i*n)+1)):((N+(2*i+1)*d/2)
+(i*n)+1))));


end

sumeehh = sum(Leftee)+sum(Lefthh)+sum(Rightee)+sum(Righthh);
sumeh   = sum(Lefteh)+sum(Righteh);
```

```
Area=(A*d);

Overlapped=(sumCentral+sumeehh-2*sumeh)/Area

end

  %--------------------------------------------------------------------
  %--------------------------------------------------------------------


% Calculate the Linear Polarization Degree (PD)
    [X,Y]=meshgrid(x,y);
    D1=abs(Phielectron.*X.* Phihole);
    D2=abs(Phielectron.*Y.* Phihole);
    AA =sum (sum(D1));
    BB =sum (sum(D2));
    RAWPD = abs((AA-BB)/(AA+BB))                    % PD of single QD
    Cgridarea=abs(Overlapped*((AA-BB)/(AA+BB)))     % PD of aligned QDs
```

Call-ELECTRICFIELD.m

```
 function[elecx,elecy]=Call_ELECTRICFIELD(voltx,volty);
 voltx = input ('%voltage applied along the x direction:      ');
 volty = input ('%voltage applied along the y direction:      ');

% Calculation of specification matrix

M = 99*99; % M is dimension of specification matrix, corresponding to number of node
% in electric field system = (xf-1)*(xf-1) because we neglect the row and column that
% refer to ground voltage

% Ex. 3*3 voltage node  V11 V12 V13
%                       V21 V22 V23
%                       V31 V32 V33
% The corresponding potential matrix is X = V11    and its dimension is sqrt(M)*1
%                                           V12
%                                           V13
%                                           V21    9*1 matrix
%                                           V22
%                                           V23
%                                           V31
%                                           V32
%                                           V33

r=sparse(sparse(diag(-4+zeros(M,1),0))+sparse(diag(ones(M-
sqrt(M),1),sqrt(M)))+sparse(diag(ones(M-sqrt(M),1),-sqrt(M))));
```

```
% Specification matrix of 3*3 voltage node
%     -4     1     0     1     0     0     0     0     0
%      1    -4     1     0     1     0     0     0     0
%      0     1    -4     0     0     1     0     0     0
%      1     0     0    -4     1     0     1     0     0
%      0     1     0     1    -4     1     0     1     0
%      0     0     1     0     1    -4     0     0     1
%      0     0     0     1     0     0    -4     1     0
%      0     0     0     0     1     0     1    -4     1
%      0     0     0     0     0     1     0     1    -4

% Specify "1" at the position i=j+1
% At the position j=i+1. "1" is specified that equals to (dimension of nodes - 1)
% Ex. 3*3 voltage node → 1 1 0 1 1 0 1 1 0
% Ex. 4*4 voltage node → 1 1 1 0 1 1 1 0 1 1 1 0 1 1 1 0

for i=1:M
    for j=1:M

        if i == j+1
            r(i,j)=1;
            if i == j+1 && mod(j,sqrt(M))== 0 %Specify "0" at the position i=j+1 and
mod(j, dimension of nodes)=0
               r(i,j)=0;
            end
        elseif  j == i+1
            r(i,j)=1;
             if j == i+1 && mod(i,sqrt(M))== 0 %Specify "0" at the position j=i+1 and
mod(i, dimension of nodes)=0
               r(i,j)=0;

             end
        end
    end
end
```

```
  %-------------------------------------------------------------------
  %-------------------------------------------------------------------

% Boundary condition at the interface of different medium

% Ex. 2 QDs                          ------------------------------
%                                   |       e1      |             |
%                                   |               |             |
%                                   |    ------     |    ------   |
%                                   |   |   e2 |    |   |      |  |
%                                   |   |      |    |   |      |  |
%                                   |    ------     |    ------   |
%                                   |               |             |
%                                   |               |             |
%                                    ------------------------------
```

```
s=sqrt(M);
dielec0=8.854187*(10^-12);
dielec1=12.9*dielec0;   %dielectric constant of GaAs (e1)
dielec2=15.15*dielec0;  %dielectric constant of InAs (e2)

% Continuity at the interface, D1=D2
% Ex.  3*3 voltage node             V11 V12 V13     Interface nodes are V12,V22,V32
%                                   V21 V22 V23
%                                   V31 V32 V33
%From D1=D2 --> e1E1=e2E2
%
% At V12, e1(V12-V11)=e2(V13-V12) --> (e1+e2)V12 = e1V11 + e2V13
% At V22, e1(V22-V21)=e2(V23-V22) --> (e1+e2)V22 = e1V21 + e2V23
% At V32, e1(V32-V31)=e2(V33-V32) --> (e1+e2)V32 = e1V31 + e2V33
%
%Compared to previously specified voltage
%                                    V12 = (1/4)(V11+V13+volty+V22)
%                                   V22 = (1/4)(V21+V23+V12+V32)
%                                   V32 = (1/4)(V31+V33py+V22)
%
% Ex. 3*3 voltage node   [-4     1     0     1     0     0     0     0     0   [V11
%                         1    -4     1     0     1     0     0     0     0    V12
%                         0     1    -4     0     0     1     0     0     0    V13
%                         1     0     0    -4     1     0     1     0     0    V21
%                         0     1     0     1    -4     1     0     1     0    V22
%                         0     0     1     0     1    -4     0     0     1    V23
%                         0     0     0     1     0     0    -4     1     0    V31
%                         0     0     0     0     1     0     1    -4     1    V32
%                         0     0     0     0     0     1     0     1    -4 ]  V33]
%
% At V12,V22,V32 the values change to
%
%                        -e1  e1+e2   e2    0     0     0     0     0     0    V12
%                         0     0     0   -e1   e1+e2  -e2    0     0     0    V22
%                         0     0     0     0     0     0    -e1  e1+e2  -e2   V32

% Boundary condition at the QDs's edge

F=s;

% Position of four edges of all QDs
for dot = -(numdots-1)*(d/2):d:(numdots-1)*(d/2)
% Ex. number of dot = 2 → numdots = 2 → dot = -(d/2):d:(d/2)

% Top edge

for i=((((F*F)+1)/2) - (A*F)/2 +dot -n)+1 : ((((F*F)+1)/2) - (A*F)/2 +dot)-1

r(i,1:s*s)= 0;

end
```

```
for i=((((F*F)+1)/2) - (A*F)/2 +dot -n)+1 : ((((F*F)+1)/2) - (A*F)/2 +dot)-1

r(i,i)= dielec1+dielec2;
r(i,i-s)= -dielec1;
r(i,i+s)= -dielec2;

end

% Bottom edge

for i=((((F*F)+1)/2) - (A*F)/2 +dot -n + (A*F))+1:((((F*F)+1)/2) - (A*F)/2 +dot +
(A*F))-1

r(i,1:s*s)= 0;

end

for i=((((F*F)+1)/2) - (A*F)/2 +dot -n + (A*F))+1:((((F*F)+1)/2) - (A*F)/2 +dot +
(A*F))-1

r(i,i)= dielec1+dielec2;
r(i,i-s)= -dielec2;
r(i,i+s)= -dielec1;

end

% Left edge

for i=((((F*F)+1)/2) - (A*F)/2 +dot -n)+1 :F:((((F*F)+1)/2) - (A*F)/2 +dot -n +
(A*F))-1

r(i,1:s*s)= 0;

end

for i=((((F*F)+1)/2) - (A*F)/2 +dot -n)+1 :F:((((F*F)+1)/2) - (A*F)/2 +dot -n +
(A*F))-1

r(i,i)= dielec1+dielec2;
r(i,i-1)= -dielec1;
r(i,i+1)= -dielec2;

end
```

```
% Right edge

for i=((((F*F)+1)/2) - (A*F)/2 +dot)+1 :F: ((((F*F)+1)/2) - (A*F)/2 +dot + (A*F))-1

r(i,1:s*s)= 0;%เซตค่าให้เป็นศูนย์ทั้งแถว

end

for i=((((F*F)+1)/2) - (A*F)/2 +dot)+1 :F: ((((F*F)+1)/2) - (A*F)/2 +dot + (A*F))-1

r(i,i)= dielec1+dielec2;
r(i,i-1)= -dielec2;
r(i,i+1)= -dielec1;

end

end

  %---------------------------------------------------------------------
  %---------------------------------------------------------------------


% Boundary condition of applied voltage
%
%                                volty (voltage applied along the y direction)
%                      ---------------------------
%                      |                          |
%                      |                          |
%          px          |                          |   voltx (voltage applied along the
%                      |                          |          x direction)
%                      |                          |
%                      ---------------------------
%                                   py
px=0;%ground
py=0;%ground

k=sqrt(M);

% Calculation of boundary matrix (matrix B)
%
% Ex. 3*3 voltage node
%
%             B = -(summation of branch connected to V11) 9*1 matrix
%                 -(summation of branch connected to V12)
%                 -(summation of branch connected to V13)
%                 -(summation of branch connected to V21)
%                 -(summation of branch connected to V22)
%                 -(summation of branch connected to V23)
%                 -(summation of branch connected to V31)
%                 -(summation of branch connected to V32)
%                 -(summation of branch connected to V33)
```

```
%Four corners ((1,1)(1,j)(i,1)(1,j))
    b(1)= -(px+volty);
    b(k)= -(volty+voltx);
    b(((k-1)*k)+1)=-(px+py);
    b(k*k)=-(voltx+py)';

%Top edge     (from (1,2) to (1,j-1))
    b(2:k-1)= -volty;
%Bottom edge  (from (i,2) to (i,j-1)))
    b(((k-1)*k)+2:(k*k)-1)=-py;

%Left boundary (from (2,1) to (i-1,1))
b(k+1:k:(k-1)*(k-1))=-px;
%Right boundary(from (2,j) to (i-1,j))
b(2*k:k:(k-1)*k)=-voltx;

%For free nodes, their values are "0"


  %-------------------------------------------------------------------
  %-------------------------------------------------------------------

% Solving for potential matrix

b=b';

TEM=r\b; % Solving matrix X by X= (A)-1(B)
%
% Ex. 3*3 voltage node
%                  X =X= V11  9*1 matriz
%                        V12
%                        V13
%                        V21
%                        V22
%                        V23
%                        V31
%                        V32
%                        V33
%Re-arranged from 9*1 matrix to 3*3 matrix, that is,       V11 V12 V13
%                                                          V21 V22 V23
%                                                          V31 V32 V33

for f=1:s*s
i=ceil(f/s);
j=mod(f,s);

if j==0
   j=s;
end
```

```
VOLT(i,j)=TEM(f);  % Potential distribution of the system

end

  %--------------------------------------------------------------------
  %--------------------------------------------------------------------

% Investigation of electric field distribution

deltaxx=2;   % One mesh is equivalent to 2 nm
deltayy=2;

% Ex(x,y) = (V(x+delta,y)-V(x,y))/delta
% Ey(x,y) = (V(x,y+delta)-V(x,y))/delta
%
% Ex. 3*3 voltage node  V11 V12 V13
%                       V21 V22 V23
%                       V31 V32 V33
%                                volty
%                      ----------------------------
%                      |                           |
%                      |                           |
%          px          |                           |   voltx
%                      |                           |
%                      |                           |
%                      ----------------------------
%                                   py
% Since px,py are ground, so Ex(i,j)=(V(i,j+1)-V(i,j))/delta
% Ex. Ex(1,2)=V(1,3)-V(1,2)
% Ey(i,j) =(V(i-1,j)-V(i,j))/delta
% Ex. Ey(2,2)=V(1,2)-V(2,2)


for i=1:s
    for j=1:s


   if  i-1 == 0

      h=volty;

    elecy(i,j)=(h-VOLT(i,j))./deltayy; %uu

   else

    elecy(i,j)=(VOLT(i-1,j)-VOLT(i,j))./deltayy;

   end

   if j+1 == s+1
```

```
        l=voltx;

        elecx(i,j)=(l-VOLT(i,j))./deltaxx;%

    else

        elecx(i,j)=(VOLT(i,j+1)-VOLT(i,j))./deltaxx;

    end

    end
end

% Contour plot of potential distribution
X1 = 1:sqrt(99*99);
Y1 = 1:sqrt(99*99);
figure(6)
mesh(Y1,X1,VOLT)
```

Call-ALIGNED_QDs.m

```
function[mass,V1,V,const]=Call_ALIGNED_QDs(d,Vp,m1,m2,Mx,My);

x0 = 0; xf=200;       % starting and end points of x axis (in nanometers)
y0 = 0; yf=200;       % starting and end points of y axis (in nanometers)


dx = (xf - x0)/Mx;      % increment in x direction = length(nm)/Mx
x = x0 + [0:Mx]*dx;     % position of sample points in x direction
dy = (yf - y0)/My;      % increment in x direction= length(nm)/Mx

y =y0+[0:My].'*dy;      % position of sample points in y direction

h=1.0545715968;         % Planck's constant ( x 10^-34 unit in Js)
hbar2=h^2;

echarge=1.6021764628;   % electron charge ( x 10^-19 C)


baremass=9.10938188;     % bare electron mass (x 10^31 kg)

me1=m1*baremass;         % effective mass of carrier in GaAs
me2=m2*baremass;         % effective mass of carrier in InAs
const=hbar2/echarge;
deltax=xf/Mx;                % x-increment = length(nm)/n
deltax2=deltax^2;
const=const/deltax2;
mass=me1*ones(Mx+1,My+1);   % define the GaAs effective mass region
```

```
% GaAs region

for i =1:My-1;
  for j = 1:My-1

V(i,j)    =bandoffsetelectron-Vb+echarge*VOLT(i,j);
% Ratio between bandoffset of electron and hole is 0.7:0.3

  end
end

% dots on left hand side

for g = 1:dotaddleft

  for i = N-A/2:N+A/2;              % position of InAs mass and barrier
    for j =  ((N-((2*g)-1)*(d/2)))-((g)*n):((N-((2*g)-1)*(d/2)))-((g-1)*n)

        V(i,j)     =0+echarge*VOLT(i,j);
        mass(i,j)  =me2;

     end
end
end

% dots on right hand side

for g = 1:dotaddright

   for i = N-A/2:N+A/2;              % position of InAs mass and barrier
     for j =  ((N+((2*g)-1)*(d/2)))+((g-1)*n):((N+((2*g)-1)*(d/2)))+((g)*n)

        V(i,j)     =0+echarge*VOLT(i,j); %Original
        mass(i,j)  =me2;

     end
end
end
```

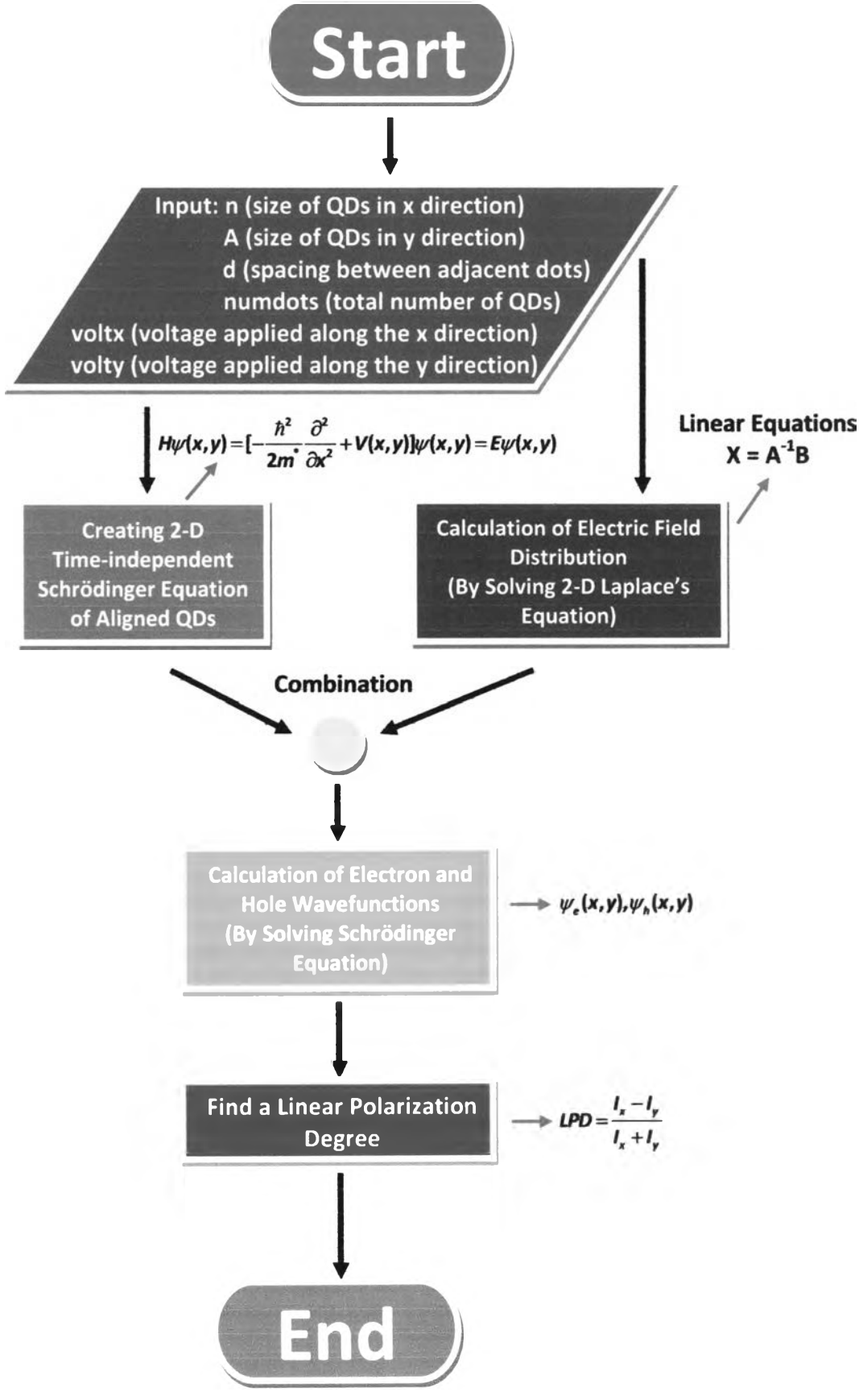
ALIGNED_QDs_eigenergy.m

```
function[phi,te,d,num_sol,V1,V]=ALIGNED_QDs_eigenergy(d,num_sol,Mx,My,Vp,m1,m2);
% Call the function to define the region of QDs

[mass,V1,V,const]=Call_ALIGNED_QD(d,Vp,m1,m2,Mx,My);
 for  i=2:Mx-1;
           for  j=2:My-1;
```

```
d(i,j)=(((1/(mass(i1,j)+mass(i,j))+1/(mass(i+1,j)+mass(i,j)))+
(1/(mass(i,j-1)+mass(i,j))+1/(mass(i,j+1)+mass(i,j))))*const+ V(i,j));

% diagonal matrix element

offd1(i,j)=[(1/(mass(i-1,j)+mass(i,j)))] *const;

% off-diagonal matrix element

offd3(i,j)=[(1/(mass(i,j-1)+mass(i,j)))] *const;


           end
  end


for i=1:Mx-1;

            for j=1:My-1;

          offd2(i,j)=[(1/(mass(i+1,j)+mass(i,j)))] *const;

          offd4(i,j)=[(1/(mass(i,j+1)+mass(i,j)))] *const;

            end
  end

offd2(end,:)=zeros(1,My-1);

offd4(:,end)=zeros(My-1,1);


for i=2:Mx-1;

         for j=1:1;

d(i,j)=(((1/(mass(i1,j)+mass(i,j)))+1/(mass(i+1,j)+mass(i,j))

+(1/(mass(i,j)+mass(i,j))+1/(mass(i,j+1)+mass(i,j))))*const+ V(i,j));


offd1(i,j)=[(1/(mass(i-1,j)+mass(i,j)))] *const;

         end

end


for  i=1:1;

    for j=2:Mx-1;

d(i,j) =-(((1/(mass(i,j)+mass(i,j))+1/(mass(i+1,j)+mass(i,j))

+(1/(mass(i,j-1)+mass(i,j)))+1/(mass(i,j+1)+mass(i,j))))*const+

V(i,j));


% diagonal matrix element

       offd3(i,j)=[(1/(mass(i,j-1)+mass(i,j)))] *const;

    end
end
      d(1,1)  = -(((1/(mass(1,1)+mass(1,1)))+1/(mass(2,1)+mass(1,1))+

(1/(mass(1,1)+mass(1,1))+1/(mass(1,2)+mass(1,1))))*const+ V(i,j));


           H=-(d(:))'; % diagonal matrix element
   offd1=(offd1(:))';  % off-diagonal element  1
   offd2=(offd2(:))';  % off-diagonal element  2
```

```
offd3=(offd3(:))'   % off-diagonal element  3;
offd4=(offd4(:))';  % off-diagonal element  4;
Mx1=((Mx-1)*(My-1));

    for i=1:Mx1
      d(i)=H(i);
      offd1(i)=offd1(i);
      offd2(i)=offd2(i);
      offd3(i)=offd3(i);
      offd4(i)=offd4(i);
    end

    t = d(1:Mx1);
       t1 = -offd1(2:Mx1);
       t2 = -offd2(1:Mx1-1);
       t3 = -offd3(Mx:Mx1);
       t4 = -offd4(1:Mx1-(Mx-1));

Hmatrix2=sparse(diag(t,0)+diag(t1,-1)+diag(t2,1)+diag(t3,-(Mx-1))+diag(t3,(Mx-1)));
% Hamiltonian matrix

[phi,te]=eigs(Hmatrix2,num_sol,'SM');   % Use Matlab function "eigs" to find
                                        % "num_sol" eigenfunctions and eigenvalues

for i=1:size(phi,1)
    if (phi(i)<0)
  phi(i)=(-1)*phi(i);
     elseif (phi(i)>=0)
  phi(i)=(1)*phi(i);
     end
end

AA= max(max(phi)); % Finding the maximum value of the wavefunction
phi = phi./AA;     % Finding the normalized amplitude of the wavefunction

K= reshape(phi,Mx-1,My-1);
Phi=zeros(Mx+1,My+1);
Phi(2:Mx,2:end-1)=K(1:end,1:end);

return
```

Calculation Flowchart



Appendix B: List of Publications

National Conference

1. **Chonlakorn Chiewpanich** , Chanin Wissawinthanon, and Somsak Panyakeow, "Comparison between two techniques for the growth of self-assembled laterally-aligned quantum dots: the superlattice template and the InGaAs induction layer", *Proceedings of the 32th Thailand's National Electrical Engineering Conference*, Vol.II, pp.915-918, October 2009.

International Conference

1. N. Chit Swe, **C. Chiewpanich**, S. Suraprapapich, S. Panyakeow, and C. Wissawinthanon, "Temperature-dependent optical polarization property of self-assembled laterally-aligned quantum dots", *Proceedings of the International Conference on System on Chip Design Challenges*, Manila, Philippines, pp.141-144, September 2010.

Vitae

Chonlakorn Chiewpanich was born in Bangkok, Thailand, on September 18th, 1985. He graduated from Nawamintrachinuthit Triamudomsuksanomklao school in March 2003. In June 2003, He entered Chulalongkorn University and received the Bachelor of Engineering in field of Electrical Engineering with GPAX 2.61 in May 2007. She was further his study in June 2007, as a master student of the Semiconductor Device Research Laboratory (SDRL). His interests are nanotechnology for III-V compound semiconductors, especially in nanophotonics devices.