Quantum transport and nanodevices

Academic Year: (2023 / 2024) **Review date: 28-04-2023**

Department assigned to the subject: Mathematics Department

Coordinating teacher: LOPEZ BONILLA, LUIS FRANCISCO

Type: Electives ECTS Credits : 3.0

Year : 2 Semester : 1

OBJECTIVES

- Understand ideas behind electron transport in low dimensional materials and devices.
- Learn basic numerical methods and use basic algorithms.
- Find and run commonly used open access simulation tools.

DESCRIPTION OF CONTENTS: PROGRAMME

1. Semiclassical description of electron transport through the Boltzmann transport equation. Different types of scattering and collision terms. Methods of integration: Monte Carlo and Galerkin methods.

2. Reduction to drift-diffusion equations for small mean free path. Maximum entropy closures.

3. Quantum transport via Wigner equations and nonequilibrium Green functions.

4. Low dimensional solids. Semiconductor superlattices: Electronic structure, minibands and subbands. Bloch oscillations and Gunn type oscillations. True random sequence generator for communications and secure commerce. Quantum cascade laser. Wide miniband superlattices, kinetic theory and drift/-diffusion equations. Fast oscillator device. Sequential quantum tunneling in weakly coupled superlattices and spatially discrete drift-diffusion equations. Charge dipole waves and excitability. Regular and chaotic oscillations and generation of true random numbers.

5. Low dimensional solids. Semiconductor quantum dots: Electronic structure, KP effective models.
The Loss and Divicenzo Quantum Computer based in Quantum Dots. Qubits based in charge and spin. Quantum Electron spin qubits in single and double QDs. Initialization, detection and read out. Quantum transport: Coulomb Blockade, Spin Blockade. Spin qubits manipulation for quantum operations. Electron dipole spin resonance. Exchange interaction ¿ swapping for 2 qubit operations. Decoherence and relaxation. Electron spin qubits in triple quantum dots. Hole spin qubits.

6. Low dimensional solids. Arrays of quantum dots: long range transfer. Dark states and quantum superpositions in artificial molecules. Adiabatic protocols for quantum information transfer. Shortcuts to adiabaticity. Spin qubit long range transfer. Photoassisted transport. Floquet theory. Light-matter interaction. Quantum cavities coupled to qubits.

ASSESSMENT SYSTEM

Homework, classroom participation and presentations of work

% end-of-term-examination:	100
% of continuous assessment (assigments, laboratory, practicals…):	0

BASIC BIBLIOGRAPHY

- D. Vasileska and S. M. Goodnick Computational Electronics. , Morgan & Claypool , 2006
- H. Haug; A.-P. Jauho Quantum Kinetics in Transport and Optics of Semiconductors. 2nd ed., Springer, 2008
- Jacoboni, Carlo Theory of Electron Transport: A Pathway from Elementary Physics to Nonequilibrium Green Functions in Semiconductors., Springer, 2010
- L. L. Bonilla and S. W. Teitsworth Nonlinear wave methods for charge transport, Wiley, 2010
- L. P. Kouwenhoven, C. M. Marcus, P. L. McEuen, S. Tarucha, R. M. Westervelt, and N. S. Wingreen Electron transport in quantum dots, pp~105-214 of Mesoscopic electron transport, L. L. Sohn, L. P.

Kouwenhoven, and G. Schön (eds.) NATO ASI Series vol. 345, Kluwer (Springer), 1997

ADDITIONAL BIBLIOGRAPHY

- A. Wacker Semiconductor superlattices: A model system for nonlinear transport, Physics Reports 357, 1-111 (2002)., Elsevier, 2002
- L. L. Bonilla and H. T. Grahn Nonlinear dynamics of semiconductor superlattices. Reports on Progress in Physics 68, 577-683 (2005), Institute of Physics Publishing, 2005
- L. P. Kadanoff and G. Baym Quantum Statistical Mechanics., Addison-Wesley, 1989
- R. Hanson, L. P. Kouwenhoven, J. R. Petta, S. Tarucha, and L. M. K. Vandersypen Spins in few-electron quantum dots, Reviews of Modern Physics 79, 1217-1265 (2007)., American Physical Society, 2007
- W. G. van der Wiel, S. De Franceschi, J. M. Elzerman, T. Fujisawa, S. Tarucha, and L. P. Kouwenhoven Electron transport through double quantum dots, Reviews of Modern Physics 75, 1-22 (2003)., American Physical Society, 2003