Electron transport in an Aharonov-Bohm (AB) ring with coupled quantum dots (QD)

We study transmission resonances in parallel coupled QD systems, electron spin in coupled QD transport, and coupled QD systems as qubits. Specifically, we investigate:

- the Fano resonant structure of coupled parallel QD's with single and double quasi-bound states,
- measurements of electron decoherence,
- spin-filtering effectiveness of various coupled QD configurations,
- qubit formation and entanglement of states, and
- potential applications of nanorings to quantum information and quantum computing.

The theoretical framework of transmission resonances and phase analysis of AB rings with embedded QD's has specific **applications** as follows:

a) Design of new types of ***electronic devices***: interference transistors, sensing devices, and quantum computer implementations.
b) Prediction of new ***techniques of fabrication*** in quantum nanodevices for electrical and optical applications.
c) ***Molecular logic gates*** composed of cyclic molecular systems coupled to multiple leads in which an external magnetic field can modulate the conductance through the AB effect.

Charge transport through DNA molecules

Electron transport is an important process that controls physical properties and chemical activities of many molecular and biological systems, including DNA. Many applications of nanotechnology, such as biosensors, solar energy, molecular and bioelectronics have greatly benefited from research on various critical electron transport phenomena. For example, charge migration in DNA is directly related to the detection of damage in DNA which may occur in the cells of human beings. DNA damage is responsible for many neurological diseases, and plays an important role in aging and in many forms of human cancer. A better understanding of the properties managing charge migration and its relation to DNA damage may lead to greater insight into damage prevention and repair.

The objectives of our study are to theoretically investigate how DNA molecules support rather high electrical currents given the right environmental condition. Therefore, we use a double-stranded DNA molecule, subject to either an electrical bias voltage or a small mechanical strain, and show nonlinear current-voltage (I-V) characteristics which exhibits a negative differential resistance (NDR). Using an advanced two-dimensional tight-binding model including hopping integrals for the next nearest-neighbors, we implement a strain-dependent DNA helix conformation in conjunction with the theories of Slater-Koster and linear elasticity. The observed NDR in the I-V curve is characterized by a peak-to-valley ratio (PVR). This higher value of PVR for an I-V curve implies a greater ability for the realization of potential applications such as logic switches and reflection amplifiers. In the Coulomb Blockade regime, where weak coupling between the leads and a DNA molecule, it is seen that the magnitudes of current and differential conductance are reduced. In addition, pronounced NDR behaviors, analogous to that of Esaki Tunneling diode, and conductance oscillations in the differential conductance are observed.

These studies further our understanding of how charge transport can play a role in determining the possibility of molecular electronic device applications (DNA-based biosensors and nano-bioelectronics) and in detecting DNA damage by mutations.

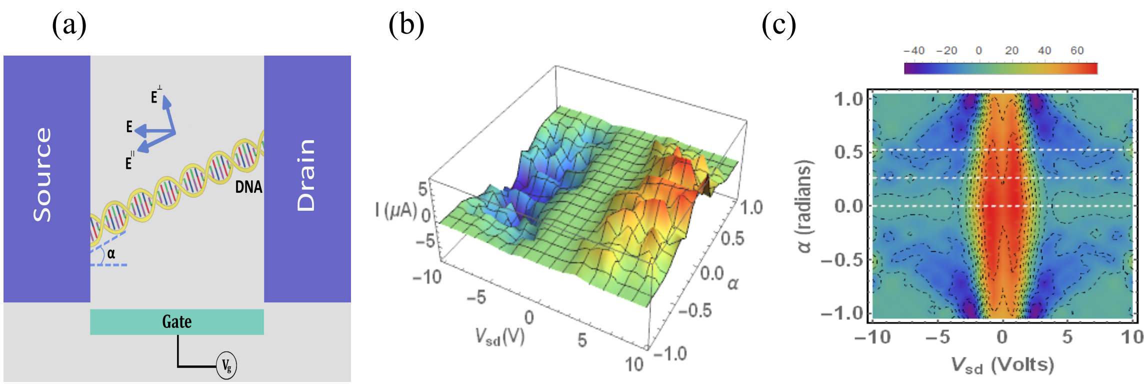

Figure: (a) Tilted DNA channel between source and drain contacts, (b) Current as a function of a source-drain voltage and tilted angle, and (c) differential conductance as a source-drain voltage and tilted angle.

Applied Physics: Radiation characteristics of a parallel-plate waveguide in the presence of a receiving waveguide antenna

We investigate the radiation characteristics of waveguide antennas located on the same impedance plane are theoretically and experimentally. We calculate the key parameters of antennas, such as the coefficient of standing waves, radiation patterns, and decoupling level between antennas in order to study the influence of surface impedance. Since a decoupling level for a fixed geometry reaches a saturation point when the reactivity of normalized impedance becomes capacitive impedance, we incorporate a corrugated structure on a conducting surface with dielectric materials. The radiation patterns in this system are examined for both an ideal conducting flange and capacitive impedance. We also perform an experiment on the frequency dependence of the decoupling level by preparing a sample decoupling device with constant depths of corrugation, and compare numerical and experimental results.