Projects 2017

You should contact your supervisor before the project, to set up a meeting time. In some projects it will be very useful to study some literature in advance.

1. Photocurrent mapping of a nanowire solar cell
Supervisor: Dan Hessman, dan.hessman@ftf.lth.se

Description: In this project you will create a two-dimensional map of how an array of nanowires converts light into current. The map will be constructed by measuring the photocurrent induced by a tightly focused laser beam while raster scanning the nanowire device. Possible outcomes of the project are a characterization of the conductivity of the transparent top contact and the identification of imperfections in the solar cell.

2. Building a setup for measuring emission pattern of nanowire-based LEDs
Supervisor: Olof Hultin, olof.hultin@ftf.lth.se

Description: Traditional nitride LEDs have high efficiency for blue light, but suffer from low efficiency in both UV and green-red due to crystal dislocations and strain from poor lattice matching. A new approach to nitride LEDs based on nanowires that can potentially solve these efficiency problems has been developed in Lund. Since light is emitted from nanostructures, the emission pattern is expected to differ significantly from a planar LED. Knowledge of the emission pattern is important for understanding the physics in these novel devices and for efficiency optimization.
In this project, you will build an experimental setup for automized LED emission pattern measurements. The setup will consist of a fixed LED chip holder and an optical fiber connected to a spectrometer. The optical fiber will be fixed to an electric stepper motor controlled by an Arduino. This is an opportunity to get hands-on experience in experimental science and develop your problem solving skills.

3. Cylindrical nanowire band structure and transport
Supervisor: Florinda Viñas Boström, florinda.vinas_bostrom@ftf.lth.se

Description: In this project you will calculate the band structure for a cylindrical quasi-1D semiconductor nanowire. You will use an effective mass-model, and include the cylindrical confinement potential in your calculations. The band structure will be used to determine the density of states and the conductivity of the nanowire. For this project you need to have some Matlab (or other programming) experience.

4. PL and PLE on Wurtzite InP nanowires
Supervisor: Irene Geijselaers, irene.geijselaers@ftf.lth.se

Description: InP is in bulk found in the cubic crystal structure of zinc-blende (zb). However in the form of nanowires, it can be grown in the hexagonal wurtzite (wz) structure. The band structure of wz InP is different from zb InP, as the bandgap is approximately 80 meV larger. The bandgap of wz InP is positioned in such a way that there is a staggered band alignment at the interface between wz and zb InP. This creates much interesting physics to be seen in wz-zb InP

heterostructures. Another difference between wz and zb InP is the bandstructure of the valence band. In the case of wz InP the valence band is split into two.
In this project the wz valence band structure will be probed using PLE. We will look at the difference between doped and undoped wz InP and at the PL of wz-zb heterostructures.

5. Solar simulation of InP NW solar cells
Supervisor: Lukas Hrachowina, lukas.hrachowina@ftf.lth.se

Description: Photovoltaics enable the direct conversion of solar energy to electricity and thus play an important role in sustainable energy production. Although III/V semiconductor solar cells reach better efficiencies than silicon based solar cells, they are mainly used in space applications because they are too expensive to compete with silicon based solar cells when efficiency is not the predominant factor. Nanowires have several superior properties compared to their bulk material and with a specific pattern of a nanowire array it is possible to reach the same efficiency of a thin film by using only a fraction of the material. In this way the price can be reduced which makes it possible to compete with silicon solar cells.
In this project you will investigate InP nanowire solar cells and measure the efficiency and other important characteristic values like V_{OC}, J_{SC}, FF, etc. with a solar simulator.

6. Band structure of GaAs and InP
Supervisor: Mats-Erik Pistol, mats-erik.pistol@ftf.lth.se

Description: In this project we will use the "standard model" to calculate the bandstructure of strained and unstrained GaAs. We will use k.p-theory which is described in the latter chapters in the book.
The strain will be both uniaxial and biaxial corresponding to a strained layer of GaAs on e. g. InP. Both the conduction band and the valence band will be modelled.

7. Real-time investigation of surface combing of single DNA-molecules
Supervisor: Oskar Ström, oskar.strom@ftf.lth.se

Description: In this project we will investigate the deposition of single DNA molecules onto a surface with our fluorescence microscopy setup. We want to study the process of the surface adsorption of the DNA and the forces involved in this. By stretching out the DNA molecules with a relatively simple and cheap technique, we can probe them on information of the genetic sequence which otherwise require costly sequencing instruments.

8. Theoretical modelling of Coulomb blockade using rate equations
Supervisor: Martin Josefsson, martin.josefsson@ftf.lth.se

Description: In this project you will write a small computer program to calculate the steady state current and conductance of a quantum dot with discrete energy levels and a large charging energy. We will focus on the regime of small tunnel couplings where the electrons tunnel one by one between the quantum dot its contacts. In order to capture the correct dynamics of the dot and be able to plot the full Coulomb diamonds it is necessary to solve the so-called rate equations. These are a set of equations that describe how the occupations of the many-body states change when electrons tunnel into or out from the quantum dot.

9. Magneto-Characterization of a Two Dimensional Electron Gas (2DEG)
Supervisor: Sven Dorsch, e-mail: sven.dorsch@ftf.lth.se

Description: In this project you will characterize the electrical transport properties of a high mobility 2DEG material using the Shubnikov-de Haas and Hall effect measurements. By applying a perpendicular magnetic field, at a sufficiently low temperature, you will manipulate the density of states at the Fermi level in a 2DEG Hall bar device leading to the magneto-depopulation of Landau levels. By analyzing the data you produce from this technique you will calculate the carrier density, mobility, Fermi wavelength and mean free path of the material.

10. Electron transport through a split-gate quantum point contact (QPC)
Supervisor: Adam Burke, e-mail: adam.burke@ftf.lth.se

Description: In this project you will measure quantized conductance through a QPC in a high mobility two-dimensional electron gas (2DEG) material. The QPC is defined by a split-gate structure on top of the 2DEG wafer. As the gates are increasingly negatively biased, the underlying 2DEG is depleted and the transport of electrons is restricted to a narrow channel. At low temperature and low source-drain bias, increasing the (negative) bias on the gates depopulates the 1D subbands in the channel. As a result, conductance decreases in steps of the quantum of conductance, ($G_0 = 2e^2/h$). With the application of larger source-drain bias, the energy spacings of the 1D subbands can be found.

11. Tuning the inter-dot tunnel coupling in parallel double quantum dots
Supervisor: Malin Nilsson, malin.nilsson@ftf.lth.se
NB. This project runs December 7-8

Description: Electrostatic gates can be used to modulate the confining potential in quantum dots (QD) and thus control the spatial distribution of the electrons and the tunneling coupling between two parallel QDs.[1] In this project, you will perform electrical characterization at 4.2 K of QDs to study and control the electron transport in parallel-QDs systems. You will analyze the data and extract the tunnel coupling between the QDs. The system we are using consists of a single QD defined in InAs nanowires by thin segments of wurtzite, acting as tunnel barriers for electron transport , in otherwise zinc blende crystal structure.[2] The small axial extension of the QD (<10 nm) leads to a strong quantum confinement and enables the QD to be fully depleted of electrons. By using pairs of local side gates and a global back gate the system can be tuned from one QD into parallel double QDs, for which we can control the populations down to the last electrons. The combination of hard-wall barriers to source and drain, shallow inter-dot tunnel barriers, and very high single-QD excitation energies (up to 27 meV), allow an order of magnitude tuning of the strength for the first intramolecular bond (tunnel coupling between the QDs). This is a highly controllable system which constitutes a playground for studies of fundamental physics such as spin transport and the evolution of the two-electron states as a function of magnetic field.

1. Nilsson, M. *et al.*, Parallel-coupled quantum dots in InAs nanowires, *Nano Lett.* submitted (2017).
2. Nilsson, M. *et al.* Single-electron transport in InAs nanowire quantum dots formed by crystal phase engineering. *Phys. Rev. B* **92,** 195422 (2016).