Rapid advances in information technology and miniaturization techniques are inevitably pushing us toward the limit of the Moore's Law. Further advances are associated with stepping into the world of quantum physics. This is a beautiful, but at the same time, difficult and responsible challenge for the science community.

Research of small-sized systems near the nanoscale reveals more and more quantum phenomena. Among the most prominent are the quantization of charge and energy levels, interference effects or Pauli exclusion principle. This world is rich in fascinating, but often non-intuitive physics. On the one hand this results in cognitive difficulties, on the other hand it tempts with many unrevealed possibilities. Exploring this field is undoubtedly one of the main goal for the contemporary physics.

Therefore, the quantum dots, also known as artificial atoms, are very promising and broadly studied systems nowadays, both experimentally and theoretically. They allow to host a small number of electrons in a very limited space and in a highly controllable fashion. Experimentally, such systems are very often realized in semiconducting nanostructures or carbon nanotubes. Their important feature is high tunability of parameters such as: size, relevant coupling strengths or gate voltages. Moreover, recently various arrangements of multiple coupled quantum dots have attracted considerable attention. Such devices allow to model and test artificial molecular systems with complex electronic structure and desired physical properties.

Quantum dot systems have many potential applications in nanoelectronics and quantum information processing technologies. Moreover, they allow to study fundamental quantum interactions and effects in nanoscopic systems. The goal of this project is to conduct the theoretical studies of transport properties in hybrid quantum dot systems in a triangular geometry. When such nanoscale system is brought in proximity to superconductor, it allows for the generation of non-local Cooper pairs – two entangled electrons spatially separated. Research to find the efficient Cooper pair splitting devices is currently very important for the quantum information technology applications.

The aim of this project is to theoretically calculate and perform comprehensive analysis of transport properties of hybrid triple quantum dot systems, with the focus on the following quantities: current and relevant current fluctuations, differential conductance and tunnel magnetoresistance. In consequence, this will allow us to find the optimal parameters and transport regimes for efficient Cooper pair splitting, as well as understand new phenomena emerging in considered systems. It is important to note, that splitting of Cooper pairs has been already experimentally observed in quantum dot systems and the measured results are in good agreement with theoretical models. This is an important factor motivating for further research in this field.

The three site quantum dot setup in triangular geometry allows us also to study various quantum interference phenomena. The interesting subset of such effects are the so-called dark states. These quantum electronic states emerge due to destructive interference, which effectively decouples the system from external electrode, while coherently trapping the electrons. In transport characteristics, this effect reveals itself as a strong current blockade, negative differential conductance and enhanced shot noise. The interplay of the interference effects and superconducting correlations is still rather unexplored, therefore performing comprehensive studies of this problem is another important goal of this project.