Fast exchange and processing of data streams constitutes the core of modern society, called for that reason an information society. The majority of communication is currently carried over optical channels, with light impulses serving as bits of information. A network of optical fibres connect continents, countries, cities and single households. However, the ever growing need for the increase in speed of data transfer and processing requires a next technological step – replacement of electric links between individual computers or computer components, like e.g. memory buses, with optical interconnects; or even a complete substitution of electronic devices with photonic counterparts, where photons replace electrons as information carriers. Although photonic integrated circuits, i.e. crucial components of photonic devices, based on various material solutions, are already available, the real revolution requires technology that would be cost-effective and allow for mass production. To satisfy that condition it is necessary to exploit technology compatible with the silicon based complementary metal–oxide–semiconductor manufacturing platform, currently used for integrated electronic devices, such as processors. However, the nature of silicon poses here a considerable challenge – due to its indirect bandgap it is very difficult to force silicon to emit light. Therefore, it is necessary to include other semiconducting material in the device. The best candidates are quantum dots formed of III-V elements, such as InAs/GaAs or InAs/InP. In order to keep reasonable cost of the device, the fabrication process must be monolithical, i.e. without additional bonding of separately grown parts. Unfortunately, another issues arise – III-V compounds have larger lattice constants than silicon, which introduces strain during growth, leading to poor crystalline quality of structures; there is also a large difference between their thermal expansion coefficient, so when a structure grown at elevated temperatures required for the process cools down, it may crack. Both factors lead to a large number of defects present in the III-V quantum dots on silicon, limiting their light emission efficiency.

The research objective of the project is to investigate material properties of III-V quantum dots on silicon by atomic force microscopy, transmission electron microscopy and X-ray diffraction in order to determine their structural properties, such as crystallographic quality, number and type of defects, amount of strain, morphology and chemical composition of quantum dots. Complementary optical spectroscopy techniques will be used to verify their emission properties, especially the role of defects and reveal dynamics of physical phenomena occurring in the structures. Experiments will be performed on ensembles of dots, where the response is averaged over the entire dot population, but also on a single dot level, where single photon emissions are recorded. This avenue of research is important from the point of view of potential quantum telecommunication applications. Obtained results will be compared with theoretical models of investigated structures. Investigated QDs will be fabricated using two approaches, either with intermediate buffer layers and/or defect filter layers between silicon substrate and III-V material, which can accommodate strain and limit the creation of defects in the part of the structure containing the dots; or by embedding dots directly in silicon matrices, in the core-shell architecture, where defects are mostly positioned at the interface between the shell and silicon matrix, leaving the emitting core defect-free.

Information gathered during the project will enable verification of the hypothesis whether InAs/GaAs(InP) quantum dots grown on or embedded in silicon can achieve crystallographic quality and optical properties comparable with III-V QDs grown on native substrates, which is a crucial condition for application of such structures as building blocks in photonic integrated circuits. Comprehensive optical and structural characterisation tools used in the project will provide also a bulk of material data on phenomena occurring in the investigated dots.