Advanced electronic integrated circuits are currently utilized on a massive scale, thanks to Si-based nanotechnology, which has been developed for many years. Modern technology is very close to reaching the performance limit of such systems, which will not be possible to improve, constantly moving towards hardware miniaturization. The possible solution of certain computational tasks may come from quantum systems, which, thanks to their unique nature related to its non-binary way of storing and processing information, will lead to completely new functionalities. Although there are already many demonstrations using the quantum system for, among others, a secure quantum key distribution, simulations of chemical molecules and nanoscale physical systems, or for quantum computation, currently there are still no mass-production of quantum devices. The best way to obtain a practical low-cost quantum system is to use on-chip photonic integrated circuits which can be incorporated with the CMOS compatible elements. It means a quick and easy way of transfering of the newly developed technology towards mass production, similar to classic electronic circuits, i.e. a system that will have micrometric dimensions and will contain hundreds of thousands of elements needed to perform complex logical operations on many qubits (photons) simultaneously.

In this project, a specific research tasks will be undertaken to fabricate a device based on a single quantum dot as on-demand single photon (qubit) source and to demonstrate the principles of on-chip operation. Fabrication and optimization of InAs quantum dots embedded in InP matrix, whose advantage is the expected emission wavelength range close to 1.55 μm, i.e. the spectral range which is important also from the point of view of data transfer with the use of a fiber optic telecommunications network, is one of the main goal of the project. Such material system has not been tested so far in the context of effective coupling of emitted photons from QD to such photonic components as directional coupler, ring resonator or multimode interferometer. Both fabrication processing and direct integration of single quantum dots to those components are demanding technological tasks, in which innovative approaches needs to be applied, such as epitaxial growth using metal-organic chemical vapor deposition, inductively coupled plasma etching and electron beam lithography, and most importantly, transfer and bonding maintaining a high-quality crystal structure on the atomic level at the interface. Additionally, to obtain high emission efficiency of quantum dot inside a waveguide, first a quantum dot is preselected by mapping its photoluminescence and then a 1D nanobeam cavity along the waveguide is fabricated in the dot position. Such photonic QD-waveguide cavity system coule be excited by advanced optical excitation schemes such as red-retuned excitation combining pulsed and continuous-wave lasers. Successful realization of all project tasks give rise to coherent control the QD emission, and thus allows to achieve best performance in terms of the purity of single-photon emission and the degree of indistinguishability of consecutively emitted photons, as well as processing of photons directed to the on-chip network for computation purposes using quantum algorithms, which are of key importance from the point of view of quantum information processing, and might lead towards modern scalable photonic based computational system revealing quantum revolution.

The project will be realized in cooperation between teams from the Wrocław University of Technology (Wrocław University of Science and Technology) and the Danish Technical University (DTU) in Copenhagen.