The great amount of scientific efforts devoted to quantum information processing is motivated by the remarkable perspectives offered by this research field. The prime example is the anticipated construction of quantum computers of unprecedented computational powers. Once built, these computers will most likely revolutionize our civilization. On the way to realize this goal with optical means stands the problem of scalability: nowadays the quantum optical experiments are carried out on huge optical tables. Low-cost technologies of upscaling the size of the system are missing. The goal of the MIODEQ project is engineering of miniaturized optical elements (beam splitters, waveguides) based on nanotechnologies such as plasmonics, and their application to transfer basic quantum optical experiments to the nanoscale. Thus, the project belongs to the pioneering field of quantum plasmonics, which aims at an integration of the nano research and quantum optical experiments. The purpose of the latter is to enable a control of the state of single photons - single light particles, the weakest possible signals. Single photons are the basis for applications for quantum computations, secure coding or teleportation. The perspective of MIODEQ is to bring these applications down to the nanoscale through a fabrication of miniaturized, stable integrated optical devices, which would not require arduous calibration and which would secure large efficiencies and high performance. Finally, miniaturized devices and circuits will be eligible for commercial applications.

The particular phenomena to be explored within MIODEQ project include interference of single quantum particles and their pairs at metasurfaces. A metasurface is a periodic array made of metal nanostructures at which one can excite quasiparticles called surface plasmon polaritons. These particles are hybrids of photons and collective excitations of valence electrons in metals. They can take up the role of photons in miniaturized quantum optical experiments. As the next goal, we plan to develop methods to retrieve so-called wavefunctions of single-photons. Such function encodes all possible information about a photon. The established techniques will set the grounds for investigations of a fictitious quantum anti-centrifugal force acting on single photons as they propagate through waveguides of bent geometries. The experiment aims at a first ever observation of fictitious quantum forces that directly impact single photon propagation.

Each of the tasks will combine both a theoretical and numerical analysis, and a related experiment. The theoretical part will involve engineering of miniaturized optical elements: the metasurface and the bent waveguide, as well as a characterization of their properties. The experimental part aims at a first-time observation of the above-mentioned quantum phenomena in the proposed systems. In all experiments within MIODEQ project, single photons will be generated from sources based on the phenomenon of spontaneous parametric down conversion. In this effect special kinds of crystals are used that, illuminated by a laser beam, may generate, in a correlated manner, pairs of photons of characteristics useful for commercial and laboratory applications. Since in this process photons are generated pairwise, one of them may be used to herald the presence of the other one, at which the direct measurement is performed. This significantly improves the signal to noise ratio.

The MIODEQ project will be realised in National Laboratory for Atomic, Molecular and Optical Physics and at the Institute of Physics at the Nicolaus Copernicus University in Toruń, in collaboration with other research units in Europe and around the world, which specialize both in nanotechnologies and in quantum optics.