Polarization of light is a characteristic property which determines the orientation of the electromagnetic field oscillations during light propagation. Light is polarized linearly if the electric field oscillates in a plane perpendicular to direction of propagation. In everyday life polarization is used to block light that is polarized upon reflection off a surface with a polarizing filter. At the end of the nineteenth century, Jean-Baptiste Biot observed that a solution of tartaric acid can rotate the polarization plane of light propagating within the sample. He attributed this observation to the fact that there are two forms of molecules of tartaric acid that are not each other's mirror images. This fact has been confirmed by Louis Pasteur who observed that each of these forms rotates the polarization plane in a different direction and their mixture does not rotate the polarization plane. This effect has been called optical activity and the objects distinguishable from their mirror image are called chiral objects.

Chirality is a property of many biologically active molecules such as aminoacids and carbohydrates. Distinguishing between enantiomers (molecules of opposite chirality) is important in medicine, because one of the enantiomers may be a medicine and the other, in a worst case, might be toxic. The immense progress in nanotechnology has enabled fabrication of artificial chiral structures. These nanostructures may be applied for polarization control, optical distinguishing between enantiomers, manipulating of objects in nanoscale using angular momentum of light and experimental studies of optics of chiral objects.

The aim of the project is theoretical analysis of optical properties of chiral nanostructures embedded in planar medium, which is any medium composed of layers. Such a medium may be for example a substrate on which the nanostructure is deposited, or a pair of mirrors with a nanostructure placed in-between. In practice, often most, nanostructures are placed in planar media, which is not without consequences on their optical properties. Light reflected e.g. off the substrate may be multiply reflected off the nanostructure. This effect may be utilized to enhance electric field or modify the spectrum of light. The innovative aspect of the project is that chirality related optical effects have been typically analyzed without considering the presence of planar medium. However, notably, planar medium has a considerable effect on polarization of scattered and absorbed light by the nanostructure or even can render an achiral nanostructure optically active by breaking symmetry resulting from the presence of the planar medium.

New electromagnetic simulation tools for nanostructures in planar media will be devised as a part of the project. We will aim at enabling simulating structures containing multiple nanoparticles of arbitrarily complicated shape (chirality requires symmetry breaking) as it takes places under experimental conditions. On the other hand, the developed techniques should enable formulating general rules regarding optical activity of nanostructures embedded in planar media.

During the project we will study nanostructures that exhibit optical activity which stems from their intrinsic chirality or that are optically active despite their own achirality due to the presence of optically active biomolecules in their vicinity. The latter case is especially practically important. Optical activity of biomolecules is generally small in comparison with their absorption of light rendering optical distinguishing between enantiomers difficult. The aim of using nanostructures is enhancing chirality-related effects in such a way that would enable light-driven enantiomer discrimination. Because of the fact that theoretical tools devised during the project enable studying the optical properties of complex nanostructures in planar media, design guidelines for enhancing optical activity of biomolecules will be proposed. One of the project goals is to find out how factors such as planar medium and nanostructure types and spatial distribution of molecules and nanoparticles influence the observed enhancement. Additionally, the possibility of simultaneous sensing of biomolecule composition and chirality will be examined.

The project will substantially extend our knowledge regarding interaction of light with chiral nanostructure and the influence of planar medium on this interaction. Due to the act that the analysis of optical activities in the project accounts for the traits of experimentally attainable nanostructures the acquired results will be of practical value for design and modelling of nanostructures exploiting optical activity related effects.