The main purpose of this project is to investigate and explain in detail the physical mechanisms leading to the emergence of the two new physical phenomena:

- The effect of routing of optical emission by magnetic field (controlling of the direction of optical emission by magnetic field),
- The ferromagnetic proximity effect (The effect of ferromagnetic polarization of excitons in a quantum well by a ferromagnetic proximity layer.

The phenomena mentioned above were observed in cooperation with a group from the Technical University of Dortmund headed by prof. Dmitri Yakovlev as part of the implementation of our previous Harmonia project in years 2015-2018. The results concerning these phenomena appeared in two publications in Nature Physics [V.L. Korenev et al., "Long-range p-d exchange interaction in a ferromagnet-semiconductor hybrid structure", Nature Physics 12, 85 (2016); S. Spitzer et al., "Routing the emission of a near-surface light source by a magnetic field", Nature Physics (2018)]. This project would be a continuation of many years of extremely fruitful cooperation of our group with the Dortmund team.

The common feature for these phenomena is the fact that they occur only in hybrid structures, i.e. structures composed of a semiconductor part and a metallic part. In the semiconductor part, very shallowly below the surface, a quantum well is placed in which charge carriers (electrons and holes) generated in the semiconductor collect. The distance of the quantum well from the metallic part is very small (on the order of a few or a dozen of nanometers), which causes the electrons in the well and metal to interact. Interactions (electric and magnetic) between electrons in the well and metal cause that the hybrid structures exhibit new properties resulting from the combination of properties characteristic for both materials from which they are made. Our research is aimed at understanding the mechanisms of these interactions. We hope that this knowledge will allow us to use the unique properties of hybrid structures in practical applications.

In order to carry out the planned research in our Laboratory of Physics and Growth of Low-Dimensional Crystals at the Institute of Physics, hybrid structures composed of Cd(Mn)Te quantum wells with CdMgTe barriers will be designed and produced, and then metallic layers will be deposited on their atomically pure surface. In the case of optical routing by mean of magnetic field, the layer will be made by gold, which will then be processed by methods to form a so-called plasmonic structure - one in which surface plasmonic polaritons are formed. Surface plasmonic polaritons are excitations that are a combination of oscillating charge movement (electrons) and the electromagnetic wave generated by this motion. Due to the presence of the electronic part, the polaritons posse spins that can coupled with an external magnetic field. Due to this coupling, it is possible to control the direction of emission from a quantum well by means of a magnetic field.

In our research, we will try to strengthen and gain greater control over the phenomenon of direction control through the generation of new structures modified both in the semiconductor part (width of the well, the height of the barriers, distance from the surface) and the metallic part (periodic structures of different thickness, spatial period etc.). It must be emphasized that the possibility of targeting the optical beam from nanometric sources can be of great importance for future magneto-optical devices.

In the Co / CdTe / CdMgTe hybrid structures, the polarization of excitons in the quantum well was observed, even though the ferromagnetic cobalt layer was spaced greater than the size of the wave function of the exciton. So the question is how this effect arises. In the previous work, we suggest that the magnetic moment is transmitted through phonons. Here, we plan to test this hypothesis. Research will consist in creating new hybrid structures, e.g. with another ferromagnet and/or quantum well parameters. In addition, we want to polarize the structure with an electric field and check how the electron concentration affects this phenomenon. For this purpose, new structures must be designed and manufactured on conductive substrates and provided with electrical contacts. A deeper examination of the mechanisms of ferromagnetic coupling in this type of hybrid structures may be important in their applications, e.g. as memory cells.

All hybrid structures produced at the PAS PAN will be investigated by advanced magneto-optical methods in Dortmund. Methods such as the magneto-optical Kerr effect, Faraday effect, time resolved photoluminescence, ODMR will be employed. The Dortmund team belongs to the world recognized leaders in the fields of steady-state and time-resolved optical and magneto-optical study of solid state nanostructures Teams from Dortmund and Warsaw have been cooperating closely and successfully for over 20 years. As a result, more than 80 joint publications have been published in the most prestigious physical journals. The previous Harmonia ended in 2018 with more than 25 papers. The success of the cooperation stems from the fact that both groups are complementary, very experienced, excellent equipped and belong to the leading ones in their specialties.