The project concerns the study of exciton polaritons, very interesting quantum particles that can be applied in various fields such as extremely accurate interferometric measurements, ultra-low power lasers or processing of information with very low energy losses.

Exciton polaritons are formed in semiconductor materials with a specially designed structure, due to the strong coupling of photons and excitons, material particles composed of electrons and "holes". Poalritons are particles having a "Schrodinger cat" structure. The quantum state contains two alternatives: cat alive when the exciton exists, or dead cat when instead of an exciton a photon exists in the system.

The project involves two major research tasks. The first one aims to explore the dynamics of phase transitions in polariton systems. Examples of phase transitions that we know from everyday life, eg. freezing of liquid or gas liquefaction, are the phase transitions of the first kind. Also known are numerous examples of phase transitions of the second kind, for example paramagnetic to ferromagnetic transition with decreasing temperature. In these transitions the system parameters change continuously. Phase transitions are often accompanied by the formation of various "defects", for example the formation of snow flakes.

In the case of phase transitions of the second kind, the formation of defects is qualitatively described by the theory proposed by Tom Kibble and Wojciech Zurek, a Polish researcher working at Los Alamos National Laboratory. This theory cannot be directly applied in the case exciton poalritons due to their strong non-equilibrium character. Polaritons, like many other particles present in semiconductors, have an extremely short lifetime, of the order of picoseconds. This means that the system must be continuously pumped by supplying energy and the creation of new particles. The theory of formation of defects in the case of non-equilibrium systems is not well developed yet. In the current project, we intend to lay the foundations for such a theory, taking as an example exciton polaritons for which the observation of phase transitions and defects is possible because of the very well developed semiconductor technology.

The second research task is to develop a theoretical model of polariton systems for semiconductors doped with magnetic ions. This task will be implemented in collaboration with experimentalists, using their experience and results already obtained. Such systems exhibit giant magnetic effects that result from the strong magnetic interaction of ions with excitons. This leads to drastic changes in the structure of excitons and their properties, which is reflected in the polarization of photons and the emitted light. Due to the involvement of spin, these results may be used in the development of spintronics, or "future electronics" based on spin interactions.