Abstract

The construction of novel optoelectronic devices is nowadays the subject of worldwide attention. Interesting effects that can be observed in photonic systems open new avenues in the constantly evolving field of optoelectronics. Resonant optical cavities are widely used in many fields of physics for localization of electromagnetic waves in structures and enhancing effects based on optical stimulation, especially with non-linear effects appearing due to the strong confinement of light.

This thesis is devoted to the spin-orbit interaction of light in microcavities filled with a birefringent material. Within this work we would like to present the advantages of the newly developed liquid crystal cavity as a possible new platform for optoelectronic devices, which will allow us to study the influence of the effective magnetic field and simulate Hamiltonians describing phenomena known, i.a., in solid-state physics. The aim of the study is to investigate and describe the spin-orbit interaction of light in an optical microcavity filled with a liquid crystal. The liquid crystal cavities have adjustable parameters such as birefringence, thickness of the liquid crystal layer, or initial orientation of the average orientation of molecules. This allows us to tune the energy of the modes into resonances belonging to different regimes. Each regime presents a different effect related to the spin-orbit interaction of light in the cavities.

The objectives of this work are experimental demonstration and theoretical analysis of spin–orbit effects observed in liquid crystal cavities:

— tunability of the photonic modes with external voltage,
— tunable optical spin Hall effect,
— optical Rashba-Dresselhaus effect,
— optical persistent spin helix state and photonic Stern-Gerlach experiment,
— testing the integration of various types of light emitters with liquid crystal cavities.

Chapter 1 of this dissertation presents the basics of the physics of polarized light, the spin-orbit interaction of light, and a description of the structure and properties (in particular optical ones) of liquid crystals and optical cavities.

Chapter 2 describes the experimental methods used during the research. Measurements of reflectivity, transmission, and photoluminescence spectra in real and reciprocal space, as well as sample preparation techniques, are described.

Chapter 3 discusses the possibility of tuning the cavity modes to successive optical mode resonances based on experimental results. At the same time, the classification (nomenclature) of successive cavity work regimes is introduced.

Chapter 4 contains a theoretical description of the studied regimes. A

description of symmetry in the system depending on the arrangement of the molecules in the cavity is presented, as well as a proposal for a description in terms of effective Hamiltonians, which makes it possible to link particular experimental observations with effects known from other fields of physics.

In chapter 5 the tunable optical spin Hall effect is described. It is shown that, thanks to the use of the tunable cavity, it is possible to observe new spin polarization patterns.

Chapter 6 presents experimental results on the optical Rashba–Dresselhaus effect that can be observed in the multimode liquid crystal cavity.

Chapter 7 shows the optical persistent spin helix as well as the photonic Stern–Gerlach experiment. This chapter contains both theory and experimental results of the spatial distribution of light polarization in the cavity for different excitation conditions.

In the chapters 5, 6 and 7 the experimental results are presented in the context of the effective Hamiltonians introduced in the chapter 4.

The following chapter - chapter 8 - contains a description of hybrid structures with emitters placed on top of a distributed Bragg reflector ($MoSe_2$ monolayers) and with an emitter inside the cavity (mCherry fluorescent protein or Pyrromethene 580 laser dye).

In the last chapter 9 the results are summarized. Possible directions of development of the research presented in the dissertation are discussed.