Streszczenie w języku angielskim

Neuromorphic networks are increasingly applied in all areas that require work with large amounts of data. In recent years, optical neural networks have been intensively developed as they can potentially replace their electronic counterparts, thanks to better energy efficiency and higher speed. Photonic systems are excellent for data transmission, but they possess weak interactions, which directly translates into high energy costs for creating nonlinear operations. Exciton polaritons, as particles having a low effective mass and strong nonlinear interactions, are an ideal platform for creating neural networks.

The subject of this dissertation is the nonlinear effects observed in exciton polaritons, investigated for their use in artificial neural networks. The main goal was to use the observed nonlinearities to create a neural network. As part of the work, semimagnetic exciton polaritons with unique magnetic properties observed in a magnetic field were examined spectroscopically.

The work focuses on nonlinear spin effects enhanced in the polariton condensate. The occupation of spin states below and above the condensation threshold in the external magnetic field was investigated. The possibilities of controlling the spin polarization of condensate by means of an external field and an excitation laser were discussed. The obtained results allowed us to prove the existence of a synthetic magnetic field resulting from the presence of disordered photonic potential on the sample. Ultimately, it was possible to estimate the magnitude of polariton-polariton interactions in the studied system.

Then, the influence of the photonic potential was discussed. Various shapes of the potentials leading to both the localization of the polaritons and their flow were considered. Two experimental configurations consisting of two condensates in an inhomogeneous potential were used to create a nonlinear response. Moreover, it has been shown that the existence of a localizing potential can lead to a reduction of the energy needed to create a nonlinear system.

The next part is devoted to nonlinear phase effects. First, the creation and annihilation of quantum half-vortices was investigated. Their properties and stability in an external magnetic field are discussed. Next, we focus on the phase effects resulting from polariton-polariton interactions. The relative change of the polaritons phase was investigated with the changing number of particles.

A nonlinear response was also obtained using time-delayed effects. For this purpose, a feedback loop was used. In addition to obtaining nonlinear emission, the condensate lifetime was estimated, and the lower limit of the exciton reservoir lifetime was obtained.

Ultimately, two opto-electronic neural networks were created and used to recognize handwritten numbers and perform speech recognizing task. Then, a fully optical XOR logic gate of high energy efficiency based on nonlinear exciton polariton emission is presented.