Rezumatul activității și a rezultatelor obținute în proiect în anul 2025

Project Code *25.80012.5007.35TC*
Project Title *"Quantum effects in optomechanical devices with double quantum dots"*

In 2025, the model of an optomechanical device consisting of a double quantum dot placed in an optical cavity was investigated. The analytical model of the device is described by an open quantum system, which takes into account the interaction of the double quantum dot with the phonons of the substrate on which it is located. This interaction plays an important role in the quantum dynamics of the device and cannot be ignored when a complete description, close to the experimental context or technological applications in photonics, is required. During the 2025 stage, the influence of phonons on both the double quantum dot and the optical cavity was demonstrated and calculated.

The quantum dynamics of the device, described by the master equation of the density matrix and the Hamiltonian of the quantum system, cannot be calculated directly due to the complexity of the analytical model. A simplification of the analytical model was made possible by applying Reservoir Theory to the quantum system expressed in the "dressed-state" basis of the double quantum dot. Thus, the phonon operators were eliminated from the system's Hamiltonian, and the contribution of the thermal phonon reservoir was expressed in the form of incoherent pumping terms introduced into the master equation, characteristic of an open quantum system. Furthermore, the master equation was projected onto the basis of the system's quantum states, and a system of equations of motion of the elements of the density matrix was deduced. This system of equations was solved numerically, within the steady-state regime. Based on the calculated density matrix elements, the quantum statistics of the model in the steady-state regime were expressed, namely: the populations of the double quantum dot, the mean photon number of the optical cavity and the second-order photon-photon correlation function.

It was demonstrated that the populations of the double quantum dot are influenced by both: the incoherent pumping rate and the temperature of the phonon reservoir. The changes introduced in the quantum dot populations also affect the way it interacts with the cavity. Thus, for sufficiently low temperatures, phonons create a population difference significant enough to amplify the cavity mean photon number. However, in the presence of phonons, the generated photons are no longer coherently distributed, and their distribution tends towards a thermal one for high values of temperature or pumping rate. This phenomenon plays an important role that cannot be neglected and can represent both an advantage and a disadvantage in the context of technological applications in photonics where amplified and coherent light sources are needed.

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