Abstract

Quantum correlations belong to one of the central concepts of quantum mechanics, and they are especially relevant from the quantum information theory point of view. Such correlations show how the quantum state of a subsystem of a multi-party one is closely related to those corresponding to the remaining subsystems. In other words, measurements performed on one subsystem affects the state and results of measurements performed on the remaining ones. The quantum correlations can exhibit their various characteristics and be of different strengths. For instance, they can be of the quantum entanglement, quantum steering, or Bell nonlocality type. Such correlations were subjects of various studies devoted not only to quantum information but also to fundamental research concerning the nature of the quantum world. Naturally, such correlations were usually considered in the models described by the Hermitian Hamiltonians.

Nevertheless, recently, great attention was paid to the models assuming that the Hamiltonian is not Hermitian but exhibits the $\mathcal{PT}$-symmetry. It has appeared that the Hamiltonian's hermiticity is not only one condition for obtaining its real eigenvalues. In 1998 Bender and Boettcher [?] showed that non-hermitian Hamiltonian exhibiting $\mathcal{PT}$-symmetry can also possess real eigenvalues. Thus, presented here dissertation concerns the topics which incorporate the quantum correlations of various types and descriptions with the application of the $\mathcal{PT}$-symmetry formalism. In particular, we concentrate here on the studies of bipartite and tripartite $\mathcal{PT}$-symmetric systems in which the balance between the gain and loss of the system's energy is assumed.

In the first chapter of the dissertation, we introduce the concepts of quantum correlations of various types. In particular, we mention the quantum entanglement, quantum steering, and Bell-type nonlocalities, pointing out the relations among them. Additionally, in that chapter, we present an introduction devoted to first- and second-order

correlations of the electromagnetic field. For all mentioned in the chapter correlations, we describe the methods of their quantification.

The second chapter is devoted to an introduction to the topics and main ideas related to the description of quantum systems by non-Hermitian Hamiltonians, primarily those exhibiting $\mathcal{PT}$-symmetric properties. When such symmetry is not broken, the eigenvalues of such Hamiltonians are real and allow to describe the physical properties of considered models. Usually, the models with balanced gain and loss related to the interaction with an environment and other external couplings are considered for such cases.

The remaining part of the dissertation is devoted to the discussion of our results concerning various forms of quantum correlations and relations among them for bi- and tripartite models (Chapters 3 and 4, respectively). Considered in those chapters, models involve two (three) interacting cavities. Additionally, we assume that one of them is excited, whereas another loses its energy. All considered models are described by the $\mathcal{PT}$-symmetric Hamiltonians, and we find the conditions for which such symmetry is not broken. We concentrate just on such situations and assume that the parameters describing the systems ensure the real values of the Hamiltonians. For such cases, we get the parameters describing the quantum correlations and discuss the relations among the latter. We show how such parameters evolve in time and depend on the interactions between cavities and the pumping/losses strength.

Finally, in the last (fourth) chapter, we discuss the tripartite model involving three cavities. As we deal with three subsystems, we discuss not only the bipartite entanglement but also its tripartite counterpart. Additionally, we show how the additional coupling between cavities, changing the model's geometry from the linear to a triangle one, changes the characteristics of the system, including the parameters describing the correlations and quantum character of the model.

Vinh Le Duc