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The Appearance of Structures of Excitons, Photons, and Biexcitons, Regular and Chaotic in Time, in Direct-Band Semiconductors

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Abstract—The dynamic properties of excitons and biexcitons in a ring cavity are studied. The nonlinearity of the problem is due to the direct binding of two excitons into a biexciton by virtue of the Coulomb attraction between them. A bifurcation analysis is carried out, revealing the points of Hopf bifurcations and period doubling. The effect of the cavity Q factor on the switching times is investigated. The possibility of experimental observation of the phenomena under study is discussed. © *2002 MAIK "Nauka/Interperiodica".*

1. INTRODUCTION

Recently, special interest has arisen in investigating the appearance, control, and damping of chaotic self-oscillations. These phenomena, associated with excitons and biexcitons in condensed media, are of interest because of their giant optical nonlinearities at the long-wavelength edge of the fundamental absorption of the crystal, short relaxation times, small energies, and short switching times. This opens enormous prospects for investigation of fundamentally new optical phenomena involving excitons and biexcitons and for practical application of these phenomena mainly in optical data processing and in the development of a new generation of computers with optical logic.

In [1–3], we studied some nonlinear phenomena in a system of coherent (in terms of the Bogoliubov treatment) excitons and biexcitons at different quantum transitions. In particular, we developed a theory of optical bistability, regular and chaotic self-pulsations, induced optical phase transitions, and one- and two-photon stationary laser generation. Also, the theory describes the appearance of dissipative structures and the dynamic transient optical chaos, which is accompanied by the creation of a system of strange attractors in the phase space.

The theory of nonlinear and chaotic oscillations has been developed for the case when the systems of excitons, photons, and biexcitons under investigation are Hamiltonian and the corresponding effects appear within a time interval less than the characteristic relaxation time [4, 5].

It should be noted that for a system of coherent photons, excitons, and biexcitons, the nonlinear cooperative phenomena under investigation have been studied only with account of the giant oscillator strength of the exciton–biexciton transitions [6, 7] in the case of one- and two-photon creation of biexcitons. However, it was shown in [8–10] that there is another nonlinear process associated with biexciton creation due to Coulomb attraction between two excitons. Taking into account this fundamentally new mechanism of the exciton–biexciton rearrangement of the semiconductor spectra, which is due to the binding of two excitons into a biexciton by virtue of the Coulomb attraction, we studied [11] the stationary optical bistability and stability of the stationary states and determined the optical switching times between the branches of optical bistability. In addition, it was demonstrated that the appearance of nonlinear periodic and chaotic self-pulsations is also possible. However, a number of fundamental questions remained unsolved in [11]. For example, the scenario of the transition of the system to the dynamic-chaos regime was not described in detail, possible dynamic bifurcations were not revealed, the corresponding bifurcation diagrams were not plotted, and the power spectrum of the appearing oscillations was not found and studied.

This paper is devoted to eliminating these drawbacks and is a logical continuation of [11]. We carried out a bifurcation analysis, revealing the Hopf bifurcation points and period-doubling bifurcations. Also, we found the scenario of the transition to optical dynamic chaos and of the possible appearance of optical turbulence and determined the power spectrum of nonlinear self-pulsations. In the case when the external pumping is a parabolic function of time, the effect of the Q factor of the ring cavity on the dynamic optical bistability was studied. Finally, possible experimental observations of the effect under consideration are discussed.

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