SEMICONDUCTORS. DIELECTRICS

Control of quasiparticle self-fluctuations in a CuCl crystal

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A theory is developed for regular and chaotic self fluctuations in crystal CuCl for a ring resonator geometry. A system of nonlinear differential equations is derived for the dynamic evolution of coherent excitons, photons, and biexcitons. It is shown that, in the unstable portions of the optical bistability curves, nonlinear periodic and chaotic self fluctuations can develop with the creation of limit cycles and strange attractors in the phase space of the system. A computer simulation is used to determine the parameters for which reliable switching takes place in the system and the parameter ranges are found within which the system undergoes a transition from strange attractor to limit cycle. The possibility of experimentally observing the phenomena studied here is discussed.
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The rapid development of technology and science places a premium on the problem of accumulating and rapidly processing a huge amount of information. As one of the most striking examples of optical self organization, optical bistability opens up vast prospects for practical applications in this area. The theoretical foundations of optical bistability have been discussed by Gibbs *et al.*,[1,2] who have described bistable materials and devices, discussed optical switching, and analyzed the instabilities and other phenomena. Applied research is currently directed at optimizing optically bistable devices: reducing their size, switching times, and power dissipation. As a rule, the switching times of bistable elements are on the order of the relaxation times of the dynamic characteristics of the device. The short relaxation times of the dynamic characteristics of excitons and biexcitons suggest that bistable optical elements with switching times on the order of 10^{-12} s can be constructed. Another, equally important, problem is the creation of bistable elements in which switching takes place with low energy dissipation and high reliability. However, the self fluctuations which develop in the unstable segments of the optical bistability curves can affect the operation of a bistable optical element. Thus, there is great interest in controlling the self fluctuations which develop in the system. Because of their low light losses and low intensities, quantum-well structures have recently been under active study.[3]

Optical bistability in the exciton spectral range was first studied theoretically by Elesin and Kopaev.[4] Kochelap *et al.*,[5,6] have worked in the same area. In our papers[7–10] based on the equations of Keldysh[11] we have constructed a theory of optical bistability, switching, and the development and decay of stochastic self fluctuations in high density, coherent exciton systems taking exciton-exciton interactions into account. These phenomena have been observed experimentally by Dneprovskiĭ *et al.*[12–14]

Optical bistability, switching, and self fluctuations of excitons and biexcitons have been studied before.[15–17] In Ref. 15, we studied stationary and nonstationary optical bistability and multistability and predicted the possible development of spatial turbulence in systems of coherent excitons, photons, and biexcitons in crystals. A scenario for the transition into dynamic chaos has been found and dynamic optical stability studied.[16] Crystal CuCl was chosen as a model with convincing experimental proof of the existence of biexcitons. A new class of nonlinear cooperative phenomena during light propagation in straight-band semiconductors has been studied.[17] The nonlinearity is caused by the direct bonding of two excitons into a biexciton as a result of their Coulomb interaction.[18,19]

In crystal CuCl, the exciton binding energy is on the order of 40 meV, so the exciton absorption band and the recombination *M* band of the biexciton are a significant distance apart. Because of the high exciton binding energy, a photon in resonance with the exciton transition frequency has a large resonance detuning relative to a transition in the region of the luminescence *M* band; thus, it is necessary to take into account the simultaneous effect of two independent light pulses, each of which is in resonance with a certain transition.

In this paper we construct a theory of regular and chaotic self fluctuations in a CuCl crystal involving coherent excitons and biexcitons. A system of nonlinear differential equa-

