Symmetric and Asymmetric Chaos in Vector-Field Lasers
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On the basis of the experimentally confirmed models the routes to symmetric and asymmetric chaos have been elucidated in four-frequency anisotropic cavity ring gas class-A lasers. The invariance properties of the model of a four-frequency ring class-A laser with the linear coupling due to backscattering [1] have been revealed. The diagrams of attractors have been calculated on the plane of the amplitude of the backscattering coefficient and detuning of the cavity frequency from the line center. The regimes, typical of both standing-wave and running-wave lasers, have been found. It has been shown that the transition from the running-wave operation to the standing-wave operation is accompanied by the pitchfork bifurcation and spontaneous phase symmetry-breaking (restoration). The pitchfork bifurcation of periodic solution, as a result of which the symmetric limit cycle is decomposed into two asymmetric limit cycles, can be accompanied by a deterministic and a noise-induced chaos [2].

With increasing tuning at constant value of the backscattering, chaotic oscillations appear as a result of the period doubling bifurcation cascade of the asymmetric limit cycle. Then after a series of inverse period doubling bifurcations two asymmetric cycles collide and disappear and the symmetric cycle originates as a result of the pitchfork bifurcation for periodic solution (symmetry is restored). When the control parameter changes in the opposite direction, the symmetric cycle is breaking into two asymmetric cycles.

In the region of the deterministic chaos, multistability of attractors with different topology has been revealed, among which are: symmetric limit cycle, two asymmetric Feigenbaum attractors and two asymmetric attractors arising when their trajectories in the phase space come through basins of both Feigenbaum attractors.

At small values of the backscattering coefficient noise-sensitive operation has been found. First, an asymmetric limit cycle of the second kind appears. The specificity of this regime, making it sensitive to noise of any physical origin, is that the intensity of one of the four waves oscillates near the lasing threshold.

With increasing tuning, as a result of nonlinear interaction, the amplitude of noise-sensitive variable grows, which results in increasing the amplitude of noisy component in power spectrum. At that this variable is fully influenced by noise and such a regime can be regarded as stochastic.

With further increase in tuning, the amplitude of noise-sensitive variable grows even more, so that preserving the complicated form of oscillations, it losses the sensitivity to noise action. Nevertheless, the amplitude of oscillations of "noisy" variable becomes high enough to affect the behavior of the other variables and to complicate their oscillations. Because the system is not sensitive to noise any more, and has a fractal dimensionality, we can regard this regime as an asymmetric chaos. With further increase in tuning this regime, transforms into an asymmetric limit cycle. Then, the pitchfork bifurcation occurs, as a result of which two asymmetric limit cycles of the second kind collide and disappear and a symmetric limit cycle with complicated form arises, which losses its stability and a symmetric chaos, arising through intermittency, is indicated.

Key Words: vector-field laser with linear coupling, multimode operation, involutive symmetry, routes to symmetric and asymmetric chaos, stochastic behavior, symmetry-breaking bifurcations