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A Nonlinear Interaction Dynamics of System of the Coupled Autogenerators: Numerical Analysis of Time Series, Chaos and Bifurcations

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Abstract: Many physical and technical dynamical systems can be considered as a set of the coupled autogenerators in the first approximation. The nonlinear interaction dynamics of a system of the coupled autogenerators is studied. The results an numerical analysis, modelling, processing and forecasting the nonlinear temporal dynamics of system of the coupled semiconductor quantum generators (autogenerators) are presented, The advanced data on the fundamental topological and dynamical invariants (the correlation, embedding and Kaplan-Yorke dimensions, Lyapunov's exponents, Kolmogorov entropy etc) of the system chaotic dynamics are listed. For the firs time it has been developed an effective temporal evolutionary dynamics prediction model.

Keywords: chaotic dynamics, system of the coupled autogenerators, dynamical and topological invariants

1. Introduction. Nonlinear Dynamics of Chaotic Laser Diodes

An experimental and theoretical study of the non-linear dynamical autogenerators systems attracts a great interest and importance in connection with aim to discover a dynamics with new fractal and deterministic chaos features (e.g. [1-3]). One of the important examples is system, which consists of autogenerators interacting with retarding. Many physical and technical systems such as multielement semiconductors and gas lasers, different radiotechnical devices and others can be considered as a set of the coupled autogenerators in the first approximation. The classical example is a set of two autogenerators (semiconductor) quantum generators, coupled by means of the optical waveguide (e.g. [1,2]). In many papers (e.g. [1-3]) it has been numerically studied a regular and chaotic dynamics of the system of the Van-der-Poll autogenerators with a special kind of inter-oscillators interaction forces and with the finite time of the signals propagation.

In our work it is performed an numerical analysis, modelling and forecasting the nonlinear temporal dynamics of system of the coupled semiconductor quantum generators (autogenerators) and obtained the total data on the fundamental topological and dynamical invariants of the system chaotic dynamics. For system of the vibrating dipoles, situated in the points with coordinates $r_i(I=1...N)$; and dipole moment vectors directed along axe z; $d_i=(0,0,d), d \equiv e_i x_i$ (e_i – effective charge of the i –th dipole) the equation of motion can be written as follows:

$$\ddot{x}_I + \varepsilon_I \left(x_I^2 - \gamma_I\right)\dot{x}_I + \omega_I^2 x_I = -\sum_{I \neq I} f_{II'} \ddot{x}_{I'}(t - \tau_{II'}) \qquad (1)$$

where ω_i are the eigen autovibration frequencies. The force in the right part describes an action on *l*–th oscillator from the radiation field of other ones. The different determinations of a force and equations for calculation of the eigen frequencies are given in Refs. [1,2].

2. Results and Discussion

The results of application of the different mathematical numerical methods to characterize the dynamics of coupled semiconductor quantum generators and discover a presence of the deterministic chaos elements in the dynamics. The nonlinear analysis numerical techniques such as the autocorrelation function and the Fourier power spectrum methods, the mutual information approach, the correlation integral analysis and false nearest neighbour algorithms, the Lyapunov's exponents and Kolmogorov entropy analysis, surrogate data method (in versions [3-6]) are used for comprehensive characterization, processing of the corresponding time series for the studied system. Table 1 summarizes the results of the Lyapunov exponent analysis as well as lists the values of the Kaplan-Yorke attractor dimension, *K* is the Kolmogorov entropy, and *P* is the average predictability. For the time series under consideration, there exist two positive exponents (indicating expansion along two directions) and two negative ones (indicating contraction along remaining directions).

Table 1. Results of Lyapunov exponents analysis for amplitude level: λ_1–λ_4 are the Lyapunov exponents in descending order, d_L is the Kaplan-Yorke attractor dimension, *K* is the Kolmogorov entropy, and *P* is the average predictability

λ_1	λ_2	λ_3	λ_4	d_L	*K*	*P*
0.0082	0.0017	–0.0047	–0.0167	3.33	0.0094	124.3

The Kaplan-Yorke dimension is equal to 3.33; this value is very close to the correlation dimension which was defined by the Grassberger-Procaccia algorithm [6]. The estimations of the Kolmogorov entropy and average predictability can show a limit, up to which the amplitude level data can be on average predicted. Surely, the important moment is a check of the statistical significance of results.

3. Concluding Remarks

To conlcude, the results of the computational analysis, modelling, processing and forecasting nonlinear dynamics of system of the coupled semiconductor quantum generators (autogenerators) are presented. The data on the topological and dynamic invariants are listed and analyzed.

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