Computational modelling dynamics of quantum and laser systems and backward-wave tubes with elements of a chaos

A.V. Glushkov, V.V. Buyadzhi, G.P. Prepelitsa, E.L. Ponomarenko and V.B. Ternovsky

Odessa State University – OSENU, Odessa, 65009, Ukraine

We numerically study nonlinear optics and dynamics of some quantum (atomic), laser systems and backward-wave tube in order to detect a chaos elements (quantum chaos). Many systems in a modern quantum physics and electronics manifest the elements of the deterministic chaos and hyperchaos in its dynamics. Chaos theory establishes that apparently complex irregular behaviour could be the outcome of a simple deterministic system with a few dominant nonlinear interdependent variables. Here we present the results of studying the dynamical chaos regime in generation of a laser with absorbing cell and chaotic self-oscillations in the backward-wave tube on the basis of numerical analysis by means a complex of advanced methods and algorithms (in versions [1,2]). In ref.[3] there have been presented the temporal dependences of the output signal amplitude, phase portraits, statistical quantifiers for a weak chaos arising via period-doubling cascade of self-modulation and for developed chaos at large values of the dimensionless length parameter. Our analysis techniques includes a multi-fractal approach, methods of correlation integral, false nearest neighbour, Lyapunov exponent's, surrogate data, memory matrix formalism [1,2]. In table 1 we present the data on the Lyapunov exponents' for two self-oscillations regimes in the backward-wave tube: i). the weak chaos (normalized length: L=4.24); ii) developed chaos (L=6.1). The correlations dimensions are respectively as 2.9 and 6.2. Our analysis confirms a conclusion about realization of the chaotic features in dynamics of the backward-wave tube. The same program is realized for detecting the chaos regime in generation of a laser with absorbing cell and multi-electron atoms in a microwave field.

Table 1. Numerical parameters of the chaotic self-oscillations in the backward-wave tube: λ_1–λ_6 are the Lyapunov exponents in descending order, K is the Kolmogorov entropy (our calculation results)

Regime	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	K
Weak chaos L=4.24	0.261	0.0001	–0.0004	–0.528	–	–	0.261
Hyperchaos L=6.1	0.514	0.228	0.0000	-0.0002	–0.084	–0.396	0.742

[1]. A.V. Glushkov, V.N. Khokhlov etal, Nonlin. Proc.in Geophys. 11, 285-294 (2004); Atm. Environment (Elsevier) 42, 7284–7292 (2008); Dynam. Systems – Theory. & Applications (Lodz, Poland) BIF-110 (2011); A.V. Glushkov, Methods of a chaos theory.-Odessa: Astroprint, (2012).
[2] V.D. Rusov, A.V. Glushkov etal, Adv. in Space Res. 42, 1614-1617 (2008); J. Atm. and Solar-Terr. Phys. (Elsevier) 72, 498-508 (2010).
[3] S.P.Kuznetsov, D.I. Trubetskov., Izv.Vuzov. Ser. Radiophys. XLVII, 1-7 (2004).