Nonlinear Resonances in Optoelectronic Artificial Spiking Neuron Based on a VCSEL and SPAD Driven by Periodic Signals and Noise

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Recently, we have proposed an optoelectronic artificial spiking neuron (ASN) based on the pair single photon-avalanche diode (SPAD) – vertical cavity-surface emitting laser (VCSEL) [1]. This type of ASN well mimics basic properties of biological neurons, such as an existence of the threshold and the refractory period, the insensitivity to the effect of the stimuli strength above the threshold, and the dependence of the neuron fire rate of the stimuli strength. On the other hand, this type of the artificial neuron represents an example of the nonlinear threshold dynamical system with probabilistic response and the deadtime. Here we demonstrate occurrence of nonlinear resonances in such a type of the ASN driven by periodic signals and noise. Specifically, we experimentally investigated three kinds of stochastic resonance, namely, for periodic, aperiodic and phantom signals. Similar study was performed for the case when noise was replaced by high-frequency signal resulting in the appearance of periodic, aperiodic and phantom vibrational resonances. The influence of the signal and noise parameters on the peculiarities of stochastic and vibrational resonances in the ASN has been studied. These results can be important from the viewpoint of enhancement of the signal propagation in artificial neurons and networks

[1] V. N. Chizhevsky, V. A. Kulchitsky, S. Ya. Kilin. Artificial spiking neuron based on a single-photon avalanche diode and a microcavity laser. Appl. Phys. Lett. V.119, P. 041107-5 (2021)

Polarization Instabilities in Vertical-Cavity Surface-Emitting Lasers

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Over the past few years, we have developed a new approach to the description of polarization phenomena in Vertical-Cavity Surface-Emitting Lasers (VCSELs), associated with the phenomenological linear dependence of the anisotropy of gain and/or losses on the value of the injection current density. This approach made it possible to formulate a fairly simple and physically very illustrative interpretation of polarization phenomena in VCSELs, when polarization switching (PS) is deterministic and consists in the transition from one linear polarization to orthogonal polarization through a sequence of partially polarized states. In particular, this approach made it possible for the first time to explain the effect of an anomalous shift in the polarization switching point with an increase in the rate of rise of the injection current. In this report, a more general than linear dependence of gain and/or losses on the value of the injection current density is analyzed. On the basis of a detailed analysis of temperature dependencies, it is shown that the most adequate representation of such a dependence is in the form of a second-order polynomial. The consequence of this dependence is the presence of no more than two PS points in the single mode regimes, the analysis of the numerical simulation results indicates that with a significant shift in PS points, the results in the region of each of them practically do not differ from the case of linear approximation. Therefore, the main attention is paid to the study of the dynamics of polarization effects at a relatively close location of PS points.

Nonlinear properties of biosuspensions

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Different possible scenarios of laser beam propagation in biological suspensions are under study accounting for movement of microparticles under the action of the gradient force of light pressure associated with their polarizability and the forward scattering force, as well as mechanisms of radiation dissipation in matter. To ensure correctness of analysis, we consider the WKB approximation of light scattering. Due to dissipative loses the polarizability of particles can be a complex quantity.