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

V.N. Chizhevsky, M.V. Lakhmitski, S.Ya. Kilin
B.I. Stepanov Institute of Physics, Minsk, Belarus
vnc@dragon.bas-net.by

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

L.I.Burov, P.M.Lobatsevich
Belarusian State University, Minsk, Belarus

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

Kseniya Pestsova, Olga Fedotova, Oleg Khasanov, Ryhor Rusetski, Tatsiana Smitnova, Alexander Bugay
Scientific and Practical Center of the National Academy of Sciences of Belarus for Materials Science, Minsk, Belarus

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.

The optical nonlinearity of the suspension is originated from the movement of particles in a field of gradient forces and, as a result, from gradient distribution of biopaticles in medium. This ensures the concentration nature of optical nonlinearity, acting similarly to Kerr nonlinearity and leading to self-focusing of radiation in the medium if the input power of laser radiation exceeds the threshold value. The threshold power is directly proportional to the square of the wavelength and inversely proportional to the square of the particle size. In a steady state, when the influence of diffusion is compensated by the action of gradient forces, soliton propagation of radiation in the biosuspension is possible. The shape of the soliton is determined by the polarizability of the particles, the diffusion coefficient, the mobility and size of the particles, their concentration in the suspension and the effective refractive index of the medium.

Modeling of coherently mode-locked lasers

Anton Pakhomov[1], Mikhail Arkhipov[2], Nikolay Rosanov[2] and Rostislav Arkhipov[1,2]
[1]St. Petersburg State University, [2]Ioffe Institute, St-Petersburg, Russia

Coherent mode-locking represents a promising approach for the generation of ultrashort pulses in lasers beyond the limitations of standard passive mode-locking. This approach is based on the coherent pulse propagation in a laser active medium what allows the production of pulses much shorter in duration than the medium dephasing time. We have performed the detailed modeling of the spatio-temporal dynamics of coherently mode-locked lasers in several arrangements. Besides the numerical solution of Maxwell-Bloch equations, the analytical approach based on the generalized area theorem was developed. Our analysis has demonstrated both the stability and self-starting properties of coherent mode-locking as well as achieving the pulse durations inaccessible by means of standard passive mode-locking.

Jones 4-Spinor and Partially Polarized Light

V.M. Red'kov[1], A.V. Ivashkevich[1], E.M. Ovsiyuk[2], V. Balan[3], A.V. Chichurin[4]
[1]B.I. Stepanov Institute of Physics, Minsk, Belarus
[2]Mozyr State Pedagogical University, Belarus
[3]University Politehnica of Bucharest
[4]The John Paul II Catholic University of Lublin

We shall present some facts of the theory of the Lorentz group which can be relevant for solving problems of light polarization in the frames of the vector approach by Stokes and Mueller, and by the spinor Jones formalism. A definite correlation exists between completely and partially polarizations of the light and the isotropic and time-like vectors of the Lorentz group.
It is known that for completely polarized light can be described by Stokes 4-dimensional vector or alternatively by Jones complex 2-dimensional vector. The Stokes 4-vector formalism may be extended to a partially polarized light, but Jones approach does not. In the present paper, starting with the Lorentz group theory, we introduce the concept of 4-dimensional Jones spinor, first for a completely polarized light. To such Jones bispinor, there correspond isotropic Stokes 4-vector, and antisymmetric Stokes tensor, the last is equivalent to isotropic complex 3-vector. This approach is extended to the partially polarized light as well. We introduce corresponding 4-spinor of Jones type and 4-vector and antisymmetric tensor of Stokes types. We have introduced the concept of minimal Jones-like 4-spinor, and have found relationships between the relevant Stokes vector and Stokes antisymmetric tensor in analytical form, which is studied numerically as well.

Tunneling times for electromagnetic pulses propagating through a plasma layer

D. Novitsky[1], M. Usachonak[1], I. Timoshchenko[2], O. Romanov[2],
L. Simonchik[1], S. Gaponenko[1]
[1]B.I. Stepanov Institute of Physics, Belarusian State University, Minsk, Belarus
[2]Belarusian State University, Minsk, Belarus

In present time, tunneling of electromagnetic radiation through media in which the propagation of homogeneous waves is impossible and electromagnetic oscillations are realized in the form of evanescent waves (e.g., through periodic media with photonic forbidden bands and narrowed