Ю. Гайдай, канд. физ.-мат. наук, В. Сидоренко, канд. физ.-мат. наук,
О. Синькевич, инж., И. Сердега, инж.
каф. квантовой радиофизики, радиофизический факультет,
КНУ имени Тараса Шевченко, Киев

ЭФФЕКТ ВЫНУЖДЕННОЙ СИНХРОНИЗАЦИИ ЧАСТОТЫ В МИКРОВОЛНОВОМ МИКРОСКОПЕ С АКТИВНЫМ ЗОНДОМ

Рассмотрен эффект вынужденной синхронизации частоты активного зонда микроволнового микроскопа под действием внешнего поля с частотой близкой к резонансной. Предложено использовать квазипериодический режим для повышения чувствительности зонда к малым изменениям диэлектрической проницаемости.

Ключевые слова: ближнеполевой микроволновый микроскоп, вынужденная синхронизация частоты

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A. Goloborodko, Ph. D., Department Nanophysics and nanoelectronics,
Faculty of Radiophysics, Taras Shevchenko National University of Kyiv

COHERENT LIGHT PROPAGATION IN OPTICALLY INHOMOGENEOUS MEDIA

Phenomenon of a depolarization for an optical signals which were propagated in media with the statistically distributed parameters has been investigated theoretically. Polarization characteristics were calculated by using a coherent matrix method. The dependence of polarization degree of wave on parameters of scattering medium has been calculated for the Fraunhofer diffraction zone.

Key words: degree of polarization, statistically inhomogeneuos medium.

Introduction. The coherent light propagation through optically inhomogeneous medium is one of the most important problem of the statistical optics [2]. Description of such propagation we could consider using of Maxwell formalism as a detailed analyze of an electromagnetic waves scattering under every fluctuation [7]. This problem takes on special significance for multiple scattering because of corresponding coefficients of stochastic equations are random field [5, 6]. Usually, such equations have not analytical solutions and are difficult for numerical analyze. Therefore, it is interesting to construct more simple models for description of the propagation process of waves through inhomogeneous medium with multiple scattering.

The model of phase screen could be considered as possible approximation for this case. Method of phase screen is familiar for scalar approximation of a diffraction problems, including, for example, wave propagation through turbulent atmosphere [4]. It can be proper for multiple scattering at some restriction. Then the propagation process of waves is considered as propagation through set of the phase screen with corresponding statistical properties.

In this work the theoretical method of the description of coherent light propagation through statistically inhomogeneous anisotropic medium by the phase screen method was proposed. Also we considered systems with multiple scattering using offered method.

Correlation matrix transformation. Correlation matrix method is the most convenient for investigation of polarization properties of the scattered light. In this case light propagation by the statistically stratified medium could be obtained as linear integral transform. The parameters of kernel of this transform are determined by the statistics of the medium. The advantage of this method consist in indifference between the statistically stratified mediums, where inhomogeneous could be produced by the inhomogeneous of relief fluctuation or refraction index fluctuations.

Let us consider general principles that were underlay our scattering model. The scattering geometry is depicted on the Fig. 1. Gaussian beam of wavelength λ normally irradiates the statistically stratified medium, which could be represented as phase screen with local inhomogeneties of refraction index ($n_x=n_x(\rho)$, $n_y=n_y(\rho)$, where $\rho=\{\xi, \eta\}$ is the coordinate in the plane of phase screen) and set of local heights $h=h(\rho)$.

Complex amplitude of the electromagnetic wave in the registering plane arbitrary point $r=\{x, y\}$ could be given by Jones vector [3]:

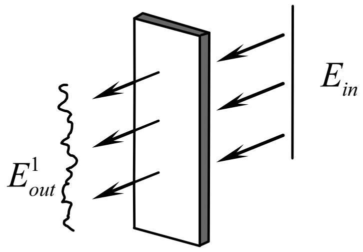


Fig. 1. Geometry of light scattering by phase screen

$$E(\mathbf{r}) = \begin{pmatrix} E_x(\mathbf{r}) \\ E_y(\mathbf{r}) \end{pmatrix}. \quad (1)$$

The relation between the vectors of scattered wave $E(\mathbf{r})$ in arbitrary point $\mathbf{r}$ with the vector $E_0(\rho)$ in general case can be expressed by the linear integral [1]:

$$E(\mathbf{r}) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} H(\mathbf{r},\rho)E_0(\rho)d^2\rho\,, \quad (2)$$

where $H(\mathbf{r},\rho)$ is random coherent point spread function (PSF) of linear optical channel. This PSF could be expressed by the Green function, which in approaching of the anisotropic phase screen could be given as:

$$H(\mathbf{r},\rho) = \frac{1}{i\lambda z}\exp\left(i\left(\tfrac{2\pi}{\lambda}\left|\mathbf{r}-\rho\right| + \phi_j(\rho)\right)\right)\cos(\mathbf{n},\mathbf{r}-\rho)\,. \quad (3)$$

here φ_x and φ_y is the random phases, which formed by the casual relief or refraction index fluctuation, and could be expressed as:

$$\phi_j(\rho) = \frac{2\pi}{\lambda}n_j(\rho)h(\rho);\ j = x, y\,, \quad (4)$$

where $n_x(\rho)$ and $n_y(\rho)$ is the fluctuations of anisotropic index of refraction, $h(\rho)$ is the random distribution of relief inhomogeneous. So the formula (2) for the Fraunhofer diffraction zone is transforming in:

$$E^1_{out}(\mathbf{r}) = \frac{\exp\left(i\frac{\pi}{z\lambda}\left(x^2+y^2\right)\right)}{i\lambda z}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\exp\left(i\frac{2\pi}{z\lambda}\left(x\xi+\eta y\right)\right)\times$$
$$\times E_0\exp\left(i\frac{\pi}{z\lambda}\left(\xi^2+\eta^2+zn(\rho)h(\rho)\right)\right)d\xi d\eta\,, \quad (5)$$

where x, y are coordinates in registering plane; ξ, η are coordinates in the scattering plane; z is the distance between the scattering and registering planes. Let us make denotation:

$$\Phi(\mathbf{r}) = \exp\left(i \frac{\pi}{z\lambda} \left(x^2 + y^2 \right) \right)$$
$$E_0(\rho) = \frac{1}{i\lambda z} E_0 \exp\left(i \frac{\pi}{z\lambda} \left(\xi^2 + \eta^2 + zn(\rho)h(\rho) \right) \right), \tag{6}$$

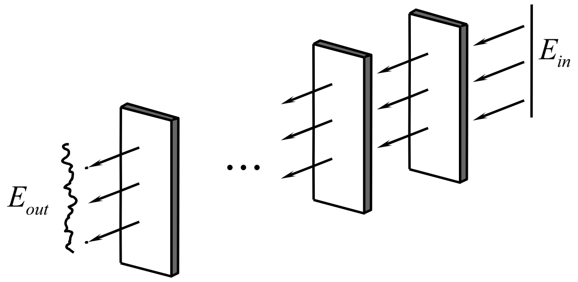


Fig. 2. Geometry of light scattering by the set of phase screens

where $\Phi(\mathbf{r})$ is the phase of the scattered wave and $E_0(\rho)$ is the gain-phase distribution of the wave in the scattering plane. In this case (5) could be expressed as:

$$E(r) = \Phi(r)\hat{F}_2 E_0(\rho). \tag{7}$$

here $\hat{F}_2$ is the linear integral 2D Fourier transform. In the case of the set phase screens (Fig. 2) total amplitude of the wave scattered by the set of phase screens are giving in the next form:

$$E^n(r) = \hat{F}_2^{n-1} \left(\Phi(r) \left(\hat{F}_2 E_0(\rho) \right) \right). \tag{8}$$

where n is the order of scattering. Expressions (8) let us the possibility to find the components of electrical field vector for scattered wave. So it becomes clear that it some aperture averaging of the random field and if it so that it reduce to defocusing scattered image.

The results of the theoretical calculations of components of electrical field are shown on fig.3.

Fig. 3 shows Capricorn constellation, which distorted by atmospheric turbulence. The parameters of turbulence are: correlation length r_k=50λ, inhomogeneous dispersions are (b) – σ=0.001n, (c) – σ=0.005n, (d) – σ=0.01n, (c) – σ=0.015n, where n is the mean refraction index. For reference fig. 3.a. is depicted original non distorted image. As can be seen from these graphs the increasing of inhomogeneous dispersion lead to image quality loss and some noise occurrence. This noise and defocusing are stir to spot of stars. In addition, the images of some stars simply meet and it is impossible to see one star of on a background of other.

For the polarization properties analyzing the elements of the coherent matrix could be giving as:

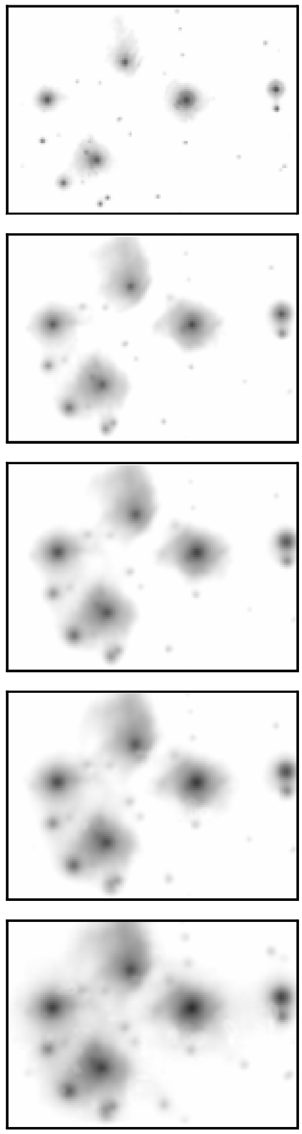
$$G_{jk}^n(\mathbf{r}) = E_j^n(\mathbf{r}) \left(E_k^n(\mathbf{r}) \right)^* ; j,k = x,y. \tag{9}$$

In general case it had to make the averaging of the components of coherent matrix under the aperture of a beam:

$$\left\langle G_{jk}^n \right\rangle = \int_{-a}^{a} G_{jk}^n(\mathbf{r}) d^2\mathbf{r}, \tag{10}$$

where a is the averaging aperture. Thus, it is possible to define the degree of polarization of the scattered waves using expressions for the elements of the coherent matrix (10):

$$P = \sqrt{1 - \frac{4\left(\left\langle G_{xx}^n \right\rangle \left\langle G_{yy}^n \right\rangle - \left\langle G_{xy}^n \right\rangle \left\langle G_{yx}^n \right\rangle \right)}{\left(\left\langle G_{xx}^n \right\rangle + \left\langle G_{yy}^n \right\rangle \right)^2}}, \tag{11}$$



a) original image

b) σ=0.001n

c) σ=0.005n

d) σ=0.01n

e) σ=0.015n

Fig. 3. Image distortion by atmospheric turbulence

If the incident wave is completely polarized, the wave scattered by diffuse surface will change the degree of polarization, because the factorization of the correlation matrix is impossible [1]. It is understandable, that any fluctuations of propagation media have to influence on light polarization.

The main results of the polarization experimental measurements [5] and theoretical calculations (11) are shown on fig.4.

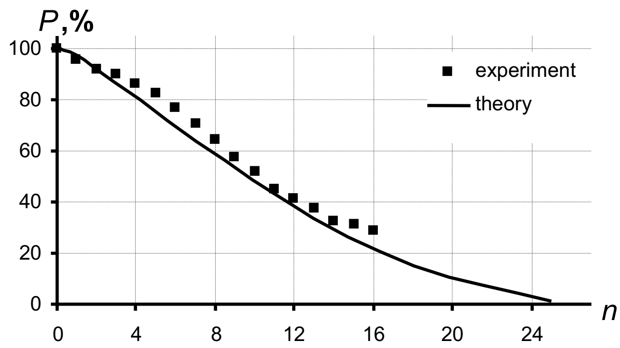


Fig.4. Dependencies of polarization degree on the order of scattering

As can be seen from these graphs the degree of polarization of the scattered wave depends on the order of scattering. Thus, every wave becomes partially depolarized on each phase screen at each scattering act. So if the number of screens is increasing ($n \to \infty$) that the depolarization to tend to a limit which of equal to 100%.

Conclusions. The mathematical model of light propagation through media with multiple scattering which was based on the approximation by sequence of the anisotropic phase screens. It has been considered case of the stratified medium, in which anisotropy is sequent of statistical inhomogeneous of the layers interfaces. The essential depolarization effect at the light propagation has been confirmed experimentally. This fact was submitted to theoretical results which obtained from proposed model.

Reference

1. Goodman G.W. Statistical optics /G.W.Goodman. John Wiley and Sons: New York-Chichester-Brisbane-Toronto-Singapore, 1985. – 487p. 2. Alloin D. M. Adaptive Optics for Astronomy / D. M. Alloin, J.-M. Mariotti. NATO ASI Series: Kluwer Academic Publ., 1994. – .423 p. 3. Azzam R.M.A. Ellipsometry and polarized light. 5th ed./ R.M.A.Azzam, N.M.Bashara. Elsevier: North Holland. 2003. – 387p. 4. Andrews L.S. Propagation of a Gaussian-beam wave through a random phase screen/ L.S.Andrews, R.L.Phillips, A.R.Weeks// J. Waves Random Media. – 1997. – Vol. 7. – P.229–244. 5. Barchuk O.I. Experimental investigations of light depolarization under multiple scattering / O.I.Barchuk, A.A.Goloborodko, V.N.Kurashov, Y.A. Oberemok, S.N. Savenkov // Proceedings of SPIE. – 2006. – Vol.6254 – 62540W. 6. Дерюгина А.И. Поляризационная структура дифрагованого излучения, распространяющегося в турбулентной атмосфере / А.И. Дерюгина, В.Н. Курашов, А.И. Мащенко // Радиотехника и электроника. – 1988. – Том 23, №11 – С. 2399–2408. 7. Kurashov V.N. Polarization changes in coherent electromagnetic radiation scattering by the rough surface/ V.N. Kurashov, V.V. Marienko, T.V. Molebna, A.G.Chumakov // Proceedings of SPIE. – 1995. – Vol. 2647. – P. 48–56.

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А. Голобородько, канд. фіз.-мат. наук, каф. нанофізики та наноелектроніки,
радіофізичний факультет, КНУ імені Тараса Шевченка, Київ

РОЗПОВСЮДЖЕННЯ КОГЕРЕНТНОГО ВИПРОМІНЮВАННЯ В ОПТИЧНО НЕОДНОРІДНОМУ СЕРЕДОВИЩІ

Проведено теоретичний аналіз явища деполяризації оптичних сигналів, що розповсюджуються оптичним середовищем зі статистично розподіленими параметрами. Дослідження поляризаційних характеристик випромінювання виконано з використанням методу кореляційної матриці. Розглянуті поляризаційні властивості оптичних полів, що сформовані в зоні дифракції Фраунгофера.

Ключові слова: ступінь поляризації, статистично неоднорідне середовище.

А. Голобородько , канд. физ.-мат. наук, каф. нанофизики и наноэлектроники
радиофизический факультет, КНУ имени Тараса Шевченко, Киев

РАСПРОСТРАНЕНИЕ КОГЕРЕНТНОГО ИЗЛУЧЕНИЯ В ОПТИЧЕСКИ НЕОДНОРОДНОЙ СРЕДЕ

Проведен теоретический анализ явления деполяризации оптических сигналов, распространяющихся в оптической среде со статистически распределенными параметрами. Исследование поляризационных характеристик излучения выполнены с использованием метода корреляционной матрицы. Рассмотрены поляризационные свойства оптических полей, сформированных в зоне дифракции Фраунгофера.

Ключевые слова : степень поляризации, статистически неоднородная среда.

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O. Ivanyuta, Ph.D.
Department Electrophysics, Faculty of Radiophysics,
Taras Shevchenko National University of Kyiv

ELECTROPHYSICS PROPERTIES THE DNA AND DNA:AU MOLECULAR CLUSTERS ON SAPPHIRE

The films DNA, DNA: Au, clusters from gel solution, which can be magnetic and electrical active in biosensor systems and to detect their functional properties by microwave techniques. Research has been focused on the application of I - V characteristics and spectra methods to recognise and predict these molecular interactions based on primary structure and associated physic-chemical properties. In results have actually shown that these molecular cluster layers on Al_2O_3 substrates can to conduct electric current and respond on power of microwave.

Keywords: DNA, UV-VIS-NIR spectra, low-energy electron point source, current-voltage characteristics.

Introduction. Deoxyribonucleic acid (*DNA*) encodes the architecture and function of living cells. DNA is made of a sequence of four bases: adenine (*A*), guanine (*G*), thymine (*T*) and cytosine (*C*) (Fig. 1), attached to a phosphate-sugar backbone and is about 0,34 nm long. Any particular sequence forms a single strand of *DNA*. Two strands may come together through hydrogen bonding of the bases *A* with *T* (*A T*) and *G* with *C* (*GC*) [1–4].

DNA's electronic and self-assembly properties bear enormous importance in nanoscience. The electrophysics properties *DNA* are interest in several disciplines in nanoscience because of their relevance to damage and mutation in molecules. The charge transport for electrophysics properties of *DNA* is central to such developments. For instance, electrophysics detection of structural changes, due to protein binding or base mismatches examined. New read-out schemes on *DNA* chips can detect for the presence of different *DNA* sequences, might exploit her a electronic properties. The phosphate ion carries a negative charge in the *DNA* molecule, which results in electrostatic repulsion of the two strands. In order to keep the two strands together, positive ions must be present in the solution to keep the negative charges neutralized. Charge transport in *DNA* can shed new light on the transport properties of other systems with supramolecules (Fig. 2). *DNA* could be a *Au* conductor because of the formation of a molecules band across the different bases. The stacking molecule is important in the conducting properties of several other organic molecules, that DNA might conduct started to be pursued with more vigor. The electron transfer through *DNA* was responsible for fluorescence quenching of an excited molecule [2–5, 9, 10].

DNA behaves as a conductor, semiconductor, or insulator, in what seems to be contradictory conclusions. The apparent contradictions have been attributed to the large phase space in which *DNA* can be prepared and probed. Many experimental conditions and attributes of the specific *DNA* used, including base sequence, length, orientation, countering, temperature, electrode contact, adsorption surface, fluctuations, and so on, could affect its conducting properties. As a consequence, although much