

Possibilities of phase correlations for dimensional photo-integrated anisotropy micro-lattices

Liubov I. Vostrikova^{1,2}

¹Rzhanov Institute of Semiconductor Physics SB RAS

²Departments of Mathematics and Natural Sciences and Informational Technologies of NSUEM, Russia

Phase correlations in first- and second- order susceptibilities micro-lattices by all-optical poling process of nonlinear interaction $\omega + \omega - 2\omega \rightarrow 0$ are analyzed. Accumulating electrostatic field of coherent photocurrent by all- optical poling is

$$\mathbf{E}(\mathbf{r}) = \mathbf{j}(\mathbf{r}) / \sigma = [\sigma_1 \mathbf{e}_1 (\mathbf{e}_1 \mathbf{e}_2) + \sigma_2 \mathbf{e}_2] E_1^2(\mathbf{r}) E_2(\mathbf{r}) \cos(\Delta \mathbf{k} \mathbf{r} + \Delta \psi); \Delta \mathbf{k} = 2\mathbf{k}_1 - \mathbf{k}_2, \Delta \psi = 2\psi_1 - \psi_2.$$

σ_1 and σ_2 are called as the coherent photo-galvanic constants.

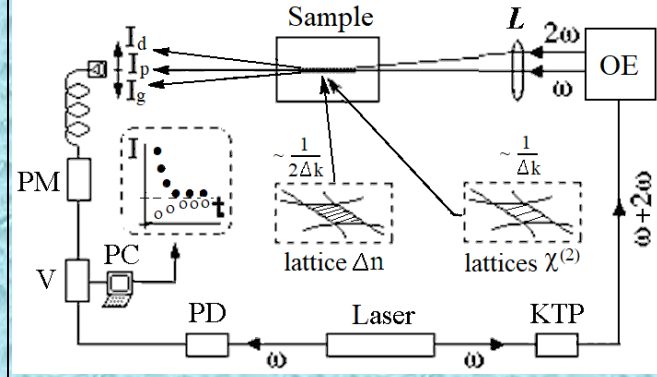


Fig. 1. Experimental realizations by all-optical poling. On making lattices of refractive index $\Delta n \sim \chi^{(3)} E^2$ (with vector $q = 2\Delta k$) and $\chi^{(2)} \sim \chi^{(3)} E$ (with Δk) in conditions of phase synchronization there are possibilities for observations of diffraction and non-linear transformations of incident light: I_d, I_p, I_g are intensities of diffracted, nonlinear parametrical converted, second-harmonic generated beams.

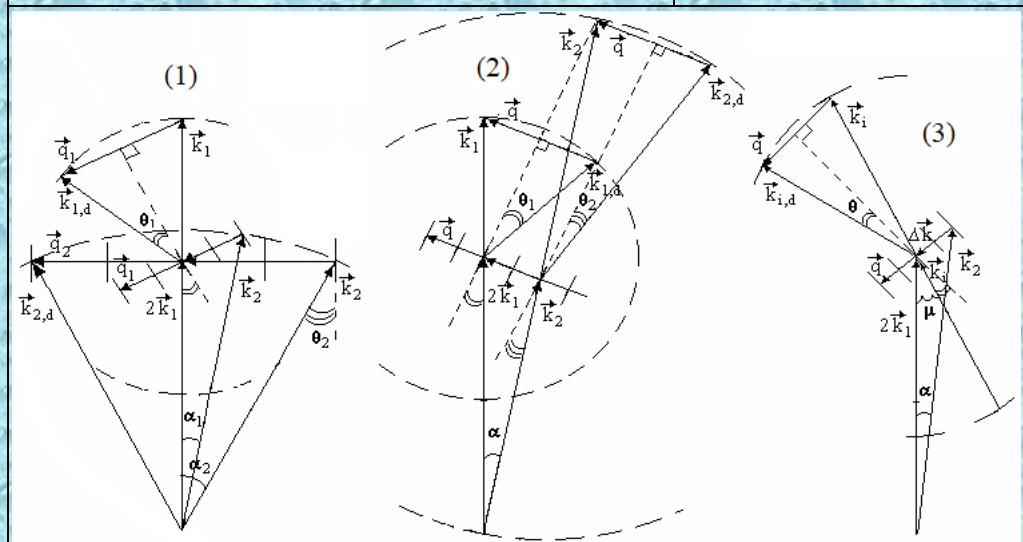


Fig. 2. Synchronous correlations of phase-matched conditions for effective Bragg diffractions on the created by all-optical poling photorefractive lattices in isotropic media: (1) - phase-matched conditions for Bragg diffractions of light radiations with wave-vectors \mathbf{k}_1 and \mathbf{k}_2 in case of normal dispersion ($n_2 > n_1$) on two different induced lattices with vectors \mathbf{q}_1 and \mathbf{q}_2 ; (2) - simultaneous phase-matched conditions for Bragg self-diffractions of light radiations with wave-vectors \mathbf{k}_1 and \mathbf{k}_2 on the same lattice with vector \mathbf{q} in anomalous dispersion ($n_2 < n_1$), (3) - phase-matched condition for Bragg diffraction of abstract frequency light radiation with wave-vector \mathbf{k}_1 .

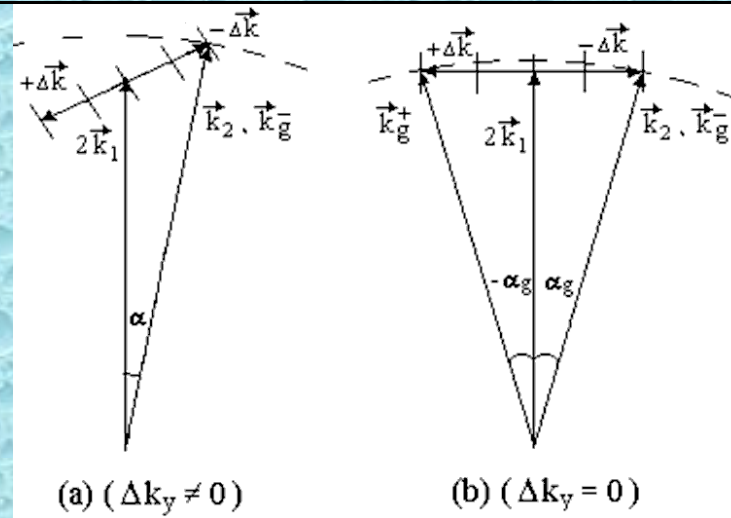


Fig. 3. Phase synchronisms on photo-integrated lattice $\chi^{(2)} \sim \chi^{(3)} E$ for nonlinear generation of one (a) or two (b) beams of doubled frequency (γ is direction of propagation of basic frequency laser radiation with vector \mathbf{k}_1). The \mathbf{k}_g^+ generated wave is analogue of the Bragg wave in linear optics but in this case there is nonlinear transformation of light simultaneously with the effective Bragg deviation of converted light of second harmonic on lattice $\chi^{(2)}$.

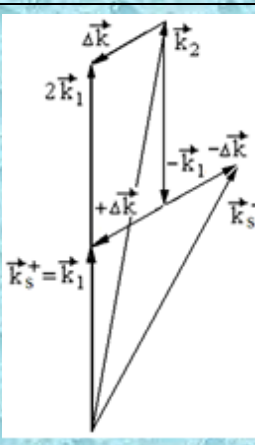


Fig. 4. Synchronism of phase correlations on photo-induced lattice $\chi^{(2)}$ for nonlinear process of degenerate parametrical down frequency conversion I_p with amplification of low light signals of basic frequency. Low signal wave with wave vector $\mathbf{k}_s = \mathbf{k}_1$ and big power pumping wave with vector $\mathbf{k}_p = \mathbf{k}_2$ interact in medium with photo-integrated $\chi^{(2)}$ lattice with vector $\Delta \mathbf{k} = 2\mathbf{k}_1 - \mathbf{k}_2$ by condition of phase synchronization $\mathbf{k}_s = \mathbf{k}_2 - \mathbf{k}_1 \pm \Delta \mathbf{k}$. As \mathbf{k}_s^+ coincide with incident basic light beam \mathbf{k}_1 , spatial phase synchronism for inducing $\chi^{(2)}$ lattice and signal wave with basic frequency is carried out automatically and there is a case of the nonlinear degenerate parametrical amplification of low signals. For this process of parametrical down frequency conversion the photo-integrated by all-optical poling susceptibility tensor of $\chi^{(2)}$ lattice: $\chi_{ijk}^{(2)}(\Omega; 2\Omega, -\Omega) = (\chi_1^{(3)} \mathbf{E}_k \delta_{ij} + \chi_2^{(3)} \mathbf{E}_j \delta_{ik} + \chi_3^{(3)} \mathbf{E}_i \delta_{kj})$, $\chi_1^{(3)} = 2\pi \chi_{ijj}^{(3)}(\Omega; 2\Omega, -\Omega)$, $\chi_2^{(3)} = 2\pi \chi_{ijj}^{(3)}(\Omega; 2\Omega, -\Omega)$, $\chi_3^{(3)} = 2\pi \chi_{ijj}^{(3)}(\Omega; 2\Omega, -\Omega)$. Maximal nonlinear conversion observed for radiation polarized along direction of induced field \mathbf{E} . But there are other non-zero components.

So, there are different possibilities of the phase-matched conditions for various linear and nonlinear conversions of light radiations on the photo-integrated lattices of the first-order $\chi^{(1)} \sim \chi^{(3)} E^2$ and second-order $\chi^{(2)} \sim \chi^{(3)} E$ susceptibilities. As the values of vectors $\Delta \mathbf{k}_i$ and \mathbf{q}_i for the arising by all-optical poling susceptibilities lattices are small in comparison with values of the vectors \mathbf{k}_i of the incident light waves that there is the broad band from the visible and near infrared spectrums for effective linear and nonlinear conversions of different frequency light radiations. The investigations can be interesting for researchers in spheres of photonics and micro-optoelectronics. The work was carried out as part of tasks of the Russian State Project FWGW-2021-0012.

REFERENCES:

- [1] Balakirev M.K., Kityk I.V., Smirnov V.A., Vostrikova L.I., Ebothe J. // Phys. Rev. A. 2003. V. 67. P. 023806-8.
- [2] Hickstein D.D., Carlson D.R., Kowligly A. et al. // Nature Photonics. 2019. V. 13. P. 494.
- [3] Vostrikova L.I., Kartashev I.A. // Bull. Russ. Acad. Sci. Phys. 2024. V. 88. № 7. P. 1055.