COHERENT IR-CONVERTER BASED ON GaAs AND $Bi_{12}SiO_{20}$

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The model of coherent IR-converter on the basis of GaAs photoconductor (PC) joined to the electrooptical (EO) crystal $Bi_{12}SiO_{20}$ have been considered theoretically. The possibility of the field transfer from the photoconductor to the EO crystal under the IR-light have been estimated that is sufficient for realization of the linear electrooptical effect in the EO crystal. Basing on the field parameters and parameters of PC and EO crystals, the sensitivity threshold of converter have been estimated. The PC-EO crystal structure on which the conversion of the IR-light (0.9-1.5 μm) into the coherent visible one have been realized, was obtained on the basis of theoretical calculations. The threshold of sensitivity of $5\cdot10^{-4}$ W/sm^2 is measured that is within of theoretical estimation.

INTRODUCTION.

The electrooptical devices, especially those of them, which can convert the noncoherent image to the coherent one in a real time scale, play a significant role in systems of optical processing of information [1-2].

When developing the different types of IR-converters [4-8]. We have interested in problem of construction of coherent IR-converter based on GaAs and $Bi_{12}SiO_{20}$ (BSO). For this purpose, a theoretical possibility of the operation of such a device has been considered, its construction has been developed and the testing has also been carried out.

EXPERIMENTAL.

The photoconductor is a plate of semiizolating GaAs:Cr of n-type conductivity, the dark conductivity at 300 K is $\sigma_{1d}=10^{-5}$ Ohm^{-1}m^{-1}. The multiplicity of the resistivity change under illumination (λ=0.9 μm) is 10^2. The impurity photoconductivity attributed to chromium was maximum at λ=1.4 μm and was observed up to 1.7 μm. The electron mobility is μ = 0.1 m^2/Vsec and a relative dielectric constant is ε_1=6. The GaAs plate in the form of disk with area of 3 sm^2 and the thickness of L_1=300 μm was polished and then a layer of transparent electrode SnO_2 was deposited on one of the sides of the crystal. The BSO crystal with the following characteristics was used. The conductivity in the dark and under illumination was $\sigma_{2d}=10^{-10}$ Ohm^{-1}m^{-1} and $\sigma_{2ill}=10^{-6}$ Ohm^{-1}m^{-1}, respectively, a relative dielectric constant was ε_2=60, and a semiwave voltage was $U_{\lambda/2}$=4 kV. The BSO crystals were obtained by the Chokhralski method in the form of boules grown in (001) direction where a maximum linear electrooptical effect was observed [3]. The disks with 3 sm^2 of area and the thickness of L_2=250-300 μm were cut off. Then the transparent electrode was deposited on one of the sides of the plate.

The photoconductor and the electrooptical crystal were pressed to each other by free sides in cassette, which provided a uniform contact over the whole contact area. The alternating voltage up to 4 kV with the frequency of 10^5 Hz was applied to electrodes of such a structure. The converter structure and the scheme of IR-image conversion to a visible one are presented in Fig.1. The signal was readout in reflection conditions according to the known method [9].

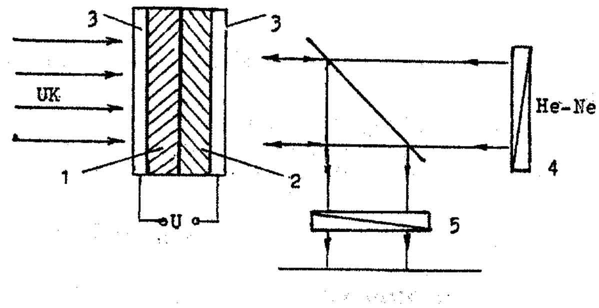

Fig.1. The structure of image converter and the scheme of the IR-image conversion to a visible coherent one.
1 – the photoconductor; 2 – the electrooptical crystal;
3 – the transparent electrodes; 4 – a polarized;
5 – an analyzer.

RESULT AND DISCUSSION.

The purpose of the present paper is to evaluate the possibility of electrooptical converter operation using the above materials. In this connection, the following problems arise:
1) if the field transfer from the photoconductor to the electrooptical crystal sufficient for electrooptical effect is possible;
2) to estimate the structure sensitivity value.

The Maxwell relaxation time ($\tau_M=\varepsilon_l\varepsilon_o/\sigma_l$) and the transit time between electrodes ($t_{tr}=L_1^2/\mu_1 U$) for our photoconductor are estimated as $\tau_M \approx 10^{-7}$ s and $t_{tr} \approx 10^{-5}$ s, respectively. As $t_{tr} \approx \tau_M$, the transit conditions of screening are not fulfilled, and we conclude that the field transfer takes place under ohmic conditions. As $I/I_0 \approx E_2^2$ (I, I_0 are intensities of readout and incident light, respectively; E_2 is the field strength in the electrooptical crystal) the dependence of E_2 on the external voltage U_0 applied to the structure, the field frequency ω and the device parameters should be determined. We are based on the system

$$\left.\begin{aligned} \sigma_1 E_1 + I\varepsilon_0\varepsilon_1 E_1 &= \sigma_2 E_2 + i\varepsilon_0\varepsilon_2 E_2 \\ E_1 L_1 + E_2 L_2 &= U_{0\omega} \end{aligned}\right\}, \quad (1)$$

where the index 1 refers to the photoconductor, and the index 2 refers to the electrooptical crystal. From the system (1), we obtain

$$E_{2\omega}^2=\frac{U_0^2\cdot\left(1+\omega^2\frac{\varepsilon_0^2\varepsilon_1^2}{\sigma_1^2}\right)}{L_2^2\left(1+\frac{\sigma_2}{\sigma_1}\right)^2\cdot 1+\omega^2\frac{\varepsilon_0^2\varepsilon_1^2}{\sigma_1^2}\left(\frac{\frac{L_1}{L_2}+\frac{\varepsilon_2}{\varepsilon_1}}{1+\frac{\sigma_2}{\sigma_1}}\right)} \quad (2)$$

Then, for the parameters of our converter

$$U_0^2/L_2^2 < E_{2\omega}^2 < (1/100)\, U_0^2/L_2^2 \quad , \quad (3)$$

i.e. the field in the electrooptical crystal can change by an order of magnitude with the change of the field frequency and the conductivity of the device operation to be stable.

The condition

$$E_{2ill}^2 = 2E_{2d}^2 \quad , \quad (4)$$

where E_{2ill} and E_{2d} are the fields in the electrooptical crystal under illumination of the photoconductor and in the dark, respectively, is used for the sensitivity estimation. Using (2) and (4), at $\omega\ \varepsilon_0\varepsilon_1/\sigma_1$=0.6, the condition (4) gives $\sigma_{1ill}/\sigma_{1d}$ = 0.438. At the intrinsic photoconductivity maximum, λ=0.9 μm, the sensitivity threshold of converter was $0{,}7\cdot 10^{-6}$ W/sm^2, while at λ=1.4 μm (the impurity photoconductivity maximum) it was $0.7\cdot 10^{-3}$ W/sm^2.

Taking these indices as rather satisfactory, we have tested our converter. The photoconductor was illuminated at $\lambda\geq 0.9$ μm, its light intensity (I_1) changed in the range 10^{-5}-10^{1} W/sm^2 of using the neutral filters. The image of stencil obtained in this case (fig.2) indicates the realization of coherent conversion of the IR light. To determine the sensitivity threshold of converter, the dependence of I on I_1 has been measured. The sensitivity threshold obtained from this characteristic (fig.3) is $5\cdot 10^{-4}$ W/sm^2 that corresponds to our estimation.

Thus, the device considered, simple by its construction and consisting of the joint plates of photoconductor (GaAs) and the electrooptical crystal ($Bi_{12}SiO_{20}$), can transform the IR image to coherent visible one without cooling.

We assume that the operation efficiency of our converter, to a great extent, is determined by a high dielectric constant of the electrooptical crystal.

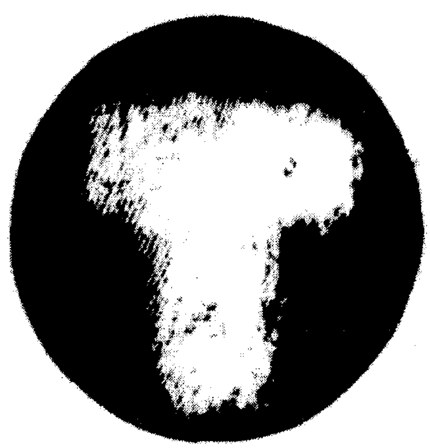

Fig.2. The image of stencil in the visible coherent light.

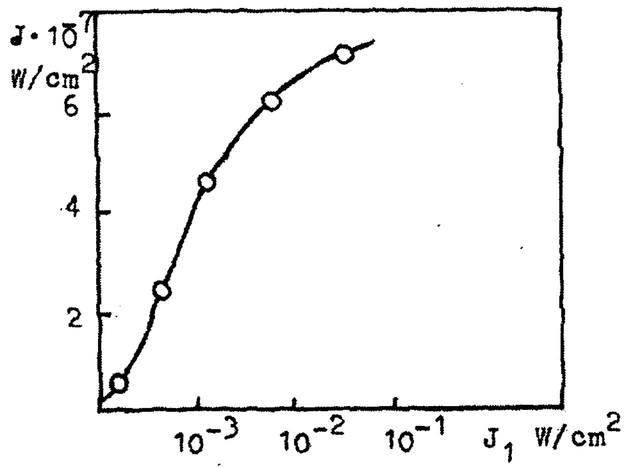

Fig.3. The dependence of the transformed coherent light intensity on the transformed IR-light intensity.

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GaAs VƏ $Bi_{12}SiO_{20}$ ƏSASINDA KOHERENT İNFRAQIRMIZI ÇEVİRİCİ

Fotokeçirici (FK) GaAs və elektrooptik (EO) $Bi_{12}SiO_{20}$ kristalın birləşməsi əsasında yaranmış koherent İQ-çevirici modelinə nəzəri baxılmışdır.

EO kristalda uzununa elektrooptik effektin yaranmasına gətirən gərginliyin fotokeçiricidən İQ işığın köməyi ilə EO kristala keçməsi imkanı qiymətləndirilmişdir. Sahənin gərginliyi EK və EO kristalın parametrlərini nəzərə alaraq çeviricinin həssaslığının astana qiyməti tə'yin edilmişdir. Nəzəri hesablamalara əsasən FK və EO kristalın strukturu yığılmışdır. Bu strukturda infraqırmızı işıq (0.9-1.5) mkm koherent görünən işığa çevrilir. Həssaslığın astana qiyməti $5\cdot 10^{-4}$ Vt/sm^2 ölçülmüşdür ki, bu da nəzəri qiymət tərkibindədir.

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КОГЕРЕНТНЫЙ ИК-ПРЕОБРАЗОВАТЕЛЬ НА ОСНОВЕ GaAs И $Bi_{12}SiO_{20}$

Теоретически рассмотрена модель когерентного ИК-преобразователя на основе фотопроводника (ФП) GaAs, сочлененного с электрооптическим (ЭО) кристаллом $Bi_{12}SiO_{20}$.

Оценена возможность перекачки поля под действием ИК-света из ФП в ЭО кристалл, достаточная для реализации в ЭО кристалле продольного ЭО эффекта. Исходя из параметров поля и параметров ФП и ЭО кристалла, дана оценка порога чувствительности преобразователя. На основании теоретических расчетов собрана структура ФП-ЭО кристалла, на которой реализовано преобразование ИК света (0.9-1.5) мкм в когерентное видимое. Измерен порог чувствительности на 0.9 мкм ($5 \cdot 10^{-4}$ Вт/см^2), который находится в пределах теоретической оценки.

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