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# Photodetector module of optoelectronic control systems for tracking the moving objects

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**Abstract**. An algorithm has been developed for modelling the signals of four-plane photodetector, when moving an axisymmetric light spot along its surface. The form of direction-finding characteristics of photodetector has been calculated for different schemes of illumination of sensitive surface of the detector, which are used in optoelectronic automatic control systems, in particular in the motion control systems for tracking moving objects. Some samples of specialized focusing microprism devices with the distribution of light spot in the focal plane as a central circle with a light ring at its periphery, which are made using diamond micro-cutting based on our simulation results, have been experimentally investigated.

**Keywords:** four-plane photodetector, microprismatic structure, direction-finding characteristics, modelling plane-focusing optics.

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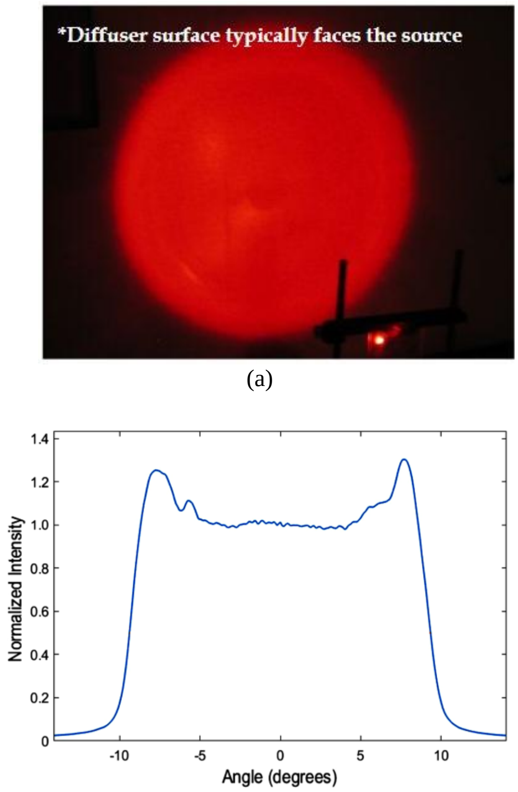
## 1. Introduction

Optical diffusers and specialized homogenizers of transmitted light beams [1] are extremely important elements in automatic control systems using four-plane photodetectors for tracking moving objects. They provide the homogenization of scattering indicatrix for light reflected from the object, which in turn guarantees the required accuracy of control systems. There are many offers for such optical elements in the market today. The widely known is a diffuser of the type EDC-15-15132-A manufactured by “Rochester Photonics Corporation” (USA), which creates a light spot in the form of a light circle with uniform illumination at the angle of scattering $\beta = 16.3$ deg. for the wavelength range $\lambda = 0.4...2.0$ µm [2]. Operation of this diffuser is illustrated in Fig. 1a, its scattering indicatrix is shown in Fig. 1b.

In recent years, the Institute for Information Recording (IIR), National Academy of Sciences of Ukraine (NASU), has proposed a new design of optical diffusers based on two-dimensional cone-shaped microrelief, which is formed on a flat rigid forming surface. Also, the plane-focusing microprism optics has been developed [3], which is very useful in optoelectronic control systems with four-plane photodetectors. In contrast to the traditional point-focusing lens systems, plane-focusing optics allows one to form in focus evenly illuminated light circle of a necessary size – the traditional lens forms in the focus a point image of the light source. This new transforming optics can replace a usual pair of optical elements “diffuser-focusing lens” in automatic control systems for tracking motion of objects. It allows one to reduce the weight and dimensions of an optical module and thus to increase the accuracy and reliability of control and monitoring of moving objects.

So, at the first stage of tracking a moving object, it is necessary to scan the space with a sufficiently wide light beam and to determine the very existence of such an object. The light reflected from this moving object is focused by a specific lens system on the corresponding photodiode matrix to determine the direction to the object. The most commonly used is the design of four-plane photodetector, similar to that shown in Fig. 2a, that is located in the focal plane of lens. A typical scheme of an optical module inherent to the control system traditionally consists of a diffuser and a lens system to form a blurred image of the object in the form of a circle on the photodiode matrix, which is most convenient for processing. This lighting scheme is shown in Fig. 2b. To accurately determine the direction to the object, the diffusers are usually used. They have a wide evenly spaced light indicatrix similar to that shown in Fig. 1a. Now the usage of plane-focusing optics [3] is considered to be more convenient.




(a)

(b)

**Fig. 1.** Operation of the optical diffuser of EDC-15-115132-A type [1] at $\lambda$ = 0.633 μm (a) and its scattering indicatrix (b).

At the second stage, it is necessary to solve the problem of automatic tracking of the position of detected object. To do this, the reflected light beam, which is focused onto the photodetector matrix as a light circle, is processed and analyzed in a certain way by the appropriate control system. This light spot should be large enough to capture the centre of the photodetector matrix, and simultaneously enough small to remain completely within the matrix area and the required range of tracking angles. In addition, it is important to know the intensity distribution within the focused spot, which provides the most accurate determination of direction. This is just the task that is analyzed in this paper.

In real conditions, a moving object is usually at hundreds meters away, and the focal length of the lens and its diameter do not exceed several tens of millimeters, so the light wave reflected from the object can be considered as a plane wave, which simplifies the calculations without significant loss of the calculation accuracy.

## 2. Algorithm of photodetector signal calculation

The direction and values of light spot offset from the centre of the matrix of square four-plane photodetectors can be calculated using the signal amplitudes ($D_1$–$D_4$) for each of these four photodiodes, provided that the light spot hits all the photodiodes simultaneously. Obviously, the total matrix signal $J$ from the illuminated object in the vertical and horizontal planes is calculated, respectively, by using the following formulas:

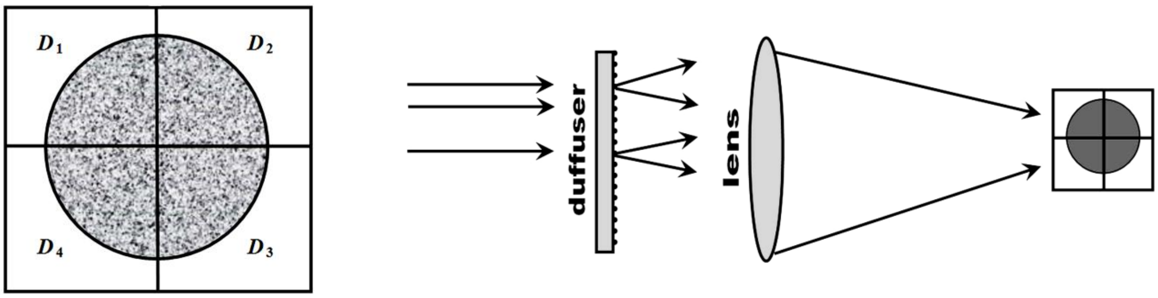
$$J_V = \{D_1 + D_2 - (D_3 + D_4)\},$$
$$J_H = \{D_2 + D_3 - (D_1 + D_4)\}. \qquad (1)$$

The signals of each photodiode $D_1$, $D_2$, $D_3$ and $D_4$ are proportional to the flux of light energy through the corresponding photodiode and are calculated as an integral of the power flux over the area of each photodiode. It should be noted that the signal calculated in this way (1) will depend on the distance to the moving object, because the light intensity decreases with increasing the distance. Therefore, to calculate the offset signal, it is advisable to use the normalized signals, namely:

$$J_{V0} = \{D_1 + D_2 - (D_3 + D_4)\}/(D_1 + D_2 + D_3 + D_4) = $$
$$= J_V/(D_1 + D_2 + D_3 + D_4),$$

$$J_{H0} = \{D_2 + D_3 - (D_1 + D_4)\}/(D_1 + D_2 + D_3 + D_4) = $$
$$= J_H/(D_1 + D_2 + D_3 + D_4). \qquad (2)$$

These normalized signals $J_N$, calculated in accord to (2), will not depend on the distance to the object, but only on the angle of the beam offset θ (the so-called tracking angle θ) relative to the initial direction of the beam.




(a) (b)

**Fig. 2.** Four-plane photodetector matrix (a) and typical optical lighting scheme (b) with a photodiode matrix.

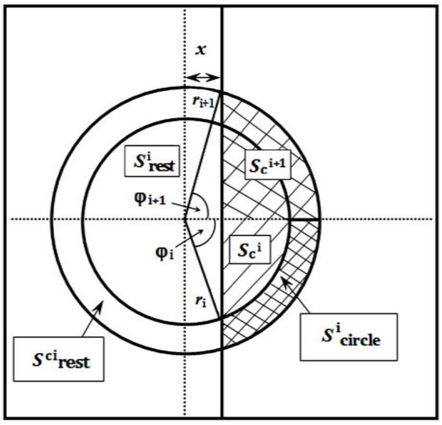



**Fig. 3.** Scheme of light spot movement along the surface of a four-plane photodetector.

To simplify the problem of forming the photodetector signal $J_N(\theta)$ depending on the tracking angle θ, let us consider the case of moving light spot along the surface of a four-plane photodetector in only one horizontal direction (Fig. 3). The angle of offset θ of the light spot from the centre of sensitive plane in the photodetector matrix is now replaced by the displacement distance $x$. It is clear that the difference signal value $J(x)$ in this case will depend on the value of $x$: $J(x) = S^i_{rest} - S^i_c$, where $S^i_{rest}$ and $S^i_c$ are the areas of the light spot to the left and to the right of the chord with $x$ coordinate, respectively.

For the case of a round light spot with the radius $r_i = r$ (case $A$), the area of the circle $S^i_c = S_c$ for the value of the chord $x = r\cos\varphi$ can be calculated as the double difference of the area of the sector with the angle $\varphi_i = \varphi$ and the corresponding triangle formed by the radius $r$ and chord at a distance $x$ from the centre. That is:

$$S_c = r^2(\varphi - \sin\varphi\cos\varphi),$$

$$S_{rest} = \pi r_i^2 - S_c = r^2(\pi - \varphi + \sin\varphi\cos\varphi).$$

Thus, the signal

$$J_A(x) = S_{rest} - S_c = \pi r^2 - 2r^2\varphi + 2r^2\sin\varphi\cos\varphi \ . \qquad (3)$$

When dividing the relation (3) to $\pi r^2$, we obtain the final expression for the calculation of the signal from the photodetector $J_N(x)$ normalized per unity:

$$J_N(x) = 1 - 2\varphi/\pi + 2(\sin\varphi\cos\varphi)/\pi \ . \qquad (4)$$

The plot of dependence (4) is shown in Fig. 4 (curve *1*).

For a light spot in the form of a ring of the radii $r_1$ and $r_2$ ($i = 1$, case $B$), the area of the circle $S_{circle1}$ for $x = r_1\cos\varphi_1 = r_2\cos\varphi_2$ (Fig. 3) can be calculated as the difference of the double area of two segments, the segment area – as the difference of the corresponding sector and the triangle formed by the chord with the coordinate $x$ and radii $r_1$ and $r_2$. That is:

$$S_{c1} = r_1^2(\varphi_1 - \sin\varphi_1\cos\varphi_1),$$

$$S_{c2} = r_2^2(\varphi_2 - \sin\varphi_2\cos\varphi_2),$$

$$S_{circle1} = S_{c2} - S = r_2^2(\varphi_2 - \sin\varphi_2\cos\varphi_2) - r_1^2(\varphi_1 - \sin\varphi_1\cos\varphi_1),$$

$$S_{rest1} = \pi\left(r_2^2 - r_1^2\right) - S_{circle1} \ . \qquad (5)$$

Accordingly:

$$J_B(x) = S_{rest1} - S_{circle1} = \pi\left(r_2^2 - r_1^2\right) - 2S_{circle1} \ .$$

When dividing the relation (5) to $(1/\pi r^2)$, we obtain the final expression for the signal from photodetector $J_N(x)$, normalized per unity:

$$J_N(x) = \left\{(r_2/r_1)^2 - 1\right\} - 2(r_2/r_1)^2(\varphi_2/\pi) + 2(r_2/r_1)^2(\sin\varphi_2\cos\varphi_2)/\pi + 2\varphi_1/\pi - 2(\sin\varphi_1\cos\varphi_1)/\pi. \qquad (6)$$

We call this dependence $J_N(x)$, obtained by moving the light spot perpendicular to the contact boundary of the planes $(D_1 + D_4)$ and $(D_2 + D_3)$, as the direction-finding characteristic of the control system in the zero phase (phase $\phi = 0$ deg.). The movement of light spot along the diagonal of photodetector matrix corresponds to the phase $\phi = 45$ deg.

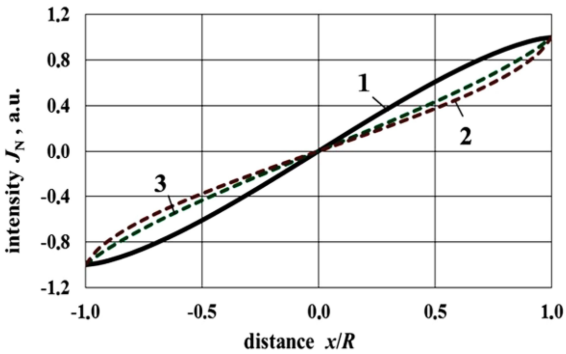



**Fig. 4.** Calculated direction-finding characteristic for the case $A$, movement of the light circle (*1*), and the case $B$, movement of the light ring (*2*, *3*).

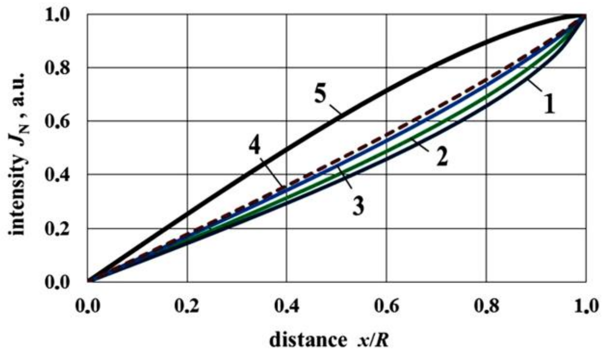



**Fig. 5.** Calculated direction-finding characteristics for the different ratios $r_2/r_1$ of light ring radii: 1.05 (*1*), 1.15 (*2*), 1.5 (*3*), 2.0 (*4*), circle (*5*).

**Table**. Parameters for calculating the direction-finding characteristics.

| $r_2/r_1$ | 1.05 | 1.10 | 1.15 | 1.30 | 1.50 | 2.0 |
|---|---|---|---|---|---|---|
| $(r_2/r_1)^2 - 1$ | 0.103 | 0.21 | 0.323 | 0.68 | 1.25 | 3.00 |
| $2(r_2/r_1)^2$ | 2.205 | 2.42 | 2.645 | 3.38 | 4.50 | 8.00 |

Results similar to those calculated using the expression (6) for the phase $\phi = 0$ deg. can be also obtained by modelling the process of moving the axisymmetric light spot along the surface of the four-plane photodetector for the phase $\phi = 45$ deg.

Specific calculations of direction-finding characteristics are convenient to perform for a certain ratio of two radii of the ring $r_2/r_1$ (Fig. 3). Thus, we can get the analytical dependence of normalized signal from the photodetector for the distance $x$, *i.e.*, the theoretical direction-finding characteristic $J_N(x)$ for the linear offset $x$. Parameters $(r_2/r_1)^2 - 1$ and $2(r_2/r_1)^2$ for different ratios of two radii $r_2/r_1$, which are needed to calculate the values $J_N(x)$ for the phase $\phi = 0$ deg., are given in the table.

Figs 4 and 5 show the plots of functions (6) for some ratios of radii $r_2/r_1$, which are obtained for the phase $\phi = 0$ deg. They illustrate the possibility of varying the nature of the direction-finding characteristics by changing the width of the light ring $\Delta r = r_2 - r_1$.

Thus, the characteristic for the ratio $r_2/r_1 = 1.05$ is shown in Fig. 4 (curve *2*) and in Fig. 5 (curve *1*); the characteristic for $r_2/r_1 = 1.15$ is shown in Fig. 5 (curve *2*); for $r_2/r_1 = 1.5$ the values $J_N(x)$ are shown in Fig. 4 (curve *3*)

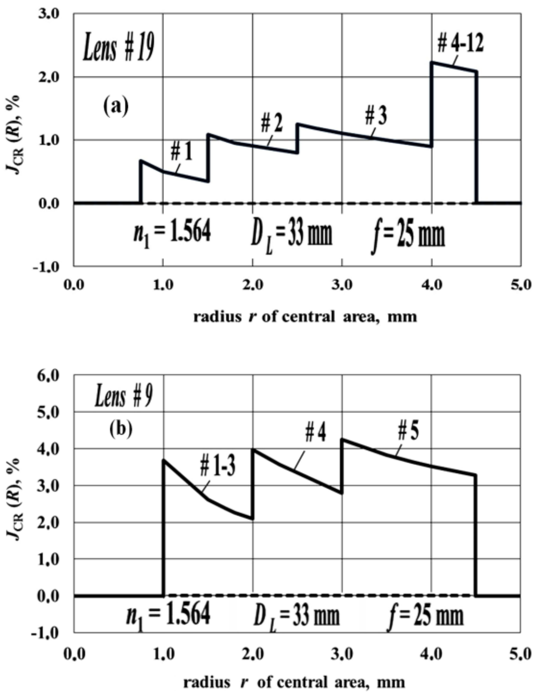



**Fig. 6.** The focus optimization scheme of the lens # 19 with the focus $f = 25$mm, which forms a light circle with an additional ring at the periphery of $r_2/r_1 \approx 1.15$ (a), and the scheme SFO for the traditional lens # 9, which forms only a light circle (b).

and in Fig. 5 (curve *3*); for $r_2/r_1 = 2.0$ the plot of function (6) is shown in Fig. 5 (curve *4*). To compare the calculated data obtained for cases *A* and *B*, Fig. 5 (curve *5*) also shows the direction-finding characteristic for the case *A* (the movement on the surface of the matrix of a light circle of radius $r$).

The direction-finding characteristics calculated for the case *B* (ring movement) in Fig. 5 have an inclination (curves *1–4*) that is opposite to the inclination of curve *5* for the case *A* (circle movement). Obviously, the combination of curves *5* and *1*, *i.e.*, moving on photodetector surface a light circle with a bright light ring at the periphery with a ratio of radii $r_2/r_1 = 1.05$, enables to obtain almost linear direction-finding characteristics, which is optional for usage in the real optoelectronic control systems.

### 3. Creation and experimental research of transforming optics

The algorithm [3] for modelling the parameters of transforming microprismatic plane optics allows forming a light circle of the required radius $r$ with almost homogeneous light distribution for a lens with a necessary light diameter $D_L = 2R_L$. To achieve this effect, an unlit "dark" area of radius $r_{0k}$ is created in the centre of the image in the lens focal plane, and the process of light beam narrowing is taken into account by applying the appropriate correction of the prismatic zones width $\Delta R_k$. Also, optimization of the focusing process is applied, which means that corresponding areas of the lens with radii $R_k$ direct the refracted light beams into certain annular areas of the image with the width $r_{0k+1} - r_{0k}$.

In addition, to be able to use the method of diamond micro-cutting [4, 5] under the practical manufacture of microprismatic optics, the refractive zones of the lens with the width $\Delta R_k$ are created from several separate prismatic elements identical in their refractive angle $\alpha_k$ and the relief depth $h_k$, with the linear size 1.2...1.5 mm [3], which is determined by the size of cutting edge of the available diamond tool.

For creating a diffuser with the lens radius $R_L = 20$ mm, which simultaneously forms in the focal plane a light circle of the radius $r$ and a light ring of the radii $r_2$ and $r_1$ with the necessary ratio $r_2/r_1 = 1.05$, we will modulate a lens that forms a uniformly illuminated circle with the radius $r = r_{0k+1} = 4.5$ mm of an additional light ring at the periphery of radius $r_{0k} = 4.3$ mm and of the width $r_{0k+1} - r_{0k} = 0.2$ mm.

It should be noted that the change in the ring width ratio within the range $r_2/r_1 = 1.05...1.15$ has a little effect on the direction-finding characteristics (see Fig. 5, curves *1* and *2*), but the practical manufacture of the lens is easier for $r_2/r_1 > (1.1...1.2)$. So, really a lens was modulated that forms in the centre of focal image a ”dark” area of the radius $r_0$ = 0.75 mm and an illuminated area of the radius $r$ = 4.5 mm as well as a light ring at the periphery with the outer radius $r_{0k}$ = 4.0 mm and the ring of $r_{0k+1} - r_{0k}$ = = 0.5 mm, *i.e.*, the ratio $r_2/r_1 \approx 1.15$ was implemented.

The scheme of focus optimization for such a lens is shown in the following Fig. 6a: microprism zones are modulated so that the first 3 zones of lens # 1–3 form the image of the radius $r$ = 4.5 mm as well as the radii of “dark” areas $r_{0k}$ = 0.75, 1.5 and 2.5 mm, respectively. The following zones of the lens # 4–12 focus the refracted rays into an additional light ring of the radius $r = r_{0k+1}$ = 4.5 mm and of the width $r_{0k+1} - r_{0k}$= 0.5 mm. We will call this scheme of focusing optimization as SFO: 1.5–2.5–4.0 (9). Due to the process of diffraction [6, 7] and to the diffuse scattering of refracted rays on the relief defects, always presented in manufactured lens, for such an optimization scheme an almost uniformly illuminated image of the radius $r$ = 4.0 mm and a light ring with $r_{0k+1}$= 4.5 mm is formed in the lens focus.

For comparison, Fig. 6b shows also the scheme of optimization SFO: 1.0(3)–2.0–3.0 to create the traditional lens-concentrator # 9 of 5 microprism zones # 1–5 [3].

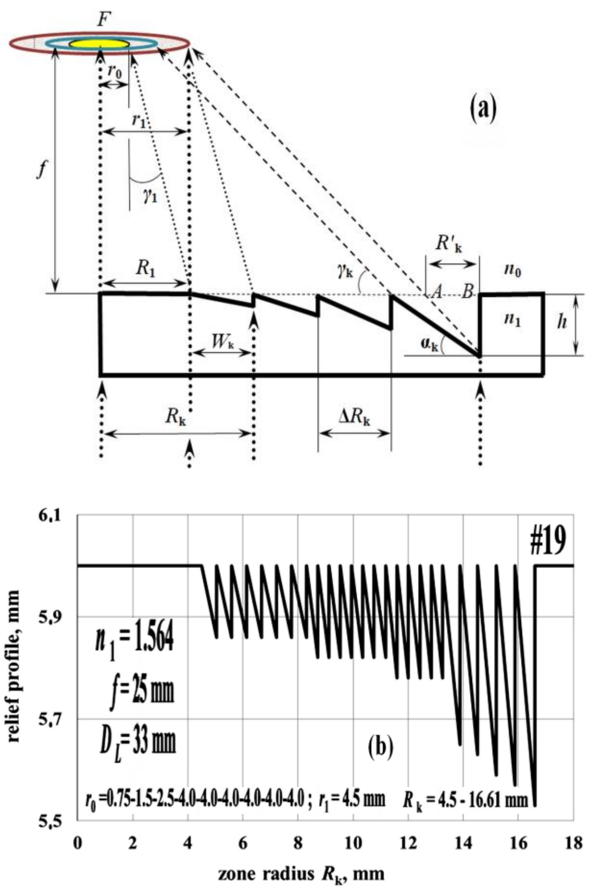



**Fig. 7.** Structure of microrelief of lens # 19 with a focus of $f$ = 25mm, which forms a light circle with a ring at the image periphery for the ratio $r_2/r_1$ = 1.15: (a) scheme of profile modelling; (b) calculated structure of the relief.

This lens forms in focus a uniformly illuminated light circle of the radius $r$ = 4.5 mm with a dark area in the centre of radius $r_0$ = 1.0 mm.

Thus, one can create a lens-concentrator that forms in the focus a uniformly illuminated circle with a light ring at the periphery. When moving such a light spot along the surface of a four-plane photodetector matrix, one can expect a certain dependence of the detector signal on the value of the spot offset from the centre of the light-sensitive zone of detector matrix.

The scheme of light beam focusing for a new transforming lens is shown in Fig. 7a. The algorithm for calculating the angles of refraction $\alpha_k$ and radii $R_k$ of microprism zones of the lens with a nominal pitch $W$ and the depth of relief $h_k$, as well as light transmission $\tau_S$ are similar to those proposed in [8]. The refractive indices $n_1(\lambda)$ were used from the data [9]. Modelling of parameters was performed for polycarbonate ($n_1$ = 1.564) for the wavelength $\lambda$ = 1.064 µm, which is most often used to illuminate the moving objects in real tracking systems.

The calculated structure of the relief for above lens-concentrator # 19 for $R_k$ < 16.6 mm is shown in Fig. 7b.

For the lens-concentrator # 19 a fairly high light transmission $\tau_S$ was obtained even up to the light diameter $D_L \approx 40$ mm, the calculated values $\tau_S$ (%) and the contribution $\omega_S$ (%) to the transmitted light flux for each zone of the lens depending on the radii $R_k$ are shown in Fig. 8.

The general view of the real lens-concentrator # 19, made by diamond micro-cutting, is illustrated in Fig. 9a.

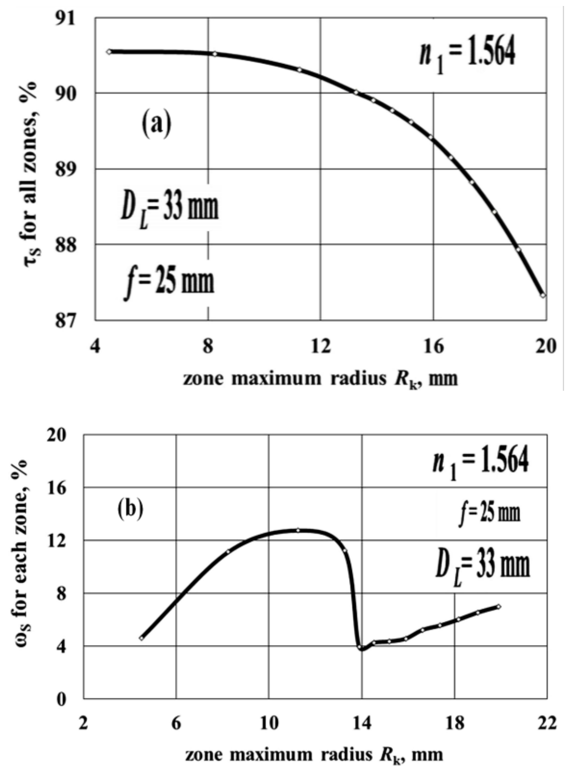



**Fig. 8.** Light transmission $\tau_S$ of all zones (a) and the contribution of each zone (b) of radii $R_k$ to total light flux for the lens concentrator # 19 of focus $f$ = 25 mm.

In Fig. 9b the image of the transmitted and transformed light beam in the lens focus is shown, which was obtained in the experimental study of this lens using a collimated laser beam of the wavelength $\lambda = 0.532$ μm and beam diameter $D_S = 60$ mm. The optical scheme of this experimental setup is discussed in detail in [3].

The direction-finding characteristics $J_N(\theta)$ for the four-plane photodetector and a certain angle $\theta$ of concentrator rotation to the direction of light beam were investigated using a special setup with an optical module that can be rotated in the light beam to the desired angle $\theta$. A round photodetector of the type FD14M with the photosensitive surface diameter $D_D = 16$ mm was used. The control-measuring module of this setup allows calculating the modules $J_N(\theta)$ by the signals ($D_1 - D_4$) of the photodetector by using the expression (2). The scheme of the experimental setup is shown in Fig. 10, in which the dotted line indicates the optical module.

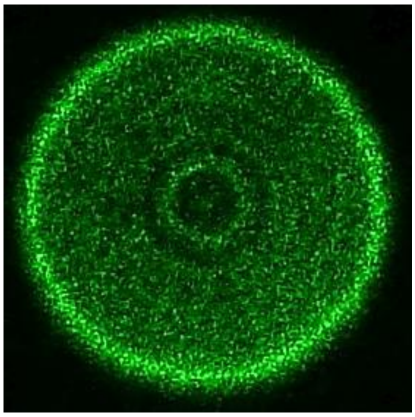
Next Fig. 11 illustrates some obtained direction-finding characteristics of the manufactured concentrators for the infrared zone of the spectrum with the wavelength $\lambda = 1.064$ μm. For clarity, the characteristics are shown when turning the lens in the light beam at an angle $\theta$ in both directions from zero position, *i.e.* for positive and negative turning angles $\theta$. The negative modulus values $J_N(\theta)$ should be understood as the values obtained by expression (2) for negative angles $\theta$. All the investigated lens-concentrators # 8, # 10, # 19 form in the focal plane a light circle of the same diameter $d_1 = 9.0$ mm. The lenses # 8, # 10 form only a light circle, concentrator # 19 forms a circle with a light ring at the focal image periphery.

Obviously, since the focal length of the lens $f$ increases, the maximum turning angles $\theta_{max}$ decrease, because the angle $\theta_{max} \approx \mathrm{arctg}\,(R_D - 0.5d_1/f)$.

Calculations showed that for a photodetector with the radius $R_D = 8.0$ mm and for the light spot of the diameter $d_1 = 9.0$ mm, the area of linear growth of the signal $J_N(\theta)$ for a focal length $f = 41$ mm corresponds to the maximum turning angle $\theta_{max} \approx 4.88$ deg. With a further increase in the angle $\theta$, the zone of slower growth of the signal $J_N(\theta)$ is extended to the value of $\theta \approx 6.26$ deg. For larger angles of lens turning, a zone of the incidence of photodetector signal $J_N(\theta)$ begins. For $f = 28$ mm, the signal $J_N(\theta)$ will increase linearly for the angles $\theta < 7.12$ deg. With further increasing the angle $\theta$, the signal $J_N(\theta)$ slowly increases up to $\theta \approx 9.13$ deg., after which the signal $J_N(\theta)$ decreases. For the focal length $f = 25$ mm, the signal $J_N(\theta)$ will increase linearly in the region $\theta < 7.96$ deg. Since the angle $\theta$ increases further, the signal $J_N(\theta)$ increases up to $\theta \approx 10.21$ deg., after which the value $J_N(\theta)$ decreases.

The obtained data showed that the maximum turning angles $\theta_{max}$ for the different focal lengths $f$ for the really measured direction-finding characteristics $J_N(\theta)$ practically coincide with the above theoretical estimates. Thus, for the lens concentrator # 19 (circle + ring, ratio $r_2/r_1 = 1.15$) of focus $f = 25$ mm (Fig. 11) the direction-finding characteristic $J_N(\theta)$ as compared to the traditional transforming microprism optics (only circle), is more linear, and has a greater maximum turning angle $\theta$, which is $\theta_{max} \approx 10.0$ deg., which totally meets the theoretical expectations.

(a)



(b)

**Fig. 9.** General view (a) and light image in focus (b) for the lens-concentrator # 19 of the focus $f = 25$ mm.

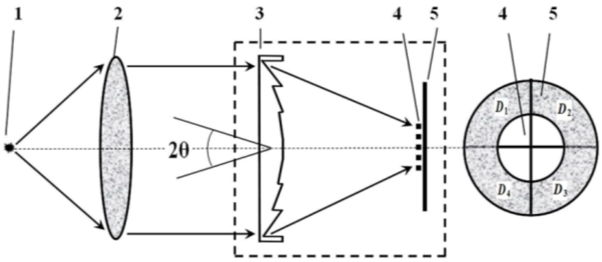



**Fig. 10.** Optical scheme of the experimental setup for studying the direction-finding characteristics: *1* – light source, *2* – collimator lens, *3* – investigated lens-concentrator, *4* – light spot in the plane of sensitive elements, *5* – quadrant photo-detector with elements # 1–4 for turning the photodetector module, $\theta$ is the angle of lens turning to the direction of light beam.

Thus, the computational and experimental data confirmed that to create automated optoelectronic control systems for tracking the moving objects, the best variant to focus the object image on the sensitive surface of photodetector matrix to obtain the direction-finding characteristics $J_N(\theta)$ is to use a lens-concentrator that forms a light circle in the focal plane with the light ring

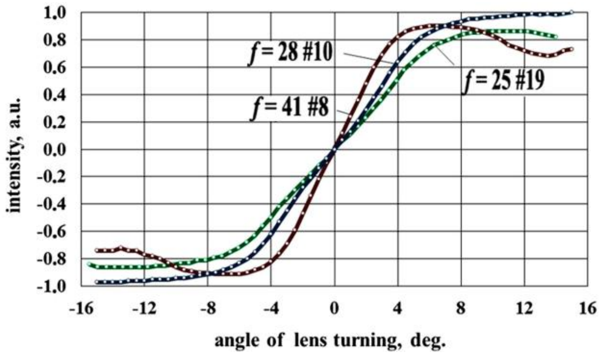



**Fig. 11.** Real direction-finding characteristics for lenses # 10 ($f$ = 27.5 mm), # 8 ($f$ = 41.0 mm) and # 19 ($f$ = 25.0 mm).

at its periphery. The obtained direction finding characteristic $J_N(\theta)$ in this case is almost linear.

To expand the linearity zone of such characteristics, it is advisable to use lenses with the smallest possible focal length $f = 15…25$ mm. In this case, the linearity zone of the direction-finding characteristic $J_N(\theta)$ in the angular space increases to the values of the turning angles $\theta = 11.0...13.0$ deg. However, due to enlarging in such lens-concentrator the microprism refractive angles $\alpha_k$ to the critical values $\alpha_{k\,\max}$ [3], the light transmittance $\tau_S$ decreases for the lenses with a small focal length $f$. Therefore, the maximum light diameter of this lens is also reduced to the values $D_L = 30…35$ mm.

## 4. Conclusions

For creating the optimal optoelectronic automated control systems for tracking the moving objects to obtain the direction-finding characteristics, the best variant for the focusing of the object image onto the sensitive surface of a photodetector matrix is the usage of a lens-concentrator, which forms in the focus a light circle with a ring at its periphery.

The algorithm of mathematical modelling of the electronic output signal was developed for optical module, when moving the light spot as circle and ring along the surface of the detector matrix. The set of calculations of geometric parameters of this specialized microprism lens-concentrators of light beams was carried out.

Experimental samples of specialized lens-concentrators were manufactured from the optical polycarbonate by the diamond micro-cutting method according to the results of modelling. The experimental study of optical and lighting characteristics of these samples showed the complete compliance of the experimental data with the obtained theoretical characteristics.

The proposed special lens-concentrators that transform the refracted light beams can be effectively used in optical modules of automatic tracking systems for moving objects instead of the traditional pair of elements "diffuser–focusing lens". Now the optimal photodetector module of automatic control systems can consist of this new plane-focusing lens-concentrator, without any diffuser, and a four-plane photodetector matrix placed in the lens focus.

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**Фотодетекторний модуль оптоелектронних систем контролю для відстеження рухомих об'єктів**

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**Анотація**. Розроблено алгоритм моделювання сигналів чотириплощинного фотодетектора при переміщенні вісесиметричної світлової плями на його поверхні. Розраховано форму пеленгаційних характеристик фотоприймача для різних схем освітлення чутливої поверхні детектора, які використовуються в оптико-електронних системах автоматичного керування, зокрема в системах керування рухом для відстеження рухомих об'єктів. Експериментально досліджено деякі зразки спеціалізованих фокусуючих мікропризмових пристроїв із розподілом світлової плями у фокальній площині у вигляді центрального кола зі світловим кільцем на його периферії, які виготовлені методом алмазного мікроточіння за результатами нашого моделювання.

**Ключові слова**: чотириплощинний фотодетектор, мікропризмова структура, пеленгаційна характеристика, моделювання плоско-фокусуючої оптики.