

x	0.0001	0.6274	2.5573	5.9640	11.2094
y	0.0400	5.0083	10.0225	15.0249	20.0064
C	0.0020	0.2503	0.5233	0.8488	1.2783
f'	-0.002	-0.147	-0.562	-1.235	-2.033

$$1. \frac{x_k - x_{k-1}}{y_k - y_{k-1}} = C_k,$$

$$2. \operatorname{tg} u'_{1k} = C_k \frac{\sqrt{n^2(1+C_k^2) - C_k^2} - 1}{\sqrt{n^2(1+C_k^2) - C_k^2} + C_k^2}$$

$$3. \sin u'_{2k} = n \sin u'_{1k}, \quad (5)$$

$$4. s'_{F'} = [y_k - (d - x_k) \operatorname{tg} u'_{1k}] \operatorname{ctg} u'_{2k}.$$

In accordance with the assumption the focus distance $s'_{F'}$ is constant for all the coordinates x , y which satisfy the equation (3). It has been obtained $s'_{F'} = 29.385$ mm.

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Magneto-Optic Modulator Using the Monocrystal YIG

The paper contains a description of a modulator giving large rotation angle of the polarization plane. Some results obtained when modulating laser beam of $1.15 \mu\text{m}$ wavelength are also given.

The magneto-optic modulation is based on the mutual interaction of optical radiation with an external magnetic field in materials, in which the optical properties depend on the applied magnetic field intensity. For modulators of the discussed type, the magneto-optic effects of Faraday and of Kerr are of practical application. The present paper deals with the first of these effects.

The Faraday effect known since 1845, has awoken new interests recently. It is due to the new materials giving large possibilities in measuring technique [2, 4, 5] and application of the effect to the investigations of semiconductors [10, 11]. Especially good proper-

ties for the design of modulators exhibits granate $\text{Y}_3\text{Fe}_5\text{O}_{12}$. Since the Faraday effect of this granate is rather large, this material was used for construction of the modulator described in the present paper.

As an optically active device a plane-parallel plate of 10 mm thickness, cut out from a single crystal of $\text{Y}_3\text{Fe}_5\text{O}_{12}$, free of impurities was used in the modulator. The crystal plate was placed in a solenoid producing magnetic field. The modulating wavelength was chosen to $1.15 \mu\text{m}$, for two reasons. The first one is the pronouncement of magneto-optical properties at this wavelength, for there lies near by the absorption edge of radiation, the second reason is the easy use of the line when working with the He-Ne laser. The transmittance of the beam through the specimen is about 0.1; thus the light intensity can produce effects which are easily measured.

The dependence of the rotation angle α of the polarization plane on the magnetic field intensity produced by the electric current I flowing through

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2. The problem of glass selection is reduced to the choice of any glass of well-known parameters. In particular the index of refraction for the chosen wavelength has to be known to a good accuracy. The glass selected was BK 516-64 (producer J. W. O. Poland, melt number 13083, Standard PN 57/6862-06, $n_d = 1.51670$, $n_C = 1.51423$, $n_F = 1.52225$, $v_d = 64.4$). The refraction index for the length $\lambda = 1.06 \mu\text{m}$ was evaluated from the dispersion formula

$$n = n_0 + \frac{C}{\lambda - \lambda_0} \quad (1)$$

where n_0 , λ_0 and C are some constants characterizing the glass. The calculations resulted in the following values $n_0 = 1.49883$, $\lambda_0 = 159.3$, $C = 7.6537$ and $n = 1.50732$.

3. In accordance with the accepted assumptions the f -number is equal to 1. Hence, assuming the acting diaphragm to be as high as 40 mm we obtain for the focal length $f' = 40$ mm. The other parameters characterizing the lens are determined by the paraxial optics formulae

$$\Delta_k(na) = \frac{h_k \Delta h}{r_k}, \quad h_{k+1} = h_k - d_k a_{k+1},$$

$$s'_{F'} = \frac{h_p}{a_p}, \quad \sigma'_{H'} = s'_{F'} - f' \quad (2)$$

where a_k denotes the angles between the light ray and the optical axis of the system, h_k denotes the intersection height of the ray with the boundary surfaces of the media, d_k is a corresponding curvature radius, f' denotes the focal length, $s'_{F'}$ is the focal distance and $\sigma'_{H'}$ is the principal point distance.

In our case $k = 1, 2$, $p = 2$, $n_1 = n'_2 = 1$, $n_2 = n$ and $r_2 = \infty$. In particular for $d = 0$ (an infinitely thin lens) the curvature radius of the aspherical surface in the paraxial region has been calculated with the help of an arhythmometer giving $r_1 = 20.293$ mm. For $d = 16$ mm (the thickness is relatively big to avoid possible deformations due to pressure difference in the object and image spaces) it has been obtained: $s'_{F'} = 29.385$ mm, $\sigma'_{H'} = -10.615$ mm, $s_F = -40.000$ mm and $\sigma_H = 0$.

4. A parametric equation of the aspheric surface profile is to be determined for the reversed pass of the light rays [4]. The requirements posed to the imaging quality (a perfect correction of the spherical aberration of a parallel monochromatic light beam) are equivalent to the condition of preserving the focal distance. Defining $a = \sin u'_2$ (u'_2 being an aperture angle in the image space) we obtain the aspheric surface profile equation in the form

$$\frac{dx}{dy} = \frac{a}{\sqrt{n^2 - a^2 - 1}},$$

$$y = (d-x) \frac{a}{\sqrt{n^2 - a^2}} + s'_{F'} \frac{a}{\sqrt{1 - a^2}}. \quad (3)$$

5. Internal approximation. The numerical method of calculation consists in evaluating the profile of the aspherical surface of the lens point after point. When changing successively the parameter a we estimate the corresponding values of x and y . The programme of calculation is determined by the following formulae:

1. $a_k = \sin u'_{2k}$
2. $A_k = \frac{a_k}{\sqrt{n^2 - a_k^2}}$,
3. $B_k = A_k d + s'_{F'} \frac{a_k}{\sqrt{1 - a_k^2}}$,
4. $C_k = \frac{1}{\frac{1}{A_k} - \frac{1}{a_k}}$, (4)
5. $D_k = C_k y_{k-1} - x_{k-1}$,
6. $M_k = 1 + A_k C_k$,
7. $x_k = \frac{C_k B_k - D_k}{M_k}$,
8. $y_k = -A_k x_k + B_k$

where $k = 1, 2, 3, \dots$

In accordance with the boundary conditions for the system of equations (3) it is assumed for the initial values of x and y the following: $x_0 = 0$, $y_0 = 0$ (for $a_0 = 0$).

6. The calculations have been made on an ODRA-1204 computer. The relation $y = F(x)$ may be determined (by tabularising) with the arbitrary accuracy. For example, we give in the table the coordinates of several points of an aspheric surface profile for the lens and the deviation from the Abbe sine condition

$$\delta f' = \frac{y}{a} - f'.$$

7. For the control computing the corresponding values of x and y are used together with the respective $C = \frac{dx}{dy}$. The following formulae are to check the results obtained

the modulator winding, was measured for the beam emitted by the He-Ne laser, LG 4B type, working on a wavelength $1.15 \mu\text{m}$, power 0.5 mW , mode TEM_{00} .

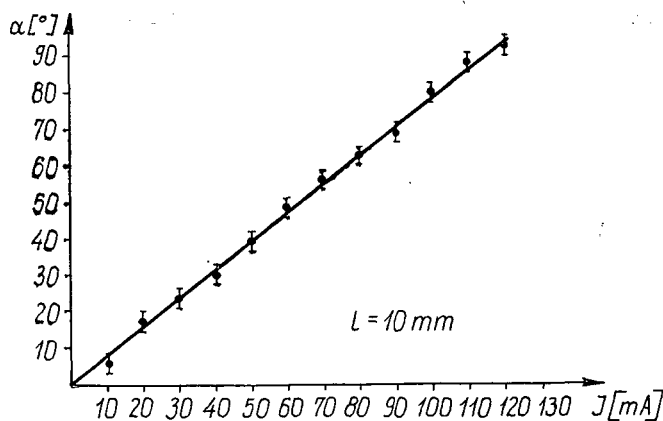


Fig. 1. The dependence of the rotation angle of the polarization of the incident light on the electric current of modulator

The obtained results are shown in Fig. 1.

The static characteristics of the modulator is described by the relation

$$I_{out} = I_{in} \cos^2(\Theta + \alpha) = \frac{1}{2} I_{in} [1 + \cos 2(\Theta + \alpha)]$$

$$= \frac{1}{2} I_{in} (1 - \sin 2\alpha) \text{ for } \Theta = \frac{\pi}{4} \quad (1)$$

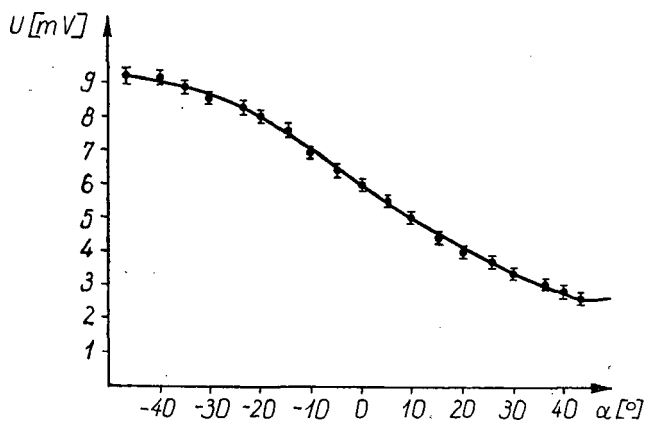


Fig. 2. The static characteristics of modulator

where: I_{in} is the intensity of the incident light, I_{out} is the intensity of the transmitted light, α is the rotation angle of the polarization plane, Θ is the angle between the analyzer and the polarization plane of the laser beam.

The static characteristics determined for our modulator is shown in Fig. 2.

The formula (1) for magnetic field changing sinusoidally in time takes the form

$$I_{out} = \frac{1}{2} I_{in} [1 - \sin(2\alpha_0 \sin \omega t)]$$

$$= \frac{1}{2} I_{in} \left[1 - \sum_{i=0}^{\infty} I_{2i+1}(2\alpha_0) \sin(2i+1)\omega t \right] \quad (2)$$

where I_{2i+1} is the Bessel function of the $2i+1$ order. With the constant describing the modulator $2\alpha_0 < \pi/4$ the expression (2) takes the form

$$I_{out} \approx \frac{1}{2} I_{in} [1 - I_1(2\alpha_0) \sin \omega t]. \quad (3)$$

A linear modulation for frequencies smaller than 20 kHz and for rotation angle values near $\pi/4$ was achieved, if condition $2\alpha_0 < \pi/4$ was fulfilled.

The upper limit of frequency can be increased by decreasing inductivity of the solenoid. The parameters of the modulator achieved so far give possibilities for various applications. For instance, the device was used in dynamic ellipsometry, where polarizing parameters changing in time were measured. The modulator is very suitable for such measurements. It seems that the described modulator will be very convenient in refractometry, for the cutting of diffraction grating (3), for measurement of electric current without inertia, can be of use in the high voltage technique.

It should be said that in many applications there is no need to have large rotation angle of the polarization plane. In such cases it is possible to diminish the thickness of the modulator plate; the modulated beam can be fed e. g. by an incandescent lamp, that is emitting near infrared radiation as well.

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