Hybrid integrated-optical devices and elements, methods and the results

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1. Introduction

Manufacturing of small-sized integrated-optical precision angle measurement devices for remote control of spatial position of reference (sensitive) elements with the use of glasses and technologies mastered in production is the actual problem in geodetic and angle measurement devices, spatial orientation systems, communication technique as well as in tasks connected with control of laser parameters, and with adjustment problems [1 ÷ 5]. Determination of properties, fields of application, development and manufacture of small-sized integrated-optical angle measurement devices are possible by carrying out the systhematic investigations of integrated optics elements, included which these devices (geodetic lens and another focusing element, waveguide, coupler, emitter, photodetector) as well as of output characteristics of the device. The experriencein works with different interfaces, and data bases permitted us to develop the structure of an universal measurement device, which provide the automation of investigations. The information support components are the modules of developed system which comprises the desription of standard procedures, mathematical models and other information from unified system data base. Using the values of this data base is provided with the base envelope of the expert system [6].

2. Devices and investigation methods

The device consist of electronic data processing optical and electronic units which are developed with account of the special requirements of the customers. The optical unit is made in form of the hybrid integrated – optical circuit (OIC) comprising the receiving and transmitting modules which are built on either separate or common substrates. Fig. 1 shows the variant of the optical unit modification with radiation coupling element. The special design of the coupling prism *4* providesd with its one part the radiation coupling in and off waveguide, respectively.

The optical unit is produced on the substrate made of the standard optical material such as K-8 glass. The geodetic lenses itself represent the spherical surfaces with the radius *R* with edges smoothed by conjugated toroidal surface to reduce the radiation losses. A method of deep grinding and polishing widely used in optical industry on standard grinding and polishing machines is adapted for manufacturing such mentioned lenses. The waveguide is produced using the industry mastered method of K^+-ion thermodiffusion from KNO_3 melt at temperature 360°C with ion exchange duration of 3 hours. The waveguides for near and middle infrared range produced by K^+-ion exchange method in K515 glass have been also used in this work. The As_2S_3 film waveguides on the KI glass substrate are discussed too. In order to determine the basic waveguide parameters (mode structure and effective mode refractive index) the known methods based on the measurements of waveguide mode synchronization angles using prism coupling devices, goniometers and the appropriate laser have been used.

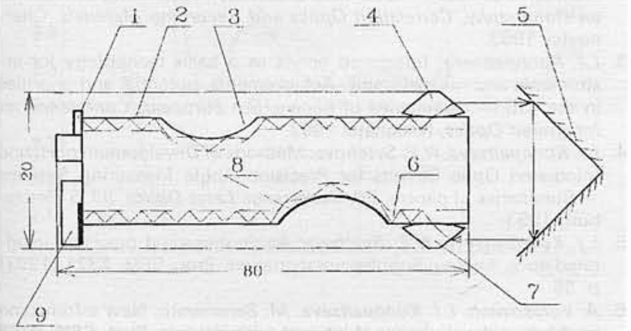


Fig 1. Hybrid integrated optical device

The measurement accuracy is high enough and it is determined by means of measurement error of synchronization angles of order of $10^{-5} \div 1 \cdot 10^{-4}$. Widely used Vencel-Cramers-Brillouine method results in error of $3 \cdot 10^{-4}$. The waveguide thickness (refractive index profiles in diffused waveguides) has been calculated using the appropriate calculation based on the effective mode refractive indices. The waveguide loss factor has bee measured by the sliding coupling prism with the use of goniometer and laser with corresponding wavelength and signal registration system. The main parameters of waveguides produced for angle measurement devices including the quality parameters of surface processing are given in Table 1.

Devices with coupling elements, especially diffraction gratings of different type (with rectangular, circular and complex ruling form as well as with sinusoidal trapezoidal, triangle or multilevel complex ruling profile with constant or variable period) [4] are used. Production of coupling elements in

Table 1

Substrate material	K-8 glass	K-515 glass	KI glass
Waveguide type	diffusion	diffusion	As_2S_3
Substrate refractive index	1.5146	1.5226	1.4576
Waveguide mode composition	3	7	4
Effective mode refractive index	1.5195 ÷ ÷ 1.5147	1.5255 (on surface)	2.232 (on surface)
Diffusion depth [μm]	4.35 ÷ 5.71	9.6	2.29
Substrate surface roughness, R_z [μm]	0.05	0.05	0.05
Losses [dB/cm]	0.2 – 0.5	< 1	2.5
Surface quality degree	I ÷ II	I ÷ II	–
Surface form deviation	1 ÷ 3, 0.5	1 ÷ 3, 0.5	–

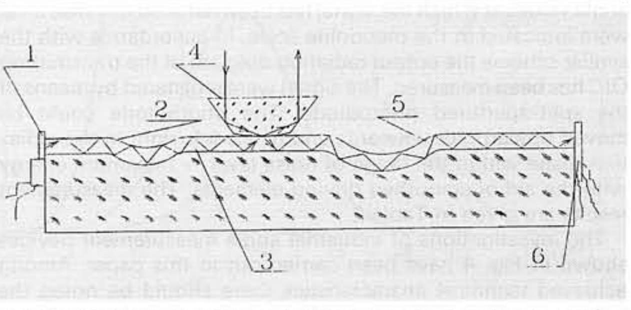
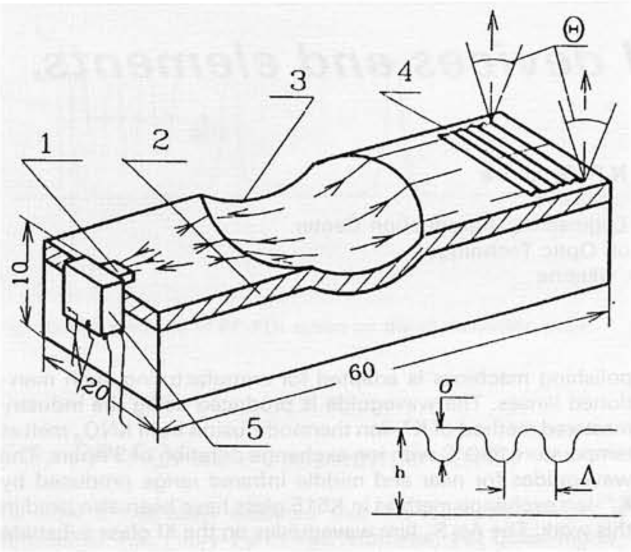


Fig 2. Hybrid transmitting-receving module with a combined inputoutput prism



Fg 3. Hybrid transmitting-receiving module with linear input-output grating

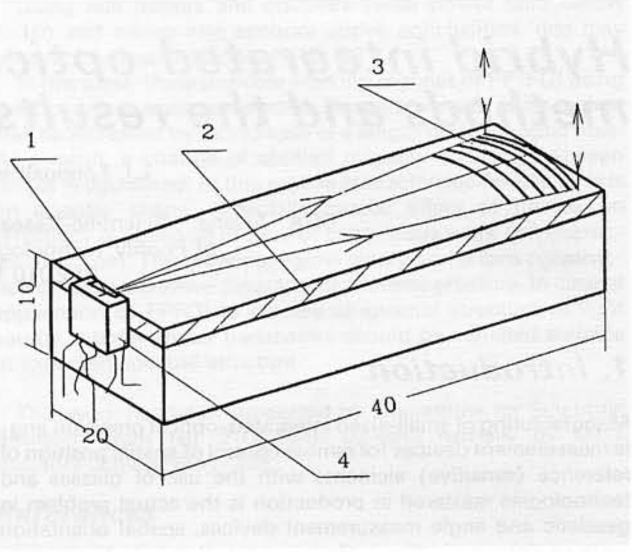


Fig 4. Transmitting-receiving module with focussing input-output grating

diffusion waveguides in K-8, K-108 and K-515 glasses with the use of ion plasma etching method (through mask being recorded in photoresistor layer) are investigated. Fig. 3 shows the receiving – transmitting module of angle measurement where the focusing diffraction coupling grating *3* is used and radiation is focused with the use of geodetic lens *3*. Fig. 4 shows the modification of receiving – transmitting module with the focusing diffraction coupling grating *3*. The main diffraction grating parameters (corrugation depth δ, grating period Λ) were measured on the base of diffraction angle corresponding to the order of light wave. Conclusion about the form of ruling in the coupling diffraction grating is presented on the base of knowledge in grating production technology. The focusing system has been tested during the coupling by diffraction (0.63 μm) by means of the typical LHN 113 laser, goniometer, horizontal microscope and eyepiece micrometer. With the aid of microscope-driving means the position of the plane of the smallest diffusion circle in the waveguide focusing element system has been evaluated visually and the circle has been measured by means of focusing the microscope onto the smallest diffusion circle. The above mentioned performances are given in Table 2. The permissible error of measurement parameters is $(6 \div 7) \cdot 10^{-3}$ μm.

The main operating parameters of IOC are the direction and halfwidth of the directivity diagram, coupling efficiency of diffraction grating, transmission factor of IOC, sensitivity etc. While measuring the field of view of the receiving OIC by means of smoothed driving elements of a rotating device the standard laser radiation has been coupled into the circuit. The coupling has been done by means of a theodolite indicating the position which corresponds to the maximum signal value received from the photodiode being a part of the receiving OIC.

Preliminary direct connection to photodiode outputs has been carried out. Using angular driving elements of a rotating device the radiation coupling direction has been changed and angle values at which the signal has been reduced till noise level were indicated in the theodolite scale. In accordance with the similar scheme the output radiation diagram of the transmitting OIC has been measured. The signal were registered by means of the split-apertured photodiode. The photodiode could be moved upwards/downwards and to the left/right in the radiation plane within the range of noise level – maximum energy with the aid of smoothed driving elements. The measurement results are given in Table 2.

The investigations of industrial angle measurement devices shown in Fig. 4 have been carried out in this paper. Among achieved technical characteristics there should be noted the following: angular resolution of 1 arc second, total field of view of 30 arc minutes, overall dimensions 20 × 20 × 80 mm.

Table 2

Grating type	diffraction	diffraction	diffraction
Ruling form	circular	linear	linear
Operating wavelength, [μm]	0.63	0.63	1.15
Corrugation depth, [μm]	0.02–0.1	0.2	0.01
Focusing length, [mm]	64	–	–
Diffusion spot size, [μm]	6	16	200
Grating period, [μm]	0.55	2.53	0.5
Halfwidth of directivity diagram, [arc minute]	0.6	5	$(2-8) \cdot 10^{-2}$
Grating size, [μm]	5 × 10	50 × 50	50 × 50
Coupling angle, [grad]	0	50	0
Substrate	K-8 glass	K515 glass	KI glass
Waveguide	diffusion	diffusion	As_2S_3

3. Conclusions

The investigations of angle measurement devices (see Figs. 1 ÷ 4) produced in the industrial conditions demonstrated their high efficiency and allowed to create a variety of designing methods, technologies and metrology having mastered industrial base.

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