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A measuring setup for examination of planar optical waveguide properties

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It is very helpful to have a special measuring device for examination of planar optical waveguides, which would be applicable both during the waveguide production and trial exploitations. The wanted setup should enable us to determine the transfer functions, attenuation, number of propagating modes, and the synchronous coupling angles for modes of various orders. Such a device has been elaborated and next built in the form of a laboratory setup. Its construction and measuremental possibilities are presented below.

Introduction

Thin-film planar light waveguides are basic components used in integrated opto-electronics. They provide not only a medium in which an electromagnetic wave propagates but also create a basis for construction of the majority of passive and active elements as well as functional systems. The propagative and optical properties of the waveguides must be examined experimentally during both the elaboration of waveguide production technology and the respective trial exploitation. This may be done by using a special measuring system, which would allow to determine the power transfer function $P(x)$, attenuation $\gamma = -dP/dX$, and propagating possibilities, i.e. the number of transmitted modes, the value of the synchronous coupling angle for definite mode orders, and the effective refractive index of the light waveguide layer. Such a system has been designed and realized in the form of a laboratory setup.

The measuring system

Fig. 1 shows the scheme of the measuring system composed of the following elements: He-Ne laser of LG-600 or LG-2001 type (producer Polish Optical Works) as a source of monochromatic light ($\lambda = 632.8$ nm), modulator, set of polarizers, converging lens (of 300 mm focal length), set of prism couplers, cylindric lens ($f = 140$ nm), semiconductor, homodyne nanovoltmeter of 232 type and an acoustic PG-19 generator controlling the modulator and synchronizing the nanovoltmeter. Among these component devices there are some factory made and some specially designed and constructed. The latter category includes the following devices: modulator, coupling unit and detector, which will be described in more details.

In order to reach a sufficiently high precision and stability, the system has been mounted on a heavy (more than 800 kg) plate with an antivibration system, using some constructional elements of the optical ZHL bench of Polish Optical Works production. The general view of the system is shown in fig. 2. Starting from the left-hand side, there are: laser, coupling unit, cylindric lens, detector, and nanovoltmeter and generator in the background.

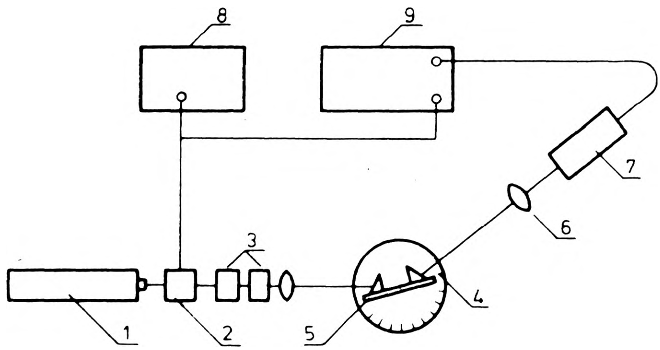

Fig. 1. Scheme of the measuring system: 1 — laser, 2 — modulator, 3 — polarizers, 4 — goniometer table, 5 — prism coupler, 6 — cylindric lens, 7 — detector, 8 — low-frequency generator, 9 — homodyne nanovoltmeter

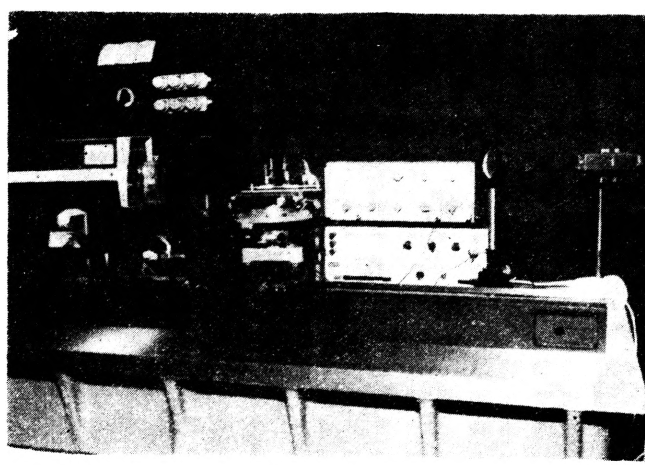

Fig. 2. View of the system for examination of the planar light waveguides

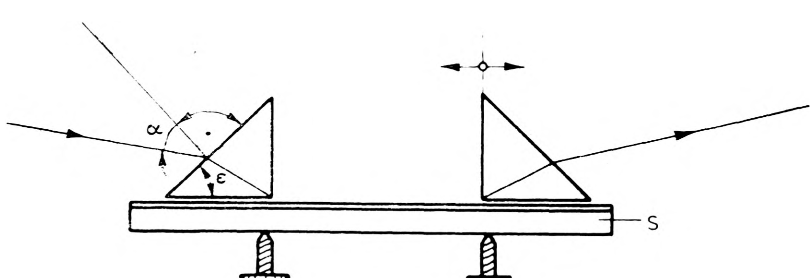

Fig. 3. The principle of prism couplings: α — synchronous coupling angle, ε — breaking angle of the prism, S — substrate with the light-guide

The most essential element of the discussed measuring system is the coupling unit allowing to realize a prism coupling, which excites modes of definite order in the layer and leads the beam out of the waveguide. The prism coupling is commonly known (see [1, 2], for instance) as one of the way of introducing the light into the thin film waveguide (as well as of its leading out). The scheme of construction and the principle of operation of the said unit is presented in fig. 3. Here, a substrate plate is shown with the formed waveguide and two identical prisms, the basis of which are parallel to the waveguide plane and distant from it by $\lambda/4 - \lambda/8$. Such a small slit between the prism and the waveguide is obtained by applying suitable "pressure". In the situation seen in fig. 3 the left-hand prism realizes the waveguide excitation and its position is constant (in the given experiment). The right-hand prism realizes the coupling leading the light out of the layer. It is movable and the coupling may occur in any distance from the exciting coupler. This enables us to determine the $P(x)$ response, where x is the distance between the both coupling points (i.e. the distance of the excited waveguide section), measured along the wave propagation direction.

The realization of the coupling unit of such simple scheme makes considerable difficulties. The high quality prism unit should assure: high coupling efficiency of 75-80%, repeativity of this coupling, mutual independence of the exciting and exit couplings, mechanical precision and stability, reliability and simultaneous fineness of the plate and prism holders, adjusting precision and read-out accuracy for both the α-angle and x-coordinate (see fig. 3).

As a result of many different designs and their experimental verifications a coupler unit has been produced, which satisfied all these requirements to the sufficient degree. The respective design is presented in fig. 4.

In the photo the plate holders with the light waveguide (external elements at the picture top) are visible together with the prism holders suspended loosely on the supports located on the guide fastened firmly with the above plate. The screws visible in the prism holders allow to adjust the air slit between the prism and the waveguide to be suitable for coupling. This design assures a possibility of realization of two

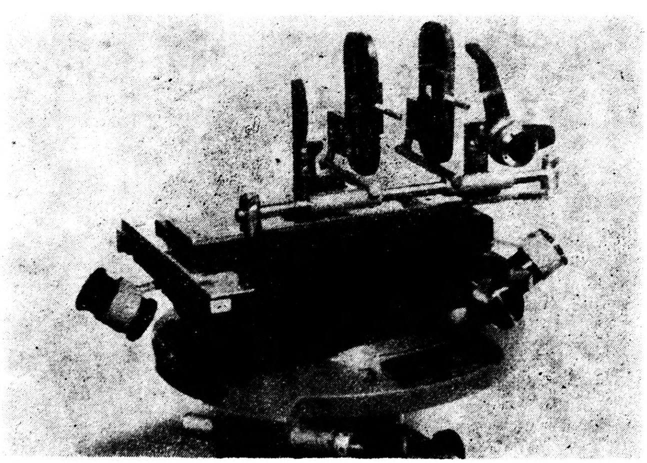

Fig. 4. Coupling unit

independent couplings without any deformation of the substrate plate. This unit is located on a microscope stage which allows to shift it precisely in the direction of the propagating wave. This facilitates the proper position of the "entrance" prism with respect to the laser beam. The microscope stage, in turn, is fastened to a goniometric head, which enables us to change the angle α (see fig. 3) and to measure its value with the accuracy to 30''. Fig. 5 shows the said coupling unit with the light waveguide

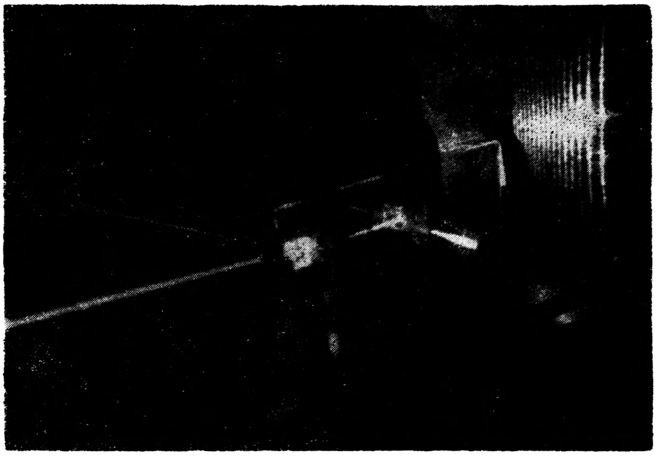

Fig. 5. Excited planar waveguide

connected and excited from the left-hand side. This photo allows to identify the elements shown in fig. 4 and moreover it presents the spectrum of 15 modes led by the light waveguide.

The next expecially elaborated element of the measuring system is the semicon-

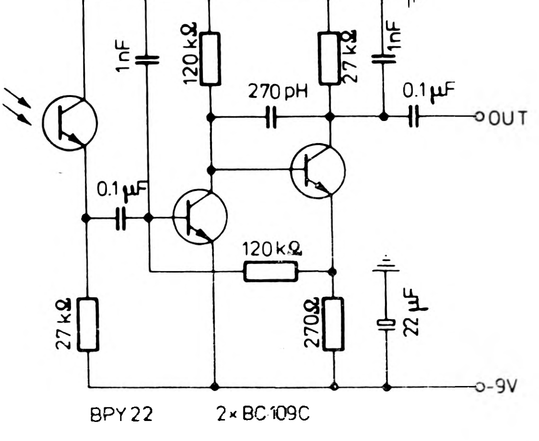

Fig. 6. Scheme of the radiation detector

ductor detector. This is a two-stage a.c. amplifier of direct amplification amounting to 10″ and built according to the scheme shown in fig. 6. This system is provided with thermal stabilisation of the working point. The detector jointly with the supplying batteries is located in the screening housing, protecting it against the perturbing effects. The detector (visible on the right-hand side of fig. 2) fastened to the *x-y* stage is adjusted to the proper position on the plate (system substrate) by means of a stand with a magnetic holder.

The last of the elaborated elements is the beam modulator controlled by an acoustic generator. This is a magnetoelectric modulator with a movable anchor provided with a nontransparent diaphragm of dimensions 1.5×2 mm positioned on the way of the ray. The mechanical resonance frequency of this element is 175 Hz. With this frequency the modulator is controlled by acoustic generator.

A cylindric lens shown in the scheme of the measuring (fig. 1) is used to transform the band beam of the chosen mode (see fig. 5) into a beam of quasi-circular cross-section. This is necessary during the measurements of the power carried by particular modes and for measuring the power distribution among these modes. In praxis, to facilitate the measurements a uniformly scattering diffuser is aplied. It is positioned in front of the detector and considerably simplifies the proper controlling of the phototransistor; the accuracy of the plate positioning in the holder on the goniometer is then less critical.

The characteristics of the measuring system

The system presented allows a practical examination of the basic propagating properties of the thin film light waveguide. Due to a possibility of quick exchange of the prisms it allows to examine the layers of different refractive index included within the limits 1.4-2.5 for $\lambda = 632.8$ nm. This setup was used for parameter measurement of the waveguide produced in the glass plates by the method of ion exchange as well as of organic waveguides deposited also on the glass substrate [3]. This practice allowed to establish the following possibilities and accuracies of the measurement: the $P(x)$ response in the 6-50 mm range of x with the accuracy $\pm 2.5\%$, the attenuation ranging from 0.3 to 30 dB/cm with the accuracy of ± 5 to $\pm 2\%$, respectively, the synchronous coupling angles with the accuracy of $\pm 30''$. The measurements of the angle α allow to determine the effective refractive index n_e for the light waveguide layer. For the case of nonuniform layer (inplantation) the impurity profile may be determined with a limited accuracy from the value of n_e [4]. In order to improve the measurement accuracy an additional measuring method should be employed like the ellipsometric or interference one.

When applying a He-Ne laser adjusted to the infrared ($\lambda = 1.15$ μm) the said system may be used also to examination of semiconductor waveguides like GaAs, for instance. The optical elements of the system are transparent at this wavelength. Of course, for practical reasons a visualisation by means of noctovisers would be necessary.

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Измерительная система для испытания свойств тонкослоистых светопроводов

Для испытаний свойств планарных светопроводов как в ходе их разработки, так и эксплуатационных испытаний, необходимым является измерительная система.
Она должна давать возможность определения: характеристики передачи мощности, коэффициента звукоизоляции, числа распространяемых модов, а также углы синхронной связи модов различного порядка. Такая система была разработана и осуществлена в виде лабораторного состава.
Описано строение и измерительные возможности этого состава.