Problems of integrated optics

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Usp. Fiz. Nauk **152**, 353–355 (June 1987)

Integrated Optics: Proceedings of the Third European Conference ECIO'85—Berlin, 6–8 May 1985/Eds. H.-P. Nolting and R. Ulrich. Springer-Verlag, Berlin; Heidelberg; New York; Tokyo, 1985. pp. 242 (Springer Series in Optical Sciences V. 48).

The book under review is the collection of texts of papers (46 papers, including 5 review papers) presented at the third international conference on integrated optics which was held in West Berlin from 6 to 8 May 1985.

The collection of articles gives a contemporary overview of the rapidly developing field associated with the study and application of optical phenomena in thin-film waveguide structures. On the basis of methods of integrated optics devices are now being developed which govern the propagation of optical radiation in thin-film waveguides (deflectors, modulators etc.), at the present time they find various applications in systems processing optical signals. Of particular significance is the miniature nature of these elements, the smallness of the amounts of energy utilized by them and their compatibility with fiber lightguides.

The aim of the conference is to bring out the most promising tendencies in the development of integrated optics and of its possibilities in the development of integrated optics (IO) elements on the basis of present-day technology.

All the reports presented at this conference were divided into five groups: Physical effects in IO structures; materials and technology of preparing IO elements; semiconductor integrated optics; modulators; applications of IO elements. In each of these groups one invited review paper was given on the pressing problem of integrated optics. In papers following them more narrow physical and applied problems of present-day integrated optics were examined.

The large review paper of the first group considered one of the most promising directions of physical investigations in present-day integrated optics—nonlinear integrated optics (C. T. Seaton, G. I. Stegeman, W. M. Hetherington, H. G. Winful). The strong concentration of the energy of optical radiation in IO waveguides leads to the fact that the nonlinear-optical effects play an important role in the process of propagation of radiation along a waveguide. The authors restricted themselves in the paper to an examination of nonlinear-optical phenomena brought about by cubic nonlinear susceptibility. The principal attention was devoted to an examination of such phenomena as the appearance of nonlinear waveguide modes, some of which do not have linear analogs, nonlinear distributed feedback and its applications, degenerate four-wave mixing, surface coherent Raman spectroscopy, etc. Nonlinear integrated optics is at present in the stage of intense physical investigation, but already such applications can be foreseen as the development of purely optical elements of signal processing (for example, convoluters, bistable switches, etc.).

Achievements in the development of IO elements are based on the successes in the technology of producing perfect IO waveguides, characterized by low losses. A special review paper (C. D. W. Wilkinson) was devoted to the application of electron-beam lithography in integrated optics. Characteristic of integrated-optics structures is the existence of a system of optical waveguides with a width of 1–8 μm and of length of the order of several millimeters, with such waveguides being capable of being bent. In order to achieve low losses the faces of these waveguides have to be sufficiently smooth (with an accuracy down to values $\lesssim 0.1$ μm). Electron-beam lithography which makes possibles direct recording of a diagram on a substrate with high resolution is at present most promising for the production of different kinds of IO structures. In order to achieve the best possible resolution one should utilize very thin resists in view of the sharp deterioration of resolution due to the scattering of electrons in thick substrates.

Although the technology of electron-beam lithography is most promising for producing IO structures, at the present time it is very expensive. One of the papers described a system of laser-beam lithography for the purposes of integrated optics. Here use is made of a direct record of a diagram on a resist by a laser beam. With the aid of this technology it is possible to produce IO waveguides of ~ 1 μm width with smoothness of faces ~ 0.1 μm. The authors of the paper (I. Ben-David *et al.*) consider that in spite of a resolution ($\gtrsim 0.6$ μm) which is worse than in the electron-beam lithography, the technology of laser-beam lithography has sufficient possibilities for realizing IO structures required at present, and apparently, is more suitable for these purposes in view of its comparative cheapness.

One of the most promising directions for the development of integrated optics is semiconductor integrated optics, in particular based on $A^{III}B^{V}$ compounds. It is especially in such structures that it is possible to combine on a single substrate sources of radiation, controlling IO elements, and photo-detectors. A large review paper examined the key elements of semiconductor integrated optics—integrated-optics lasers (Y. Suematscu). At the present time considerable progress has been achieved in the development of IO dynamic single-mode semiconductor lasers. As a rule these are lasers with distributed feedback, which retain the single-mode oscillation regime at modulation frequencies up to 2 GHz (at a modulation frequency of ~ 1.9 GHz the line width of the oscillations of such lasers is 0.3 nm). Under the same conditions in lasers with the usual Fabry-Perot resonator the oscillation spectrum turns out to be strongly broadened (~ 10 nm at wave lengths of 1.5–1.6 μm). Dynamic single-mode semiconductor lasers with distributed feed-back producing radiation of ~ 1.5–1.6 μm wavelength should find wide application in wide-band fibre-optic communication lines, with the attainable normalized transmission band limited by dispersion possibly approaching the theoretical limit (~ 25 Gbit/s$\cdot$km$^{1/2}$).

At the conference data were presented on such elements promising for applications as a semiconductor laser with a controlling circuit capable of 2 Gbit/s made on a single substrate; a Mach-Zender interferometer based on the heterostructure GaAs–GaAlAs, etc.

A special group of papers was devoted to modulators—the most highly developed integrated-optics elements. This section contains the text of a review paper devoted to the study of parametric processes in waveguides based on $LiNbO_3$ (D. B. Ostrowsky). Here the principal attention is paid to the effect of generating the second harmonic IO waveguides in $LiNbO_3$ produced by the diffusion of titanium, proton exchange and combined action of both technologies. The results obtained, as a rule, in view of the low effectiveness of the interaction, so far do not allow one to give practical recommendations, but the author considers that difficulties can be overcome.

And finally, considerable attention has been paid to different applications of IO elements. These applications are basically associated with the use of IO elements as sensors, demultiplexers, communication elements, etc. The review paper devoted to the prospects of producing optical computers (A. W. Lohmann) should be noted. In discussing the common problems standing in the way of their realization the author emphasized IO elements which could be used in optical computers. These are basically networks of IO communication elements—commutators. If a single commutator can be switched in 1 ns, then a readjustment of 1 million channels can be carried out in less than 1 μs.

On the whole the level of the reports presented at the conference reflects the present-day level of development of integrated optics, and the book is doubtlessly useful for physicists and chemists interested in the problems of integrated optics and in the technology of the growth of integrated optics structures.