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HIGH-SPEED GUIDED-WAVE ACOUSTOOPTIC AND ELECTROOPTIC SWITCHES*

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ABSTRACT

Progress on the guided-wave acoustooptic and electrooptic sequential switches for optical time-multiplexing and -demultiplexing is described in some detail. The performance figures obtained so far indicate their potential use for future ultra-high data rate fiber/integrated optics systems.

I. INTRODUCTION

Various kinds of high-speed switches are needed in the projected high data rate fiber/integrated optics communication systems (1). In this paper some preliminary results on two guided-wave sequential switches which are being investigated at CMU are presented. The sequential switches include an acoustooptic deflector which utilizes the Bragg-diffraction from standing surface acoustic waves and an electrooptic deflector which utilizes the Bragg-diffraction from the grating created by means of interdigital finger electrodes. Both types of switches employ an optical guiding layer on a Y-cut $LiNbO_3$ substrate having a small number of TE modes.

employ it for the projected ultrahigh data rate fiber and guided-wave optics systems. We have carried out some preliminary guided-wave time-division multiplexing/demultiplexing experiments at 75 - to 150 - Mbits/s bit rates using two surface acoustic waves propagating in opposite directions in an out-diffused optical guiding layer on a Y-cut $LiNbO_3$ plate (4) to study this guided-wave counterpart. The interdigital finger transducers were fabricated on the top of the optical guiding layer. Shown in Fig. 1a is the simulated composite data train (75 - Mbits/s) from a mode-locked He-Ne laser. The demultiplexed data streams are shown in Figs. 1b and 1c. The performance figures obtained are the cross talks of approximately -10 db and -20 db, respectively, for the 0th- and the 1st-order channels at 100 mw electric driving power. The relatively large cross talk with the 0th-order is a result of the relatively large fractional loading of the optical pulses, defined as the ratio of the optical pulse width and the period of the electric driving signal (2). In an advanced design with improvement in the transducer conversion efficiency, optimization of the optical and acoustical parameters of the device as well as the reduc-

II. ACOUSTOOPTIC SWITCHES

The optical grating created by a standing acoustic wave oscillates at twice the acoustic frequency and, therefore, can be used to sequentially switch a high bit rate optical pulse train. Utilizing this principle an ultrafast acoustooptic multiplexer/demultiplexer using a $PbMoO_4$ standing ultrasonic Bragg-cell (SUBC) has been constructed and tested at 1-to-4-Gbits/s (2). Based on the performance figure obtained and its extrapolation the $PbMoO_4$ SUBC was shown capable of processing up to 15-Gbits/s. Consequently, the acoustooptic multiplexing/demultiplexing scheme has been considered one of the most attractive schemes for the realization of an ultra high bit rate time-multiplexed optical communication system (3).

Since the driving power of a guided-wave or thin-film acoustooptic multiplexer/demultiplexer can be one to two orders of magnitude lower than that of its bulk-type counterpart (which is already very small compared with devices using traveling acoustic waves), it is advantageous to tion of the fractional loading, an even better performance figure at multi-gigabit/s bit rates should be achievable. Thus, by employing a number of the acoustooptic sequential switches, arranged in a tree configuration, individual channels in a high data rate time-multiplexed communication system may be separated spatially. The tree may also be employed in reverse for the time-multiplexing of individual channels.

In addition, a guided-wave acoustooptic random-access switch which utilizes the Bragg-diffraction from travelling surface acoustic waves is being explored. Preliminary results indicate that desirable performance figure can be achieved with this type of switch by using a wideband technique which was recently developed by us (5). This type of random-access switch is expected to be useful for multiport switching in future fiber/guided-wave optics systems.

III. THE ELECTROOPTIC SWITCH

An electrooptic Bragg-diffraction grating can be created when a voltage is applied across an array of interdigital finger electrodes which are deposited on the top of an electrooptically-active

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waveguiding layer. Thus, when the light beam is incident upon the electrooptic grating at a Bragg angle, θ_B, when $\theta_B = \sin^{-1}(\lambda/2d)$ in which λ is the wavelength of the guided-light and d is the periodicity of the interdigital finger electrodes, a portion or all of the incident light power may be deflected at a fixed angle $2\theta_B$ from the incident light direction (6). Clearly, if the applied voltage is time-varying (e.g. sinusoidal) the electrooptic Bragg-grating is capable of sequentially switching an optical pulse train. As in the acoustooptic sequential switch, the frequency of the driving signal can be either one-fourth or one-sixth of the composite bit rate. An electrooptic sequential switch based on the above principle has been fabricated and tested at a relatively low switching rate. An array of interdigital finger electrodes was deposited on the top of a Y-cut out-diffused $LiNbO_3$ plate. Shown in Figs. 2a and 2b are the 75-Mbits/s simulated composite pulse trains from a mode-locked He-Ne laser and the 1st-order demultiplexed pulse train. The cross talk in the 1st-order channel is seen to be very small. The cross talk in the 0th-order demultiplexed pulse train could also be reduced to a very small value when an optimum synchronization between the optical pulse train and the driving voltage was implemented. The peak driving voltage required for the above performance figure was measured to be 8 volts. As in the acoustooptic sequential switch, a number of the electrooptic sequential switches may be arranged in a tree configuration for the optical time demultiplexing and -multiplexing in high data rate optical communication systems.

REFERENCES

1. S. E. Miller et al., "Research Toward Optical-Fiber Transmission Systems," Proc. IEEE 61, 1703-1751 (Dec. 1973); C. M. Stickley et al., "Anticipated Uses of Fiber and Integrated Optics in the Defense Department," Paper WB1-1, Topical Meeting on Integrated Optics, Jan. 21-24, 1974, New Orleans, Louisiana.

2. C. S. Tsai and S. K. Yao, "Bragg Diffraction by Standing Ultrasonic Waves with Application to Optical Demultiplexing," J. Appl. Phys. 43, 5081-5084 (Dec. 1972); C. S. Tsai and S. K. Yao, "Standing Wave Ultrasonic Bragg-Cell with Application to Ultrahigh Data Rate Optical Communication Systems," 1973 International Electron. Devices Meeting, Technical Digest, 220-222.

3. G. Lee and M. Ross, "High Data Rate Optical Communication Systems," Presented at the NSF Meeting on Optical Communication Systems, May 29-30, 1974, University of Colorado, Boulder, Colorado.

4. I. P. Kaminow and J. R. Carruthers, "Optical Waveguiding Layers in $LiNbO_3$," Appl. Phys. Lett., 22, 326-328 (April 1973).

5. C. S. Tsai et al., "A High Performance Acoustooptic Guided-Light Beam Device Using Intersecting Surface Acoustic Beams," Post Deadline Paper D.12, Integrated Optics and Fiber Optics Communication Conference, NELC, San Diego, Calif., 15-17 May, 1974. (To be published in

IV. CONCLUSION

The experimental results obtained so far indicate that guided-wave acoustooptic and electrooptic sequential switches with advanced design are capable of providing desirable performance figures. It has also been demonstrated that they are both easy to design and to fabricate. The two sequential switches described in this paper are expected to be useful as interface devices between high-capacity computers as well as the optical connecting networks in fiber/guided-wave optics systems (7) in addition to its use for optical time-multiplexing/demultiplexing in ultrahigh data rate communication systems.

Appl. Phys. Lett.).

6. J. F. St. Ledger and E. A. Ash, "Laser-Beam Modulation Using Grating Effects," Electron. Lett., 4, 99-100 (March 1968); M.A.R.P. deBarros and M.G.F. Wilson, "High-Speed Electrooptic Diffraction Modulator for Baseband Operation," Proc. Inst. Elect. Eng., vol. 119, 807-814 (July, 1972); J. N. Polky and J. H. Harris, "Interdigital Electro-Optic Thin-Film Modulator," Appl. Phys. Lett., 21, 307-309 (Oct. 1972); J. M. Hammer et al., "Fast Electrooptic Waveguide Deflector Modulator," Appl. Phys. Lett., vol. 23, 176-177 (Aug. 1973); J. M. Hammer and W. Phillips, "Low-Loss Single-Mode Optical Waveguides and Efficient High-Speed Modulators of LiNb$_x$Ta$_{1-x}$O$_3$ on LiTaO$_3$," Appl. Phys. Lett., 24, 545-547 (June 1974); and C. M. Verber et al., "Electro-optically Modulated Thick Phased-Gratings for Integrated Optics Applications," Paper D10, Integrated Optics and Fiber Optics Communication Conference, NELC, San Diego, Calif., 15-17 May, 1974.

7. H. F. Taylor, "Optical Waveguide Connecting Networks," Electron. Lett., 10, 41-43 (Feb. 21, 1974).

Fig. 1 Guided-Wave Acoustooptic Demultiplexer/Multiplexer Using Standing Surface Acoustic Waves.

- (a) A Simulated 75-Mbits/s Composite Pulse Train
- (b) Demultiplexed Pulse Train (1st-order channel)
- (c) Demultiplexed Pulse Train (0th-order channel)

(Time Scale: 10 ns per division)

Fig. 2 Guided-Wave Electrooptic Demultiplexer/Multiplexer Using Bragg-Grating.

- (a) A Simulated 75-Mbits/s Composite Pulse Train
- (b) Demultiplexed Pulse Train at 37.5-Mbits/s (1st-order channel)

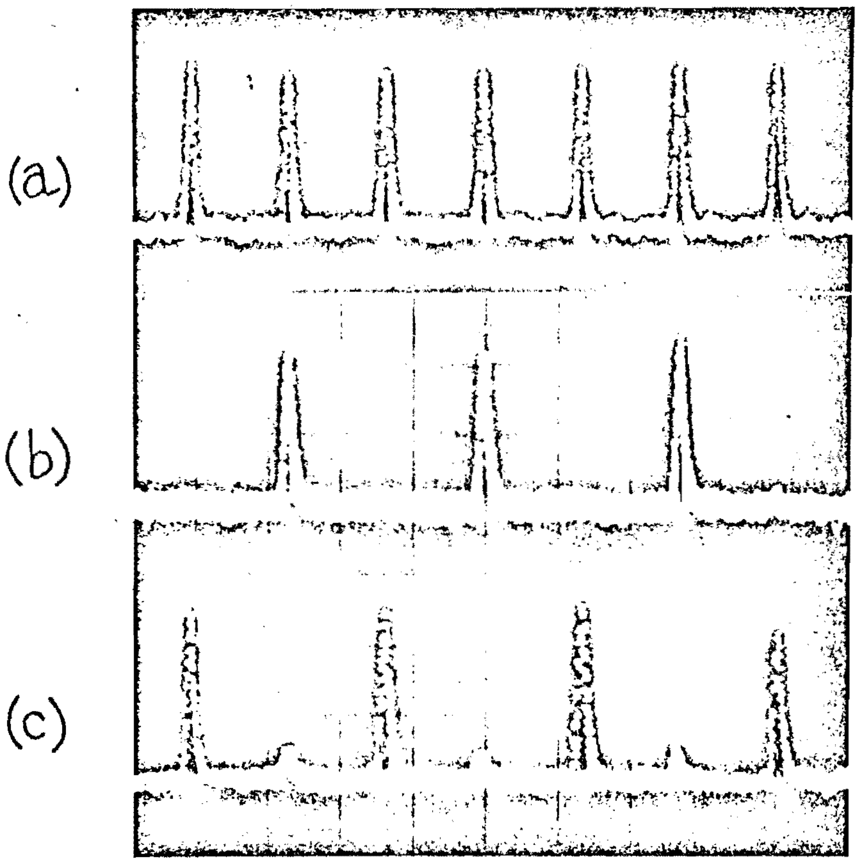

Fig. 1 TSAI, Yao, Alhaider & Saunier

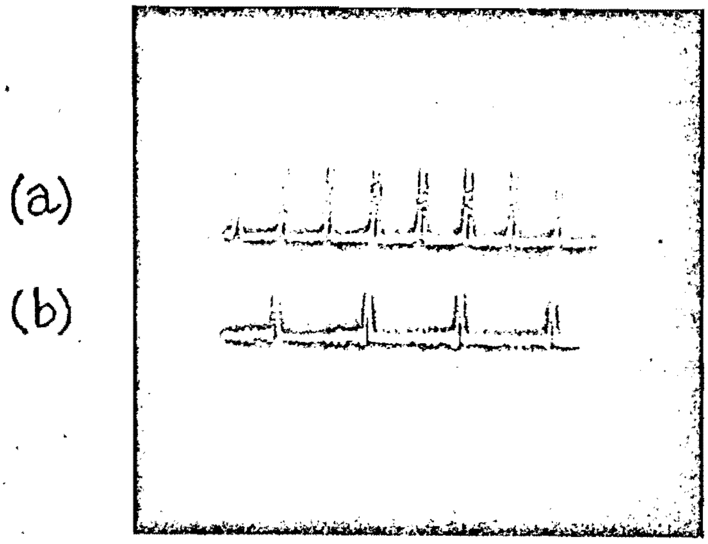

Fig. 2 Tsai, Yao, Alhaider & Saunier