SIGNAL PROCESSING USING GUIDED-WAVE ACOUSTOOPTIC BRAGG-DIFFRACTION IN $LiNbO_3$ WAVEGUIDES*

I. W. Yao and C. S. Tsai
Department of Electrical Engineering
Carnegie-Mellon University
Pittsburgh, PA 15213

ABSTRACT

Real-time processing of rf signals using guided-wave acoustooptic Bragg-diffraction in $LiNbO_3$ waveguides has been studied both theoretically and experimentally. Good performance figures for convolution have been achieved by employing multiple tilted surface acoustic waves: time-bandwidth product of 305, dynamic range of approximately 50 db, total rf power of 310 mW for maximum convolution output and the frequency resolution of 1 MHz (defined at zero convolution output).

Processing of rf signals in real time, e.g. convolution and correlation, using bulk-type acoustooptic interaction configuration was studied by a number of workers in recent years.(1,2) Extension of the study to the guided-wave interaction configuration was suggested as a result of the progress in the fabrication of both optical wave guides and surface acoustic wave (SAW) devices on Y-cut $LiNbO_3$ substrates and of the fact that a more efficient interaction can occur in this configuration.(3,4,5) Recently, this more efficient interaction was demonstrated in the guided-wave acoustooptic convolution experiment which employed outdiffused Y-cut $LiNbO_3$ waveguides.(6,7) Acoustooptic convolution experiment in As_2S_3 optical waveguide has also been reported.(8)

We have demonstrated that by employing multiple tilted SAWs in Y-cut $LiNbO_3$ waveguides very good performance figures for convolution are achievable with this guided-wave configuration. These performance figures far exceed those obtained previously. In this paper we summarize the device configuration, design, fabrication and measurement of the guided-wave convolver and the measured performance figures.

The device configuration which was employed in this study is shown in Fig. 1. An optical waveguiding layer of approximately 2μm thick was first created on top of a Y-cut $LiNbO_3$ substrate using in-diffusion technique.(9) A Y-cut $LiNbO_3$ substrate possesses an attractive combination of acoustic, piezoelectric, optical, acoustooptic and electrooptic properties, and can provide very efficient Bragg diffraction.(7) Two end-to-end identical SAW array transducers, which are characterized by staggered center frequenceis (163, 194 and 230 MHz) and propagation axes tilted with respect to each other, were then deposited on the top of the waveguide. We had previously shown that the multiple tilted SAWs generated by such an array transducer satisfy the Bragg condition in each frequency band and thus enable a broad composition frequency response to be realized.(10) A rutile prism was used to couple an unguided light beam from a He-Ne laser at 0.6328μm and a second rutile prism was used to couple out both the Bragg diffracted and the undiffracted light beams. The best through-put coupling efficiency was as high as 18 percent. The aperture of the guided-light beam which determines the total storage time could be varied from 1 to 10 mm, with a slight degredation in the uniformity of the light beam for the widest aperture.

In the convolution experiment, one pulse-modulated rf signal (say, reference signal) was applied to one array transducer to generate a SAW and the other pulse-modulated rf signal (signal to be processed) was applied to the other array transducer to generate a second SAW. Since the two SAWs propagate in opposite directions the Bragg-diffracted light from one SAW is up-shifted and that from the second SAW is down-shifted by their corresponding acoustic frequencies. The two diffracted light beams overlap and thus can be collected by a lens and then mixed in a photodetector. It can be shown that the electrical output from the photodetector contains a component which is a convolution of of the two rf signals. This convolution signal has a carrier frequency equal to the sum of the two acoustic frequencies and can be further processed by means of a heterodyne receiver and then displayed in a wide-band oscilloscope. Typical waveforms of the convolution for signal-pulse and double-pulse rf signals at the center frequency of 160 MHz are shown in Fig. 2(a) and 2(b), respectively. We have also measured the related ambiguity function(11) by having the frequency of one rf signal fixed and that of the second rf signal varied. The measured results are found to agree well with the calculated values. Performance figures of this preliminary device are summarized as follows:

1. Time-Bandwidth Product: 305
   Time aperture 2.9μs, Bandwidth 105 MHz, Center frequency 200 MHz
2. Dynamic Range: 50 db
3. Total RF Power Requirement: 310 mW for maximum convolution output, Electrical-acoustical conversion efficiency of each array transducer: -15db
4. Optical Through-Put Coupling Efficiency: 18%
5. Ambiguity Function (Doppler Frequency Resolution): 1MHz

We note that better performance figures are achievable by optimizing the parameters of the convolver described above. We note also that the comparative advantages of such guided-wave acoustooptic convolvers over their bulk counterparts are:

1. More efficient diffraction, less RF drive power;
2. More flexible in the transducer design/fabrication, much easier for the implementation of multiple SAWs;
3. Smaller size, light weight; less critical with isolation and alignment problem;
4. Possibility for batch fabrication, less cost; and

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5. Compatible with future fiber/integrated optic systems, suited for a number of wideband applications.

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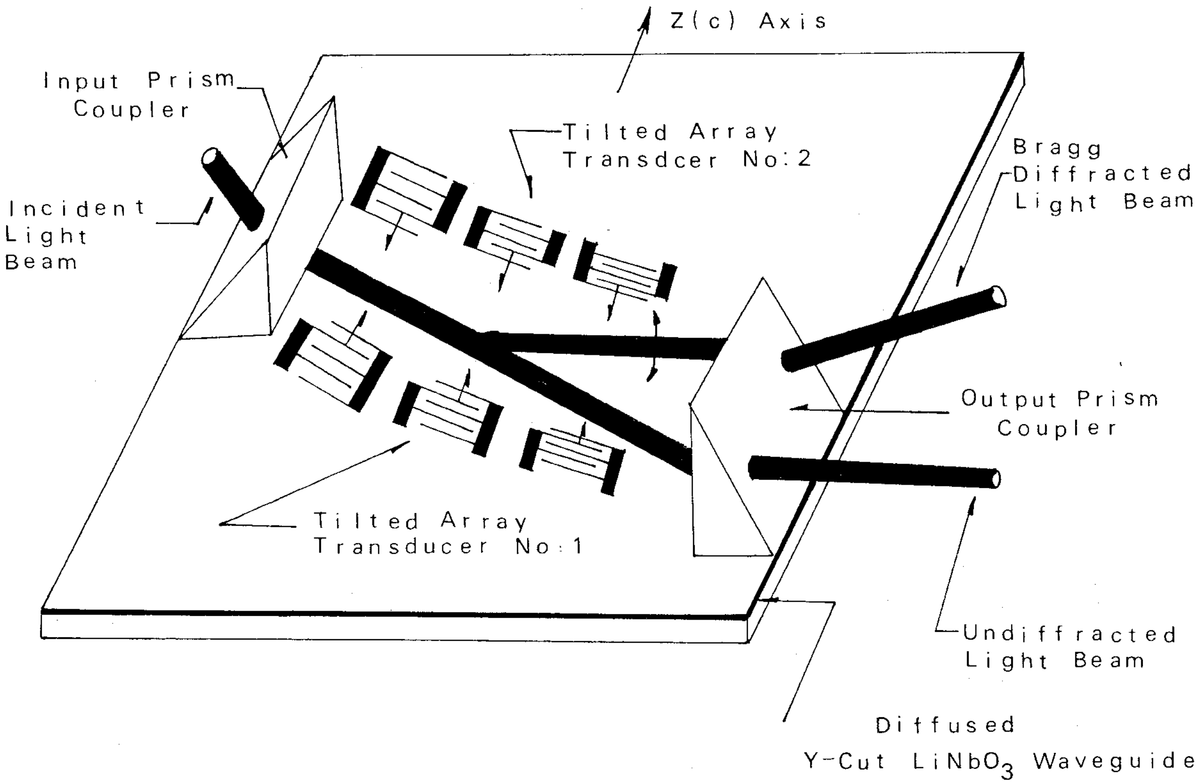
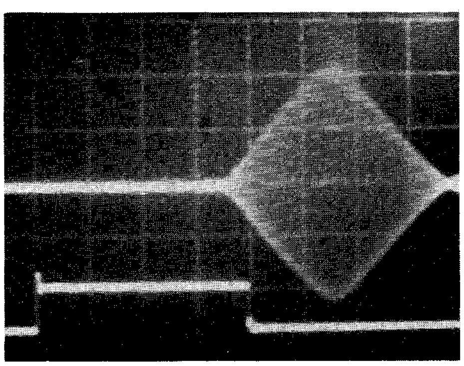
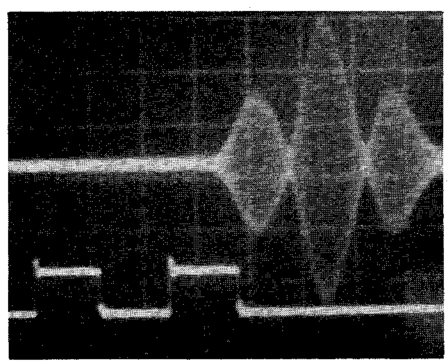


Fig. 1 Guided-Wave Acoutooptic Signal Processing Using Multiple Tilted Surface Acoutic Waves in $LiNbO_3$ Waveguide



(a)



(b)

Fig. 2 Pulse-Modulated RF Signals (Lower Traces) and Their Corresponding Autoconvolution Outputs:

(a) Single RF Pulse: Center Frequency (160 MHz), Vertical Scale (20 mV/Div.), Horizontal Scale (0.5μs/Div.)

(b) Double RF Pulses: Center Frequency (160 MHz), Vertical Scale (10 mV/Div.), Horizontal Scale (0.5μs/Div.).