9-6 Bragg Diffraction of Optical Guided-Waves by Acoustic Surface-Waves in ZnO Films Deposited on Nonpiezoelectric Substrates.

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Bragg diffraction of optical guided-waves by acoustic surface-waves has been already demonstrated in the films deposited on piezoelectric substrates, such as α-quartz and $LiNbO_3$ plates[1,2]. In the Bragg diffraction experiments, up to this time, piezoelectric substrates have been indispensable for the exitation and propagation of acoustic surface-waves in the waveguides. Recently, it has been clarified that piezoelectric ZnO films are available for the excitation and detection of acoustic surface-waves on nonpiezoelectric substrates[3,4]. In the present study, nonpiezoelectric substrates with the piezoelectric ZnO films are substituted for the piezoelectric substrates. As the ZnO film is also an expectable material for optical waveguides[5,6,7], it is employed here for both an optical waveguide as an interaction medium and acoustic surface-wave transducers.

The experimental structure is indicated schematically in Fig. 1. The ZnO film is deposited onto a fused quartz substrate by the dc diode sputtering as reported in previous papers[8,9]. The mean c-axis orientation of the film employed is almost normal to the substrate. The thin film part acts as an optical waveguide and the thick film parts as acoustic surface-wave transducers. For a sample described here, the thickness of the ZnO film is 1.5 μm for the thin film part and 9.6 μm for the thick film parts. A pair of interdigital electrodes for acoustic surface-wave transducers are prepared between the ZnO film and the substrate. The center frequency of the transducers is around 130 MHz, at which the effective coupling constant has been determined to be the maximum value for the film without shorting plane ($k_0h \sim 3$ for the film thickness of 9.6 μm)[10]. The distance between the sending and the receiving transducers is 15 mm. A pair of rutile prism couplers are employed for the excitation and detection of the optical beam in the film-guide. A 6328-Å laser beam is prism-coupled into the ZnO film, and the optical guided-wave, thus excited, propagates approximately normal to the propagation direction of the acoustic surface-waves. When the Bragg condition is satisfied, the optical guided-wave is

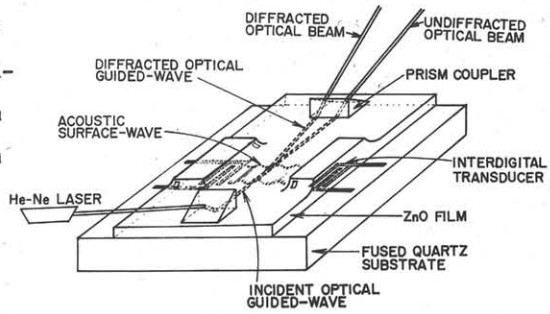

Fig.1. Experimental structure for Bragg diffraction in a ZnO film on fused quartz substrate.

$\Lambda \sim 23.8\,\mu m$ $\nu \sim 3.1$ km/p

diffracted.

In the present experiment, the Bragg diffraction is investigated by observing the deflection of the optical beam through the output prism coupler. Either the deflected beam or the depletion of the undeflected beam is detected by a photomultiplier. A typical oscilloscope display taken under the diffraction experiment is shown in Fig. 2. In this case, the optical guided-wave is a TE_0 mode and the frequency of the acoustic surface-wave is 130 MHz. In the photograph, the trace (a) is the output of the receiving transducer, and the traces (b) and (c) are the outputs of the photomultiplier. When the undeflected optical beam is detected by the photomultiplier, a depletion in the optical beam is observed as seen in the trace (b), during the acoustic surface-wave pulse intersects the optical guided-wave. On the other hand, a deflected beam is detected for the same period as seen in the trace (c), when the photomultiplier is set at the deflected angle of $2\Theta_B$ from the direction of the undeflected beam, where Θ_B is the Bragg angle. The deflected angle is measured to be 1°32' in air.

The diffraction efficiency is determined by either the fractional decrease in the output from the undeflected optical beam or the ratio of the output of the deflected optical beam to that of the undeflected optical beam. The observed maximum efficiency is 96 % at 2.7 watts of the electrical input power. The theoretical analysis of the Bragg diffraction in the waveguides including the case of mode conversion and the theoretical considerations will be given in relation to the obtained experimental results.

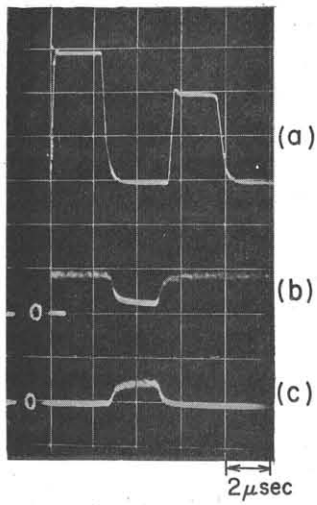

Fig.2. Oscilloscope traces of the deflection experiment: (a) output of the receiving interdigital transducer; (b) depletion in the undeflected optical beam; (c) deflected optical beam pulse.

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