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A2-2 Efficient Mode Conversion between TE and TM Modes of Optical Guided Waves by Acoustic Surface-Waves

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It has been shown by several authors[1)-5)] that the acoustic surface-waves can be utilized for deflection and modulation of the optical guided waves. Recentry, the experiment on the mode conversion between TE and TM modes by acoustic surface wave with conversion efficiency of about 1% has been reported[6)] in a TeO_2 film deposited on quartz substrate. The mode conversion of the optical guided waves is of interest because of the applicability of the acoustic surface-wave to the TE⇌TM mode convertor in integrated optics.

In this paper, an efficient mode conversion between TE and TM modes of the optical waves guided in a thin film by acoustic surface-wave is demonstrated. A mode conversion efficiency as high as 88% has been obtained by optimizing the thickness of the ZnO film fabricated on a fused quartz substrate at the acoustic frequency of 226 MHz.

The experimental arrangment is illustrated in Fig.1. The ZnO film was fabricated on a fused quartz substrate by dc diode sputtering[7)]. The mean c-axis orientation of the film is almost normal to the substrate. The waveguide is, therefore,transverely isotropic within a film plane. A pair of interdigital transducers was located obliquely by about 18° to the propagation direction of the optical guided waves so that the Bragg condition is easily adjusted by a small rotation of the sample with respect to the incident optical beam. Each transducer has 20 finger pairs, 2.5mm aperture length and a 12 μm period. The thickness h of the ZnO film at the transducer part has been determined to be 5.3 μm to maximize the effective coupling factor[8)]. The observed center frequency of these transducers were 226 MHz, and the minimum insertion loss was about 20 dB. A 0.6328 μm laser beam is coupled into and out of the waveguide by means of a pair of rutile prism couplers.

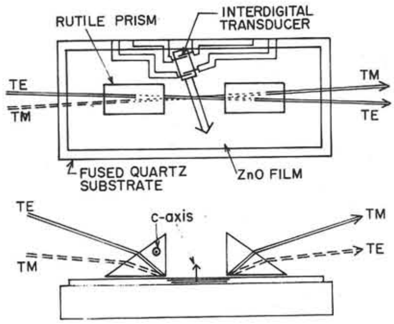

Fig.1 Experimental arrangment.

When the Bragg condition $k_{TE}-k_{TM}=\pm K$ (where k_{TE},k_{TM} and K are the wave vectors of TE mode optical wave, TM mode optical wave and acoustic surface-wave, respectively) is satisfied, the mode conversion between TE and TM modes occours. The TE and TM waves enter into the rutile prisum as an extrodinary and an ordinary waves, respectively. Thus, these two waves emerge from the output prism as two separated beams. The intensities of these two beams are detected by a photomultiplier.

The experimental results of the mode conversion between TE_0 and TM_0 modes are plotted in Fig.2 as functions of the acoustic power. The parameter is the thickness of the ZnO film. The efficient mode conversion as high as 88% has been obtained in the 5μm thick waveguide with an acoustic power of 350 mW. The mode conversion efficiency decreases with decreasing the film thickness.

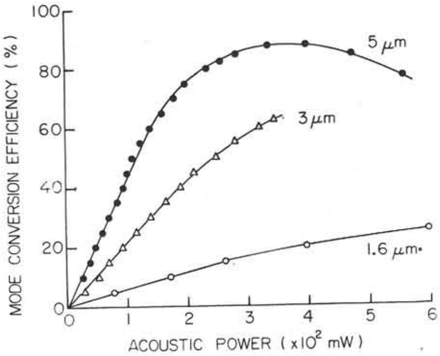

Fig.2 Experimental results of mode conversion efficiencies between TE_0 and TM_0 modes. The parameter is the thickness of the ZnO film.

To compare the experimental results of the thickness dependence of the mode conversion efficiency with the theory[9], the mode conversion efficiency was caiculated theoretically within a small signal limit. In the calculation the unknown photoelastic constant p_{44} of ZnO was varied as a parameter. The calculated results are shown in Fig.3 as functions of the film thickness. In the figure the efficiencies obtained in the experiment are also plotted. From the figure it can be said that rather thick film is required to accomplish the efficient mode conversion between TE and TM modes. This is because that the acoustic strain component S_{xz} (x is the direction of the acoustic wave propagation and z is normal to the waveguide), which mainly contributes to the mode conversion, vanishes at the film surface and gradually increases with increasing the depth from the surface untill the depth reaches about a quarter of the acoustic wave length.

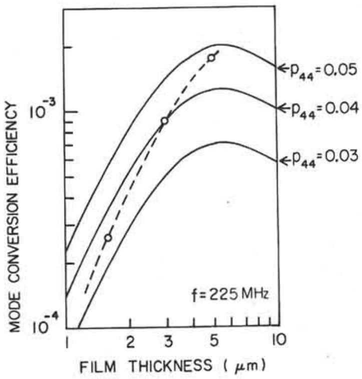

Fig.3 Thickness dependence of the mode conversion efficiency for a unit acoustic power(1mW) and a unit beam width(1mm).
——;calculated theoretically
-o-;observed

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