주기적으로 분극 반전된 $LiNbO_3$를 이용한 우수한 광 소멸성의 Bragg 변조기

Extinction Ratio Enhanced Bragg Modulator based on Periodically Poled $LiNbO_3$

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Modulators based on Bragg diffraction in periodically poled $LiNbO_3$ (PPLN) offer the potential to overcome disadvantages inherent in the more conventional acousto-optic and electrooptic modulators, such as low efficiency in the infra-red and high driving voltages. Previous works[(1),(2)] showed that the extinction ratio of laser beam was low because of the presence of internal field in PPLN. We fabricated a PPLN that had no index grating when external electric field was absent.

A schematic view of the Bragg modulator device is shown in Figure 1. A z-polarized He-Ne laser beam is incident on the y-face with an internal angle of θ_{int}. The sample has periodically poled structure forming a grating of length d and period Λ with the grating k-vector parallel to the x-axis of the crystal. By applying a uniform electric field, E between the $\pm z$ faces, the change in extraordinary index across a domain wall is expressed as $\Delta n_e = n_e^3 \, r \, E$, where r is electro-optic (EO) coefficient and n_e is refractive index of extraordinary wave. The largest electro-optic coefficient is accessed by using z-polarized light with a value of r_{33}= 33 pm/V[(3)]. The first-order diffraction efficiency of the Bragg grating is given by[(4)]

$$\eta = \sin^2\left(\frac{\pi \Delta n_e d}{\lambda \cos\theta_{int}}\right),$$

where $\sin\theta_{int} = \lambda/(2n_e\Lambda)$

For periodic poling, a Cr/Au electrode of 3 μm width and 8mm length was deposited on +z face of a 0.2 mm thick LN wafer, and liquid LiCl electrode was used on -z face. The grating period was 10 μm. Domain reversal was achieved by applying a single pulse of 21.0 kV/mm to the wafer with 500 ms pulse duration. Figure 2 shows etched domain patterns of +z, y and -z faces, respectively from left to right and the duty ratio is about 50%.

In order to remove the refractive index contrast across the domain walls, the sample was annealed in air atmosphere at 350℃ for 12h to allow the internal field to relax in the reversed domain followed by slow cooling (1℃/min) to room temperature. Using a polarizing microscope, it was confirmed that the refractive index contrast between the domain walls of opposite polarization disappeared after annealing.

Fractional diffraction efficiency of 1st- and 0th- orders are plotted in Figure 3. The 1st-order diffraction efficiency at 0 V is about η_f= 0.002 as expected and the maximum efficiency is about η_f = 0.37 at ±40V. Low diffraction efficiency might be caused by nonuniform duty ratio of PPLN. However, an extinction ratio of about 200:1 could be achieved after the annealing treatment.

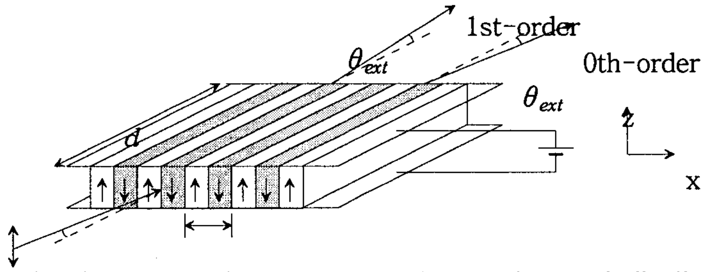

Fig. 1 Schematic diagram of the Bragg modulator using periodically poled $LiNbO_3$.

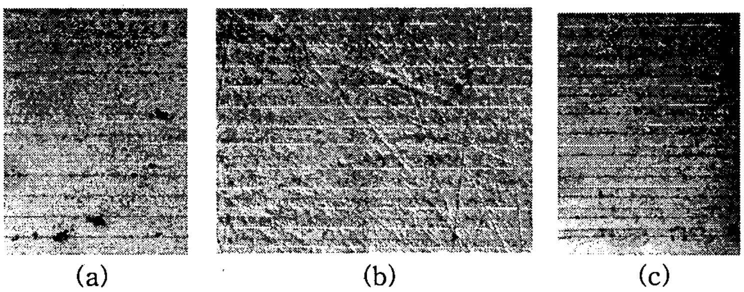

Fig. 2 Etched domain patterns of (a)+z, (b)y, and (c)-z faces of PPLN.

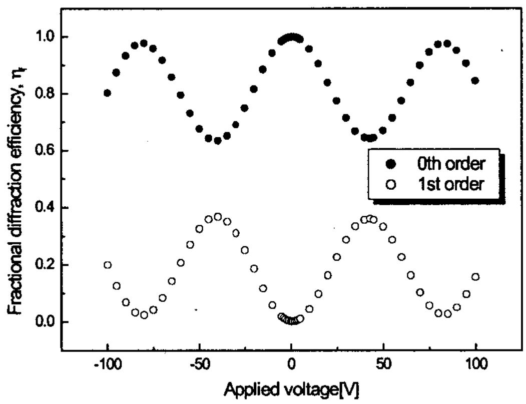

Fig. 3 Fractional diffraction efficiency of 1st and 0th orders with an applied voltage.

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