10:30 am Invited CMG1 Photorefractive thin films and waveguides
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The fabrication of photorefractive waveguides for use in holographic processors, integrated-optic applications, and optical memory devices is a particularly desirable goal. To date, small diameter (600 μm) crystal fibers of materials such as Nb:LiNbO₃ have successfully been grown, but their bulk and surface optical quality can be poor, and clad fibers are not readily available. Planar guides of Ti indiffused photorefractive LiNbO₃ are more easily fabricated, but the materials of most interest to the photorefractive community, such as BaTiO₃, SBN or BSTO, have not been produced as low-loss waveguide structures, apart from a few reports on highly multimode thin cleaved crystal waveguides.

The use of guided wave structures in photorefractive media has the obvious advantage of optical confinement and its consequent reduction in material response time.3,4 The planar structures of typical guiding dimension 1-5 μm, this reduction is expected to be two or three orders of magnitude. Thin film optical materials have been produced previously using various techniques involving thin film growth, but the single crystal oriented nature of such films is often poor or irreproducible. We discuss here the three techniques of laser ablative growth, ion-beam implantation, and in-diffusion for fabrication of planar guides in BaTiO₃, SBN, and BSTO.

Laser ablation is a relatively simple and convenient method for thin film optical growth. Provided attention is paid to such deposition parameters as substrate temperature, and incident laser flux, ~1-μm thick single crystal epitaxial layers can be grown on suitable lattice matched substrates. So far, we have had success with BSTO grown on ZrO₂ for which single crystal growth of the correct phase Ba₃GeO₅ has been achieved. The growth chamber used is illustrated in Fig. 1. BaTiO₃ on LiF has also been reported, but waveguide quality films were not produced as the substrate was cleaved rather than polished. There is also the problem of postgrowing these ferroelectric films. We are currently growing BaTiO₃/LiF thin films on polished substrates.

Ion-beam implantation via 2-3 MeV He⁺ and H⁺ ions has also been used to form guides in BaTiO₃, SBN-65, SBN-52, and BSTO. Typical guide dimensions produced fall in the region of 2-20 μm, but so far the guide losses are rather high (~30 dB/cm), and the material's photorefractive response is minimal. Postannealing typically reduces these losses, but oxidation/reduction treatments may be required to restore the material's photorefractive response. Finally, we are also starting work on indiffused (Ti and Cr) guides in BSTO and BGO.

We discuss our progress so far in waveguide growth techniques, loss measurements, photorefractive characteristics, and prospects for the future.


11:00 am CMG2 Temporal evolution of the photorefractive effect in annelaled proton-exchanged LiNbO₃ waveguides
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Waveguides based on proton exchange (PE) in LiNbO₃ substrates are of significant interest. They are integrated photonic applications; in particular, they are useful for efficient second-harmonic generation, because of their strong nonlinearity, large optical confinement, and simple fabrication process.

Recently, restoration of the nonlinear coefficients of the PE LiNbO₃ waveguides by thermal annealing was reported. Although it is known that the PE LiNbO₃ waveguides have higher resistance to the photorefractive effect than Ti-diffused LiNbO₃ waveguides, quantitative measurements of the effect in annealed proton-exchanged (APE) waveguides as well as the PE waveguides have not been reported to date.

In this paper, we report on the quantitative measurements of the photorefractive effect at irradiation wavelengths (λi) of 532 and 633 nm in APE LiNbO₃ waveguides by using a technique similar to that used for Ti-diffused waveguides. From measurements of the temporal behavior of the photo-induced index change caused by irradiation for several hours, the saturated-index change, buildup time constant, and photorefractive sensitivity in APE LiNbO₃ waveguides were determined and compared to Ti-diffused waveguides.

Figure 1 shows an experimental setup to measure the photorefractive effect. The APE waveguides were fabricated by proton exchange at 220°C for 20 min in benzoic acid, and subsequent annealing at 350°C for 6 h in the presence of only the lowest-order mode at 1.3 μm. Irradiation light produces an optical phase retardation between the two interferometer arms.

\[ \Delta n(T) = \Delta n_0 (1 - e^{-\lambda}) \]

where \( \Delta n_0 \) is the saturated index change, and \( T \) is the time constant. Figure 2 shows the time dependence of the photo-induced index change for two irradiation intensities fitted to Eq. (1) for 220 min of exposure.

The results are summarized in Table 1, where we have also listed the photorefractive sensitivity (S cm/j) defined by

\[ S = \Delta n_0 / I / \Delta T \]

where \( I \) is the irradiation intensity. For comparison, we have also listed the results for Ti-diffused waveguides. The photorefractive sensitivity in APE waveguides, which is measurable at λ₅₃₂ nm, is at least three orders of magnitude smaller at λ₆₃₃ nm than that of Ti-diffused waveguides at λ₅₃₂ nm. A comparison of the time constants indicates that the conductivity of the APE LiNbO₃ waveguides is lower than that of Ti-diffused waveguides. However, based on Glass's model, the smaller saturated index change in APE waveguides indicates that the absorption coefficient, the electro-optic coefficient, and Glass's constant may be smaller to account for the reduction in the sensitivity S, because S is independent of the conductivity.

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11:15 am CMG3 Photorefractivity in doped nonlinear polymers
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Photorefractive polymer materials offer a number of potential advantages over...