Investigation into bulk optical Bragg deflectors based on an electro-optically induced grating in periodically poled lithium niobate

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Many solutions exist for making laser modulators including acousto-optic (AO) and bulk electro-optic (EO) devices. However, another class of modulators based on Bragg diffraction in periodically poled materials offers the potential to overcome disadvantages inherent in the more conventional types, such as low efficiency in the infra-red and high drive voltages. These devices are an extension of early work on grating based EO devices, for example those by Hammer [1] and Barros & Wilson [2], but by making use of periodic poling they allow additional design freedom. This in turn allows fast switching, high efficiency and simple construction as demonstrated in periodically poled lithium niobate at 633nm [3],[4].

$$\eta = \sin^2\left(\frac{\pi \Delta n d}{\lambda \cos\theta_{int}}\right) \quad \text{\{Eqn 1\}}$$

$$\sin\theta_{int} = \frac{\lambda}{2n\Lambda} \quad \text{\{Eqn 2\}}$$

The first order diffraction efficiency of a thick Bragg grating is given by Eqn 1 [5], where η is the diffraction efficiency, λ is the wavelength in free space, θ_{int} is the internal angle between the incident light and y-axis of the crystal, d is the length of the grating and Δn is the change in refractive index due to the applied field. This efficiency equation only holds if the Bragg relation, Eqn 2, is simultaneously satisfied, where Λ is the period of the grating. For a given grating period a large range of wavelengths may be used by altering the launch angle, with the only constraints being set by the device geometry. This means that for a given wavelength it is possible to design the device to give high diffraction efficiency whilst taking into consideration fabrication constraints.

The design of the modulator devices is shown in Figure 1. It consists of an area of periodically domain inverted regions forming a grating of length d and period Λ. By applying a uniform electric field, E, between the $\pm$ z faces a periodic refractive index change is induced. The devices were fabricated using 500μm thick, z-cut lithium niobate and the grating was photo lithographically patterned on the –z face and poled using liquid electrodes [7]. To lower the capacitance of the device, the top electrodes were reduced to strip electrodes matching the dimensions of the grating.

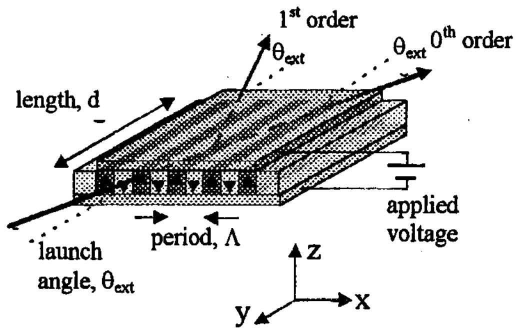

Figure 1: Schematic diagram of the periodically poled $LiNbO_3$ modulator device

We will present the first results on Bragg EO modulators operating at 1.064μm, describe their fabrication and present an investigation into the design considerations for such devices. We will also report our findings on the optimisation of modulator designs for shorter wavelengths. Problems are usually encountered at visible and blue wavelengths due to the strong photorefractivity of lithium niobate at these wavelengths. However in a poled device the poling is known to reduce the photorefractive effect [6], giving a degree of flexibility not present in other modulator designs. The effect of device temperature and annealing history on the diffraction efficiency and device bias will also be presented.

References:

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