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Optoelectronic Scheme for Generation of Time Bound Low-Frequency Electronic Signal Using Multi-Passing of Light

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Abstract: Linear electro-optic effect or Pockels effect is not only a very effective way to control the intensity or phase of a propagating radiation but it can also be used to generate a low-frequency electronic signal. Low-frequency electronic signal is useful in many real-world applications like bio-medical, signal processing, gravitational wave detection, etc. In this paper, the authors proposed a scheme for generation of time bound low-frequency electronic signal using multi-passing scheme of light through a Pockels cell with sawtooth electrical biasing. The Pockels cell is used in an amplitude modulation scheme.

Keywords: optical switch, frequency and amplitude modulation, optical feedback, multiple modulators in series

1 Introduction

When optical radiation propagates in a specific direction through a crystal in the presence of an applied electric field, the refractive index (r_i) of the crystal changes with the applied electric field. This electro-optic effect has wide range of applications in optical switches, amplitude, phase or in frequency modulation of light, etc. [1–5]. If the change in the r_i linearly varies with the applied electric field, then this is called linear electro-optic effect or Pockels effect. If the electric field is applied along the *c* axis (*z* axis) of a Lithium niobate ($LiNbO_3$) crystal, the principal refractive indices are

$$n_x = n_o - \frac{1}{2} n_o^3 r_{13} E_z$$

$$n_y = n_o - \frac{1}{2} n_o^3 r_{13} E_z$$

$$n_z = n_e - \frac{1}{2} n_e^3 r_{33} E_z$$

where n_o, n_e are constant refractive indices of the material (basically n_o and n_e are the refractive indices for the ordinary and extraordinary rays) without the electric field, r_{13} and r_{33} are the material electro-optic coefficients and E_z is the applied electric field along the *Z* direction. n_x and n_y are the refractive indices of the material in the presence of the electric field applied along *z* direction, with the light polarized along a specific *x* and specific *y* directions, respectively.

The optical radiation is incident on a $LiNbO_3$ crystal of length 'ℓ' and thicknesses '*d*' and propagates along *y* axis. The incident optical wave is polarized along 45° to the *z* axis in the *x*-*z* plane as shown in Figure 1. The incident light will decompose into two components along *x* and *z* directions and after passing through the crystal, the output radiation passes through an analyzer whose pass axis is perpendicular to the pass axis of the initial polarizer. The output from the analyzer is an amplitude modulated wave. The $LiNbO_3$ crystal is biased electrically by a modulating voltage *V* in transverse mode, i.e. the field direction (along *z*) is perpendicular to the propagation direction of light beam (along *y*). After traversing a length ℓ of the crystal along *y* direction, the two components of the output wave are

$$E_x(l) = E_x(0) e^{i\left[wt - n_o k_0 l + \frac{1}{2} n_o^3 k_0 r_{13} \frac{Vl}{d}\right]} \text{ and}$$

$$E_z(l) = E_z(0) e^{i\left[wt - n_e k_0 l + \frac{1}{2} n_e^3 k_0 r_{33} \frac{Vl}{d}\right]}$$

The output wave after passing through the analyzer is of the form

$$E'_{o/p} = \frac{1}{\sqrt{2}} \{E_x(l) - E_z(l)\}$$
$$= \frac{1}{\sqrt{2}} \Big\{ \frac{E_0}{\sqrt{2}} e^{i\left[wt - n_o k_0 l + \frac{1}{2} n_0^3 k_0 r_{13} E_z l\right]}$$
$$- \frac{E_0}{\sqrt{2}} e^{i\left[wt - n_e k_0 l + \frac{1}{2} n_e^3 k_0 r_{33} E_z l\right]} \Big\}.$$

$$E'_{o/p} = \frac{E_0}{2} \left\{1 - e^{-i\gamma}\right\} e^{i\left[wt - n_o k_0 l + \frac{1}{2} n_o^3 k_0 r_{13} \frac{Vl}{d}\right]},$$

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