ELECTRO-OPTIC INTERFERENCE FILTER LIGHT MODULATOR

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Electro-optic light modulation utilizing the Pockels effect in potassium dihydrogen phosphate (KDP) or similar materials usually requires either a high modulating voltage or a long crystal structure depending upon the particular modulation technique utilized. An electro-optic interference filter modulator has been developed which operates at greatly reduced voltages and power having a compact structure and the potential of high modulation rates.

The modulator is a Febry-Perot interference filter which is capable of being tuned by utilizing an electro-optic material as the interference filter dielectric. The operation of the modulator can be described quantitatively as follows. If the mirrors individually have reflectances R, the light intensity transmitted by the filter is given by:

$$I = \frac{I\,m}{1 + A^2 \sin^2 2\pi X} \qquad (1)$$

where

I = the transmitted intensity

Im = maximum transmitted intensity (limited by absorption in mirrors and crystal)

$A^2 = \frac{4\,R}{(1-R)^2}$

X = Optical path measured in wavelengths

$= \frac{n\,t\,\cos\phi}{\lambda_o}$

n = index of refraction of dielectric

ϕ = angle of incidence

t = distance between mirrors

λ_o = wavelength of incident light

From this equation we see that the device passes only narrow bands of light centered on the wavelengths λm for which the optical path is an integral number, m, of half wavelengths. Thus:

$$\lambda m = \frac{2\, n\, t \cos \emptyset}{m}$$

$$\lambda m = \frac{2\, n\, t}{m} \qquad : \emptyset = 0 \tag{2}$$

The optical path length for an electro-optical crystal is known to depend upon the applied voltage. For the particular material, direction of polarization, crystal orientation and electric field used the relationship is:

$$X = X_o \pm KV$$

$$= \frac{n_o t}{\lambda_o} \pm \frac{n^3 r_{63}}{2\lambda_o} V \tag{3}$$

where

n_o = ordinary index of refraction of KDP

r_{63} = applicable electro-optic constant of KDP

V = applied voltage

t = crystal thickness

With the interference filter adjusted so that operation is within one of the pass bands with no voltage applied, the change in voltage required to produce a given change in intensity is approximately:

$$\Delta V = \frac{Im^{\frac{1}{2}} (I_1 - I_2)^{\frac{1}{2}}}{2\pi KA \quad (I_1 I_2)^{\frac{1}{2}}} = \frac{\lambda_o (1-R) \quad Im^{\frac{1}{2}} (I_1 - I_2)^{\frac{1}{2}}}{2\pi\, n_o^3 r_{63} R^{\frac{1}{2}} \quad (I_1 I_2)^{\frac{1}{2}}} \tag{4}$$

where ΔV is the modulating voltage change and I_1 and I_2 are the output intensities at the respective maximum and minimum of modulation. The resultant modulation is approximately linear from 0.4 I m to 0.9 I m. The required modulating voltage is independent of thickness and reduced appreciably from that required with a Pockels cell.

In particular a modulator was constructed utilizing the above principals and produced 50% intensity modulation of a 6328A laser beam with an applied voltage of 88 volts rms. This corresponds to about one watt of modulator circuit power loss per megacycle of bandwidth.

A modulating voltage in the order of 25 volts and modulator powers of 1.2 milliwatts per megacycle of bandwidth are seen as practical values for future models. The modulator utilized a KDP crystal about twenty-five thousanths of an inch thick with a liquid fill between the KDP and mirror surfaces. The liquid was chosen to have an index of refraction matching that of KDP and thus reduce internal reflections at the crystal surface. The thirteen layer dielectric mirrors had reflectances of 98.4% at 6328A. The high optical Q of the interference filter is the only inherent bandwidth limiting factor of the modulator limiting the maximum modulating frequency to about one Gc.

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