before this operation. In the case of Fig. 5, by the lock-on procedure of the MB pair, a part of the lock-on filament between A and M near the electrode M will be unlocked by the same reason. Since this part of the filament is outside of the switch-on filament and lock-on filament between M and B, it can not be locked on again.

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ELECTRONICALLY TUNABLE ACOUSTO-OPTIC FILTER*

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Experimental results on a new type of electronically tunable optical filter are described. Tuning from 7000 to 5500 Å has been obtained by changing an acoustic driving frequency from 750 to 1050 MHz. A band pass of less than 2 Å, a corrected peak transmission of 50%, and an average skirt rejection ratio of about 45 dB have been obtained.

This letter reports the first experimental results on a new type of electronically tunable optical filter.[1] The filter makes use of collinear acousto-optic diffraction in an optically birefringent medium.[2] A crystal orientation is chosen such that an incident linearly polarized optical signal is diffracted into the orthogonal polarization by the acoustic beam. For a given acoustic frequency, only a small range of optical frequencies satisfy the $\bar{k}$ vector matching condition, and only this small range of frequencies is cumulatively diffracted. If the acoustic frequency is changed, the band of optical frequencies which the filter will pass is changed. In the present experiment, tuning from 7000 to 5500 Å has been obtained by changing the acoustic frequency from 750 to 1050 MHz. A band pass of less than 2 Å, a corrected peak transmission of 50%, and an average skirt rejection ratio of about 45 dB have been obtained.

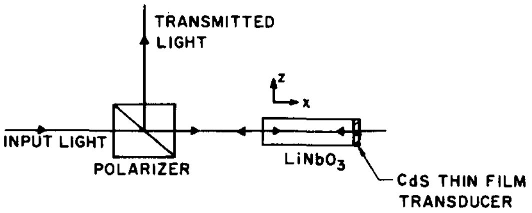

Fig. 1. Schematic of tunable optical filter.

In the filter configuration described here, and shown in Fig. 1, linearly polarized light is normally incident on a 1.8-cm-long crystal of 90° cut LiNbO$_3$, and propagates collinearly with a longitudinal acoustic standing wave along the x axis of the crystal. The incident light may be polarized along either the y or z axes. Diffraction into the orthogonal polarization occurs via the p_{41} photoelastic constant, and is only cumulative if $|k_o| - |k_e| = |k_a|$, where the subscripts o, e, and a denote the ordinary and extraordinary optical waves, and the acoustic wave respectively. This will be the case if the optical and acoustic frequencies f_0 and f_a are related by

$$f_0 = \frac{c}{V}\frac{1}{|\Delta n|} f_a , \qquad (1)$$

where c/V is the ratio of the optical velocity in vacuum to the acoustic velocity in the media, and Δn is the birefringence of the crystal. For LiNbO$_3$ for the orientation shown, $V \cong 6.57 \times 10^5$ and $\Delta n \cong 0.09$; and thus $f_0 \cong 5.1(10^5) f_a$.

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The pass band of this type of filter is of the form $\sin^2 x/x^2$,[1] and has a half-power width determined by the condition $|\Delta k L'| \cong 2\pi$, where L' is the total (round-trip) interaction length of the optical and acoustical fields. Neglecting the dispersion of the refractive indices, this gives a half-power bandwidth of about

$$\text{B.W.} \cong \frac{1}{2|\Delta n|L}\,\text{cm}^{-1}\,, \qquad (2)$$

where L is the length of the $LiNbO_3$ crystal. This gives a theoretical bandwidth of about 3.1 cm^{-1} or about 1.1 at 6000 Å. It should be noted that no secondary or higher-order pass bands are present.

The $LiNbO_3$ crystal was polished flat and parallel in order to enhance the longitudinal acoustic resonances which occured every 0.18 Mc/sec. From Eq. (1) this corresponds to an optical frequency spacing of about 3 cm^{-1}, which from Eq. (2) is about equal to the theoretical resolution of the filter. The width of the acoustic resonances was about 0.03 Mc/sec yielding an acoustic finesse of 6. The CdS thin film transducer had an area of 1.8 mm^2 and was centered at about 864 MHz (corresponding to 6328 Å). It had a half-power tuned bandwidth of about 15%, and a 17-dB electrical-to-acoustical conversion loss at 864 MHz.

The experimental tuning curve of the filter is shown in Fig. 2 and was obtained using a mercury arc light source and Beck reversion spectroscope. Further tuning was limited by the bandwidth of the CdS transducer. The resolution over this range was sufficient to just resolve the successive acoustic resonances (3 cm^{-1} apart). The average rejection ratio against frequencies outside of the pass band was 45 dB, and is a measure of the extent to which the crystal is strain free. The half-power angular aperture was estimated to be about 0.03 rad.

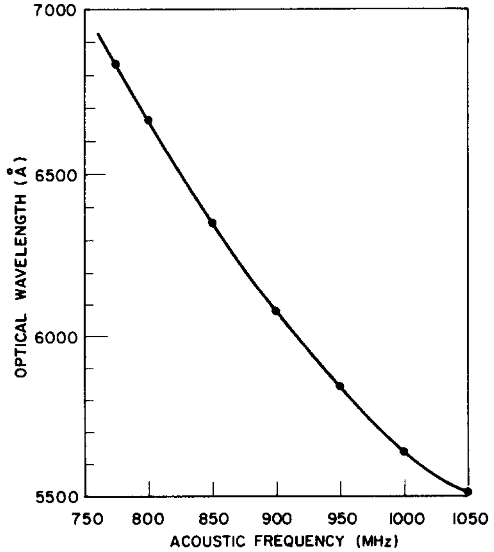

Fig. 2. Tuning curve.

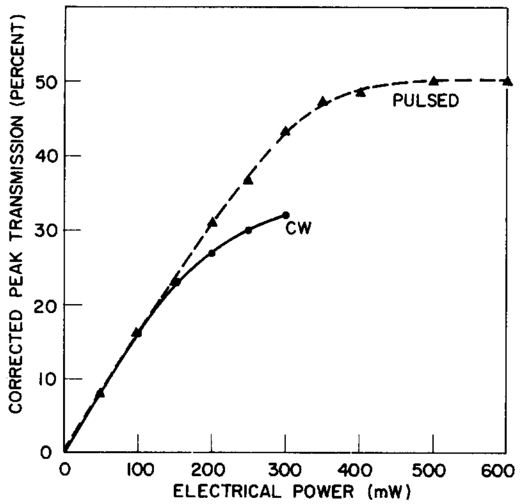

Fig. 3. Corrected peak transmission versus electrical power. Transmission is corrected for optical losses at the crystal input face and at the acoustic transducer. 50% corrected transmission corresponds to a measured transmission of 21%.

Peak filter transmission was measured using a He–Ne laser, and results are shown in Fig. 3. The data shown are corrected for optical losses experienced at the crystal input face and at the acoustic transducer. The reflection coefficients of these surfaces were 15 and 58%, respectively. It is seen that at about 500 mW of electrical input power corrected transmission has saturated at 50%. This maximum results because of additional conversion to sidebands which have the same polarization as that of the input signal. As a result of crystal heating, the maximum corrected cw transmission was limited to about 30%.

It should be noted that our 17-dB transducer loss is about 10 dB greater than may be obtained.[3] Improved transducers, somewhat larger crystals, and the use of appropriate optical coatings should make it possible to approach 50% transmission with electrical powers less than 25 mW.

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