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TeO_2 ACOUSTO-OPTIC TUNABLE FILTER

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1. Introduction

An acousto-optic device has three major functions, i.e. modulation, deflection and filtering of a light beam. The modulation and deflection were acomplished most efficiently by using an anisotropic diffraction based on the OPTICAL ACTIVITY in TeO_2 crystal in 1972.(1) The filter had remained insufficient although $CaMoO_4$ was reported in 1970.(2) The filter, however, was found by us to be quite practical by using an anisotropic diffraction based on the BIREFRINGENCE in TeO_2 crystal in 1974.(3)

2. Operation principle

A light diffraction by sound selects a light with a definite wavelength. This selective diffraction occurs quite effectively when the light beam travels in the direction far from the optic axis ⟨001⟩ and the shear sound is launched in the direction ⟨110⟩ in TeO_2. The diffraction behavior is easily explained with the wave vector diagram shown in Fig. 1. A filter configuration by using this FAR OFF AXIS ANISOTROPIC diffraction is depicted in Fig. 2.

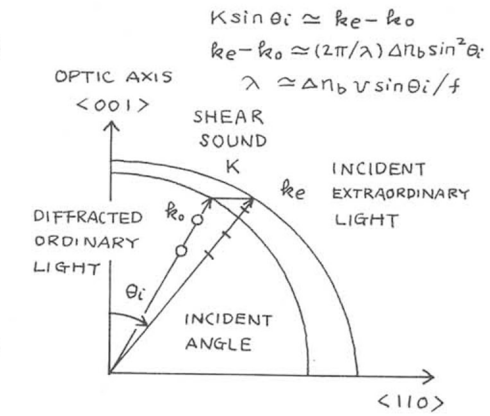

Fig. 1. Wave vector representation for far off axis anisotropic diffraction.

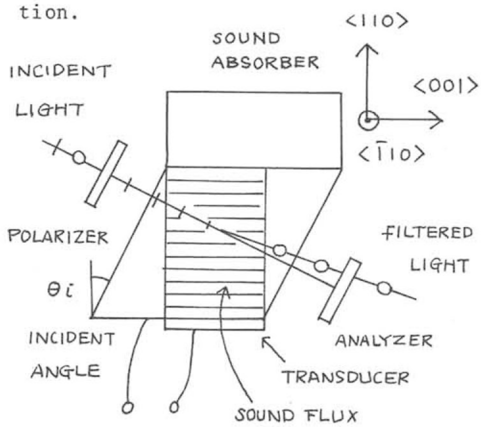

Fig. 2. Schematic of TeO_2 acousto-optic tunable filter

3. Tuning of light wavelength

The light wavelength λ to be tuned is determined by sound frequency f with birefringence Δn_b, sound velocity v, light incident angle θ_i as parameters. Measured light wavelengths quite well fit to the calculated curve plotted in Fig. 3. The simply approximated expression

$$\lambda = \Delta n_b v \sin\theta_i / f \qquad (1)$$

also indicates well the whole behavior of the filter operation. The visible light can be tuned by the sound frequency below 100 MHz.

4. Bandwidth of filtered light

The bandwidth $\Delta\lambda$ of the filtered light is estimated by

$$\Delta\lambda = 0.9\frac{\lambda^2}{\Delta n_b' L'} \qquad (2)$$

where, $\Delta n_b' = \Delta n_b \sin^2\theta_i$, $L' = L/\cos\theta_i$ are the birefringence and the light·sound interaction length of the light beam along the propagation direction. Measured bandwidth was 18 Å for L = 1.5 cm, λ = 6390 Å, θ_i = 21.4°. This value is larger than the calculated value of 10 Å due to misalignment of an optical system. The bandwidth can be changed from several Å to several hundreds Å by changing the incident angle.

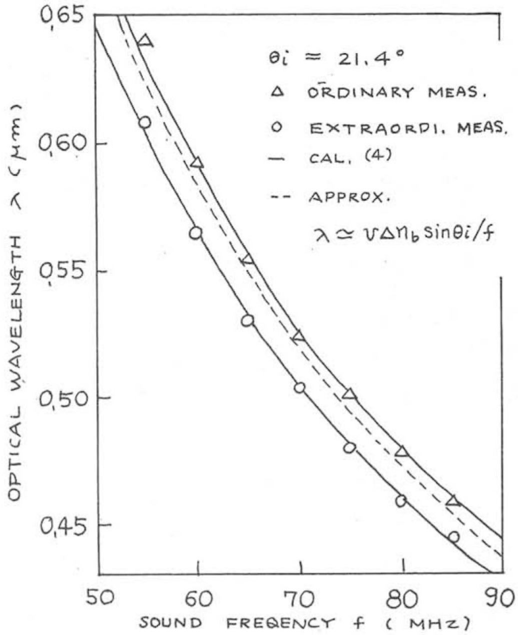

Fig. 3. Tuning Curve

5. Acoustic power for 100% light transmission

The acoustic power Pa100 for 100% light transmission is calculated by

$$\mathrm{Pa100} = \frac{1}{2}\lambda^2\left(\frac{H}{L}\right)\frac{1}{Me} \qquad (3)$$

where H, L are the height and the length of the transducer, Me is the acousto-optic figure of merit which is $n^6p^2/\rho v^3$ and 1200×10^{-18} sec^3/g at 6328 Å.[5]. The 95% peak optical transmission for L = 1.5 cm, H = 0.4 cm was obtained with the C. W. electric input power of 52 mW for theoretical acoustic input power of 45 mW.

6. Summary

This TeO_2 acousto-optic electronically tunable filter has excellent properties as summarized below. (1) The acoustic power required for 100% light transmission is extremely small (1/600 that of $CaMoO_4$). (2) The bandwidth of filtered light is variable in a wide range. (3) The response time is very short; about 10 μsec. (4) The intensity of the filtered light can be modulated. (5) The crystal of TeO_2 has a good optical quality.

(1) A. W. Warner, D. L. White, and W. A. Bonner; J. Appl. Phys. 43, 4489 (1972).
(2) S. E. Harris and S. T. K. Nieh; Appl. Phys. Lett. 17, 223 (1970).
(3) T. Yano and A. Watanabe; Appl. Phys. Lett. 24, 256 (1974).
(4) By data in N. Uchida; Phys. Rev. B 4, 3736 (1971).
(5) T. Yano and A. Watanabe; J. Appl. Phys. 45, 1243 (1974).