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Visual-aural properties of some optical glasses

Ultrasonic waves generate in gases, liquids and solid-state bodies periodic density fluctuations. The refractive index differences resulting therefrom act on light beams like a diffraction grating.

The diffraction of laser beams by ultra-sound is applied in many areas of visual communication (beam deflection, beam scanning, Q-switching, holographic storage with x-y deflection systems, visual computers, visual correlators).

In addition to some crystals, optical glasses of high refraction are suitable materials for sound-light modulation. The deflection efficiency (1) is a measuring size for their qualification as acoustic light deflectors [1] :

$$\eta = \frac{\pi^2}{2} \cdot \frac{n^6 \, p^2}{\rho \, v^3} \cdot \frac{W}{H \, \lambda^2} \cdot P_{ak} \qquad (1)$$

p	photo-elastic tensor component
v	sound velocity within medium
n	refractive index
ρ	density
H	length of sound fields
P_{ak}	acoustical power

The figure of merit

$$M_2 = \frac{n^6 \, p^2}{\rho \, v^3} \qquad (2)$$

is a function only of the material properties of the visual-aural deflector used.

The photo-elastic tensor components p_{11} and p_{12}, required for determining the figure of merit, are yielded by the measurement of the refractive index variations resulting from the mechanical stresses for light oscillating in parallel ($\Delta n_{\parallel}$) with and perpendicular ($\Delta n_{\perp}$) to the direction of stress [2].

$$p_{11} = \frac{2E}{n_o^3 \sigma (2\mu^2 + \mu - 1)} \cdot \left[2\mu \Delta n_{\perp} + \Delta n_{\parallel} (1 - \mu) \right] \qquad (3)$$

$$p_{12} = \frac{2E}{n_o^3 \sigma (2\mu^2 + \mu - 1)} \cdot (\Delta n_{\perp} + \mu \Delta n_{\parallel}) \qquad (4)$$

E	modulus of elasticity
μ	Poisson's ratio
n_o	refractive index of strain-free glass
σ	mechanical stress

The dependence of the refractive index variations $\Delta n_{\parallel}$ and $\Delta n_{\perp}$ on the mechanical stress σ has been determined interferometrically in a bending tensile test [3].

The sound velocity in longitudinal direction results from the relation

$$v_{long} = \sqrt{\frac{E}{\rho} \cdot \frac{1-\mu}{(1+\mu)(1-2\mu)}} \qquad (5)$$

The photo-elastic tensor components and the visual-aural figure of merit of some optical glasses are given in the following table for wave length 0.6328 µm. Further literature [4,5,6].

In addition to a high visual-aural figure of merit, little ultra-sound attenuation and low absorption in the visible region of the spectrum are desired. Are given the sound attenuation for various acoustic frequencies and the internal transmittance for $\lambda = 0.6328$ µm with a specimen thickness of 1 cm.

Tests performed on new glasses showed that the visual-aural properties can be further improved. A figure of merit of $M_2 > 20 \cdot 10^{-18}$ sec^3/g has already been attained. However, the attenuation losses of approx. 4 db/cm at 50 mHz and of approx. 8 db/cm at 100 mHz are still relatively high. We will be pleased to receive inquiries on the subject.

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Visual-aural properties of some SCHOTT glasses for $\lambda = 0.6328$ µm

Glass type	F2	SF2	SF6	SF14	SF57	SF59
Refractive index	1.617	1.644	1.799	1.756	1.840	1.943
Modulus of elasticity (kp/mm^2)	5910	5650	5660	6640	5560	5250
Sound velocity v_{long} (m/sec)	4300	4080	3580	4090	3460	3200
Density (g/cm^3)	3.61	3.86	5.18	4.54	5.51	6.26
Poisson's ratio	0.225	0.231	0.248	0.235	0.253	0.269
Photo-elastic tensor components						
p_{11}	0.18	0.19	0.21	0.18	0.22	0.27
p_{12}	0.25	0.24	0.22	0.21	0.22	0.24
Visual-aural figure of merit						
M_2 (p_{11})	2	3	6	3	8	19
M_2 (p_{12})	4	4	7	4	8	15
(10^{-18} sec^3/g)						
Sound attenuation						
50 mHz	~1	~1	2.3	1.2	1.4	5.3
100 mHz	~2	~2	5.4	2.5	5.2	12.0
(db/cm)						
Internal transmittance for $\lambda = 0.6328$ µm with d = 1 cm	0.997	0.998	0.998	0.995	0.997	0.998