LIQUID GATE

CHOICE OF INDEX OF REFRACTION OF LIQUID TO SUPPRESS DIFFRACTION SPECTRUM

STAT

Tests were made on a single sample of each of 5 films. A Ronchi grating was printed on each sample and then bleached off so as to leave a transparent thickness grating in the emulsion. When placed in the negative plane of a coherent light enlarger ($\lambda = 6328 Å$) the grating caused a diffraction spectrum, the intensity of which was determined by a suitable photocell. Liquids of various indices of refraction were applied to the film (both sides) to suppress the spectrum; the results were as follows:

FILM TYPE	INDEX FOR GREATEST SPECTRUM SUPPRESSION	SUGGESTED USEFUL RANGE (CURVES FAIRLY FLAT)
E.K. 4400	1.66	1.62 to 1.70
E.K. 4401	1.36	1.32 to 1.42
E.K. 4404	1.58	1.54 to 1.62
E.K. 5401	1.60 (Approx)	N / A
E.K. 8401	1.58	1.56 to 1.62

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LC:lc
9/13/63

STAT

[redacted]

COHERENT LIGHT ENLARGER AND SPATIAL FILTER

3rd Progress Report: 13 Aug to 9 Sept 63

The breadboard enlarger has been lined up with lens #1 and enlargements have been made in coherent light. These enlargements show the general characteristics to be expected. The various artifacts are being traced by further experimentation which is currently in progress. A break down of the [redacted] camera and shutter has caused some delay.

The optical design for the prototype has been completed for lens #1, but the design for lens #2 is not yet complete. Lens #1 design calls for six spherical elements and should therefore be much easier to fabricate than an aspheric lens design which had been anticipated in the proposal. Lens #1, the two collimating lenses, the two cell windows, and a plate for the spatial filter plane were released for optical fabrication.

The optical design for lens #2 of the prototype is not yet complete because the optical designer has been unable to work on it. If lens #2 is a simple lens (and this is expected) another two weeks delay should not affect the schedule. However, the absence of a design is delaying the opto-mechanical layout, cell fabrication, and those mechanical design aspects contingent on it.

The engineering analysis and customer review, which is scheduled for the week of 23-27 September is tentatively scheduled for 25-26 September.

[redacted]

10 September 1963

[redacted]

[redacted]

STAT

COHERENT LIGHT ENLARGER AND SPATIAL FILTER

2nd Progress Report: 9 Jul to 12 Aug 63

The breadboard enlarger has been set up except for Lens #1. Without Lens #1, the spectrum is formed by Lens #2, and this spectrum was used to find the correct liquid index for each of the five films so far provided by the customer, using bleached Ronchi gratings.

A 16-inch focal length collimator objective is now being used as a temporary substitute for Lens #1. This will be used to find approximate exposure and focus, and to make trial enlargements of test images, which have also been printed on the supplied film.

Lens #1 for the breadboard is now in the final stages of figuring and its lateness, if held to one more week, will not affect schedule.

The optical design for Lens #1 and Lens #2 of the Prototype is now due one week late, but the Optical Designer is working through vacation. By some schedule manipulation, we can probably absorb one further week of delay without prejudice to final delivery.

A trial spatial filter was made, but has not yet been fully evaluated. As it appears to be irregular, improved coating jigs are being fabricated.

Some of the required film has not been provided, and this has necessitated "borrowing" from other Special Projects film.

[redacted]

STAT

12 August 1963

mb

Change of Refractive Index with Temperature

STAT

In a recent technical memo* it was stated that as a result of the Lorenz-Lorenz law

$$\frac{n^2-1}{n^2+2} = (\text{constant}) \times \text{density}, \qquad (1)$$

the coefficient of index of refraction, n, variation with temperature, θ was

$$\frac{\partial n}{\partial \theta} = \beta \left(\frac{n^4+n^2-2}{6n}\right) \qquad (2)$$

where β is the volume thermal expansion coefficient of the liquid.

The purpose of this memo is to call attention to the fact that the Lorenz-Lorenz law is not accurately valid and that, therefore, Equation (2) is subject to error. To illustrate this we consider experimental data for water and 99+% pure Ethyl alcohol, at 20°C.

Material	n	$\frac{n^4+n^2-2}{6n}$	β	predicted $\frac{dn}{d\theta}$	observed $\frac{dn}{d\theta}$
Water	1.333	0.368	2.07×10^{-4}	-0.76×10^{-4}	-1.0×10^{-4}
Alcohol	1.360	0.405	1.12×10^{-3}	-4.5×10^{-4}	-4.06×10^{-4}

*MDR-106
(note typographical error in Eq. 1)

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Branch Research

The values of n, β, and observed dn/dθ are taken from the handbook of Chemistry & Physics (32nd Ed). As can be seen the errors are not great but they can be significant.

The invalidity of the Lorenz-Lorenz "law" arises from quantum mechanical coupling between adjacent atoms (or molecules). In solids the coupling is high and the law is very poor. In gases the law is good. In liquids, the accuracy is intermediate, and one might expect that accuracy would be improved as the temperature approached the liquid's boiling point. This could explain why the (20°C) prediction above is better for alcohol than water, although the true situation is almost certainly more complex than has been indicated here.

STAT

[illegible]/mq
[illegible]-11-63

CHANGE OF LIQUID'S REFRACTIVE INDEX WITH TEMPERATURE

STAT

In many coherent optical systems, it is desirable to have liquid gates in which objects of non-uniform thickness are immersed in a liquid having the same refractive index. Thus, for instance, only transparency differences recorded on film will affect the transmitted light and the thickness irregularities will not alter the optical phase. Because the refractive index is temperature sensitive, it may be necessary to control the temperature and/or temperature uniformity of the liquid; and for this reason, the change of refractive index with temperature for a liquid was investigated.

The Lorenz-Lorentz law states

$$\frac{n^2-1}{n^2+1} = c\rho$$

where n is the refractive index, ρ the density, and c a constant. If θ is the temperature, and β the coefficient of cubical (volume) expansion,

$$\frac{dn}{d\theta} = \frac{\partial n}{\partial \rho}\frac{d\rho}{d\theta}$$

$$= \left\{\frac{n^4 + n^2 - 2}{6\rho n}\right\}\left\{-\rho\beta\right\}$$

$$= -\beta\left\{\frac{n^4 + n^2 - 2}{6n}\right\}.$$

Thus, $dn/d\theta$, a quantity which is seldom tabulated, can be evaluated in terms on n and β, both of which are commonly tabulated. The bracketed term has been evaluated:

n =	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7
Bracketed term =	0	0.10	0.21	0.33	0.45	0.59	0.74	0.91

STAT

Since n (and therefore, the bracketed term) is not likely to be a quantity which can be varied to suit the engineer's or experimenter's wishes, it is clear that liquids with low k are most favorable. If n is also variable, liquids with low n should be selected.

As a rule of thumb, the change in optical path will be about one wavelength (0.6 μ) per millimeter of liquid path per degree Centigrade. (From the American Institute of Physics Handbook 4-62, β ranges in the decade from 0.2×10^{-3} to 2.0×10^{-3} $°C^{-1}$.)

[redacted] STAT

21 October 1963

ERRATA SHEET
for

TECHNICAL MEMORANDUM [redacted] STAT

CHANGE OF LIQUID'S REFRACTIVE INDEX WITH TEMPERATURE

The second paragraph should read:

The Lorenz-Lorentz law states

$$\frac{n^2-1}{n^2+2} = c\rho$$

[redacted] STAT

mb

STAT [redacted]

Dear John:

This progress report was prepared to satisfy internal reporting requirements. I believe it will help you follow our progress to receive these, so we will plan to send you future ones as well.

Milt
Milt
10 Jul 63

[redacted]

STAT

8 July 1963

COHERENT LIGHT ENLARGER AND SPATIAL FILTER

Progress Report: 1 Jun to 8 Jul 63

Project assignments were made as scheduled. [redacted] project engineer. [redacted]

STAT

The only task not on or ahead of schedule is the fabrication of the breadboard lens (#1), the start of which was delayed one week awaiting the optical design. If the Manufacturing Department can complete its work on this lens in six instead of the originally estimated seven weeks, we will be back on schedule by the ninth week. Otherwise, we may need to use overtime during the breadboard test phase (10th-16th weeks) to recover the week delay. The two condenser lenses are progressing satisfactorily in the Optical Model Shop.

The customer has furnished a T-5 lens as required, and has our order for the required film. Also, the customer has provided some reports on previously contracted spatial filtering which apparently was not very successful; and we will avoid those pitfalls. A soft plastic which the customer believes may be useful instead of a liquid gate was shown to us and is to be investigated experimentally.

Orders have been placed for the prototype raw glass (oversize), the breadboard optical bench, shutter, pinholes and several gate liquids. The laser and plane-parallel disks are already on hand.

The breadboard will start to be set up in the [redacted] "green room" during the next month.

STAT

[redacted]

STAT

mb

Standard Dist.
External Dist. - JC, GT
JP, ELT
Cust/Contr (2) via CMH