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Minimizing the effects of the relief image in a coherent system through index matching

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Minimázing the Effects of the Relief Image In a Coherent System Through Index Matching

BY

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"Minimizing The Effects Of The Relief Image In A Coherent System Through Index Matching."

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Abstract

The effect of the relief image in a coherent optical system was minimized by matching the average refractive index of the emulsion n_e with that of a liquid of a known refractive index n_l. A match of n_e and n_l was determined by minimizing the intensity of the first side order of the Fraunhofer diffraction pattern of a sine-wave image. A match of n_e and n_l can be made exactly only when the surface gelatin associated with the silver and the differential tanning effects of development are not present. Under other conditions n_e is not homogeneous. The intensity of the Fraunhofer pattern was however reduced from 70% of the d.c. in air to only 0.25% of the d.c. in a liquid of n_l which approximates n_e best.

Introduction

To measure the effects of the relief image when it is in contact with liquids of different refractive indices has these benefits:

1. When n_e (the refractive index of the emulsion) and n_l (the refractive index of the liquid) are matched, amplitude variations (in a coherent system) can be measured, independent of phase variations. Thus some of the problems in measurement can be reduced in seriousness when only density information is desired.
2. It would, through an independent measure of the refractive index of the liquid, give a new and useful tool for measuring the refractive index of the emulsion while it is on the base performing its imaging functions. By measuring the relative intensities of the Fraunhofer pattern while the film is immersed in a series of liquids with various refractive indices, it can be determined when the relative intensity (with respect to the central order) of the first side order is at a minimum. At this point n_l and the average n_e are the same. (Fig. J).

Introduction - Continued

The experiment considers the possibility that refractive index is a matter of variability around a mean rather than a single number.

Theory

In photographic emulsions there is invariably a relief effect associated with the removal of the unexposed silver halide from the emulsion by the fixing process. (Fig. C)[2]. In a coherent optical system the varying retardation of the wave front associated with the relief image, produces a Fraunhofer diffraction pattern by phase differences at different points in the image (Fig. A). Such a process is the equivalent of a Fourier transform. The Fraunhofer diffraction pattern of periodic information yields a central order(D.C.) and side orders. (Fig. B). The ratio of the side to central order is proportional to the modulation of the periodic information. If the side orders are zero then the modulation is zero and there is no periodic information going through the system. Evidence of local inhomogeneities in the emulsion would be that the relative intensity of the first order does not go to zero but minimizes at the average n_e. (Fig. J) Inhomogeneities in refractive index could be caused by unequal drying of the gelatin, from the tanning effect of development, and the removal by the fixer of unexposed silver, both of which set up stresses in the gelatin.

Objective

To find the extent to which the effects of the relief image (in a coherent optical system) may be reduced through a technique of index matching. The extent of the effect was determined by measurement of the Fraunhofer intensity spectrum.

Procedure

By imaging on the film a sinusoidal modulation of intensity, processing, removing the silver, the Fraunhofer diffraction pattern of the remaining relief image, can be measured.

Procedure:

1. Synthesize optically[1] harmonic-free sine waves from spatial filtering of a 5 cy./mm. ronchi ruling. A mercury arc (100 watt) was used with a 100 micron pinhole, a 24" collimator, a 10" transforming and 10" inverse-transforming lenses (Fig. A). The +1 and -1 orders of the ronchi ruling were passed to give a sine wave of 10 cy./mm. (Fig. B). A 30 sec. exposure was used with SO-243 film.
2. The film was developed in D-19 for 8 min. at 68F.
3. The resulting images were treated in one of two solutions (Fig. F).
   a. The copper etch solution (used after fixation) attacks metallic silver and removes the silver and the gelatin associated with it. This solution removes mostly surface gelatin, as most of the silver is formed at the surface (Fig. G).

Procedure - Continued

3. b. The ammonium bichromate bleach changes the silver to silver bromide which is then removed by fixing. The surface gelatin (associated with imaging) is not removed (Fig. H).

4. Liquids of various refractive indices were produced by mixing cargile refractometer liquids of index 1.457 and 1.624. A liquid gate was used to put these liquids in intimate contact with the emulsion.

5. An Abbe refractometer was used to obtain values of index for the fluids.

6. With a given image in the liquid gate, a densichron was used to measure intensity relative to the d.c. of the first side order of the Fraunhofer pattern. Such measurements were repeated with liquids of different refractive indices.

7. When the intensity of the first order is at a minimum we have our best estimate of the average n_e of the emulsion (Fig. J).

Procedures - Continued

8. Using a camera at the image position (Fig. A) the reimaged diffraction pattern was photographed with the central order (d.c.) suppressed. The purpose of suppressing the central order was to increase the visibility (modulation) of the sine waves formed by the side orders and to photograph them.

Results

From the plot of refractive index vs. log relative intensity (Fig. J) a minimum was determined by fitting a regression curve to the data ($I = -162.160n^2 + 498.943n - 381.5460$) and setting the first derivative equal to zero and solving for n ($n = 1.5384$). The effects of the relief image, measured as relative intensity of the first side order, were reduced from 70% of the d.c. in air to 2.5% in a liquid of index 1.47 and to only 0.25% at our best estimate of the refractive index i.e. 1.5396. With a liquid of approximately 1.5384 ($N = 1.5396$) in contact with the emulsion the sine waves from both the etch and the bleach were reimaged suppressing the central order. When immersed in a liquid of refractive index 1.5396, in the etch case periodic information was not present because the relief image was suppressed. But in the case of the bleach periodic information was present (Fig. T).

Conclusions

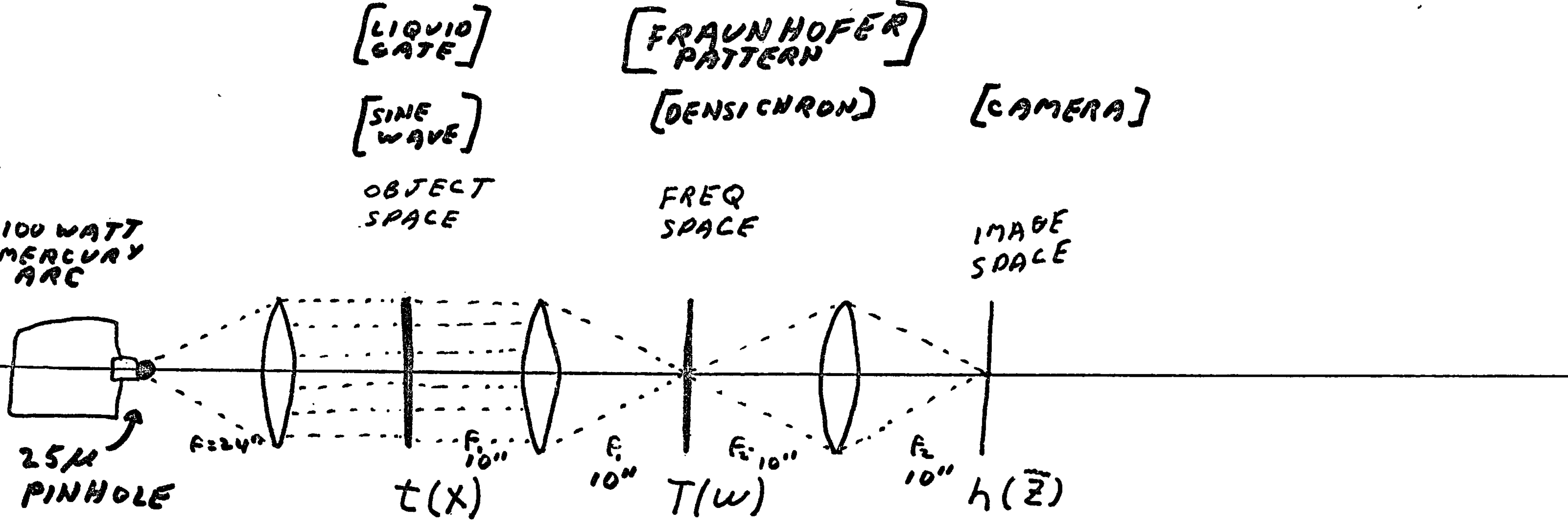
1. The refractive index of the emulsion is not homogeneous in refractive index.
   a. Because with a liquid of index 1.5396 in contact with the etched sine waves for which the gelatin associated with imaging (surface gelatin that formerly held the silver metal) is not present, the refractive index can be matched i.e. the Fraunhofer pattern disappears.
   b. But with the same liquid in contact with the bleached sine waves for which the gelatin associated with imaging is present, the refractive index of the emulsion cannot be matched i.e. the Fraunhofer pattern does not disappear (Fig. T).
2. The effects of the relief image can be eliminated in gelatin only when the effects of imaging are not present i.e. an etch where the surface gelatin has been removed or in the case of eliminating the effects of a scratch in the emulsion.

Discussion

1. Inhomgeneities in refractive index could be caused by differential hardening (orientation of the gelatin) and the suspension of particles in the gelatin. The former is a property of the surface (imaging) gelatin. (Bleach rather than etch). The latter is a property of the bleached (chromate) and the unbleached (silver) emulsions.
2. The question whether 0.25% relative intensity in the first order will affect amplitude measurements is yet to be answered.

Literature References

1. R. E. Swing and M. Shin, Phot. Sci. Eng., Vol. 7, No. 6 (1963)
2. J. Altman, Applied Optics, Vol. 5, P.1689 (1966)



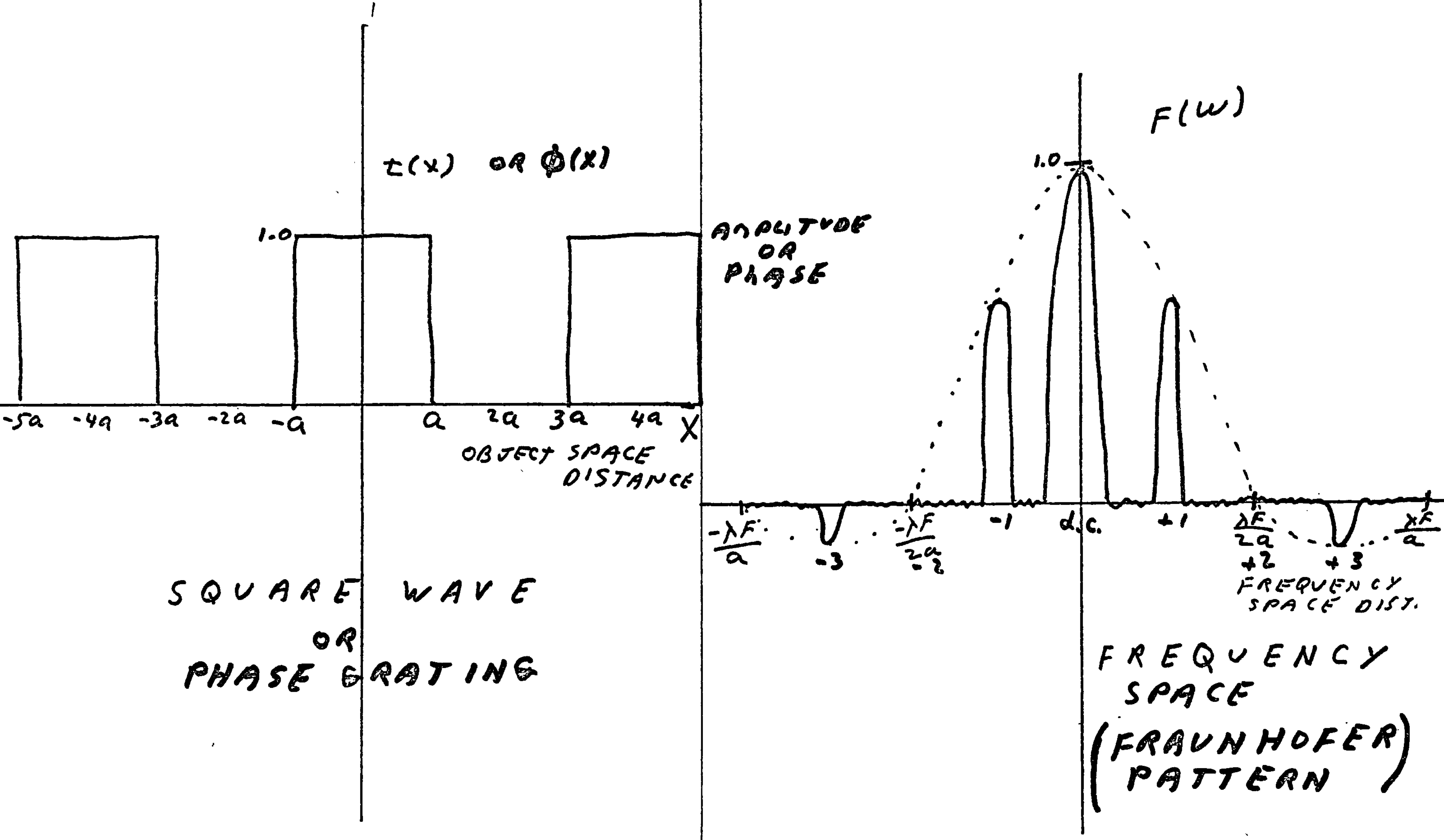
$$T(w) = F[t(x)]$$

$$h(\tilde{z}) = F^{-1}[T(w)]$$

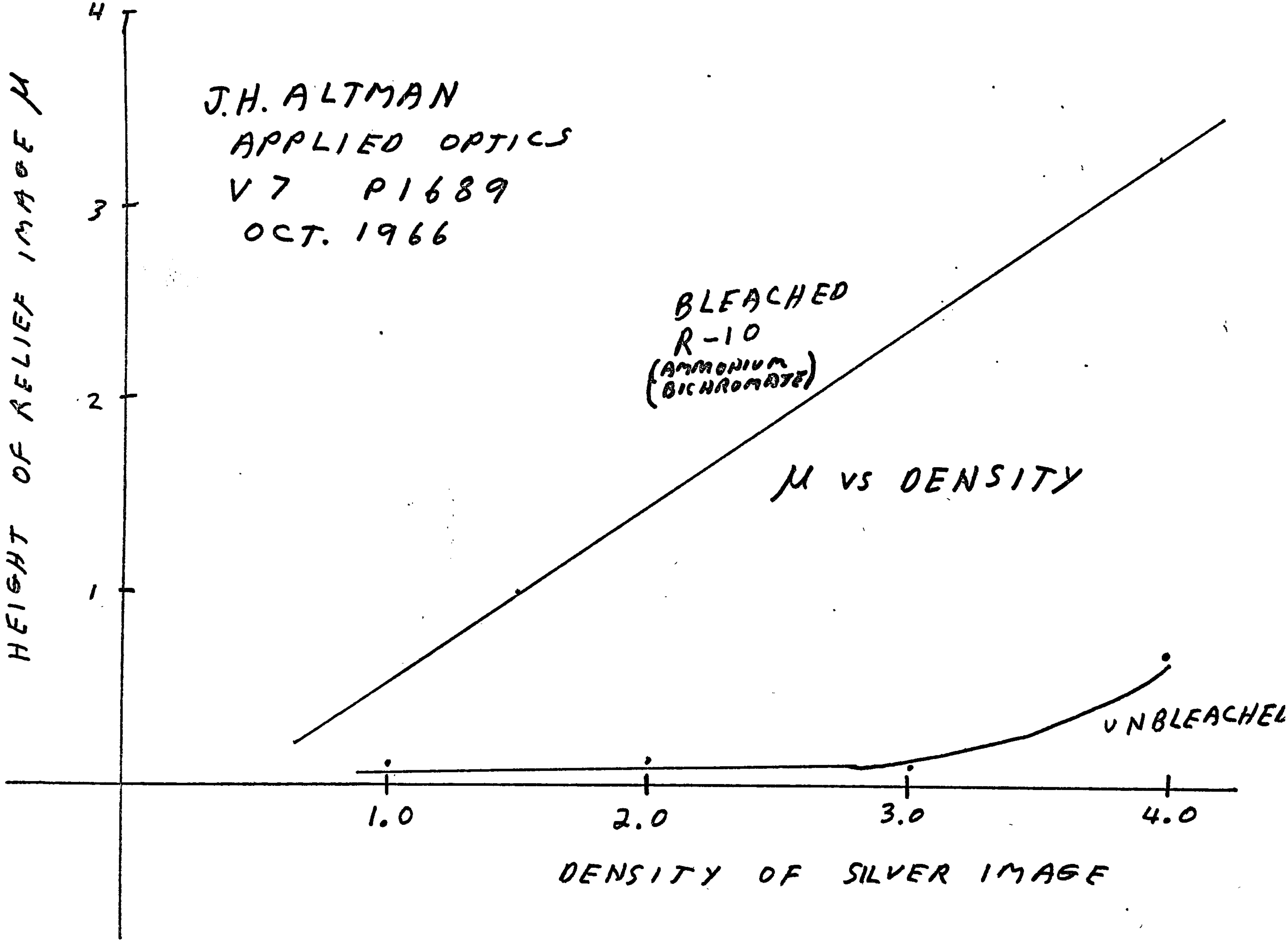
COHERENT OPTICAL SYSTEM

$F[\ \ ]$ IS FOURIER TRANSFORM

$F^{-1}[\ \ ]$ IS FOURIER INVERSE TRANSFORM



t(x) OR Φ(X)
1.0
-5a -4a -3a -2a -a a 2a 3a 4a X
OBJECT SPACE DISTANCE
AMPLITUDE OR PHASE
SQUARE WAVE OR PHASE GRATING
F(w)
1.0
-λF/a -3 -λF/2a -2 -1 d.c. +1 λF/2a +2 +3 λF/a
FREQUENCY SPACE DIST.
FREQUENCY SPACE (FRAUNHOFER PATTERN)


J.H. ALTMAN
APPLIED OPTICS
V 7 P1689
OCT. 1966
HEIGHT OF RELIEF IMAGE μ
1
2
3
4
BLEACHED
R-10
(AMMONIUM BICHROMATE)
μ VS DENSITY
UNBLEACHED
1.0
2.0
3.0
4.0
DENSITY OF SILVER IMAGE

KODAK R-10 BLEACH

A

WATER	500 ML
AMMONIUM BICHROMATE	20 GRAMS
H_2SO_4	14 ML

B

NaCl	45 GRAMS
H_2O TO MAKE	1 LITER

A + B + 10 WATER

ETCH

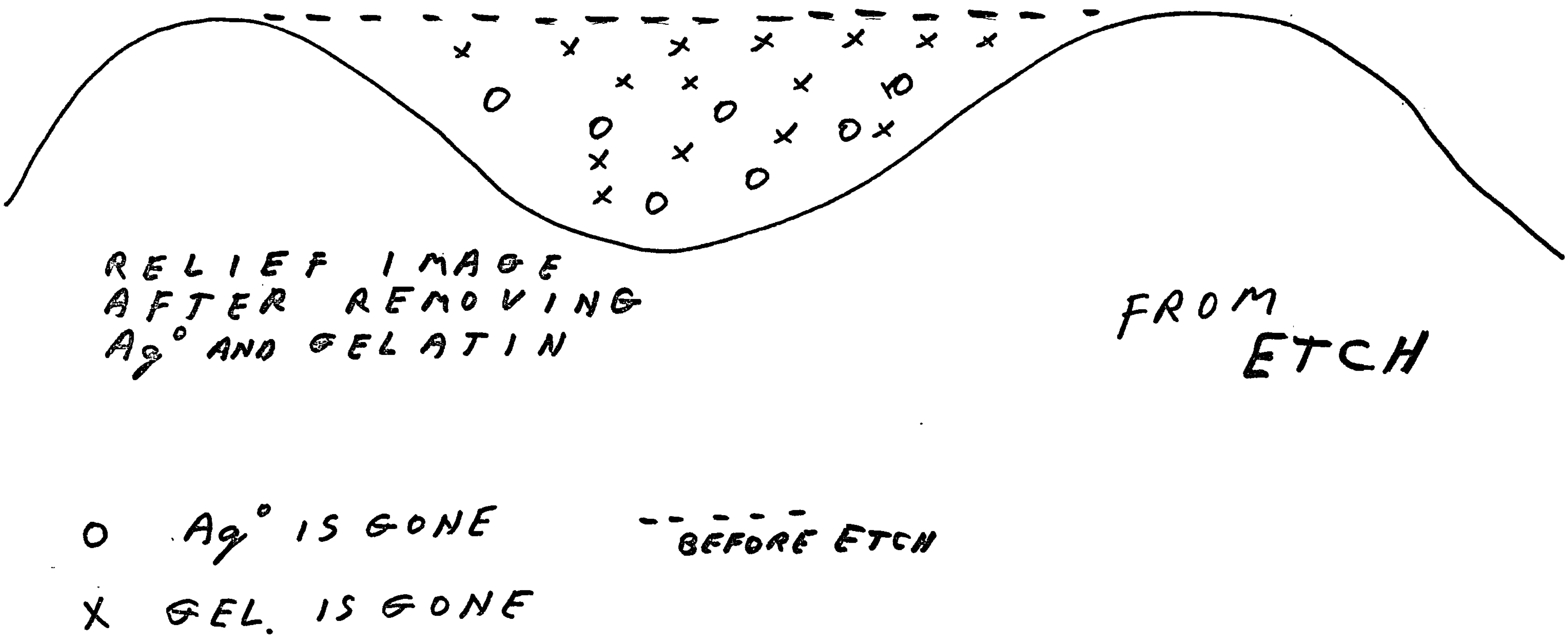
A

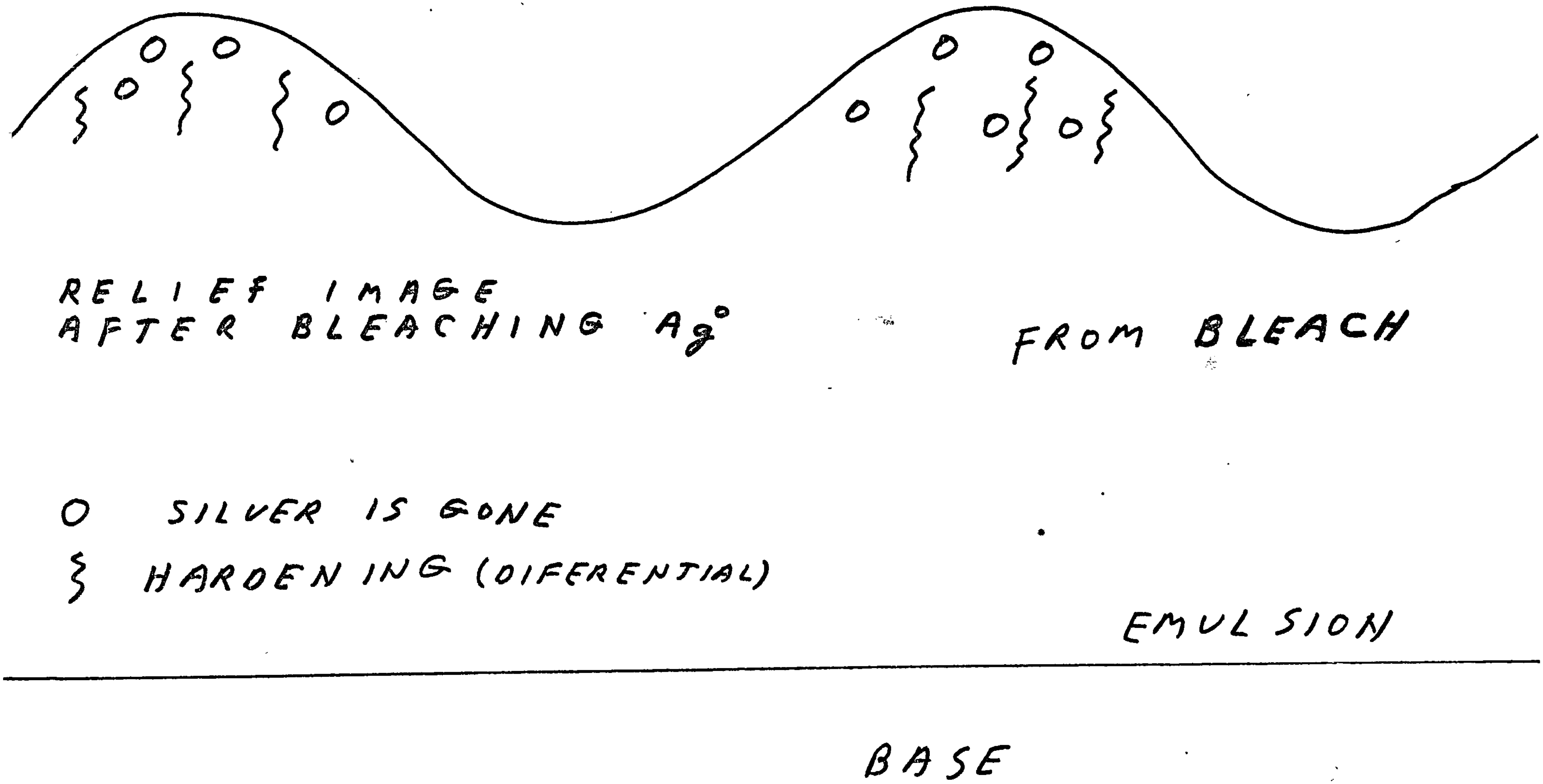
HAc	20 OZ (FL)
H_2O	48 OZ (FL)
CUPRIC NITRATE	27 OZ
KBr	1.3 OZ
H_2O TO MAKE	1 GAL.

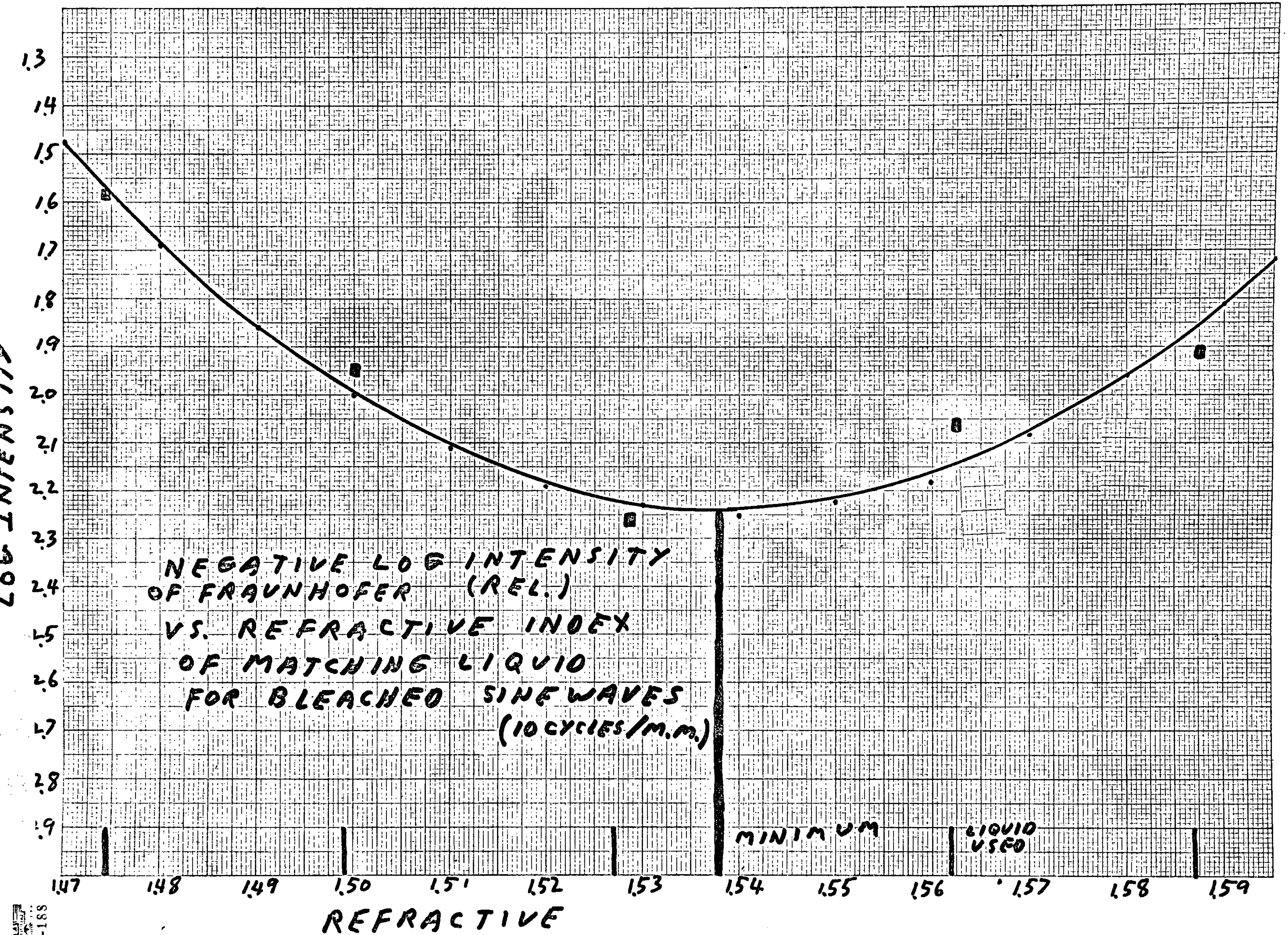
B

3% H_2O_2

A + B


RELIEF IMAGE
AFTER REMOVING
Ag° AND GELATIN
FROM ETCH
O Ag° IS GONE
- - - - - BEFORE ETCH
X GEL. IS GONE


RELIEF IMAGE
AFTER BLEACHING Ag°
FROM BLEACH
O SILVER IS GONE
HARDENING (DIFERENTIAL)
EMULSION
BASE


NEGATIVE LOG INTENSITY
OF FRAUNHOFER (REL.)
VS. REFRACTIVE INDEX
OF MATCHING LIQUID
FOR BLEACHED SINEWAVES
(10 CYCLES/M.M.)
MINIMUM
LIQUID USED
LOG INTENSITY
REFRACTIVE
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
1.47
1.48
1.49
1.50
1.51
1.52
1.53
1.54
1.55
1.56
1.57
1.58
1.59