ERIM

FORMERLY WILLOW RUN LABORATORIES, THE UNIVERSITY OF MICHIGAN

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MEMORANDUM TO: I. Cindrich

FROM: C. Leonard C.L.

SUBJECT: Construction of Precision Low Frequency Gratings

Several problems were encountered and dealt with in the production of precision low-frequency gratings.

1. Plane alignment of two constructing point sources
2. Plate-holder alignment
3. System stability
4. Determination of optimum modulation
5. Uniform modulation across plate

The basic set-up consisted of two pinholes 9.4 cm apart on one end of the HOE optical table and the plateholder located in the far end of the adjoining darkroom at 9.1 meters. This produced a fringe pattern of 20 lines/mm with the 5145Å light used, with a theoretical error of 1/100λ in the fourth order.

The z plane alignment of the two-point sources was the most difficult set-up problem. The first technique used was to insert a 60" focal length, f/10 lens and collimate both beams. A second technique used was to locate the pinholes equidistant to a flat parallel plate and align this plate perpendicular to the unexpanded beam. Both seemed to produce satisfactory results.

The plateholder was aligned by observing the unexpanded beam reflection off a flat plate, centering it on the opposite beam.

The fringe pattern was observed under magnification and found stable for one to two seconds. One approach was to record this on Kodak 131-01 plates and then copy onto the 649F emulsion, which had the required emulsion thickness. When a box of 649F plates was found that had a four-fold sensitivity improvement, one second exposures were found adequate, and direct copies were made.

The last two problems required a study of processing techniques and the resulting diffracted orders. The pure relief image at 20 ℓ/mm behaves practically as a Bessel function. The optimum modulation was determined by the requirements that the light be uniformly (as possible) distributed into the 0th thru 4th orders. Two possibilities existed: the first and fourth orders could be chosen as minimum around an argument of 3.4 radians, or the first and second could be minimum around 4.5 radians. The higher argument was a little better, and targeted for this study.

Further studies into the optimum modulation indicated that a complex modulation, that, is amplitude plus phase, was best. The relative power into the minimum orders was thereby doubled. In effect, the amplitude modulation smeared out the power in the phase gratings orders. The processing technique to achieve the complex modulation was to bleach until the hologram was about fifty percent transmitting, then quickly stop it in fixer.

All components of the bleach were varied: concentrations of ammonium dichromate, sulfuric acid, and salt, and choice of salt. The ammonium dichromate just effected the speed, so a lower concentration was determined, to better control the bleach end-point. The sulfuric acid not only affected the speed, but also, the uniformity over the plate and the modulation attained. The concentration was chosen near the peak of the modulation, but slightly on the low concentration side of the peak, where better uniformity was attained. The presence of salt in the bleaching solution extended the density range (higher) over which satisfactory results could be attained, perhaps for greater uniformity. The chlorine and iodine modifications did not increase the modulation at the lower densities. At higher concentrations of iodine, the modulation did increase, but appeared very non-linear with respect to density. Bromine did increase the modulation by fifty percent. In general, the approach was to aim for the peak of the modulation against density, so that the uniformity might be best over the plate. Another reason for choosing the 4.5 radian point over 3.4. In the actual case, the development time and developer freshness seemed to have direct bearing on the results, i.e., uniformity and modulation so that the given results are less exact than desired. Fresh developer and shorter development times are more desirable.

In terms of round numbers, the decrease in acid concentration increased the maximum modulation from two unto four to five radians. The use of the bromine modification increased the modulation unto six to eight.

The amplitude modulation tended to average the orders, so that attaining exact modulation and uniformity were not as critical. The amplitude modulation tended to cut the higher orders, especially for greater modulations, so that a higher phase modulation was required. Thus, the higher modulation bromine bleach was suitable.

To attain the direct copies a 1/2 to 1 second exposure was recorded and developed 3 to 6 minutes until densities of about 0.8 were attained. For the previous indirect copies exposures were increased to attain a development time of only 1 to 2 minutes and densities between 1.0 and 1.5 achieved, thus giving perhaps a littl better uniformity and higher modulation. After short-stopping, fixing, washing, drying (optional), the plates were bleached in a solution composed of 1,1,20, 2 parts of 20 gm/liter ammonium dichromate, 3.5 mℓ/liter sulfuric acid, water, and 92 gm/liter potassium bromide, respectively. That is a 2 and 8 times decrease in ammonium dichromate and sulfuric acid, respectively. The time varied from 45-50 seconds for the oighter direct copies to 1½ to 2 minutes for the indirect copies. These were rinsed for a couple of seconds, then fixed two minutes, washed, and dried. A methyl alcohol bath was used after the wash for dye removal and faster drying.

CL:sd

cc: B. J. Chang
W. S. Colburn
J. R. Fienup
J. Upatnieks
File

SUMMARY OF PLATES PRODUCED

Description	An Indirect Copy; (darker)	An Indirect Copy; (lighter)	A Direct Copy (cleaner); (small darker spot)	A Direct Copy; (cleanest)
Percent Transmitted	29.9	42.5	27.6	36.0
Percent in:				
0th Order	9.8	18.1	14.2	14.3
1st "	12.3	16.2	12.4	5.1
2nd "	7.1	6.2	17.1	14.3
3rd "	7.3	9.1	9.4	14.3
4th "	8.7	8.6	3.1	6.5
5th "	6.9	5.3	0.7	2.0
6th "	4.2	2.6		0.5
7th "	2.1	1.1		
OFF AXIS NOISE LEVEL (db)				
at 20 ℓ/mm	64.9	68.8	73.8	71.4
" 40 "	67.5	70.4	74.7	73.8
" 60 "	70.6	70.4	73.8	77.2