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REPLICA GRATING STUDY
NGR-22-091-002

INTERIM REPORT - PHASE VII
July 1, 1969 - June 30, 1970

College of the Holy Cross
Worcester, Massachusetts 01610

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Submitted by:	College of the Holy Cross Worcester, Massachusetts 01610
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Contract No.:	NGR-22-091-002
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ABSTRACT

Particle irradiation tests were continued on concave gratings. Tests after irradiation by a Dynamitron Accelerator at levels of 3.6×10^{14} and 3.6×10^{15} e^-/cm^2 have been completed. At the lower irradiation level, a lowering of the efficiency of the gratings was observed, while any change in beamwidths at half and tenth power points fell within our experimental error. At the higher dosage, however, definite deterioration of some gratings was found. Also, a further general lowering of grating efficiency was noted, as at the lower irradiation level.

Beta irradiation of plane Pyrex gratings and substrates by selected radioisotopes has been continued. An estimated dosage of 2.0×10^{15} e^-/cm^2 at energy levels from 0.1 to 2.0 Mev produced no visible surface distortion upon interferometric examination.

1. PURPOSE OF EFFORT

1.1 Thermal Vacuum Stressing

Work on the thermal skid has been temporarily suspended.

1.2 Particle Irradiation

Cumulative particle irradiation of concave gratings has been continued. Tests on gratings after irradiation dosages of 3.6×10^{14} and 3.6×10^{15} e^-/cm^2 by a Dynamitron Accelerator have been completed. Thus we are able to compare these results with the results previously obtained after a similar irradiation of 3.6×10^{13} e^-/cm^2. These tests have been completed on five replica gratings: two with BSC-2 substrates, and two with Pyrex substrates and Dynasil one with a substrate. With data compiled earlier in the program, the final irradiation level enables us to draw some definite conclusions about grating deterioration and performance at these high irradiation levels.

Low level beta irradiation by selected radioisotopes has continued in order to find the possible effects of long-range wide-spectrum irradiation on plane gratings and surfaces.

2. NATURE OF EFFORT

2.1 Irradiation by Radioisotopes

The irradiation of plane Pyrex gratings and substrates by low intensity radioisotope sources as described in the Phase IV report has continued. Interferometric (Twyman-Green type) examination of the irradiated surfaces after exposure to approximately 2.0×10^{15} e^-/cm^2 at energy levels ranging from 0.1 to 2.0 Mev showed no recognizable surface distortion. As noted earlier, discoloration of the substrates was observed after irradiation with certain radioisotopes.

2.2.2 Irradiation by Dynamitron Accelerator

As noted in the Phase VI report, after particle irradiation of 3.6×10^{13} e^-/cm^2 the grating substrates became discolored. Likewise after dosages of 3.6×10^{14} and 3.6×10^{15} e^-/cm^2, Pyrex and BSC-2 substrates became progressively darker brown, while Dynasil remained only barely clouded. In the BSC-2 substrated gratings, a blistering of the grating surface was evident, looking like deep scratches in the grating, but actually being raised ridges. This blistering effect was also evident beneath the grating surface, looking like bubbles formed between the substrate and the aluminized coating. This effect caused such deterioration of the gratings that any results whatsoever were impossible to obtain for one of the gratings, while only severely limited quantitative results were obtained with the other.

Also, after the 3.6×10^{14} e^-/cm^2 irradiation, the gratings were quite hot to the touch, remaining so for some time after the irradiation process was stopped. On the subsequent irradiation of 3.6×10^{15} e^-/cm^2, steps were taken to eliminate this effect to assure us that no unnecessary thermal stressing took place. After this last irradiation, only a general warming of the gratings was noticeable.

After the 10^{14} level of irradiation, no conclusive deterioration of grating performance was noted with respect to half and tenth power points. However, a general lowering of grating efficiency was evident. All other changes fell within our experimental error, but the tendency seemed to indicate better grating resolution.

As mentioned above, irradiation at a level of 3.6×10^{15} e^-/cm^2 just about ruined those gratings with BSC-2 substrates. However, the Dynasil grating showed a definite improvement in performance over the results obtained at the previous irradiation level. One of the Pyrex gratings showed no change at all, while the other Pyrex grating showed a slight deterioration. All three of these gratings also showed a small loss in efficiency.

2.2.3 Interferometric Concave Grating Test Bed

Laser shearing interferograms of the irradiated grating surfaces were taken. No significant deformation of the grating surfaces was noted, except in the case of the gratings with BSC-2 substrates. As noted before, ridges in the grating surfaces were plainly visible. However, the shearing interferograms indicated further severe deformation of the grating surfaces. These results are from comparisons of interferograms taken after each successive irradiation, with the BSC-2 deformation taking place after the 3.6×10^{15} e^-/cm^2 irradiation level.

2.2.4 Ultra-High Vacuum Test Bed

Construction of the special Optical Component Holder has been completed. Work on a suitable cooling mechanism for the Optical Component Holder is now underway.

3. CONCLUSIONS TO DATE

In our irradiation studies, a good degree of consistency of results was found with respect to substrate types. Manufacturer inconsistencies can thus be ignored. In other words, Pyrex gratings, as an example, all performed similarly regardless of manufacturer. Also, even though the irradiated gratings were actually hotter after the 3.6×10^{14} e^-/cm^2 irradiation than after the 10^{15} level, and the more severe grating deterioration was after the latter dosage, thermal effects of the irradiation were probably less important than the irradiation itself. Hence the poor performance of the BSC-2 substrates after intense irradiation is significant. Pyrex gratings seemed reasonably stable from our tests, while the Dynasil actually seemed to improve. Further conclusions on this last substrate can only be achieved after further irradiation. A summary of selected grating data after Dynamitron irradiation is shown in Table I.

The shearing interferograms provided a good method of finding surface distortions, although in only the case of the BSC-2 was the method overwhelmingly conclusive.

Since most of the area of damage in the BSC-2 gratings seemed to be between the substrate and the aluminized coating, this might be a significant area for investigation.

4. PLANS FOR THE FORTHCOMING SIX-MONTH PERIOD

In accordance with discussions with the Project Monitor and subsequent receipt of approval from him, emphasis in the forthcoming period will be shifted to refractive index studies of space related-optics.

TABLE I

(Selected Data For 2945Å Line of Helium)

Grating Substrate*	Irradiation Level (x3.6e$^-$/cm^2)	Half-Power Beamwidth (Å)	Tenth-Power Beamwidth (Å)	Efficiency (%)
Pyrex-D	0	0.300	0.660	1.76
	10^{13}	0.250	0.615	1.80
	10^{14}	0.262	0.548	1.65
	10^{15}	0.288	gross	--
Pyrex-J	0	0.200	0.380	32.0
	10^{13}	0.245	0.502	35.6
	10^{14}	0.242	0.508	30.0
	10^{15}	0.272	0.612	29.0
Dynasil	0	0.305	0.560	--
	10^{13}	0.325	0.588	32.1
	10^{14}	0.270	0.477	25.2
	10^{15}	0.230	0.465	23.4
BSC2-B	0	0.270	0.560	36.0
	10^{13}	0.246	0.490	28.0
	10^{14}	0.234	0.446	32.0
	10^{15}	gross	gross	--
BSC2-J	0	0.130	0.305	38.9
	10^{13}	0.175	0.385	32.0
	10^{14}	0.238	0.427	27.5
	10^{15}	>0.800	gross	--

*Suffixed letter indicates manufacturer

5. PERSONNEL

5.1 Senior Staff

While each of the staff participated in some phase of all the tests, the principal area of responsibility of each investigator is as shown:

Dr. Roy C. Gunter, Jr., Holy Cross College--principal investigator.

5.2 Student Staff

Although many students have been involved in one phase or another of the program, the following were those with specific assignments:

James Fienup--line profiles, irradiation tests, interferometric test bed, and ultra-high vacuum test bed.

John Levreault--line profiles, irradiation tests, interferometric test bed.

5.3 Support From Other Laboratories

Mr. Lester Lowe, AFCRL--Irradiation tests.

Dr. Paul M. Waters, Dr. Richard F. Woodcock, Mr. Samuel F. Walton, Mr. Colin Yates, Central Research Laboratory of American Optical Company--glass stressing and tests.

Mr. Richard Schmitt and colleagues of the Jarrell Ash Company Grating Laboratories--replication and tests.

Dr. Warren Shields and Mr. Russell Cowing of the New England Deaconess Hospital Cancer Research Institute--radioisotope measurements.

Dr. Eugene Coyner, E.I. Dupont de Nemours--consultation on wide range thermal refrigerants.

Dr. Martin Saepoff, Dynasil, Inc.--samples of Dynasil.

Mr. John D. Barker, General Electric, Inc.--samples of GE125 and GE151.

Mr. L. M. Donley, Owens-Illinois, Inc.--samples of Cervit.