INVESTIGATION OF SPECTRAL PROPERTIES OF ULTRAVIOLET GRATINGS

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Melvin A. Pittman
Professor of Physcis
Principal Investigator

Old Dominion College
Norfolk, Virginia

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I. INTRODUCTION

This report summarizes research activities during the first six months period conducted under Grant NGR-47-003-004. This grant is an extension of Grant NGR-47-006-027, which was in effect during the previous year. The facilities and personnel working on this project are described in Section VIII.

This investigation is part of a general program to determine whether optical components are damaged when subjected to a simulated space environment. This laboratory was concerned with determining the possible damage caused by electron impact to plane gratings which are used in the ultraviolet region. Since reliability, availability, and cost, which favor replica gratings, are major considerations in constructing flight instruments, it becomes necessary to determine whether replica gratings as well as masters can be satisfactorily used. According to available data, the electron total dose in a one year orbit may be as high as 10^{15} electrons/cm^2. This dosage was simulated by using the Langley Research Center Dynamitron to irradiate the gratings in vacuum with a 1 Mev electron beam.

II. METHOD OF STUDYING GRATINGS

The procedure adopted to determine any change in the characteristics of the gratings was to test their performance in our laboratory, to irradiate them at the NASA facility, and then to repeat the initial laboratory tests. The efficiency of gold replica gratings were measured as a function of wavelength. This was effected by determining the first order to zeroth order intensity ratio (I_1/I_0), which is a measure of the blaze, and zeroth order to MgF_2 mirror intensity ratio, (I_0/I_m), which is a measure of the reflective power of the grating. The relative efficiency of the grating in first order was obtained by multiplying the two ratios.

$$E(\lambda) = (I_1/I_0)(I_0/I_m) = (I_1/I_m)$$

As a consequence of this procedure, we were able to minimize any error that might have been introduced due to source fluctuation.

III. EXPERIMENTAL CONFIGURATION

The experimental configuration used for testing gratings before and after irradiation can be considered in two parts, the ultra-violet monochromatic source and the test chamber. The two chambers, which have individual pumping and control systems, are separated by a manually controlled gate valve. The ultra-violet source consisted of a Hinteregger lamp operated with a mixture of 0.5mm of Ar and 0.2mm of He. This lamp was excited by an A. C. power supply at 1500V and a current of 60ma. The dispersion of the ultra-violet radiation was accomplished with a 1 meter normal incidence vacuum monochromator. The testing chamber consisted of a .3 meter plane grating monochromator with its entrance slit mounted at the position of the exit slit of the 1 meter instrument. A detecting system consisting of a sodium salicylate scintillator and an EMI 9514 photo-multiplier is mounted at the exit slit. The experimental configuration is shown in Figure 1.

IV. EXPERIMENTAL PROCEDURE

The operating procedure consisted of mounting the grating in the test chamber. The chamber was then brought to operational pressure, the gate valve opened and a spectral line selected with the 1 meter monochromator while the grating in the test chamber was in zeroth order position; this intensity was recorded. Then the grating in the test chamber was advanced to first order and second order and then returned to zeroth order position, with an intensity recorded at each position. This enabled ratios (I_1/I_0), (I_2/I_0) to be obtained in a two minute period with the last zeroth order intensity providing a check of the lamp's stability. The 1 meter monochromator was then advanced to a new wavelength and the procedure repeated. These tests were performed using six spectral lines between 1048Å and 1302Å.

Having completed this set of measurements, the 1 meter monochromator was scanned through these same lines leaving the grating in the test chamber in zeroth order position. This procedure served to monitor long term stability in the source lamp. The test grating was then removed and a shelf-reference MgF_2 mirror replaced the grating in the test chamber and the scan of the six lines repeated to obtain mirror intensities I_m for each of the wave lengths previously mentioned. The ratios (I_0/I_m) were obtained from this set of data and the corresponding set of data for the grating. This procedure required about one and a half hours.

V. IRRADIATION PROCEDURE

Gratings were irradiated in February 1968, at which time it was decided to remove the gratings immediately after irradiation and return them to our laboratory for tests.

Following the operating procedures normally used by the Dynamitron personnel, a grating was irradiated for thirty minutes while the target assembly was cooled by water at a temperature of 54^{o}F. Upon removal of the target assembly immediately after the beam was cut off, a film was observed on the grating. As a result of a series of tests initiated to solve the contamination problem, the following procedures were adopted: (1) Gratings at room temperature were installed in the target chamber. (2) The target assembly was cooled by room temperature water which was turned on just prior to irradiation. (3) The grating was left under vacuum for forty-five minutes after the beam was cut off. (4) Nitrogen was used to bleed the target chamber up to atmospheric pressure.

These procedures were used to simultaneously irradiate two gratings, one of which was shielded from the beam by a 100-mil aluminum cover. Thus both the irradiated and companion gratings were subjected to the same vacuum system. The target was bombarded at the rate of 10^{11} electrons/cm^2/sec at an energy of 1 Mev with a total dose of 10^{15} electrons/cm^2. The gratings showed no evidence of contamination. These procedures differ from those used for the preliminary irradiation runs in July 1967, at which time the gratings were cooled below room temperature and were left overnight in the Dynamitron vacuum system after irradiation.

VI. RESULTS

The method outlined in Section II was used to perform measurements of the ratio (I_1/I_0) for the following spectral lines: 1048Å, 1135Å, 1200Å, 1216Å, 1243Å, and 1302Å. As an example of the results of these measurements, data for grating number 1-Al-B3 are shown in Figure 2. As is indicated by the scatter of the points, there is generally good agreement between the different measurements.

Figure 3 shows the relative efficiency (I_1/I_m) of the irradiated grating number 1-Al-B3 both before and after irradiation. The corresponding data for the companion grating number 1-Al-B2, which was shielded from the beam during irradiation, are shown in Figure 4. Values plotted in these two figures represent the average of six measurements before irradiation and three measurements after irradiation. After the efficiency had been measured four times for each grating before irradiation, it was necessary to store the gratings for approximately one month while solving the contamination problem referred to in Section V. In order to check for any time-dependent variation in the efficiency, two additional sets of measurements were performed on the gratings just prior to irradiation.

Our tests show that neither the exposed nor companion grating has undergone any significant change in either reflectivity or first order efficiency. Hence these results indicate that there is no deterioration in spectroscopic performance of gold replica gratings when subjected to 1 Mev electrons at a total dose of 10^{15} electrons/cm^2.

VII. FUTURE WORK

The additional experiments suggested in this section should further elucidate the spectral properties of ultra-violet gratings subjected to a simulated space environment.

(a) The exposed and companion gratings referred to in this report could be subjected to additional radiation of 1 Mev electrons. By successively increasing the dosage and performing spectrometer tests, it should be possible to determine the maximum orbital time for satisfactory performance by gold replica gratings.

(b) Another companion set of replica gratings could be subjected to a variable dose of lower energy electrons. Thus the maximum orbital time could be investigated as a function of the energy of electrons in a space environment.

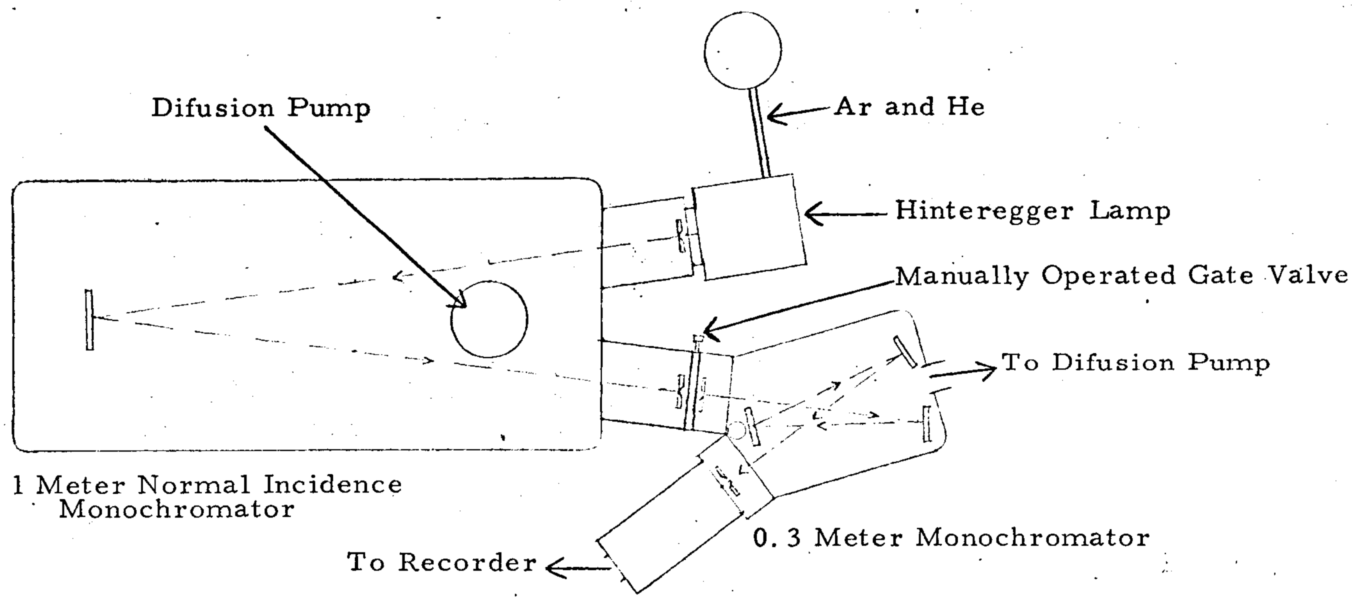
(c) After performing tests on the family of replica gratings, the master grating could be subjected to radiation. By using the results of the investigations suggested in (a) and (b), it should be possible to conduct extensive tests before damaging the master grating.

VIII. FACILITIES AND PERSONNEL

The newly remodeled facility for research in Optics and Spectroscopy has been completed. This involved installation by the College of adequate electric power, water supply and compressed air lines. In addition, it was necessary to align, calibrate, and check equipment that was transferred. To put the laboratory into operation it has been necessary to become familiar with local suppliers and acquire sufficient stock.

The completion of the facility was made possible through the co-operation of the Physics Faculty and through extensive work done by two graduate students, who work half-time in the research laboratory. One of these students is being paid by funds provided by this grant and he is in the final stage of completing his Masters thesis. The College also provided an electrical technician who is available as needed. The faculty personnel directly involved in this research are Dr. Melvin A. Pittman, Dean, School of Sciences; Dr. George S. Ofelt and Dr. Robert L. Kernell, Associate Professors of Physics; and Dr. Jacob Becher, Assistant Professor of Physics.

The personnel available for the summer will be the above mentioned faculty whose full-time will be devoted to research at the laboratory. In addition, two high school teachers, who will be assigned to specific problems, will be serving as Research Participants as part of our National Science Foundation Supported Program.



EXPERIMENTAL CONFIGURATION

Figure 1

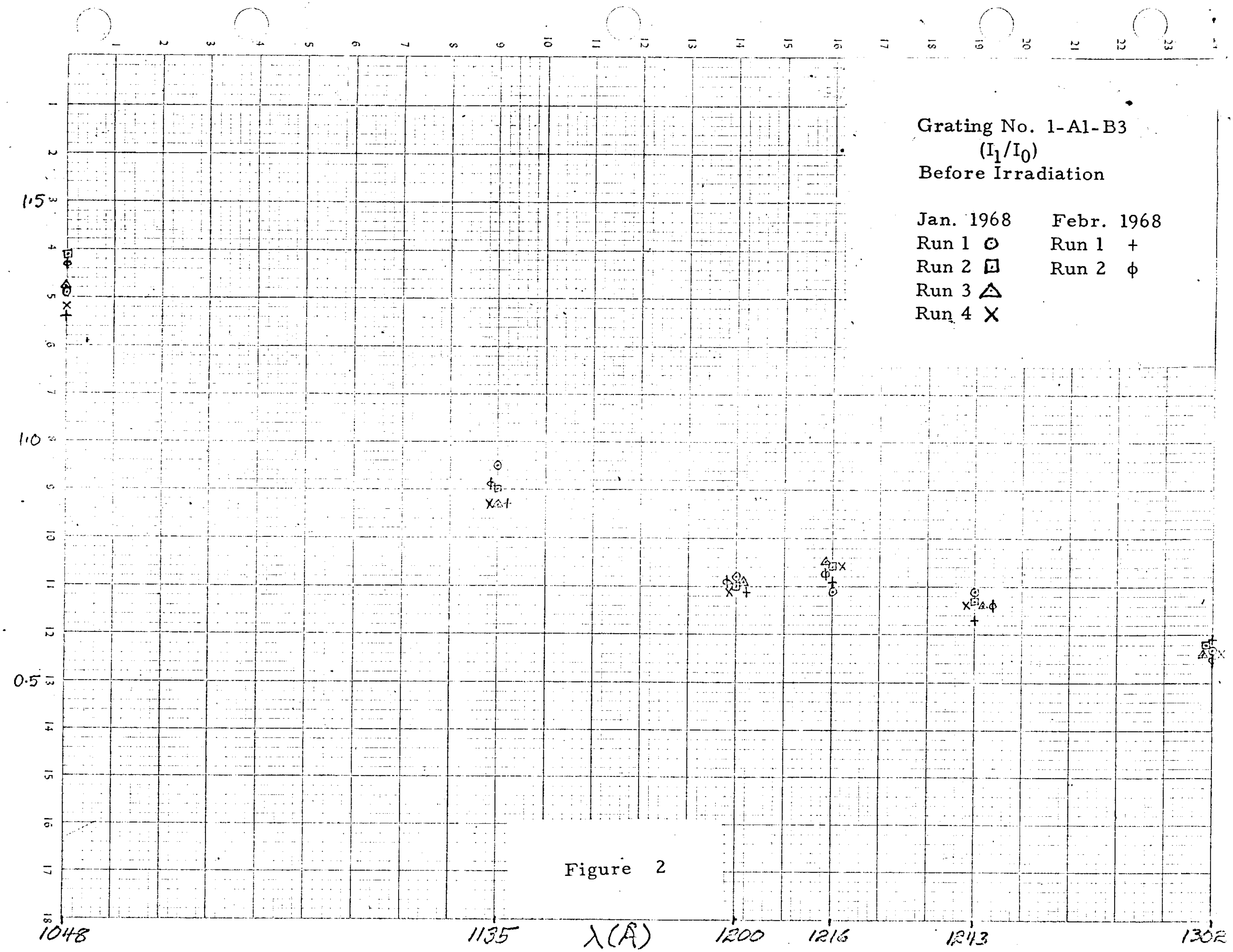
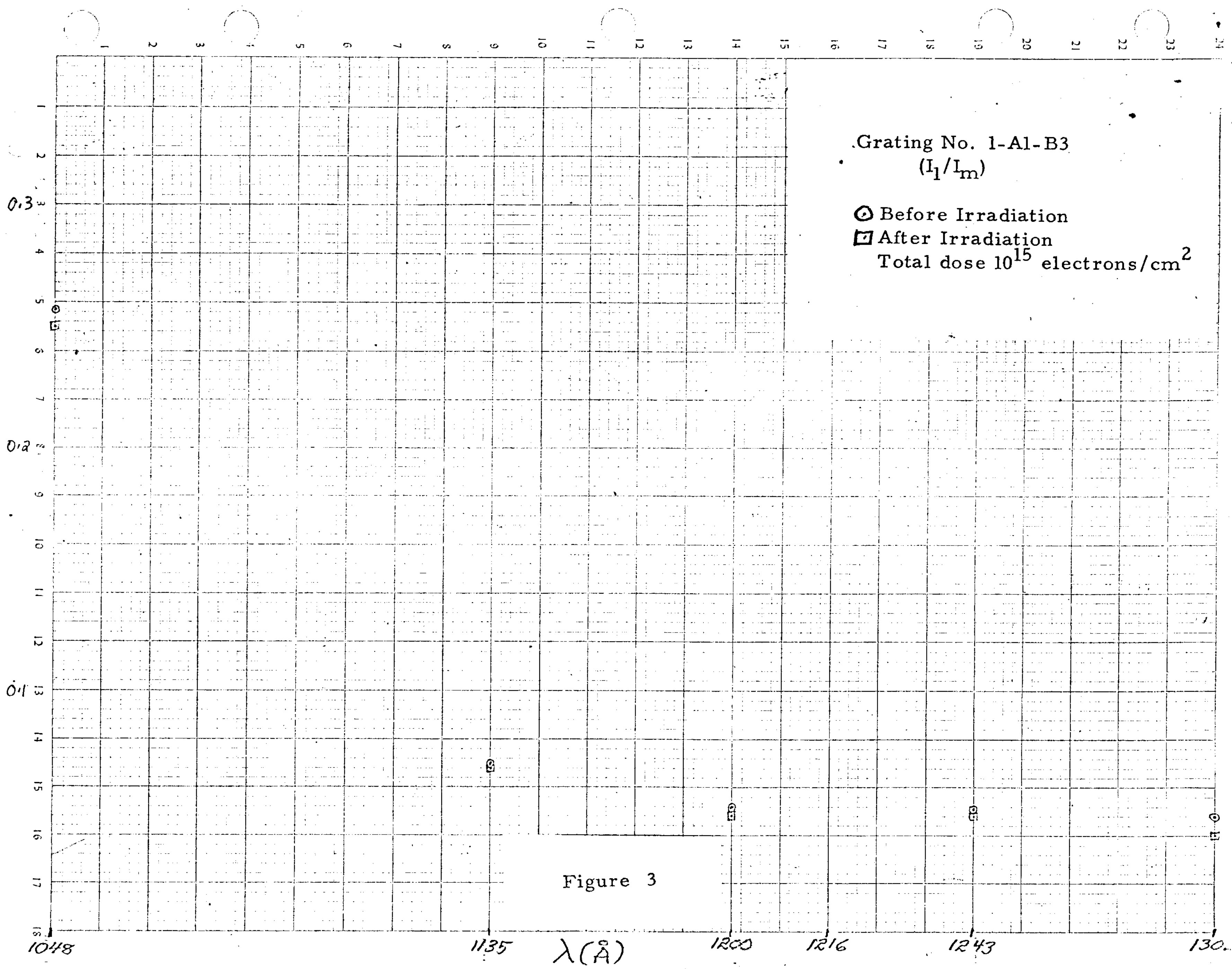

Grating No. 1-A1-B3
(I_1/I_0)
Before Irradiation
Jan. 1968
Run 1 ⊙
Run 2 ⊡
Run 3 △
Run 4 X
Febr. 1968
Run 1 +
Run 2 ϕ
1.5
1.0
0.5
1048
1135
λ(Å)
1200
1216
1243
1302

Figure 2



Grating No. 1-Al-B3
(I_1/I_m)
Before Irradiation
After Irradiation
Total dose 10^{15} electrons/cm^2
0.3
0.2
0.1
1048
1135
λ(Å)
1200
1216
1243
130.

Figure 3

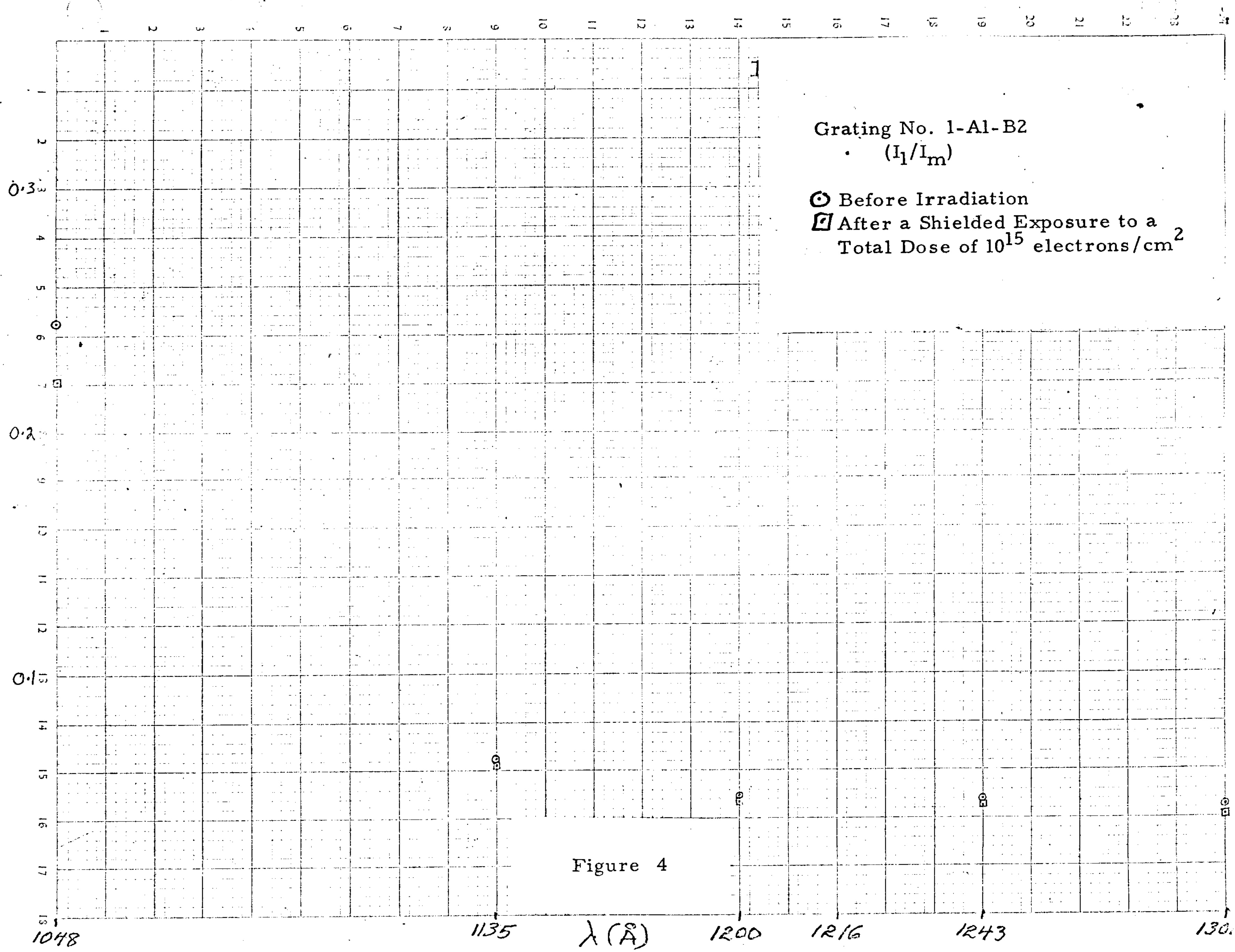

Grating No. 1-Al-B2
(I_1/I_m)
Before Irradiation
After a Shielded Exposure to a Total Dose of 10^{15} electrons/cm^2
0.3
0.2
0.1
1048
1135
1200
1216
1243
130.
λ (Å)

Figure 4