Report MCR-73-317

STUDY OF X-RAY OPTICS

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Final Report for Contract NAS 8-29861

Prepared for
MARSHALL SPACE FLIGHT CENTER
Huntsville, Alabama

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

This program involved the testing of a polished Kanigen coated beryllium mirror in a soft x-ray telescope to be flown on a Skylark sounding rocket. This mirror was polished by Applied Optics Center of Burlington, Mass. This telescope was tested in a similar way that soft x-ray telescopes were tested previously.[1-5] This test involved inserting the telescope in a 220 foot long vacuum line and taking photographs of an x-ray resolution source. These photographs were then used to evaluate the performance of the telescope mirror as a function of distance from the focal plane and the angular distance off the telescope axis. A second test was made in which a point source was used to study the imaging characteristics by means of a pinhole and proportional counter placed in the telescope focal plane. A third test was conducted using a position sensitive detector supplied by the Mullard Space Science Laboratory, University College London, England. This is the detector that will fly on the Skylark mission and its performance was evaluated during this program.

RESOLUTION STUDIES

The x-ray source used for this test was an 8.34 Å aluminum source that was essentially monochromatic with small contributions from 8 Å K_β radiation and 6.94 Å tungsten radiation. The anode

voltage was 6.0 KV and the anode current was 30 ma.

The x-ray photographs taken with the Kanigen coated beryllium used a twelve-wire filament configuration which produced a uniform x-ray intensity in the source.

A Buckbee-Mears JT 4.2 bar and dot resolution chart was used for all photographic data taken in this test. This chart has eleven bar sets of 5.3, 4.46, 3.75, 3.15, 2.65, 2.23, 1.88, 1.58, 1.32, 1.11, and 0.94 arc seconds angular resolution. A set of nine dots of the same angular spacing is also placed on the chart. Figure 1 is a photograph of the resolution chart.

Two types of film were used in this test. Film type SO-212 was used for data runs 126-128. This film was developed in Kodak D-19 at 68°F for 8 minutes, washed in distilled water for 30 seconds (to remove jet backing), stop bath was for 30 seconds, and fixed in Kodak rapid fixer for 2 1/2 minutes. A 30 minute rinse was followed by a photo-flow solution and the film was dried. At the start of the 30 minute rinse, it was necessary to supply light rubbing to the film to remove the jet backing not removed during the 30 second wash in distilled water. Film type 2483 photomicrographic color film was used for data runs 133-135 and 137. This film was processed by the standard Kodak E-4 process for color film.

The exposures were cut and mounted in 2-inch by 2-inch slide holders to protect the photographs. Each slide has a label

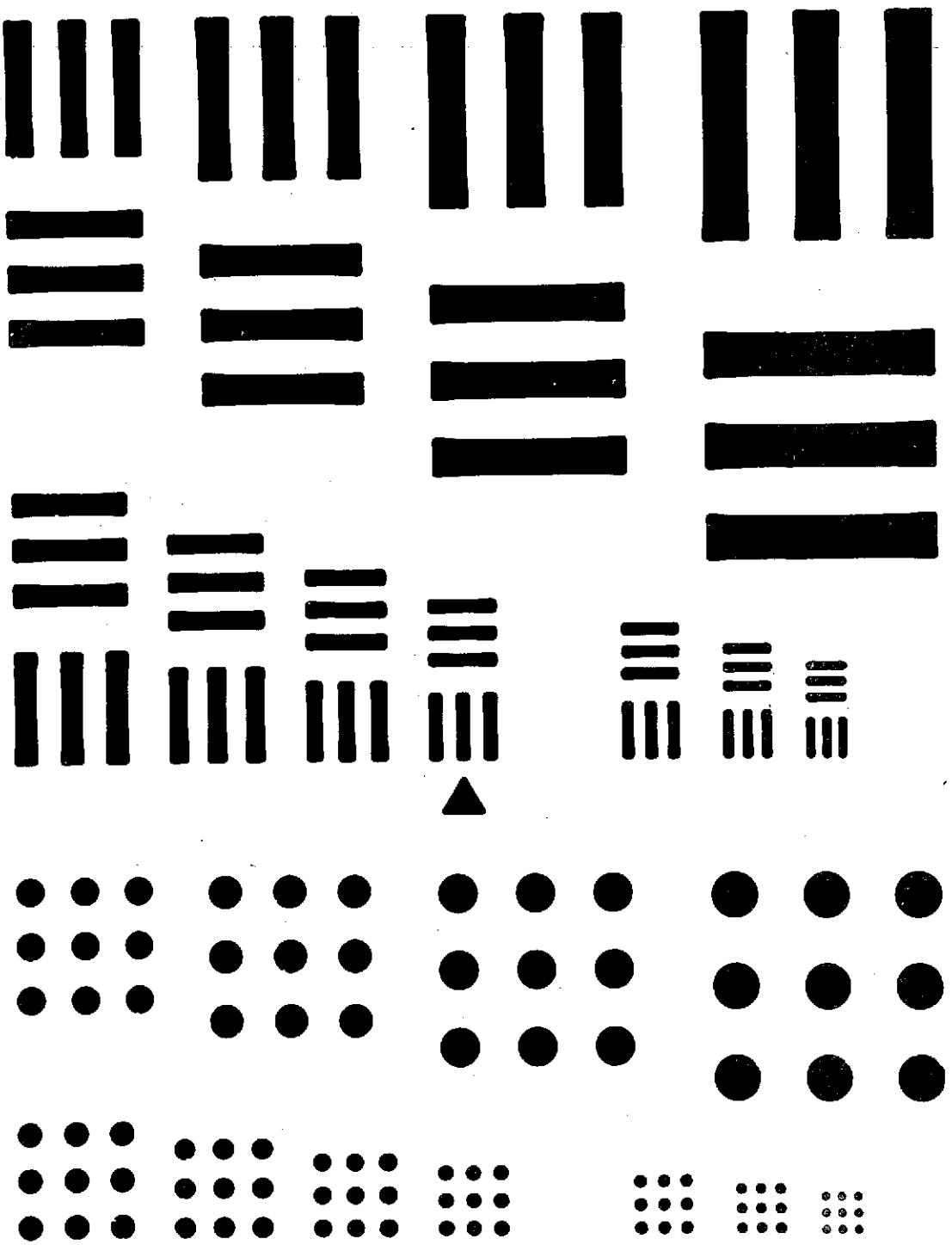

Figure 1. JT 4.2 Bar and Dot Resolution Chart

giving the run and exposure number, the wavelength, the relative distance as measured on the adjustable mechanism housing, the azimuth angle $\emptyset$, and the elevation angle θ. When the slide is held so that the label is in the left hand corner, the photograph has the same orientation as if the observer were viewing the image in a ground glass screen attached to the telescope.

The telescope assembly (Government furnished property) was placed in the test chamber. The test chamber and 200-foot long line were evacuated. The pressure was reduced to approximately 1.0×10^{-5} Torr as measured by an ion gauge which was placed in close proximity to the beryllium mirror. Exposure of the resolution chart were then made using the camera which was provided with the telescope assembly.

Using the SO-212 film in this telescope, the 5.3, 4.46 and 3.75 arc second vertical bar groups and the 5.3 and 4.46 horizontal bar group could be resolved. Using the 2483 type photomicrographic color film in the telescope, both vertical and horizontal bar groups from 5.3 arc seconds to 2.65 arc second angular resolution could be resolved. This indicates that, for a well polished mirror, the resolution of the telescope may be limited by the film rather than scattering from the mirror surface.

POINT SOURCE TEST

A method of testing an x-ray telescope is to produce a point source of x-rays and see how well the telescope recreates the image of the source. By comparing the number of x-rays counted at the center of the image to the number of x-rays entering the telescope, the reflecting efficiency can be obtained. An indication of the scattering properties of the telescope can be obtained by measuring the x-radiation which is reflected away from the main focused beam.

The camera magazine was replaced by a proportional counter mounted on an X-Y scanner. A 6-position rotary holder was placed directly in front of the proportional counter. Three of the positions housed pinholes: a 2.54×10^{-3} cm diameter (1 mil diameter) pinhole, a 7.62×10^{-3} cm diameter (3 mil diameter) pinhole, and a 2.54×10^{-2} cm diameter (10 mil diameter) pinhole. The other three positions were as follows: A blank position, a vertical knife edge and a horizontal knife edge. The pinholes were placed in the focal plane of the telescope and a 10 arc second point source was examined by sweeping the 7.62×10^{-3} cm diameter (9 arc seconds) pinhole across the image in 3 arc seconds steps until a 30 x 30 arc second matrix around the peak was formed of the point source. A contour of the source was then made and is shown in Figure 2. These contours give an indication of the scattering property of the telescope by

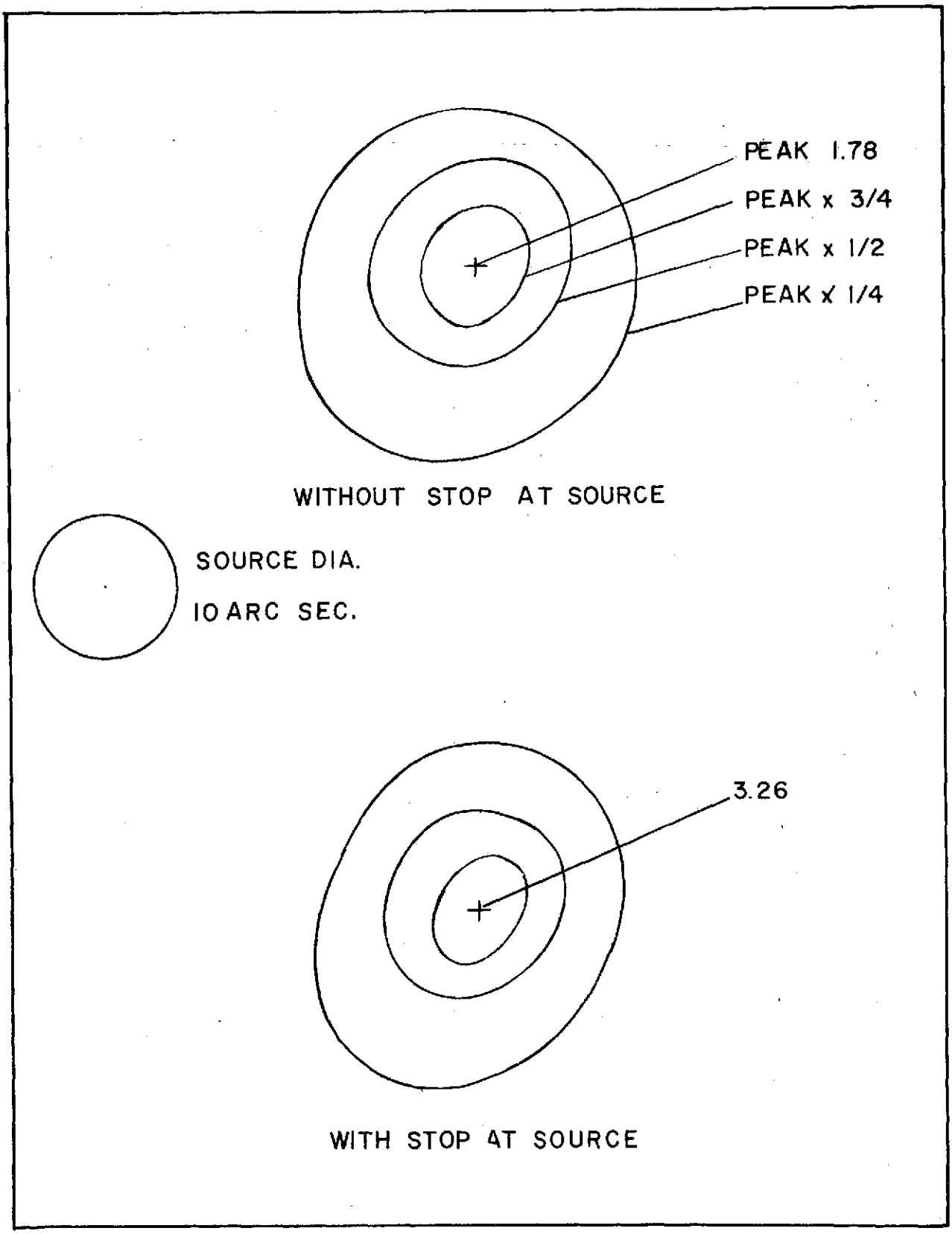

Figure 2. Skylark Metal Mirror 9 Arc Sec. Pinhole Scan Contours

examining the shape of the image and by seeing how much radiation falls outside the peak area of the focused image. The efficiency is computed by measuring the flux incident on the telescope and comparing that with the intensity recorded behind the 9 arc second pinhole. The efficiency represents the intensity from a 10 arc second source that is focused on a spot of 9 arc seconds diameter. The number at the peak is the efficiency of the telescope at 8 Å. Both absorption in the mirror and scattering of intensity away from the focused beam will affect the efficiency measured. Some unwanted radiation, either scattering or fluorescing from the source chamber, was found to be present. A stop was made that filled the diameter of the source chamber and was placed directly in front of the source holder. Two 5.08 cm diameter holes in the stop allowed the x-radiation from the pinhole source only to pass down the line to that telescope.

Gas flow (90% argon - 10% methane) proportional counters were used to measure the incident x-ray intensity and focused x-rays through the various apertures. Both counters were operated at 1400 volts and at the proper gain so that the peak of the radiation spectrum occurred at the same position on a multi-channel analyzer. Both counters had a 0.635 cm diameter (.250 inch) window of 1/4 mil thick mylar.

Table I gives the ratio of the reflected beam to the incident beam for the various apertures in the rotary holder of the X-Y scanner. These values were all taken at the point of peak intensity and for the telescope axis, i.e., $\theta = 0$ (azimuth) and $\phi = 0$ (elevation).

The efficiency for this telescope, using the 9 arc second pinhole data is as follows: for 8 Å = 3.26%, for 13.3 Å = 4.1% and for 44 Å = 1.37%.

Table I. Pinhole Aperture Efficiency Data

	Without Stop	With Stop At Source		
Aperture	At Source 8.3 Å	8.3 Å	13.3 Å	44 Å
.003 in.	.382	.833	1.11	.37
.010 in	1.582	2.97	3.68	2.67
.250 in	11.21	15.95	18.02	11.26
#6	5.18	70.2	6.92	4.82
#10	6.45	87.3	11.38	4.01

$\theta = 0$ $\phi = 0$

Skylark Metal Mirror

POSITION SENSITIVE DETECTOR TEST

The position sensitive detector was furnished by the Mullard Space Science Laboratory, University College London, England. Since this detector operated on a delayed coincidence signal output, the special delay amplifiers and coincidence circuitry was built, furnished, and operated by University College London personnel.

The resolution chart sources used for this test were as follows: (1) 30 arc second bars separated by 6 arc minutes 8 Å (2) three 45 arc second pinholes separated by 45 arc seconds and 1 arc minute - 8 Å and 44 Å, (3) two 45 arc second pinholes separated by 3 arc minutes.

The data obtained in this test was in the form of Polaroid pictures taken of an oscilloscope trace. These photographs were taken by the UCL personnel back to Mullard Space Science Laboratory so that they could analyze the results and determine the resolution of the position sensitive detector.

The position sensitive detector was placed on the adjustable mechanism housing of the telescope in the test chamber. The test chamber and 200 foot long line were evacuated to a pressure of 1×10^{-4} Torr as measured by an ion gauge placed in close proximity to the telescope assembly. Focus tests and resolution tests were then made with the position sensitive detector.

CONCLUSIONS

The results of this test on a polished Kanigen coated beryllium mirror can be compared with the results of a previously tested unpolished Kanigen coated beryllium mirror[5]. The polishing of this mirror increased the efficiency from 0.06% to 3.26% for 8 Å x-rays. The resolution of this mirror increased from approximately 15 arc seconds to 3.75 arc seconds resolution on the Buckbee Mear resolution charts. There was no comparable data at 13.3 Å and 44 Å.

The overall effect of the polishing on this Kanigen coated beryllium mirror has made its performance comparable to previously tested fused silica mirrors.

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