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Optical testing of a gamma-ray telescope mirror

D. V. Udupa, R. P. Shukla and G. D. Saksena
Spectroscopy Division, Bhabha Atomic Research Centre, Bombay 400 085

Abstract. A large size concave mirror for use in the gamma-ray telescope TACTIC was tested. Focal length of the concave spherical mirror of diameter 600 mm was measured to be 401.2 cm using the Ronchi test. The surface accuracy of the mirror was estimated to be about Lambda/2 by visual observation of the fringes obtained. The spot size of the mirror for a nearly collimated beam was measured to be about 0.5 mm, whereas the computed size of the spot for a spherical mirror is about 0.1 mm. The reflectivity of the mirror was measured to be about 83% in the visible region.

Key words : gamma ray—optical mirror

1. Introduction

The gamma-ray telescope TACTIC proposed to be set up by Nuclear Research Laboratory will consist of 38 concave optical mirrors. Each of these mirrors is 600 mm in diameter, 40 mm in thickness and having a focal length of 4 m. They are coated with aluminium. One such mirror was tested for (1) radius of curvature, (2) surface figure, (3) spot size, (4) reflectivity in the wavelength range of 400 nm to 600 nm.

The details of the setup and the testing procedures are presented. A mirror mount was designed, which could hold the mirror rigidity and has freedom of fine angular alignment in vertical and horizontal planes as shown in figure 1.

2. Radius of curvature measurements

The radius of curvature was expected to be about 8 metres. The *F#* i.e. focal length *f*/diameter *D* of the mirror is thus 6.8. The Ronchi test (Malacara 1978) is a simple and convenient method to test large radius of curvature concave mirrors with a medium *F#*. The setup for the Ronchi test is as shown in figure 2. A small thermal source O illuminates the test mirror M through a coarse transmission grating G as shown. The grating G called as the Ronchi ruling has equal opaque and transparent parts with a spatial frequency of 4 lines/mm. The image of G as formed by the mirror M is made to overlap on G. In general, the image of the grating does not have the same spatial frequency as G and it may even be distorted depending on the distortion in the mirror. This results in a type of Moire' fringes between grating G and its image. The fringes are observed by placing the eye behind G. When the

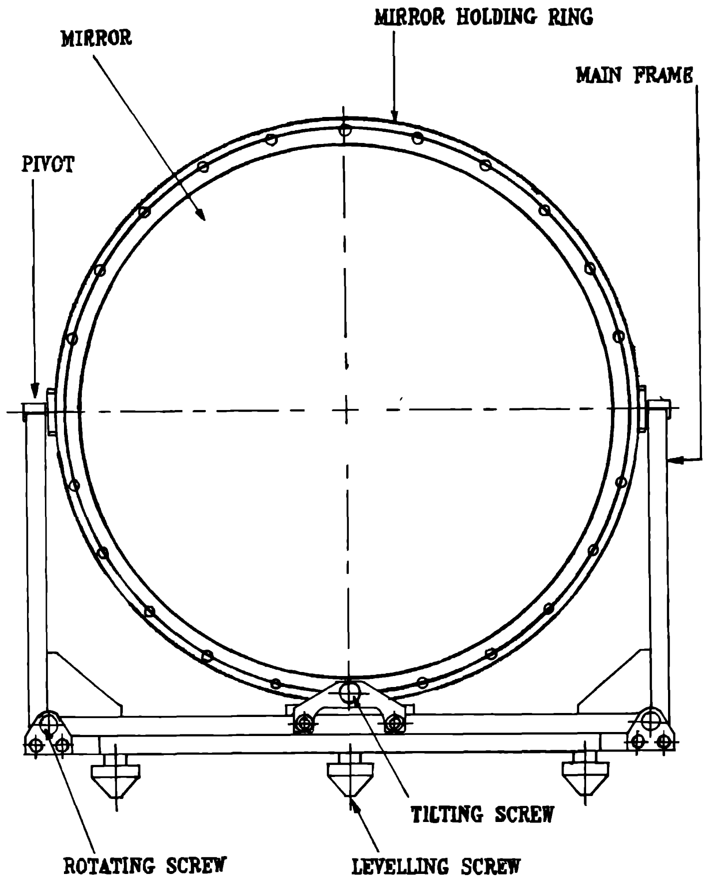

Figure 1. Mirror mount assembly.

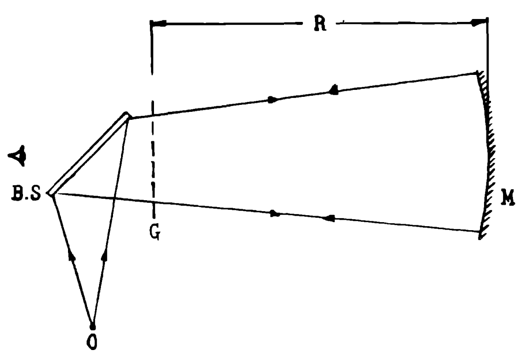

Figure 2. Ronchi test.

grating is placed at precisely the centre of curvature of the concave mirror, the image exactly overlaps the grating and a Moire' fringe of uniform intensity is seen provided the mirror is free from surface defects. For a defective mirror, a Moire' fringe of uneven intensity will be observed. To determine the radius of curvature, the grating is slowly moved along the axis of the mirror till a fringe free field of view or a fringe of nearly uniform brightness is obtained. The distance between the grating and the mirror then gives the radius of curvature. This distance can be measured using a steel tape.

3. Surface figure of the mirror

The nature and the number of fringes seen in the Ronchi test bears a complex relationship with the surface shape of the mirror. For a perfect spherical mirror, a fringe of uniform brightness is formed when the Ronchi grating is placed exactly at the centre of curvature of the mirror. If the grating is displaced slightly away from the centre of curvature on either side, equidistant straight fringes will be formed parallel to the grating rulings for a perfect mirror. If the mirror shape is deviating from sphericity, the fringes will deviate from straightness. By observing the nature of the fringes, hills or valleys in the centre or zonal errors can be detected. Thus a visual observations by a skilled observer can provide an estimate of the quality of the mirror.

4. Spot size measurements

The size of the image formed by focusing a parallel beam of light at the focus of the mirror is the spot size. This was measured using a nearly parallel beam of light generated by a point source kept at a large distance (~ $20f$) from the mirror. A microscope objective of magnification 40 in front of a He-Ne laser source was used to focus the laser beam onto a pinhole of diameter 10 micron, which was kept at a distance of 70 metres from the mirror. The image was taken on a ground glass plate and the spot size was directly measured using a graticuled magnifier.

The spot size can also be computed based on the assumption that the mirror is the surface of an exact sphere. The major contribution to the spot size of an on axis image from a single spherical mirror will be because of spherical aberration. The linear spot size at the focus is calculated from the following equation (Smith 1966) :

$$\text{Spot size} = \frac{f}{128\,(F\#)^3}.$$

For our case, $f = 4$ m, $D = 600$ mm, and $F\# = 6.8$. This gives a spot size of 0.1 mm. The increase in the measured value of the spot size may be attributed to the surface distortions of the mirror.

5. Reflectivity measurements

Figure 3 shows the setup used for reflectivity measurements. It consists of a mercury arc source S and a 0.25 m Czerny-Turner scanning monochromator M. The condensing lens L1 focuses the beam from the source to the entrance slit of the monochromator. The lens L2 is used for focusing the beam from the exit slit to the photo detector D1 after reflection from the mirror and the intensity at each wavelength is measured. The direct intensity at each wavelength is also measured by removing the mirror from the path of the beam and placing the photo detector at D2. The reflectivity of the mirror was calculated by taking the ratio of the intensity of the reflected light to the intensity of the direct light. The maximum possible error in the reflectivities is estimated to be about 2%.

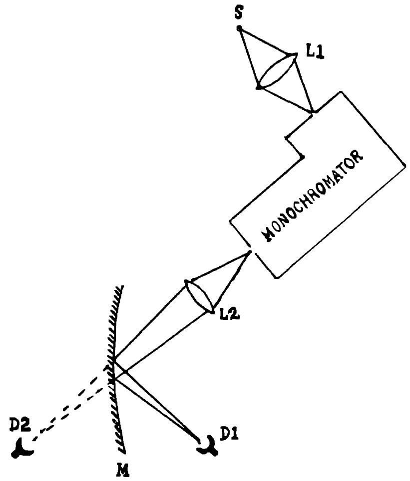

Figure 3. Reflectivity measurement set up.

6. Results

1. Measured value of radius of curvature = 802.4 ± 0.2 cms.
2. Estimated surface figure ~ lambda/2
3. Measured spot size = 0.5 ± 0.05 mm
4. Theoretical spot size = 0.1 mm.
5. Reflectivity in the visible region = 83%.

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