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Reflectometer for Reflectance Measurement of Cherenkov Counter Mirrors

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The Physics Department was asked by E-665 and E-756 to build a reflectometer to give them a means of checking the reflectance of their mirrors. A reflectometer was built modeled after the one constructed by Rutherford-Appleton Laboratory in England. The attached is an exerpt from "The Design of the Optical Components and Gas Control Systems of the CERN Omega Ring Imaging Cherenkov Detector" by R. J. Apsimon et al., published in Nuclear Instruments and Methods in Physics Research A241 (1985) 339-362 North Holland, Amsterdam. The Physics Department has an instruction manual for operating the reflectometer.

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4.3. Measurement of mirror reflectivities

The reflectivity of the mirrors was measured at the Rutherford Appleton Laboratory with the specially designed reflectometer shown in figs. 16 and 17. This device is unique in design in that it allows the reflectivity of large curved mirrors to be measured at any point on their surfaces, and has an integral laser alignment system. The mirror under test is attached via its mounting ring to a moveable platform and sealed into a vacuum vessel, inside which it can be rotated through 360° and translated along half a diameter (fig. 18a). The VW principle of operation of the reflectometer is shown diagramatically in fig. 19. Ultraviolet light from a deuterium arc passes through a wavelength-selecting vacuum uv monochromator and enters the device, to be reflected – depending on the mirror configuration – between the moveable plane mirrors and the mirror under test before being detected by an intensity-measuring photomultiplier tube coated with p-terphenyl wavelength shifter. In the W configuration the uv beam – with a spot size of 5 mm – is reflected from the test mirror surface at an angle of 10° from two points 44 mm apart.

Great care was taken to ensure that the moveable components in the reflectometer were correctly aligned so that intensity measurements were always made at the same point on the photocathode. Provision was made to inject a laser beam into the mirror system via a pair of 45° angled mirrors (fig. 18b). The alignment was adjusted until the laser beam crossed predetermined points on two translucent targets mounted near the output port. This meant that the reflectometer axis was correctly aligned in position and angle, and the two alignment mirrors could be swung out of the path of the uv beam ready for measurements to begin. If necessary, as part of the alignment procedure, the plane of the test mirror could be adjusted by means of a 3-point mounting on the vacuum vessel support truck (fig. 17). This was fitted primarily to allow mirrors of different radii of curvature to be measured; the mirror plane could be tilted to compensate for the change in radius.

In normal operation, the reflectometer vacuum vessel was evacuated to 10^{-4} mbar to eliminate the absorbtion of uv by oxygen and water vapour, which becomes serious at wavelengths below 195 nm.

The mirrors were set up in the V reference configuration and the intensity measured firstly over a range 170–230 nm in 5 nm steps. The wavelength scan was then repeated in the W configuration with the uv beam being reflected from the centre of the test mirror, all data being transmitted to an on-line computer over a CAMAC dataway so that reflectivities could quickly be calculated at each wavelength. Reflectivity measurements were then taken at a further 9 points on each

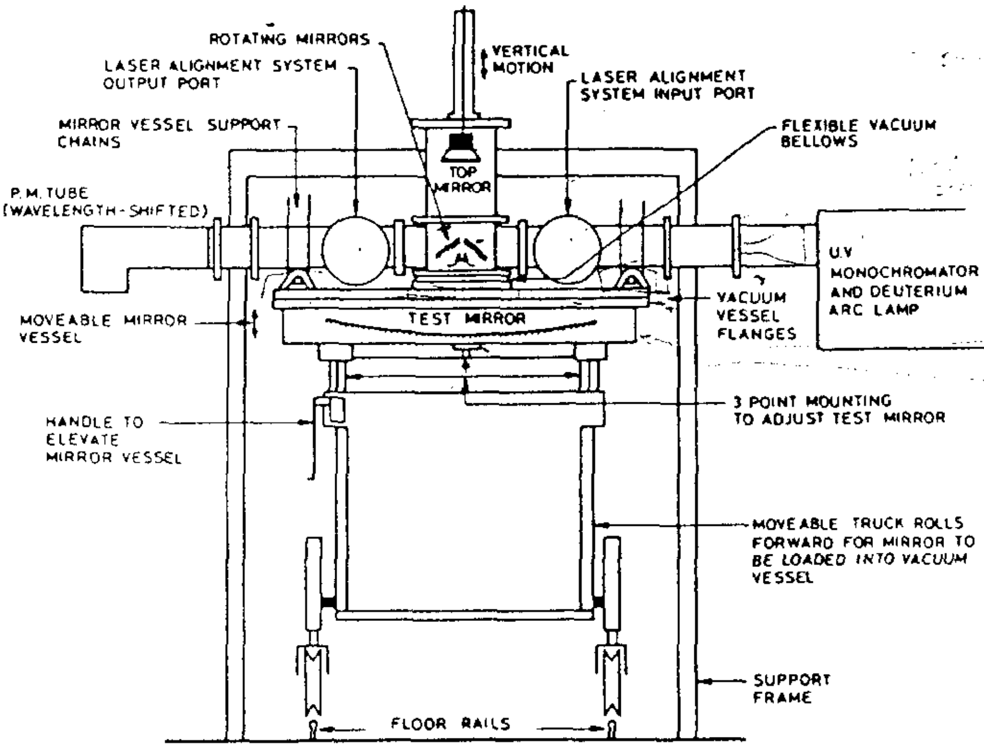

Fig. 17. uv reflectometer – detail of elevation.

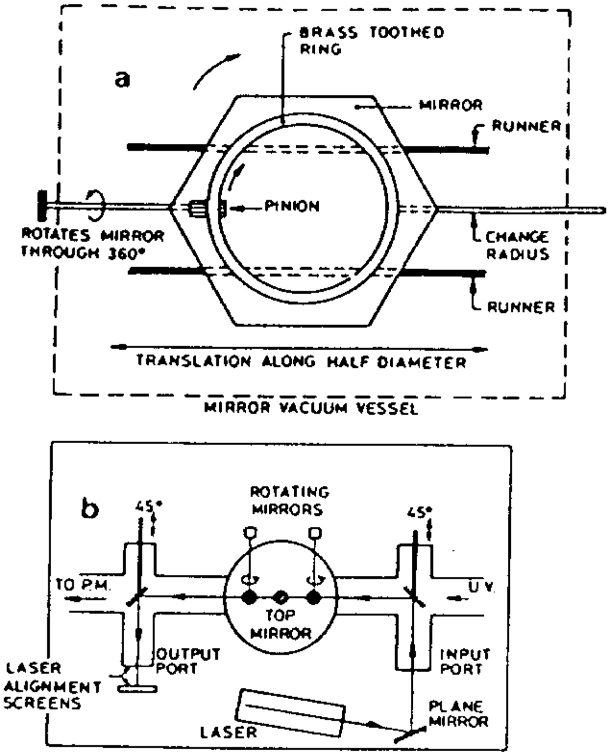

Fig. 18. (a) Method of measuring reflectivities at different points on a mirror surface. (b) Plan view of reflectometer showing the laser alignment system.

mirror; at 3 points spaced at 120° intervals at radii of 10, 20 and 25 cm. The two uv impact points on the test mirror were 22 mm tangentially equidistant from the nominal measurement positions.

Fig. 3 shows the average reflectivity as a function of wavelength for the 80 mirrors, each of which has been measured at 10 positions. No systematic geometrical variation of reflectivity was seen in the mirror sample, and the variations between individual mirrors were generally less than 3%. Occassionally, however, a "bad coat" was applied to a mirror which showed up as a dramatic reduction in reflectivity, particularly below 200 nm. In these few cases it was, however, possible to remove the defective coating according to the following procedure:

i. Wash with 1% nitric acid in distilled water to remove MgF_2 coating.
ii. Wash with 1% sodium hydroxide in distilled water to remove aluminium coating.
iii. Wash with detergent.
iv. Wash with distilled water.

All mirrors recoated after being washed in this way gave "second pass" reflectivities entirely consistent with the curve of fig. 3. All the mirrors used in the RICH had

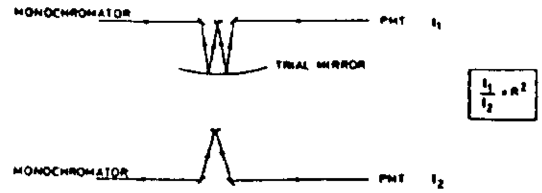

Fig. 19. The VW principle of operation of the reflectometer.

a minimum average reflectivity of 75.5% at 170 nm and 88% at 230 nm.

Tests were made to establish whether mirror reflectivities deteriorated significantly with time. Over a period of 15 months, no significant deterioration was seen in the reflectivity of a test mirror that had been stored in a protective wooden crate under normal laboratory conditions of temperature and humidity (fig. 20). We believe, therefore, that no deterioration of mirror surfaces is likely to occur in the clean atmosphere of the RICH (sect. 5). At all times mirrors were handled with gloved hands, avoiding any contact with the coated surface, and care was taken never to breathe directly on them, since it would have been impossible to restore the reflectivity of a blemished surface without a complete recoat.

4.4. The measurement of mirror optical distortions

The design requirement that the point error on each Cherenkov photoelectron should not exceed 3 mm gave us a criterion with which to specify the maximum allowable optical distortion of each mirror. Given the likely contributions to the spatial resolution from other factors it was demanded that optical distortions at the focal plane contribute at most ± 1 mm to the point

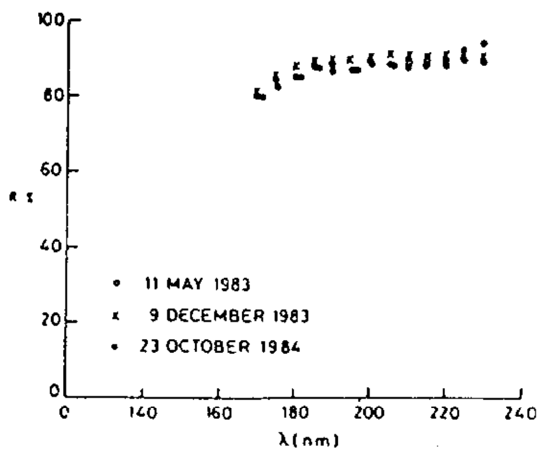

Fig. 20. Degradation of uv reflectivity with time.