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Nuclear Instruments and Methods in Physics Research A 553 (2005) 172–176
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
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Ronchi test for flat mirrors

N. Estrada, J. Engelfried*, A. Morelos

Instituto de Física, Universidad Autónoma de San Luis Potosí, Mexico

Available online 30 August 2005

Abstract

One of the RICHes in the velocity spectrometers of the proposed CKM experiment requires a flat mirror, situated in the high intensity kaon beam. To reduce the interaction background for the experiment, this mirror has to be as thin as possible. First glass prototypes were produced in Mexico. To test the surface quality of these prototypes, we extended the Ronchi method so flat mirrors can also be tested. We present the methods and report on results of our measurements.

PACS: 29.40.Ka; 42.79.Bh; 42.87−d

Keywords: RICH detector; Mirrors; Ronchi method

1. Introduction

This work reports on how we used the Ronchi test, originally only designed for spherical mirrors, for flat mirror characterization. The High Energy Group of the Instituto de Física of the Universidad Autónoma de San Luis Potosí is participating in the design, prototyping and construction of two Ring Imaging Cherenkov Detectors [1,2], Kaon-RICH and Pion-RICH for the proposed CKM [3] experiment at Fermilab, as part of a collaboration with several US and Russian research groups.

The Kaon-RICH detector is schematically shown in Fig. 1. It contains one spherical and two flat mirror, to focus the Cherenkov radiation onto a photomultiplier array.

Both, spherical and flat mirrors, can be manufactured to a surface quality of about $\frac{1}{10}\lambda$, for example for astronomical applications. In a RICH detector, other sources limit the overall ring radius resolution, so that a quality of only about $1\,\lambda$ is sufficient. For this RICH detector, the flat mirror is in the path of a high-intensity kaon beam, and has to present as low mass as possible to minimize the number of interactions.

A thinner mirror will deform more during the polishing process, leading to a lower surface quality. The optimization of these two parameters

*Corresponding author. Tel.: +52 444 826 2362; fax: +52 444 813 3874.
E-mail address: jurgen@ifisica.uaslp.mx (J. Engelfried).

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doi:10.1016/j.nima.2005.08.052

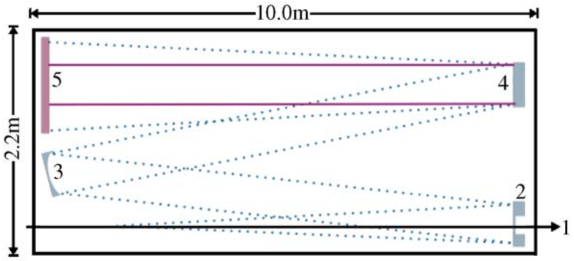

Fig. 1. Schematic drawing of the proposed Kaon RICH. The Cherenkov light produced by the charged beam (1) reflects off two flat (2,4) and one spherical (3) mirrors and is focused on a photomultiplier array (5).

is the objective to reach in producing and analyzing different prototype flat mirrors.

2. Ronchi method for spherical mirrors

The Ronchi Method [4] is a simple method to apply for the characterization of mirrors. It does not require special equipment, only a grid of equally spaced parallel lines, the Ronchi grating.[1] Light reflected from a mirror illuminated by a line source present a shadow pattern ("Ronchigram") when intercepted by the grating.

When the grid is placed exactly at the image point of a perfect spherical mirror, the pattern observed by eye or a video camera is either nothing or the whole mirror. Moving the grating slightly produces parallel strips of light and dark lines. By just counting the number of lines (N_{bands}) and applying geometry constants shown in Fig. 2, we obtain an average radius of curvature R via the following set of equations:

$$\frac{X}{Z} = \frac{D}{I} \quad N_{\text{bands}} = \frac{X}{G} \quad I = Z + Y$$
$$I = \frac{DY}{D \pm GN_{\text{bands}}} \quad \frac{1}{S} + \frac{1}{I} = \frac{2}{R}.$$

To obtain also local information, we use the fact that the distance between two lines depends on the (local) radius, by substituting N_{bands} by its differential in the above equations. More details about the method can be found in Refs. [5,6]. In this way we obtain a detailed analysis of the mirror surface. Fig. 3 shows a Ronchigram of a spherical mirror obtained with the experimental setup described above.

[1] For these measurements we used a Ronchi grating with 50 lines/in.

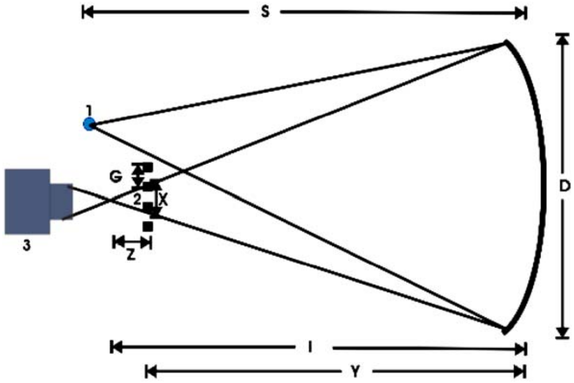

Fig. 2. Schematic of the experimental setup to measure spherical mirrors. A narrow gap light source (slit) (1) illuminates the (spherical) mirror, the reflected light is intercepted by the Ronchi grating (2) and recorded with a video camera (3).

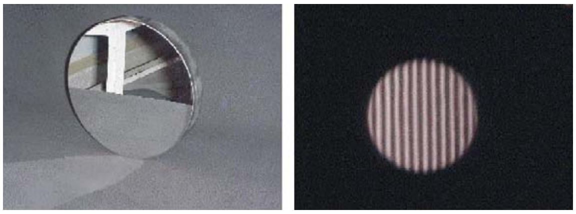

Fig. 3. Ronchigram (right) of the spherical calibration mirror (31.5 cm diameter, 4 m nominal radius) (left).

3. Data analysis

For the analysis we developed a program written in C. From a snapshot of the Ronchigram taken with a high resolution black-and-white CCD camera,[2] we store the 8-bit intensity values in a two-dimensional array. The exposure time is very short so we do not depend on air current and similar effects. In slices perpendicular to the shadow pattern we adjust several Gaussian's to

[2] SONY SSC-M374.