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RONCHI TEST AND TRANSVERSAL SPHERICAL ABERRATION

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SUMARIO

La prueba de Ronchi es sumamente útil para determinar la calidad de sistemas ópticos que tendrían aberración de esfericidad transversal, aún en el caso de estar perfectamente construidos. El propósito de este artículo es el de describir un método para calcular el ronchigrama; se supone que se puede calcular la aberración transversal para cinco rayos diferentes, que partan de un mismo punto luminoso sobre el eje óptico.

Introduction

There is a very intimate relation between the transversal spherical aberration and the Ronchigram that is produced by means of a Ronchi ruling. It is of course assumed that the ruling has a low frequency, so that the geometrical interpretation of the Ronchi pattern can be used.

The Ronchi test is nearly always limited to systems which, if perfect, would produce straight fringes and any deviation from straightness would mean the presence of aberrations. (Ronchi 1964)

Exceptions to this rule are the cases of some concave mirrors. For instance, the shape of the fringes has been computed for parabolic surfaces tested at the center of curvature (Sherwood 1959) and also for general aspherical surfaces (Malacara 1965) but not for any reflecting or refracting system having spherical aberration.

The purpose of this paper is to calculate the ronchigram of any system with spherical aberration, when tested on axis.

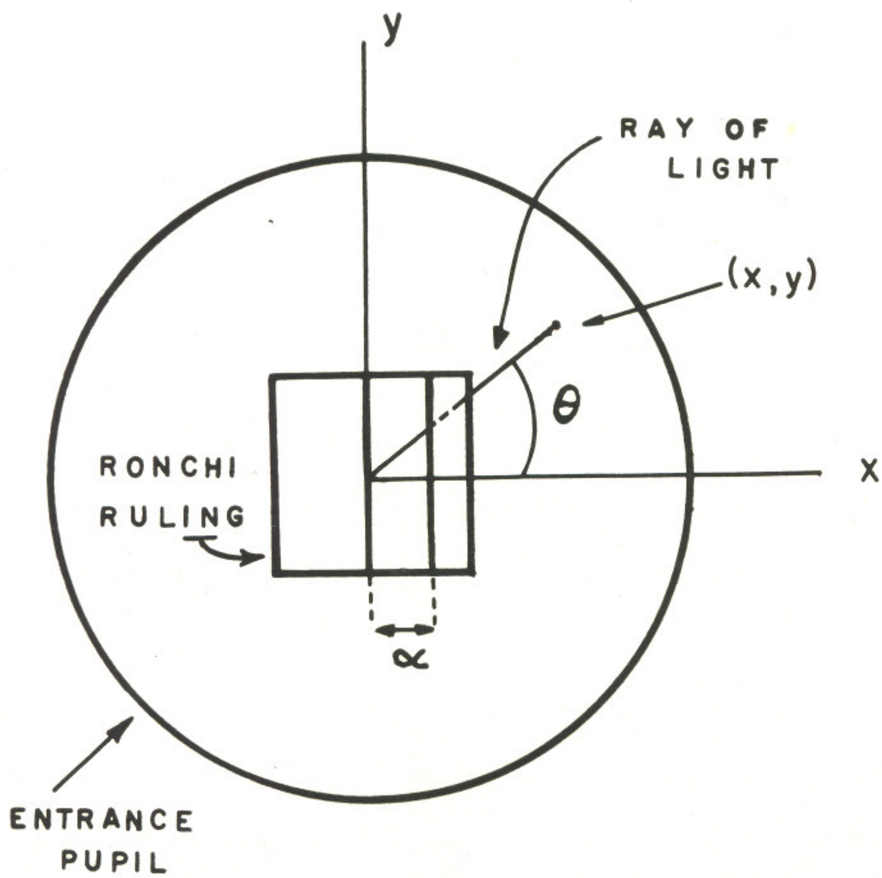

Figure 1.—*Entrance Pupil and Ronchi Ruling Viewed along the Optical Axis.*

Finding of the Ronchigram

The ronchigram of a system having spherical aberration can be calculated assuming that the transversal aberration TA is a function of the distance S, between the ray and the optical axis, over the entrance pupil.

A view along the optical axis of an optical system and a Ronchi ruling is represented in Fig. 1, where α is the distance between the central line on the ruling, and the line that intercepts the ray coming from a dark fringe.

The quantities x, y and θ, shown in Fig. 1, are defined as follows:

$$\cos \theta = \frac{\alpha}{TA\,(S)} = \frac{x}{S} \quad , \tag{1}$$

thus

$$x = \frac{\alpha\, S}{TA\,(S)} \quad . \tag{2}$$

also:

$$y = [S^2 - x^2]^{1/2} \tag{3}$$

If D is the separation between two lines on the Ronchi ruling, α is given by:

$$\alpha = n\, D, \tag{4}$$

where n is an integer. A fringe on the ronchigram could be found by calculating many points (x, y) inside the entrance pupil for a constant value of α, assuming that TA (S) is known for any value of S.

If R is the radius of the entrance pupil, the following inequality must be satisfied:

$$0 \leqslant x \leqslant S \leqslant R \tag{5}$$

Thus, in order to find the Ronchi fringe for a given value of n, x and y are computed by giving S many values which lie between zero and R. After giving a value to S and calculating x by means of equation (2), it might happen that $x > S$; this would mean that there is no fringe crossing the circle with radius S.

To find the whole ronchigram, n is increased from zero to a value such that:

$$\alpha \geqslant TA_{max} \quad , \tag{6}$$

where TA_{max} is the maximum value of the transversal spherical aberration for rays inside of the entrance pupil. The values of n that satisfy this condition give all the Ronchi fringes for the optical system.

Calculation of TA (S)

The transversal spherical aberration on axis can be represented very accurately by a polynomial of the ninth order as follows:

$$TA\ (S) = a_1\, S + a_3\, S^3 + a_5\, S^5 + a_7\, S^7 + a_9\, S^9 \tag{7}$$

Thus, the coefficients a_i can be found by means of a matrix inversion after computing $TA\ (S)$ for five different value of S, using any ray tracing procedure.

When $TA\ (S)$ is calculated for all desired points inside the aperture, the highest value is taken as TA_{max}.

Since the term $a_1\, S$ represents the defocusing term, the ronchigrams for several different settings of the Ronchi ruling can be obtained with only one ray tracing, changing only the coefficient a_1.

All the necessary calculations can be made very easily with the aid of an electronic computer.

Applications of the Method

This method of using the Ronchi test is very useful when figuring some optical systems; some examples are given below.

a) A Schmidt plate corrector can be tested against the spherical mirror to be used with this plate, as shown in Fig. 2.

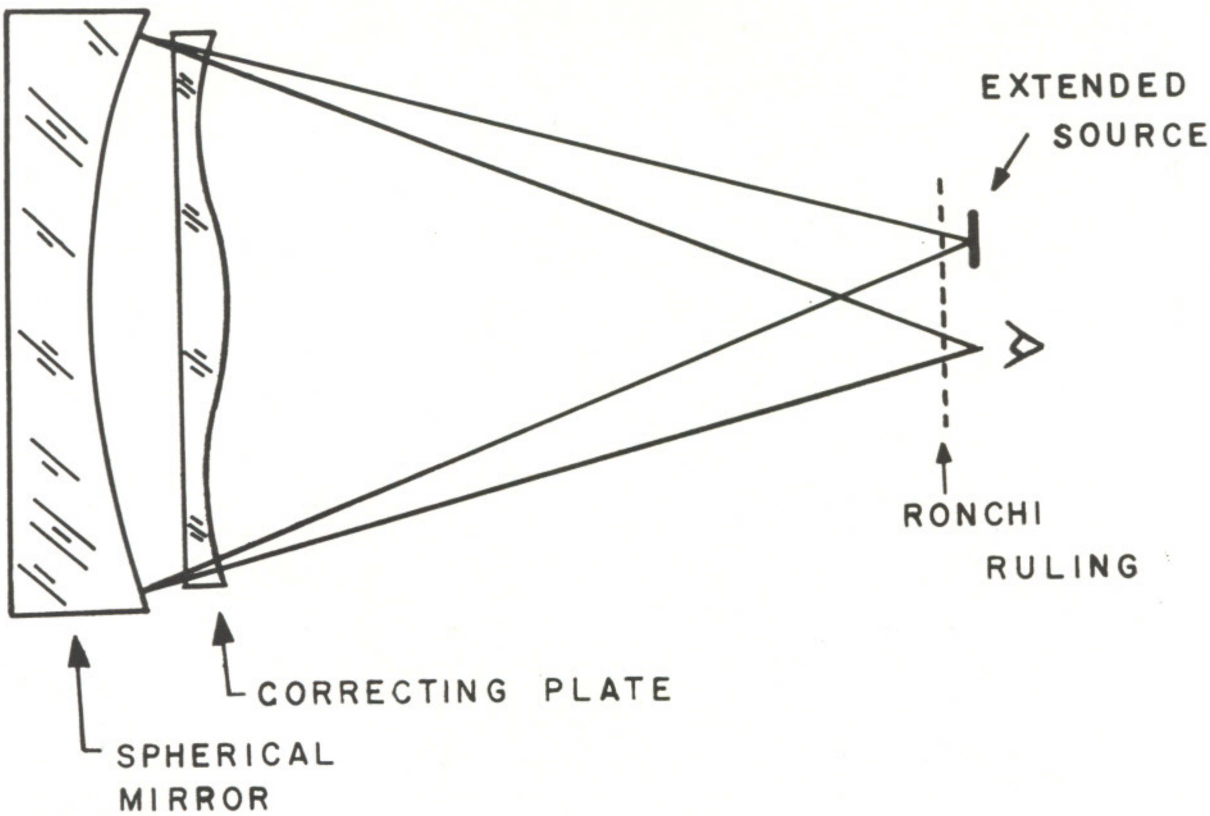

Figure 2.—*Testing of a Schmidt Correcting Plate.*

b) The testing of a large refractor objective for an astronomical telescope generally requires a flat surface as big as the objective, or a collimated beam of light with the same aperture. The objective can be Ronchi tested with a source at a finite distance, by computing its transversal aberration. This is shown in Fig. 3.

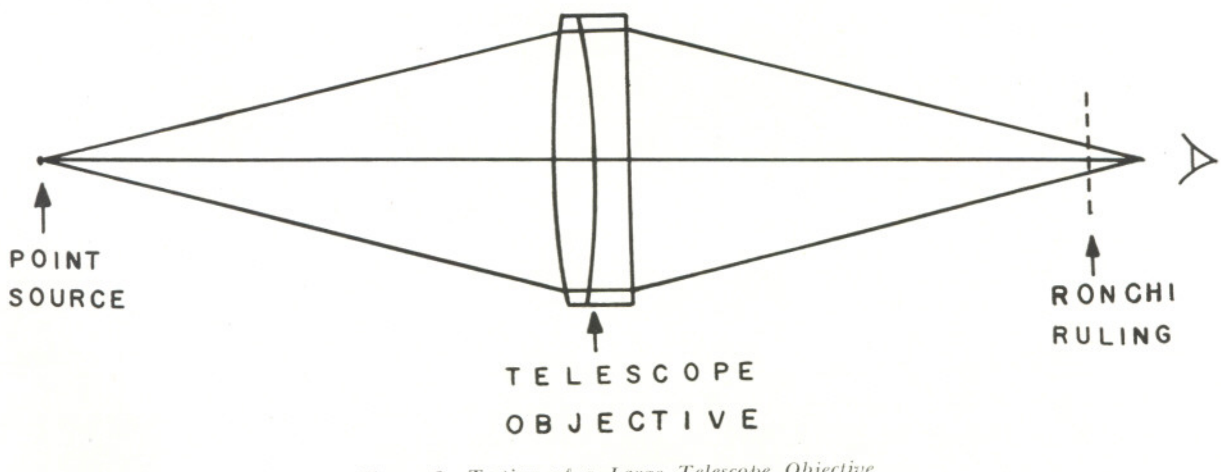

Figure 3.—*Testing of a Large Telescope Objective*

Many other types of systems could be tested in the same way, without having to use a collimated beam of light.

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