Null Ronchi Gratings as a function of period

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Abstract. In this work is presented in a simple manner, a method to generate null Ronchi gratings. This method considers the period of the Ronchi grating as a function of the x and y positions over the grating, compared to the currently known methods which utilize ray tracing or spot diagrams for the null Ronchi gratings calculus. We compare null Ronchi gratings reported in the literature against gratings calculated with our method. We have found that our method can calculate the Ronchi gratings for any conical surface in a satisfactory way.

1. Introduction

It is well known that a pattern of curved fringes is observed when the Ronchi test is used to test aspherical surfaces [1] (see fig. 1). Thus, for the technicians in an optical workshop is more difficult to observe the deviation of the pattern produced by aspherical surfaces compared with the pattern generated by spherical surfaces, where the fringe pattern is straight and equally spaced.

![Image a)](image1)

![Image b)](image2)
Figure 1. Ronchigrams, a) hyperbolic, b) parabolic and c) spherical surface.

The technique that is used to eliminate the curved fringes of the aspherical surfaces pattern is to use a special kind of Ronchi grating, which has curved fringes unequally spaced (Fig. 2), these kind of gratings are also called null Ronchi gratings [1].

Figure 2. a) Classical and b) null, Ronchi grating.

This kind of gratings acts as an optical compensator, which compensates the asphericity of the surface, causing that the observed fringe pattern will be only influenced by the aberrations of the system; if the system has no aberrations, the observed pattern will have straight and equally spaced fringes [1,2].

Ray tracing and solving a system of linear equations are the most common used method to calculate these kind of gratings [2]. A simpler way for this calculation was proposed by Hopkins and Shagam [3], which use a spot diagram to design null Ronchi gratings.

In this work, a new technique for generating null Ronchi gratings is proposed. This technique is based in the lateral share interferometry formalism. The technique considers the period of the grating as a function of the $x$ and $y$ positions, and not as constant, as it is traditionally done.

2. Null Ronchi gratings calculus
The wavefront aberrations are defined in the exit pupil of the system under test, by using the Rayces equations given in 1964 [1], as

$$\frac{\partial W(x, y)}{\partial x} = -\frac{TA_y}{r} ; \quad \frac{\partial W(x, y)}{\partial y} = -\frac{TA_x}{r} .$$  \hspace{1cm} (1)
Assuming a Ronchi grating with a spacing \( d \) between the slits from a point \((x, y)\) in the \( m \)-th fringe, we may write, in general, as

\[
\frac{\partial W(x, y)}{\partial x} = -\frac{md}{r},
\]

where \( W(x, y) \) represents the original wavefront which can be expressed by a polynomial function (i.e. Zernike, Seidel, Kingslake, etc.), or by the sagitta differences between the conical surface under test \((z(x, y))\) and the osculating sphere \((z_0(x, y))\) \([1, 4]\), in our case the wavefront of an optical system, which only presents primary aberrations can be described by the polynomial aberration given by Kinglake in 1925 \([5]\), as

\[
W(x, y) = A(x^2 + y^2) + By(x^2 + y^2) + C(x^2 + 3y^2) + D(x^2 + y^2),
\]

where \( A, B, C \) are the spherical aberration coefficients, coma and astigmatism, respectively. The last coefficient \( D \) is the defocusing term, given by the distance \( l \) from the Ronchi grating to the paraxial center of curvature, as

\[
D = \frac{l}{2r^2}.
\]

Due to the conical surfaces only present spherical and focus aberration, the Eq. 1 is reduced to the following manner

\[
\frac{\partial}{\partial x}\left[A(x^2 + y^2)^2 + D(x^2 + y^2)\right] = -\frac{md}{r}.
\]

Solving Eq. (5) for the grating period, we obtain

\[
-\frac{r}{m} \left[\frac{\partial}{\partial x}\left(A(x^2 + y^2)^2 + D(x^2 + y^2)\right)\right] = d.
\]

Notice that spherical aberration in a conical surfaces only depends to the conic constant and the paraxial radius of curvature, which can be described as

\[
A = \frac{|k|}{8r^3}.
\]

Substituting Eq. (4) and Eq. (7) in Eq. (6), we obtain the equation for calculate the period of the grating point to point on the null Ronchi grating, as

\[
-\frac{r}{m} \left[\frac{\partial}{\partial x}\left(\frac{|k|}{8r^3} (x^2 + y^2)^2 + \frac{l}{2r^2} (x^2 + y^2)\right)\right] = d.
\]

### 3. Experimental Results

In the last section, we have defined the set of equations needed to simulate the null Ronchi gratings for any conical surface. To validate the above equations, it was performed a simulation of a hyperbolic surface of 35 cm diameter, 110 cm paraxial radius of curvature and a conic constant value of -3.5. The position of the ruling was 109.15 cm from the vertex of the mirror. The null Ronchi grating was...
calculated by using ray tracing program and also with our method. We found that by using our method the null Ronchi grating was a similar to the ray tracing but not identical (Fig. 3).

![Figure 3. Calculated grating with a) our method and b) ray tracing.](image)

This error is due to the form of calculating the null grating because our method only calculate the period of the grating in the $x$ direction, but when the slits are bent produces diffraction in both $x$ and $y$ directions. A solution to this problem was to make a cubic fitting to the data set. By applying this fitting to the null grating computed with our method, we obtain the same result that the calculated grating calculated with ray tracing (Fig. 4).

![Figure 4. Calculated grating with a) our corrected method and b) ray tracing.](image)

As an example, we used the analysis described by D. Malacara and A. Cornejo [2] to calculate the null Ronchi grating corresponding to a parabolic surface with 30 cm in diameter and 302 cm of curvature radius; where they used ray tracing and the solution of a linear equation system.
We can notice that the grating generated by our corrected method (Fig. 5b) is identical to the grating calculated by D. Malacara and A. Cornejo (Fig. 5a).

A simpler method that can be found in the literature is the analysis described by G. Hopkins and R. Shagam [3] to calculate the null grating by using a spot diagram, corresponding to a parabolic surface with 20 cm in diameter and an f/3.

We can notice that our corrected method can also reproduce the results obtained by G. Hopkins and R. Shagam in 1977 (Fig. 6).

4. Conclusions

It has been shown that by considering the period of the Ronchi grating as a function of the x and y positions, it can be calculated in a simple manner the null Ronchi grating associated to different conical surfaces, this is because our proposal is able to reproduce in a satisfactory manner the results presented by D. Malacara and A. Cornejo in 1974 and the results presented by G. Hopkins and R. Shagam in 1977.

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