# Sensor nulo de Shack-Hartmann para evaluar una superficie cóncava esférica y una parabólica

*Null Shack-Hartmann Sensor for evaluating a concave spherical surface and a satellite dish*

**Benito Canales Pacheco**
Universidad Tecnológica de la Sierra Hidalguense, México
canales321@hotmail.com

**León Felipe Austria González**
Universidad Tecnológica de la Sierra Hidalguense, México
león_austria@hotmail.com

**Raymundo Sergio Noriega Loredo**
Universidad Tecnológica de la Sierra Hidalguense, México
snoriegal@gmail.com

**Luis Alberto Ruiz Aguilar**
Universidad Tecnológica de la Sierra Hidalguense, México
lruizaguilar@gmail.com

## Resumen

Actualmente existen muchas pruebas ópticas que analizan una superficie o un sistema óptico. Según la literatura científica las hay de dos clases, dependiendo del método que utilicen: las denominadas no interferométrícas, es decir, la prueba de Hartmann, Alambre, Estrella, Foucault, Ronchi [1]. Dichas pruebas permiten obtener información sobre la derivada del frente de onda (∂w/∂y). Por otro lado, están las denominadas pruebas interferométricas, por ejemplo: el Interferómetro de Tyman Green, Fizeau, Newton, Murty (desplazamiento lateral) [2]. Con este tipo de pruebas se obtiene información directa del frente de onda (W). El presente trabajo utiliza el principio físico de la prueba de Hartmann para construir un sensor de frente de onda tipo Shack-Hartmann, que permita evaluar una superficie óptica esférica y una parabólica.

Palabras Clave: Sensor, Schack-Hartman, parabólica

## Abstract

There are currently many optical tests that analyze a surface or an optical system. According to the scientific literature there are of two kinds, depending on the method used: the so-called not interferometric, i.e., Hartmann test, Alambre, Estrella, Foucault, Ronchi [1]. These tests provide information about the derivative of the wave front (∂w/∂y). On the other hand, are the so-called interferometric tests, for example: the Green Tyman Interferometer, Fizeau, Newton, Murty (side-scrolling) [2]. With this type of evidence is obtained information directly from Wavefront (W). This paper uses the physical principle of the Hartmann test to build a wavefront sensor type Shack-Hartmann, that enable to assess a spherical optical surface and a satellite dish.

Key words: Sensor, Schack-Hartman, parabolic.

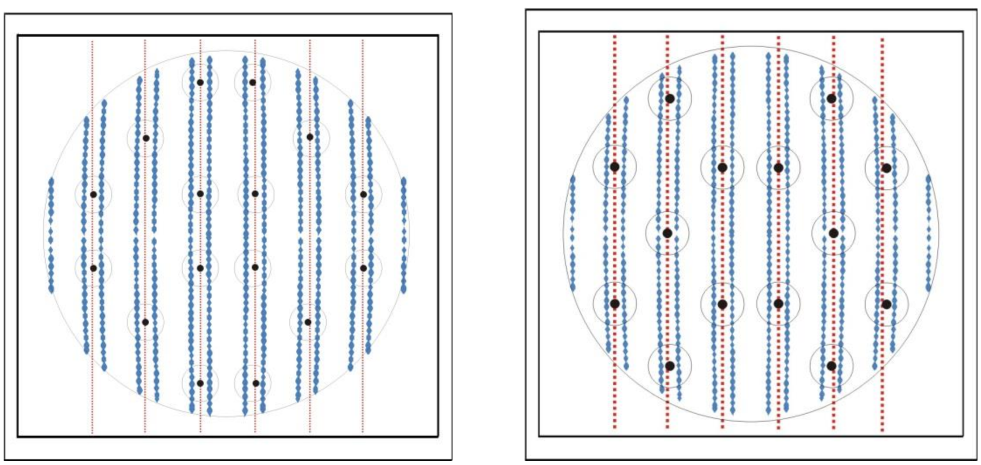
**Fecha recepción:** Enero 2015 **Fecha aceptación:** Junio 2015

## Introduction

The Ronchi and Hartmann tests are very useful to assess spherical surfaces, whose errors can be estimated through deviations from a standard reference in contrast with one experimental [1-5]. With the advancement of technology, these tests have had some modifications, but still retaining the same principles of geometric analysis. Among the best known are the sensor of Wavefront Shack-Hartmann (SH) [6], which consists of an array of microlenses of the same focal length, with a CDD (Charge-Coupled Device) camera, placed in the focus of the lenses. When a perfect spherical wave front passes through the SH, each micro-lens concentrates the light in CCD camera, forming a distribution of equally spaced points (waypoints). This device has been an alternative to optical testing since it is simple, compact and relatively insensitive to mechanical vibrations; It has even having a large number of applications in different areas of science and technology, including the Vision Sciences and Astronomy. Returning to the characteristics of the sensor of the Wavefront, in this work intends to build a sensor Shack-Hartmann type to simulate evaluate a concave spherical and parabolic surface.

**Design and construction of a null Shack-Hartmann sensor**

Null Shack-Hartmann sensor is a combination of the Shack-Hartmann test and null test of Ronchi. Its design and construction were obtained different void grids using a computer program [7]. In Figure 1, the skeletonization of zero Ronchi gratings is to evaluate a spherical surface (see figure) and a satellite (Figure b). In both figures they strip with a certain inclination, especially in the upper and lower edges are observed; the deviation is measured from a straight line drawn in the center of each strip. You can also observe a distribution of black spots indicate where to put the mini-lens, references that follow the curvature of the grids (see Figure b). However, in the figure, the locations of the mini-lenses are held vertically aligned. The distribution of the lenses were chosen such that the sensor has a larger field of analysis on the test surface.



a) b)

Figure 1. Ronchi grid zero to a surface; a) spherical, b) parabolic.

Characterization of null lenses Ronchi sensor Shack-Hartmann type.

As mentioned in the previous section, a Shack-Hartmann sensor consists of an array of microlenses each equally spaced with the same focal length. Therefore in this section the characterization process to use lenses described. To carry out this process an optical arrangement (see Figure 2), consisting of a source of helium-neon laser light to illuminate a spatial filtering system is used, allowing to expand the beam; immediately collimating lens is placed, which produces a plane wavefront incident on the lens under test, and the refracted light converges to its focus. Finally, with a vernier the focal length of the test lens is calculated. The parameters found in the 16 lenses were; a focal length of 10 mm and a diameter of 7mm.

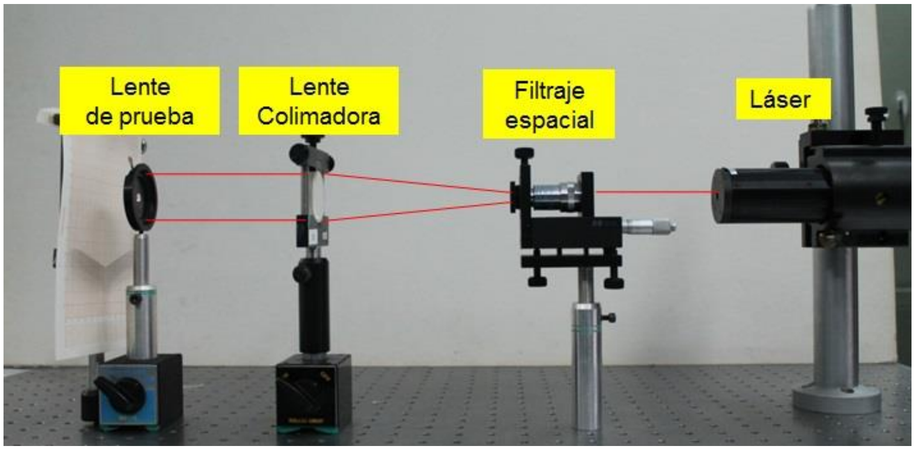
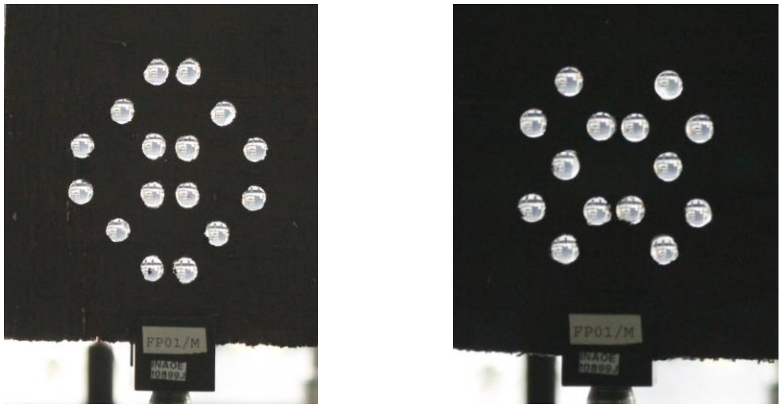



Figure 2. Experimental setup of a collimator system.

## Construction of a null sensor Shack-Hartmann type Ronchi

With zero Ronchi gratings shown in section 2.1, we proceeded to build a Shack-Hartmann sensor using the following methodology. First, the grid is printed on a piece of wood 65 x 65 mm and a thickness of 1.6 mm. Second, using a milling machine the holes on references on the grid is made; It is worth noting that the benchmarks follow the curvature of the strips, being more noticeable at their upper ends. Third were embedded each of the lenses on each hole. In Figure 3 the sensor built images, particularly the figure shows a zero to evaluate a spherical surface lens comprising sensor 16 are shown, whereas Figure b shows a sensor lens 14 to evaluate a parabolic surface.



a) b)

Figure 3. null sensor Hartmann-Shack Ronchi to test a surface, a) spherical, b) parabolic

The optical sensor device constructed called null Shack-Hartmann type Ronchi, is used as a tool to test a spherical surface of 14 cm in diameter, a focal length of 55. 8 cm and a satellite of 5.2 cm diameter with a distance of 32 cm. The tests were performed using an experimental arrangement (see Figure 4), which consists of a fiber source of white light is cast close to the center of curvature of the test surface, which allows light to the lens producing a reflection of incident light towards its center of curvature. Then the null sensor at a distance of 85 cm was placed spherical mirror; each sensor lens forms an image of the source, resulting in a distribution of points (see Figure 5). This same procedure was performed for the parabolic surface, in which case the zero was placed at a distance of 71 cm mirror sensor.

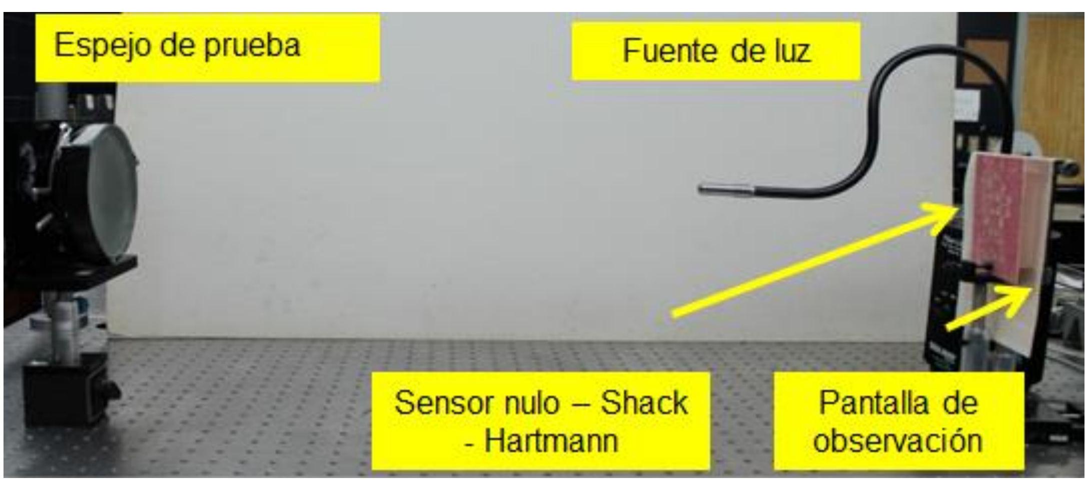
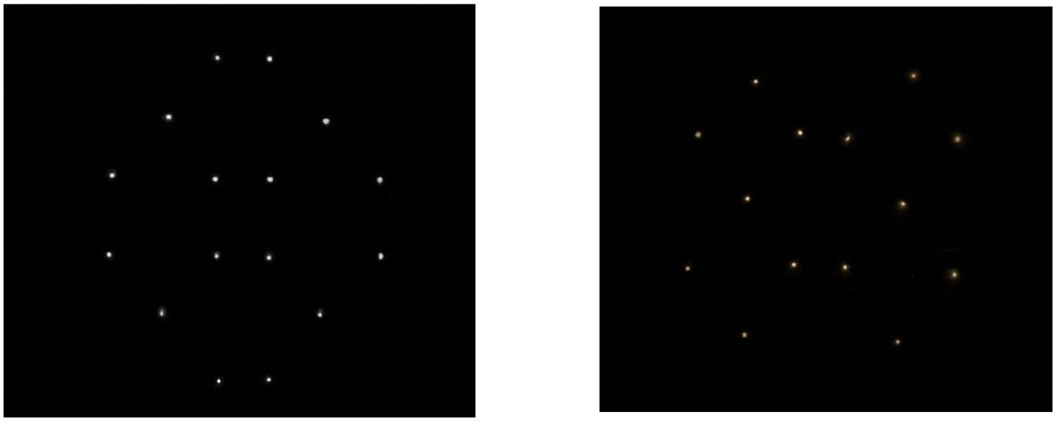



Figure 4. Experimental setup to evaluate a spherical and parabolic surface.

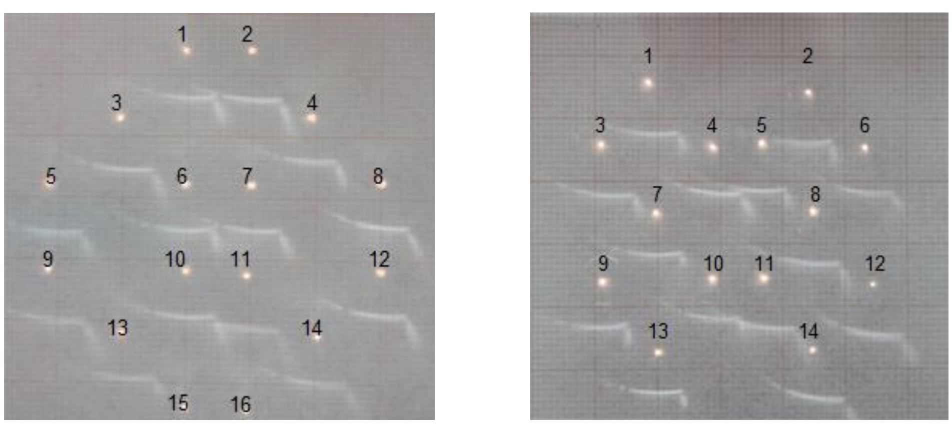


a) b)

Figure 5. Experimental Hartmanngrama a surface, a) spherical b) parabolic.

## Results

The Hartmanngramas shown in Figure 5 were analyzed to know the positions and deviations of the points relative to a reference system. For analysis as translucent paper millimeter observation screen, where you can see the positions of each of the light spots formed by the mini-lens (see Figure 6) it was placed. To measure the deviations were taken as reference points 3, 4, 5, 6, 7 and 8; the results obtained are shown in Table 1. In the case of the parabolic surface the same procedure was performed with reference to the points 7, 8, 9, 10, 11 and 12; and the results obtained are shown in Table 2.




a) b)

Figure 6. Experimental Hartmanngrama a surface, a) spherical b) parabolic.

Table 1. Experimental data points shifts Hartmanngrama respect to a reference position corresponding to the spherical surface.

| Number of points | Displacement Hartmann points Grama | Number of points | Displacement Hartmann points Grama |
|---|---|---|---|
| 1 | 0±0.05 mm | 9 | 0±0.05 mm |
| 2 | 0±0.05 mm | 10 | 0±0.05 mm |
| 3 | 0±0.05 mm | 11 | 0.5±0.05 mm |
| 4 | 0±0.05 mm | 12 | 0±0.05 mm |
| 5 | 0±0.05 mm | 13 | 0.5±0.05 mm |
| 6 | 0±0.05 mm | 14 | 0.5±0.05 mm |
| 7 | 0±0.05 mm | 15 | 0±0.05 mm |
| 8 | 0±0.05 mm | 16 | 0±0.05 mm |

Table 2. Experimental data of displacements Hartmanngrama points relative to a reference position corresponding to the spherical surface.

| Number of points | Displacement Hartmann points Grama | Number of points | Displacement Hartmann points Grama |
|---|---|---|---|
| 1 | 0.25 ±0.05 mm | 8 | 0±0.05 mm |
| 2 | 0.25 ±0.05 mm | 9 | 0±0.05 mm |
| 3 | 0 ±0.05 mm | 10 | 0±0.05 mm |
| 4 | 0 ±0.05 mm | 11 | 0±0.05 mm |
| 5 | 0 ±0.05 mm | 12 | 0±0.05 mm |
| 6 | 0.25 ±0.05 mm | 13 | 0.25±0.05 mm |
| 7 | 0±0.05 mm | 14 | 0±0.05 mm |

## Conclusions

This work has demonstrated the feasibility of using a Null sensor Shack-Hartmann type Ronchi to evaluate spherical and parabolic optical surfaces. They were characterized mini-lenses 16, measuring its focal distance and diameter.

## Bibliography

A. Cornejo-Rodríguez (2007). "Ronchi test", in Optical Shop Testing, D. Malacara, Wiley, New York, p. 317.

A. Cordero-Dávila; A. Cornejo-Rodríguez; O. Cardona Núñez (1990). Null Hartmann and 169 Ronchi Hartmann tests, Appl. Opt. 29 4618–4621.

D. Malacara; A. Cornejo (1974). Null Ronchi test for aspherical surfaces, Appl. Opt. 13 176, 1778–1780.

G.H. Hopkins, R.H. Shagan (1977). Null Ronchi gratings from spot diagram, Appl. Opt. 178 16, 2602–2603.

A. Cordero-Dávila; A. Cornejo-Rodríguez; O. Cardona Númez (1992). Ronchi and 171 Hartmann tests with the same mathematical theory, Appl. Opt. 29, 172 2370–2376.

D. Malacara-Dobledo; I. Ghozeli (2007). "Hartmann, Hartmann-Shack, t and other screen tests", in Optical Shop Testing, D. Malacara, Wiley, New York, p. 361.

A.M. Zárate Rivera (1989). "Paquete de Ronchigramas para PC" en Reporte técnico No. 70, INAOE, Departamento de cómputo.