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TELESCOPE SIMULATOR FOR TESTING ASTRONOMICAL INSTRUMENTS

O. Harris, E. Luna, M. Pedrayes, and V. García

Instituto de Astronomía
Universidad Nacional Autónoma de México

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RESUMEN

Se construyó un instrumento de laboratorio que permite probar, calibrar o dar servicio a instrumentos astronómicos, sin tener que usar un telescopio. El aparato consta de un sistema óptico que produce una imagen con las características de la producida por un telescopio apuntado a una estrella. Este aparato puede producir imágenes de telescopios que van de una relación focal F/7.5 hasta F/30, lo cual cubre las relaciones focales de los telescopios que actualmente están en operación en el Observatorio Astronómico Nacional. La distancia de la platina a la imagen se puede variar de 250 mm a 370 mm máximo y la imagen se puede desplazar en el campo dentro de radio de 5 mm con respecto al eje óptico. Se pueden usar dos tipos de fuentes luminosas, un laser en el rojo y una lámpara miniatura de filamento (luz blanca). También se pueden insertar filtros de gelatina o de interferencia en la parte del haz colimado.

ABSTRACT

A laboratory instrument was designed and constructed that allows testing, calibrating, and servicing astronomical instruments without the use of a telescope. The instrument has an optical system that produces an image similar to the star image produced by a telescope. The simulator covers the range of F/7.5 to F/30 focal ratios; this is the range of focal ratios of the telescopes in operation at the Observatorio Astronómico Nacional. The distance between the base plate and the image plane can vary from 250 mm to 370 mm and it is possible to move the image position in a field 5 mm in radius around the optic axis. Two types of light sources are available; a laser in the red $\lambda = 632.8$ nm and a miniature incandescent lamp (white light source). It is also possible to insert gelatin or interference filters in the collimated beam.

Key words: **INSTRUMENTATION – MISCELLANEOUS — TELESCOPES**

1. INTRODUCTION

During the final stages of construction of astronomical instruments to be attached to telescopes, it is necessary to perform tests and calibrations. This is usually made attaching the instrument to the specific telescope for which the instrument was designed. The instruments development laboratories of the Observatorio Astrónomico Nacional are located in Ensenada B.C. and México City, 240 and 3000 km from the telescopes site. Under these circumstances, a Telescope Simulator seemed to be a reasonable solution to the problems of transportation and testing times for an instrument in the final stages of construction. With the possibility of performing most of the tests at the laboratory, the risks of transportation would be reduced and the telescope time for testing could be used by researchers in astronomy.

2. OPTICAL SYSTEM

The system has two main parts: the collimator and the objective or focusing lens; the first one is an inverted Cassegrain type telescope and the second is a Cooke triplet (Cox 1964). Besides, there is a set of two lamps, a microscope objective and a pinhole as point source; it also has a flat mirror to fold the beam down 90 to the test instrument (Figures 1 and 2). This optical system allows a range of focal ratios from F/7.5 to F/30; this range covers all the focal ratios of the telescopes of the Institute of Astronomy presently in operation at the two sites. At San Pedro Mártir there are three telescopes; the largest telescope (2.1-m) with three configurations: F/7.5, F/13.5, and F/30, the Harold Johnson telescope (1.5-m) with a focal ratio F/13.5, and the 84-cm with F/15; at Tonantzintla, Pue., there is only one telescope (1-m) with a focal ratio F/15 (Noble & Harris 1990). The diameter of the collimator and focusing lens is determined by the working distance and focal ratios of the telescopes to be simulated by this instrument; for our case, these parameters are 50 cm and F/7.5. It was decided to use an inverted telescope as collimator in order to reduce the length of the optical path and therefore have a more compact instrument. The focusing lens cannot be substituted by a shorter optical system, because of the optical cone needed to simulate the different telescopes at OAN (Noble & Harris 1990).

In order to detect problems of the instrument being tested with the telescope simulator it is necessary to have a consistent quality of its outgoing wavefront. This means that the size of the resulting image must be smaller than the necessary resolution of the instrument being tested. Since the collimator works only on axis, it was decided to use a Cassegrain type telescope as collimator, because it produces an aberration free image on axis. The second optical system needs to produce an image far enough from its last element, that is, it should have a large enough back focal length to permit the reproduction of the distances from the base plate to the focal plane, and this must be possible for all the telescopes to be simulated; for this reason it was decided to use a Cooke triplet, that produces a very good quality image on axis and has a back focal length very similar to the effective focal length (Cox 1964). Both optical systems were designed specifically for this instrument and were constructed at the laboratories of Centro de Investigación Cientifíca y Enseñanza Superior de Ensenada and Instituto Nacional de Astrofísica, Optica y Electrónica. The combination of the collimator and the objective lens produces an image of 13 μ; this is equivalent to 0.14 arc seconds for the shortest focal length telescope, the 0.84-m at SPM. This size is smaller than the minimum resolution needed by any of the instruments in operation and the smallest image produced by any of the telescopes at the Observatory. The main parameters of the two optical systems are given in Table 1.

The focal ratio is adjusted by means of an iris diaphragm in the collimated beam. In the same region it is possible to introduce filters, gelatin or interference, in order to select the spectral range needed.

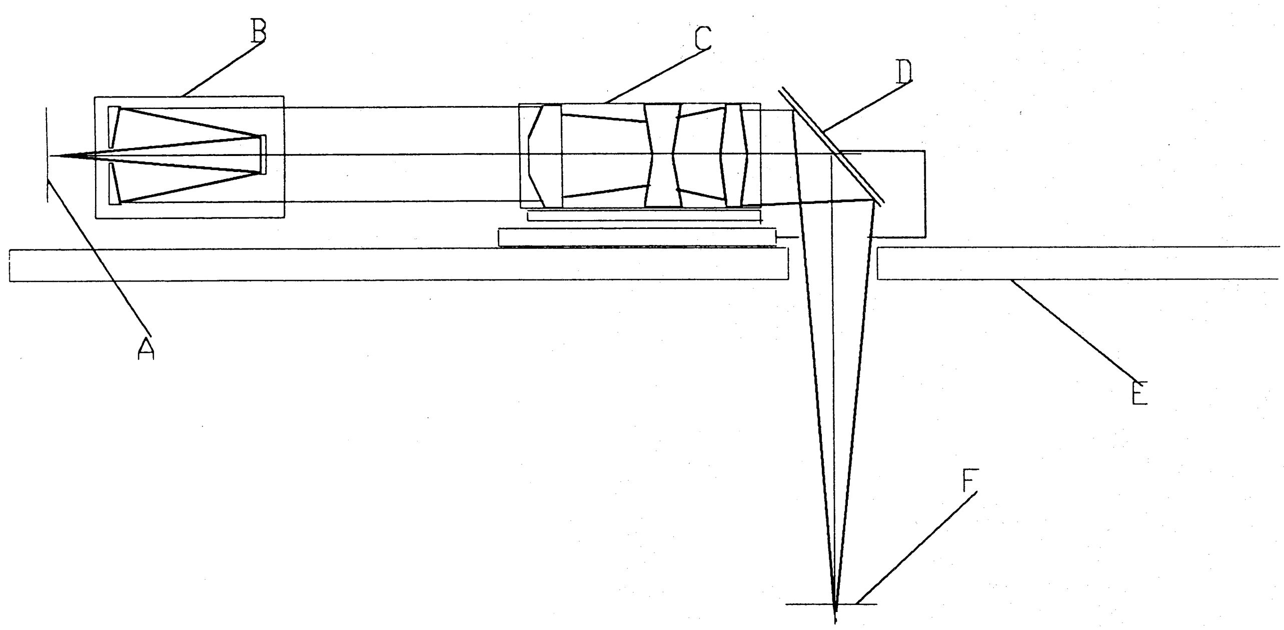

Fig. 1. Optical diagram of the Simulator. A) Pinhole, B) Collimator, C) Focusing Lens, D) Flat Mirror, E) Base Plate, F) Focal Plane.

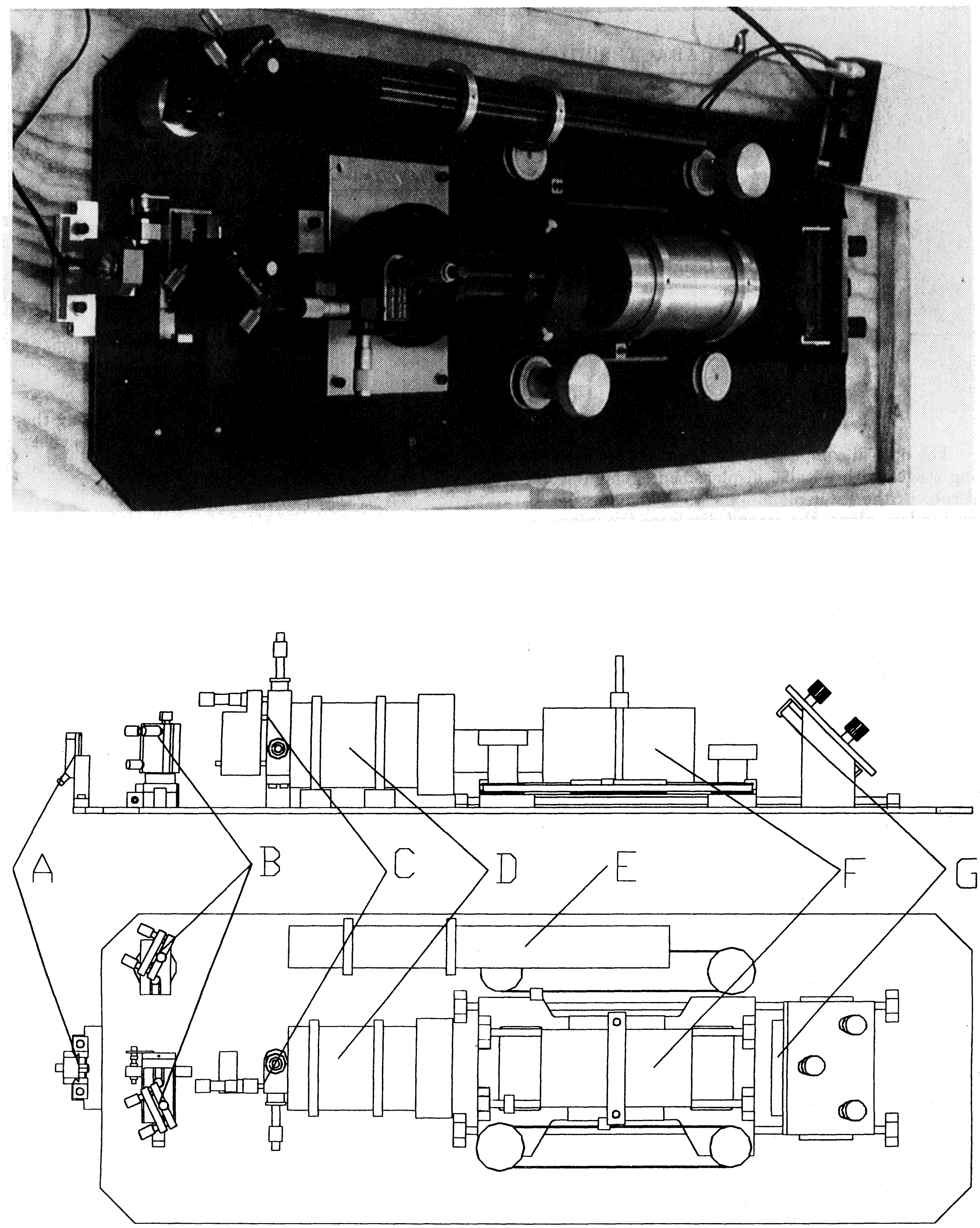

Fig. 2. Top view of the instrument. A) White Light Source, B) Laser Beam Deflector Mirrors, C) Microscope objective and pinhole mount, D) Collimator, E) Laser, F) Focusing lens, G) Flat mirror.

TABLE 1

CHARACTERISTICS OF THE OPTICAL SYSTEM

Collimator	
Effective Focal Length, (EFL)	525.64 mm
Focal Ratio	F/7.5
Type	Inverted Cassegrain Telescope (2 mirrors)
Objective	
Effective Focal Length, (EFL)	525.64 mm
Back Focal Length	453.14 mm
Focal Ratio	from F/7.51 to F/30
Type	Cooke Triplet (3 elements)

3. MECHANICAL DESIGN

The optical components are mounted on two sliding stages with parallel displacements; the first one displaces the focal plane axially, by moving the focusing lens alone; the second displaces the image on the focal plane, moving the focusing lens and the flat mirror together. The desired focal ratio is obtained by means of an iris diaphragm at the pupil, between the collimator and the focusing lens. The reference element for the alignment of the simulator is the pinhole at the object position. The light sources, the collimator, the focusing lens, and the flat mirror have adjustment screws for their proper alignment. The optic axis of the simulator is perpendicular to the base plate within an error of 0.05 and is centered with respect to the geometrical center of the base plate hole within an error of 0.5 mm. All the mechanical parts were designed and constructed in our mechanical department at Ensenada.

4. LIGHT SOURCES

The telescope simulator has two types of light sources: a filament micro-lamp and a laser beam. With these two sources it is possible to adjust most of the instruments. The laser is a helium-neon laser with emission at $\lambda = 632.8$ nm, and 5 mw power output. The use of the laser beam allows the alignment of the components of the instrument being tested using the back reflections on each optical surface; this should be done without the use of the beam expander, (microscope objective) and collimator. The objective does not disturb the laser beam, but the back reflections on it might cause some confusion on the reflected beams from the instrument, during the alignment procedure. With some practice this effect can be discriminated.

5. CONCLUSIONS

It is important to say that there is no indication of any previous publication on an instrument as this. We are the first ones to report the construction of a prototype instrument that can be duplicated in any other laboratory for astronomical instruments development. Some field tests have been performed with the simulator with good results. Two types of instruments, already in operation at the Observatory, have been checked: a grating spectrograph and a photometer. In the spectrograph, a problem of vignetting was reported, and with the test a complete evaluation of the vignetting was obtained and a minor problem was solved. The photometer was checked for alignment during its general maintenance. After performing these tests, some changes were made to the Simulator, simplifying its alignment. The construction of large telescopes of a new generation requires a more precise calibration of the instrumentation for these telescopes. A scaled version of this telescope simulator might become a kee instrument for this purpose, and it is relatively easy to scale and construct a larger version of a telescope simulator.

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Víctor García, Oswaldo Harris, Esteban Luna, and María Pedrayes: Observatorio Astronómico Nacional, I. Astronomía, Apartado Postal 877, 22830 Ensenada, B.C., México. (harris@bufadora.astrosen.unam.mx)