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HartRAO Hartebeesthoek Radio Astronomy Observatory

Optical configuration and optical tests of the HartRAO Lunar Laser Ranger

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The Hartebeesthoek Radio Astronomy Observatory, in collaboration with the Observatoire de la Côte d'Azur (OCA) and NASA are developing a dual Satellite/Lunar Laser Ranging system in South Africa. This project will strengthen the International Laser Ranging Service network and limit the biases caused by the under representation of satellite and lunar laser ranging in the Southern Hemisphere. The new system will be designed and developed as a permanent lunar laser ranging system with high precision laser and electronic equipment to achieve millimetre accuracy. The telescope used is a 1-m Classical Cassegrain donated by OCA. Limited technical details of the telescope exist so tests need to be conducted to determine the optical characteristics and performance of the telescope. Optical testing will determine parameters such as the reflectivity, focal lengths, radii of curvature, aberrations in the mirrors and the overall quality of the optical system. The primary mirror and its support structure will both be analysed by finite element analysis software to determine gravitational distortion. Taking into account the mirror weight, thickness and glass type, we can determine the deformation error of the mirrors and see how that affects the image quality of the telescope. Based on the RMS wavefront variation over the optical surface, an estimation can be made on how good the mirror was figured. The accuracy of the technique will be verified once the optical quality of the system has been established through a star test. A mirror of high quality should yield a surface accuracy of approximately 25 nm rms. A coudé path will be created by directing a laser beam into and through the telescope via a connecting tube and a set of reflective mirrors. A high quality mirror will mean minimal loss of light in each reflection through the coudé optical path. We report on progress to date and describe the tests conducted and instruments built.

1. Introduction

The HartRAO LLR will be a highly accurate system, consisting of integrated optical, mechanical, electronic and software units. The LLR requires the development of several new subsystems, including characterization and constant monitoring of the optical systems. This project focusses on the characteristics of the optical path that will be traversed by the laser beam: from the laser table through the coudé path and through the telescope. Characteristics under investigation include the various reflection coefficients of all optical components, optical path environmental conditions (temperature, pressure, humidity) and overall system parameters. These data will aid system monitoring, validation and quality checks.

2. LLR Telescope

The telescope (tube assembly depicted in Figure 1) is a 1-m Classical Cassegrain donated by OCA. Both the primary and secondary mirrors are of a honeycomb design, which means that the mirror has holes at the back for support and ventilation as well as to reduce mass. The substrates are made from Schott Zerodur ceramic glass material through a technique of fusing glass plates and a core together at high temperatures. The primary mirror is held in place by a whiffle-tree floatation cell (Figure 2). The mirror cell is one of the most critical parts of a telescope as it influences the overall accuracy of the telescope. The secondary assembly is supported by a three vane spider made of aluminium and steel.

Figure 1: Telescope tube assembly.

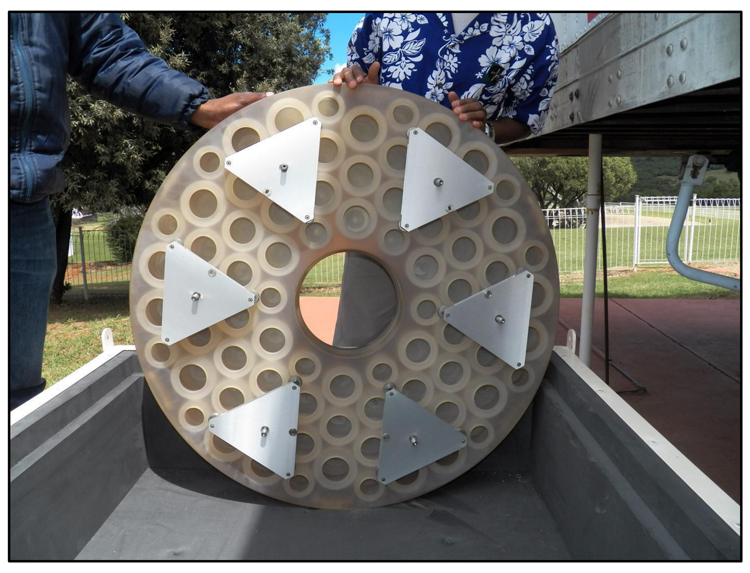

Figure 2: Honeycomb primary mirror with whiffle-tree support.

3. Telescope mirrors: cleaning and coating

During laser ranging, the telescope is exposed to dust and other particles. This reduces the reflectivity of the mirrors, hence limiting the capability of observations. Studies have revealed a direct relationship between the detection capability of a telescope and the cleanliness and efficiency of the coatings (Dierickx, 1992). To ensure maximum reflectivity, mirror surfaces have to cleaned and re-aluminized from time to time. The frequency depends on numerous factors. Mirror cleaning is a delicate process and one should avoid damaging the optics during this process.

A visual inspection of the primary mirror's coating was done by illuminating the mirror from behind with an LED light source. This revealed major degradation of the coating (Figure 3).

Figure 3: Coating degradation on primary mirror.

4. Coudé path

In order to achieve the desired high photon return rate, the optical components chosen for the coudé path should be of the highest specification and precision. Components were chosen to ensure minimal loss of photons for the integrated system.

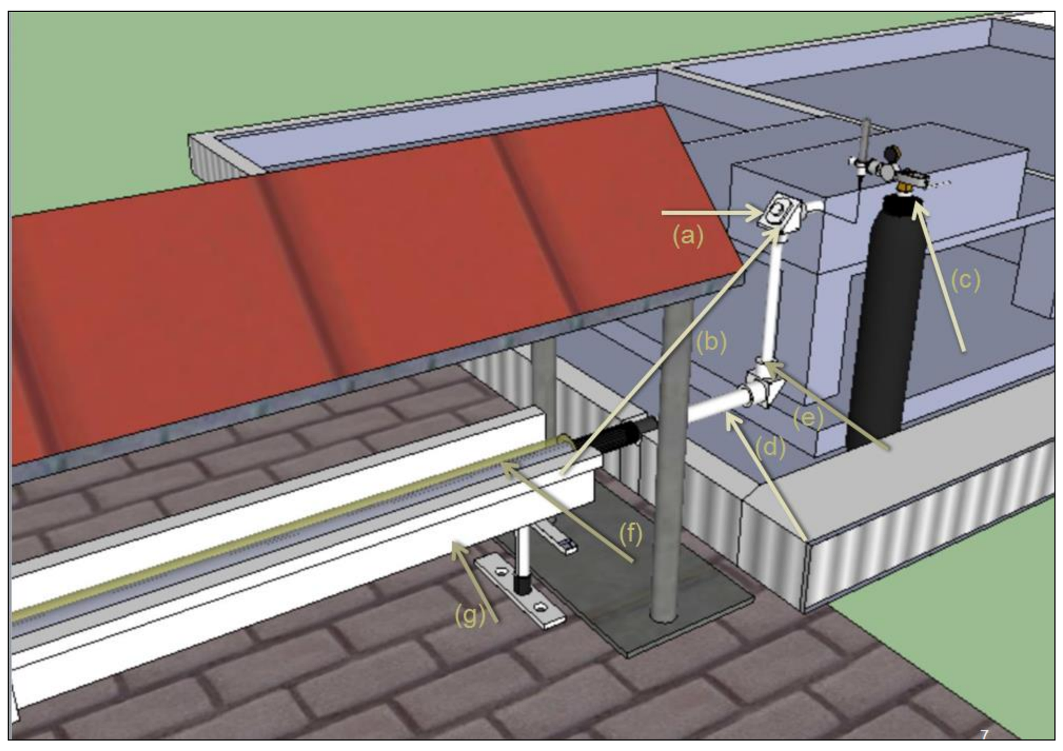

Figure 4: Coudé path with various components indicated and listed in Table 1.

Table 1: Coudé components specifications.

Component	Specifications
(a) Dielectric coudé mirrors	Diameter = 50 mm Flatness = λ/10 Reflectivity = 99% @ λ = 532 nm Peak power ≥ 1. 25 GW
(b) Mirror Mounts	Kinematic mounts, high precision
(c) Dry Nitrogen gas	Purity: 99.5%
(d) Beam delivery tube	Diameter = 65mm Anodized aluminium
(e) Path purge adapters	Diameter = 65mm
(f) Pipe insulation	Polyethylene Operating temp.-40 to +90 °C
(g) Protective cover	Galvanized steel

5. Measurements, Tests and Simulations

Before ranging can commence, optical measurements will be done on both the laser and the optical mirrors situated in the optical path.

Power measurements: A Gentec power meter was purchased to measure the laser power at numerous positions within the optical path, to ensure that the desired requirements are met. Various power heads will ensure that we can measure various energy levels accurately.

Spectroscopic measurements: An Ocean Optics HR4000 spectrometer with a complete set of accessories was purchased to conduct different types of measurements (spectroscopic, reflectance) on both the optics inside the telescope as well as the optical path components. It has a resolution of $\pm$0.2 nm for the wavelength range 350 - 850 nm. It will be used to test reflectance at various wavelengths of the various components, as well as to verify laser operational wavelengths.

Simulations: In order to analyse any deflections on the mirror surface due to gravity, a deformation model will be created by using the ANSYS structural engineering software package to do finite element analysis. These simulations will enable us to determine by how much we operate under the 25 nm surface deflection limit.

6. References

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