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# CANARICAM: CAPABILITIES AND CURRENT STATUS

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RESUMEN

La Universidad de Florida ha desarrollado una cámara versátil del IR medio para el Gran Telescopio de Canarias de 10.4-m. El instrumento CanariCam utiliza un solo detector de silicón dopado con arsénico de 320×249 pixeles, enfriado a menos de 10K. CanariCam estará listo para observaciones de primera luz en el GTC, ofreciendo capacidad de obtener imágenes limitada por difracción mediante un juego extenso de filtros, espectroscopía de resolución baja y moderada, un modo coronográfico y, por primera vez en longitudes de onda del infrarrojo medio, un modo de polarímetro de doble haz. Describimos brevemente el instrumento y presentamos pruebas recientes de laboratorio del instrumento.

ABSTRACT

The University of Florida has developed a versitile mid-infrared camera for the 10.4-m Gran Telescopio CANARIAS. The CanariCam instrument uses a single 320×240 pixel arsenic-doped silicon detector, coolded to less than 10K. CanariCam will be ready for 1st light observations on the GTC, offering diffraction limited imaging through an extensive set of filters, low- and moderate-resolution spectroscopy, a coronographic mode and, for the first time at mid-infrared wavelengths, a dual-beam polarimeter mode. We breifly describe the instrument and present recent laboratory testing of the instrument.

*Key Words:* **INSTRUMENTATION: MISCELLANEOUS — INSTRUMENTATION: POLARIMETERS — INSTRUMENTATION: SPECTROGRAPHS — METHODS: OBSERVATIONAL**



## 1. INTRODUCTION

CanariCam is a state-of-the-art multi-mode camera being developed at the University of Florida for use at the 10.4-m Gran Telescopio CANARIAS (GTC). Delivery of CanariCam to the observatory has been timed to offer instrument availability for first light observations and minimize storage time. This paper describes the camera and its key observational modes. CanariCams electronics are nearly identical to those of T-ReCS, the Gemini South mid-infrared camera, and the reader is referred to Telesco et al. (1998) for a more detailed description of them. CanariCam is optimized for use at 8-25$\mu$m, the so-called mid-infrared wavelength region, but it is useful for certain key engineering observations down to 2$\mu$m. The goal has been to provide the GTC astronomical community with an outstanding workhorse multi-mode instrument for use in the atmospheric windows near 10$\mu$m ($\sim$7.5-13.5$\mu$m) and 20$\mu$m ($\sim$16-26$\mu$m). The detector is an arsenic-doped silicon, blocked-impurity-band (BIB, or IBC) device from Raytheon, with peak QE in the 8-25$\mu$m region and a rapid decrease in QE at longer wavelengths. In addition to the selection of this particular detector device, optimization for the mid-IR has entailed: (1) matching the plate scale of the instrument to the pixel size of 50$\mu$m, so that the point-spread-function (PSF) is Nyquist-sampled at 8$\mu$m, (2) selecting various window, filter and coating materials that maximize throughput at these wavelengths, (3) designing the electronics so that the detector can be read out rapidly enough to prevent saturation in the high-thermal background that is characteristic of the mid-infrared regime, and (4) designing the cryostat to operate below 10 K and minimize background radiation from all extraneous sources.

Outstanding image quality, high throughput, and excellent mechanical stability are key characteristics of CanariCam. These properties must be achieved in the context of operational convenience, long-term reliability, and reasonable development and maintenance costs. As a facility workhorse instrument, CanariCam must possess a special combination of simplicity and outstanding performance. CanariCam will meet or exceed these expectations, and it is expected to be user-friendly to the GTC technical and astronomical staff who must support it.

Detailed descriptions of the instrument can be found in Packham et al. (2005, 2004), and Telesco et al. (2003), and the interested reader is directed to those papers for the instrumental design. In the rest

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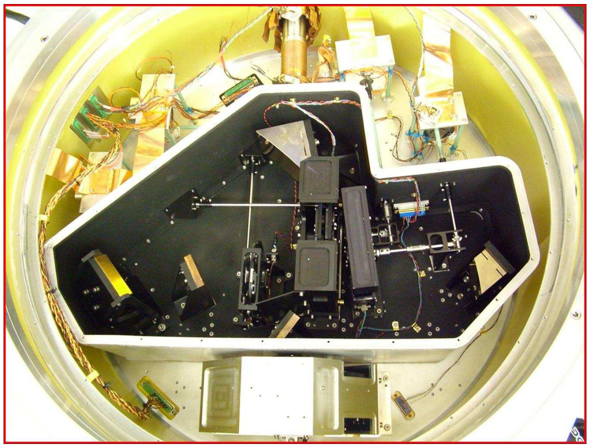

Fig. 1. Entrance window side of CanariCam, clearly showing two of the three off axis parabolic mirrors, three of the folding flat mirrors, the entrance aperture box and the filter and Lyot wheels.

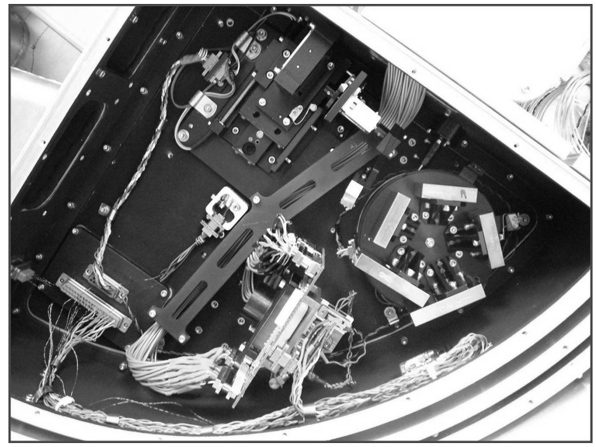

Fig. 2. Array side of CanariCam, clearly showing the grating turret (lower right), array (lower middle) and Wollaston prism slide (top middle).



of this paper, we describe the instrument at status and recent test results (Figures 1 y 2).

## 2. CURRENT STATUS

CanariCam is nearing the completion of the integration and optimization stage in the laboratory. Rehearsals for the pre-shipment acceptance tests have either been made or are in an advanced stage of preparation, and indeed some of the existing test results may be used at part of the instrument acceptance tests. All instrumental components are installed and have expereicned up to 5 thermal cycles, with the sixth and possibly penultimate cool down prior to formal acceptance testing imminent at the time of writing (October 2006). The optics are performing as expected, save for a slightly higher than expected level of distortion. The four spectroscopic modes perform entirely as designed, as do the coronographic and polarimetric modes.

The electronics are performing excellently, with minor modifications needed to improve data transfer and increase efficiency. Correlated quadruple sampling (CQS, Sako et al. 2003) has been successfully implemented to reduce the intrinsic array artifacts and is in regular use for all testing and optimization. The instrument is under software control from the final software configuration, and is performing with minimal downtime.

Acceptance testing of CanariCam is envisaged for the early part of 2007, with integration to the observatory to follow shortly after that. In preparation for the science with CanariCam, three parallel groups that make up the CanariCam Science Team have met twice with a view to pooling existing data, planning new observations with existing observatories in preparation for the onset of regular observing with the GTC/CanariCam combination. At least three peer reviewed papers have been published as a direct result of this collaboration, with several more in progress (Packham et al. 2005; Roche et al. 2006; Alonso-Herrero et al. 2006).

## 3. LABORATORY TESTING

Detailed laboratory optimization and testing is nearing completion, with a view to progressing to acceptance testing in early 2007. All aspects of the instrument are tested, including the four science modes and two engineering modes, combined with the reliability of the mechanisms and array electronics, and the robustness of the software control system, and where needed the status and alarms database. In this section we discuss some results that are indicative of the standards of the instrument.

Of primary importance to CanariCam is excellence in the image quality. The enclosed energy has been measured to be better than 96% of the diffraction limited encircled energy across the field of view, easily passing the requirement of 80% of the diffraction limited encircled energy. At the time of writing, no ghosts have been detected and other image quality tests show similarly positive results.

Spectroscopy in both low and moderate resolution modes, for the 10 and 20$\mu$m gratings, show the expected dispersion and resolution, as tested using the narrow band filters or the internal polystyrene calibration source. The coronographic mode has been tested by confirming accurate and precise rota-

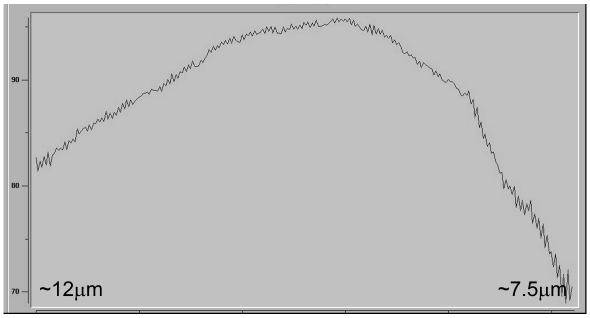


Fig. 3. The degree of polarization vs. wavelength in spectropolarimetry mode for a 100% polarized source.

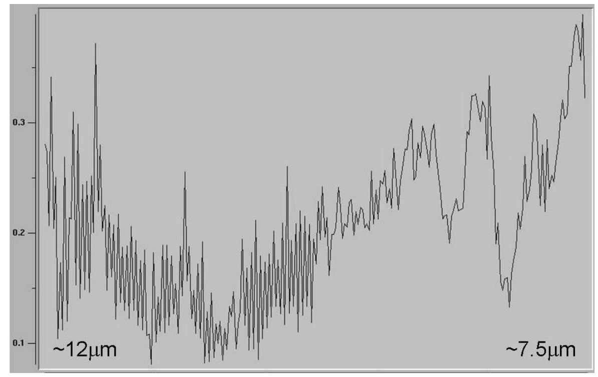


Fig. 4. The degree of polarization vs. wavelength in spectropolarimetry mode for a 0% polarized source.

tion of the complex-shaped Lyot mask and insertion of the simple obscuring spot at the telescope focal plane.

Through use of an external wire grid polarizer, imaging polarimetry shows the expected efficiency change through the 10$\mu$m window. The efficiency change through the 10$\mu$m waveband is due to the composite nature of the half wave retarder, and as it can be fully characterized, can be calibrated out of the data. Excitingly, the Wollaston prism shows a high level of transmission out to $\sim$20$\mu$m, offering the possibility to extend polarimetry to the 20$\mu$m window. Whilst CanariCam polarimetry will be the most accurate polarimeter on any telescope, the possibly to observe polarimetricaly out to 20$\mu$m would be unique. The transmission of the Wollaston prism peaks at $\geq$ 92% and no ghosts have been detected. The measured instrumental polarization is $\leq$ 0.2%, and the peak efficency of polarization is $\geq$ 97%.

The spectropolarimetry capability of CanariCam shows an excellent response, with both a similar level of polarization efficiency and roll-off (Figure 3) and low instrumental polarization (Figure 4).

## 4. CONCLUSION

Testing of CanariCam has so far shown the design and performance to meet or exceed the instrument's requirements. Delivery of CanariCam to the GTC observatory will ensure readiness for 1st light observations for the GTC community.

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