The Canarias InfraRed Camera Experiment (CIRCE): Optical and Opto-mechanical Design and Manufacture

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ABSTRACT

We report on the design status of the Canarias InfraRed Camera Experiment (CIRCE), a near-infrared visitor instrument for the 10.4 meter Gran Telescopio Canarias (GTC). In addition to functioning as a 1-2.5 micron imager, CIRCE will have the capacity for narrow-band imaging, low- and moderate-resolution grism spectroscopy, and imaging polarimetry. CIRCE’s all-reflective aspheric optical design offers excellent throughput and image quality. We present an analysis of the optical layout and the progress of the opto-mechanical design and manufacture.

Keywords: instrumentation:miscellaneous, infrared:general

1. INTRODUCTION

The Canarias InfraRed Camera Experiment (CIRCE) is a near-infrared (1-2.5 \( \mu \text{m} \)) instrument for the Gran Telescopio Canarias (GTC) 10.4-meter telescope. First light on the GTC is currently scheduled for 2006. While two instruments, CanariCam (covering 5.0-28.0 \( \mu \text{m} \)) and OSIRIS (covering 0.4-1.0 \( \mu \text{m} \)) will be immediately available upon completion of the telescope, EMIR, the near-infrared facility instrument, will not be on-line until after the GTCs inception. We designed CIRCE to observe the currently uncovered wavelength range and fill the gap between first and second generation instruments.

CIRCE has an all-reflective aspheric optical design that offers excellent throughput and image quality. We offer the results of our analysis of the optical layout, concentrating on characteristics such as enclosed energy and field-of-view. We then discuss the design of opto- and cryo-mechanical components including the mirrors, brackets, and filter wheels.

2. INSTRUMENT DESCRIPTION

CIRCE will be a cryogenic re-imager with a standard collimator/camera design similar in its basic layout to most modern astronomical infrared cameras, including the Wide-field InfraRed Camera (WIRC)\textsuperscript{1} and FLAMINGOS-2. However, CIRCE differs significantly from these instruments in its all-reflective optical system using diamond-turned aspheric mirrors. This approach is a natural step in the development of similar diamond-turned complex aspheric systems for use in astronomical applications at the University of Florida, including the Gemini-South facility mid-infrared imager/spectrograph (T-ReCS), the GTC facility mid-infrared imager/spectrograph (CanariCam), and the new near-infrared image-slicing integral-field spectrograph (FISICA). Such an optical approach provides significantly improved image quality and throughput as compared to more traditional refractive designs (which typically require ~10 lenses for performance to match CIRCE). While diamond-turned aspheres have been historically difficult to test and align, there have been significant advances in their manufacture and testing over recent years. The University of Florida has considerable experience in handling and aligning them within the necessary tolerances for the above-mentioned instruments, providing confidence that we can implement the CIRCE design successfully.

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Figure 1 illustrates the basic components of CIRCE. Incoming light from the telescope will pass through the cryostat entrance window, inside of which all components will be kept at temperatures of 77K to eliminate contaminating thermal near-infrared emission. At the telescope focus, CIRCE will have a “slit wheel”, including an imaging field stop (3.4 × 3.4-arcmin), a long slit for grism spectroscopy, and a partial-field imaging stop for Wollaston polarimetry (3 × 1.5-arcmin). After the telescope focus, two fold mirrors compress the design into the necessary envelope requirements. Then a 2-mirror collimator will produce an image of the telescope exit pupil at a Lyot stop, which blocks stray light from reaching the detector. CIRCE will have two filter wheels fore and one aft of the Lyot stop, placing bandpass filters (both broad- and narrow- band) in the collimated beam, allowing the study of the infrared colors and emission features of science targets. After the filter wheel, a 4-mirror anastigmatic camera will bring the light to a focus on the HAWAII-2 2048×2048-pixel infrared detector. Of the six powered mirrors in the collimator/imager section, five are conics, while the last is a sixth order asphere.

CIRCE spectroscopy includes two grisms, both of which are derived from designs for the FLAMINGOS-2 instrument for Gemini (and share the grating ruling masters custom-built for FLAMINGOS-2). The first grism will cover the 1.25 − 2.4µm bandpass instantaneously at a resolution of R=410 at 1.25µm and R=725 at 2.20µm (all resolutions are FWHM for a 3-pixel slit). The second grism will cover a single band instantaneously at a resolution of R ~ 1500 (3-pixel slit) in its 3rd order (K-band), 4th order (H-band), or 5th order (J-band). The CIRCE optics will maintain seeing-limited image quality with the grism in the optical path over the entire bandpass.

CIRCE will also have a sub-framing readout mode that will enable high-speed imaging photometry in any filter (broad- or narrowband). The MCE-3 electronics can support continuous frame rates faster than 1 Hz over fields-of-view exceeding 1×1-arcmin. In addition, CIRCE’s optical design includes a Wollaston prism polarimetric...
3. CURRENT PROGRESS

3.1. Optical Design

We concluded the primary optical design phase, including a slight modification to the initial concept that compressed CIRCE into the envelope size specified for the Bent Cassegrain Port of the GTC, and proceeded with a detailed analysis of the current layout. Figure 2 shows an enclosed energy diagram for CIRCE. We note that throughout most of the field, CIRCE reaches enclosed energy values > 80%. Even at the corners, one 18 micron pixel contains ~70% of the light from a point source. The 0.10 arcsec plate scale will provide seeing limited images even in excellent atmospheric conditions; preliminary models suggest that it will produce images with < 0.25 arcsec intrinsic FWHM. Also, the planned 3.4 × 3.4 -arcminute field is 25 times larger than NIRC/KECK and 3 times larger than NIRI/Gemini.

3.2. Opto-Mechanical Design

Once we completed the optical layout and analysis, we began work on the mechanical designs necessary for manufacture of the mirrors. We completed 2-D drawings of the optics using AutoCAD and submitted them to several manufacturers for review.

A unique and specialized solution to optical testing surfaced in our discussion with Janos Technology. Instead of testing each optic separately to ensure that it is within specification, Janos will test the entire system in concert. This novel technique encompasses the bench, bracket, and mirrors, and allows for immediate correction of alignment problems at the production facility.

We began 3-D designs of the eight CIRCE mirrors and brackets (Figure 3) and the 1.5 × 1-m optical bench. Using techniques previously employed in the design of other successful University of Florida instruments, we modeled the optical surfaces and locations with AutoCAD and used this template to create the correct hole patterns for mirror blocks, brackets, and bench.
The brackets, bench, and mirror blanks are currently in production at the University of Florida. We expect delivery of all critical pieces to Janos and return of the mounted brackets and mirrors within the next six months.

### 3.3. Cryo-Mechanical Design

Since the goal of CIRCE is to design, build, and integrate a powerful and useful instrument in a short amount of time, we chose to draw from the proffered expertise and skill of other instrumentation teams at the University of Florida. We used cryostat designs from both FLAMINGOS-1 and FLAMINGOS-2 as the basis for the CIRCE cryostat. Similarly, we modeled the CIRCE filter, grism, and lyot wheels and filter box after the FLAMINGOS-2 design. This design philosophy will also ensure the efficiency of all cryo-mechanical component production.

The CIRCE filter box (Figure 4) will hold five geared wheels. Of the five wheels, three will contain narrow- and broad-band filters. Each filter wheel (Figure 5) will hold five filter cartridges (Figure 6) designed for 70 mm-diameter, 6 mm-thick circular filters. These cartridges will ensure that disassembly of the filter box will not be necessary to remove and insert filters. While this will allow for simple exchanges during cryostat warm-ups,
CIRCE’s 12 filter capacity should meet the nightly needs of most observers. The design of the grism wheel, positioned at the aft of the filter box, is similar to that of the filter wheels. The grism wheel will house four grism cartridges with one “open” space for use when CIRCE is in imaging mode. While the lyot wheel is identical to the filter wheels, its specialized cartridges will allow us to tilt masks in the lyot stop to meet CIRCE’s optical design specifications.

We completed design of the filter box and wheels and manufacture is now underway. We currently have the filter, grism, and lyot gear blanks in-hand, Upon completion, we will test each cryo-mechanism prior to integration using a specially designed test cryostat available at the University of Florida.

The CIRCE slit wheel at the telescope focal plane offers a new challenge. The envelope specifications place specific limitations on the slit wheel design. To overcome these constraints, we are currently studying several options, including a decker wheel and slit “fan”. We will continue to explore these concepts in the coming months and expect design completion before the return of the optical bench.

Figure 5. A CIRCE filter wheel. The spaces hold filter cartridges (Figure 6), which allow for easy insertion and removal of filters.

Figure 6. A CIRCE filter wheel cartridge. Each cartridge will house a filter 70 mm in diameter and 6 mm thick.
4. CONCLUSION
The Canarias InfraRed Camera Experiment (CIRCE), a near-infrared visitor instrument for the GTC, will provide a unique and powerful complement to the telescope’s facility instruments. With optical designs currently in their final stages, we expect that within six months, opto- and cryo- mechanical components, including the brackets, mirrors, optical bench, and filter wheels, will be ready for testing and integration. We will then move on to refining and integrating all mechanical and electronic components, meanwhile continuing to design and implement additional features such as imaging and spectro-polarimetry, adding to CIRCE’s myriad scientific uses.

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