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The Dark Energy Camera - a New Instrument for the Dark Energy Survey

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The Dark Energy Survey (DES) is a next generation sky survey aimed directly at understanding the mystery of the accelerated expansion of the Universe. DES is designed to measure the dark energy equation of state parameter with four complementary techniques: galaxy cluster counts, weak gravitational lensing, angular power spectrum and type Ia supernovae. We present an overview of the DES instrument (DECam) which will be mounted at the prime focus of the Blanco 4m telescope at Cerro Tololo Interamerican Observatory (CTIO). DECam includes a 3 square degree focal plane covered by 62 2kx4k CCDs, a five element optical corrector, up to eight filters, a modern readout and control system, and the associated infrastructure for operation in a new prime focus cage. We will use the 250 micron thick fully-depleted CCDs developed at Lawrence Berkeley National Laboratory (LBNL). DECam also includes design features to enhance the image quality and the efficiency of operations. DECam will be devoted to the DES for 30% of the time over five years and will otherwise be available to the community as an NOAO facility instrument. We will review the status of the construction of the instrument.

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1. Introduction

The Dark Energy Survey Camera (DECam) is the instrument currently being built to carry out the Dark Energy Survey (DES). The goal of this project is to reduce the uncertainty on the cosmological parameter w to a few percent. It will be met using the four most promising cosmological probes described by the Dark Energy Task Force in [1]. See [2] for more details on the scientific goals and methods of this survey.

These four techniques imply the usage of a wide field mosaic of Charged-Coupled Devices (CCD) as a detector, covering the optical and near-infrared range. It will be mounted on the primary focus of the 4-meter CTIO Blanco Telescope, in substitution of the current instrument. The sky coverage of the survey will be a 5000 square degree area on the southern celestial cap, including an overlap with an equatorial band used by the Sloan Digital Sky Survey (SDSS). It will obtain deep multi-color images reaching magnitude ~ 24 for 10-sigma detections in each of the bands.

Some of the performances of the telescope and camera are listed in Table 1.

Blanco Telescope Effective Aperture	4m
Optical Corrector Field of View	2.2 degrees
Filters	SDSS g,r,i,z,Y
Wavelength range	400-1050 nm
Effective area of CCD focal plane	3 sq.deg
CCD pixel format/total pixels	2K x 4K / 520 Mpix
Focal plane scale	0.27 arcsec/15μm (pixel)
Readout speed	250 kpix/s
Noise requirement	7 electrons
Survey area	5000 sq.deg.
Survey time	525 nights
Limiting mag. (10σ, 0.9 arcsec seeing, AB system)	g=24.7,r=24.2,i=24.4,z=23.9

Table 1: Expected performances of the telescope and camera

2. DECam description

2.1 Optical corrector

The set of lenses used for optimizing the image quality and resizing the field of view of the telescope constitutes the optical corrector of the camera (A in Figure 1). In the case of DECam, five fused silica lenses produce an unvignetted 2.2 degree diameter image area. The lens diameters range from 500 to 900 mm and have a total weight of approximately 500 kg. They are supported by a conical and cylindrical section (barrel), and held in place via steel cells to these elements.

2.2 Filters and shutter

The shutter and filter system are mounted between the third and fourth lens in the barrel (B in Figure 1).

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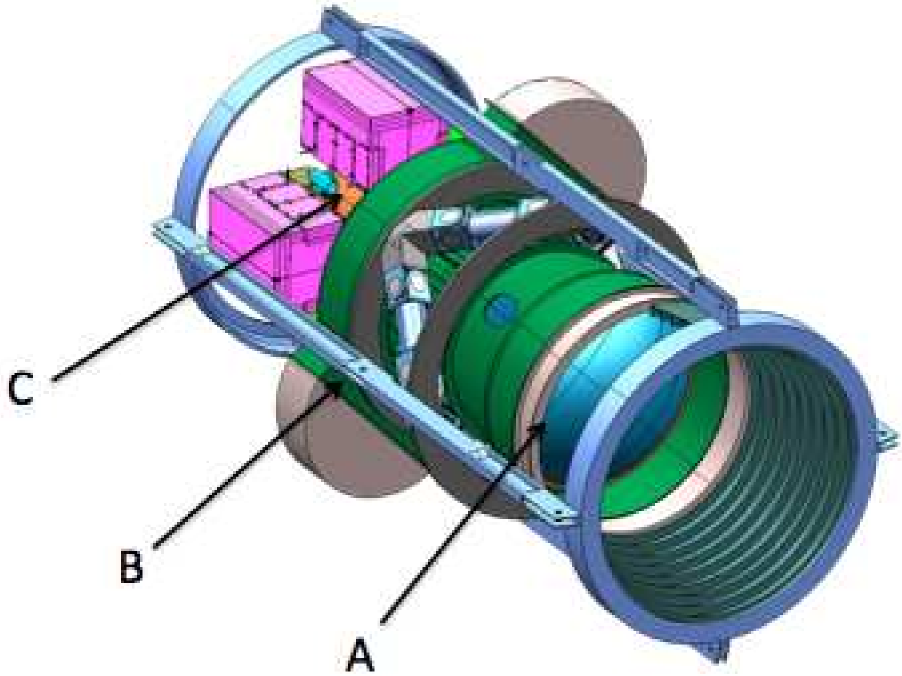

Figure 1: Schematic drawing of DECam

The filter wheel is an exchange mechanism housing the five DES filters (plus additional empty slots for other uses from the community). These are the *griz* system from SDSS plus the Y-filter, to be used in conjuction with infrared observations from the VISTA experiment. The filters themselves will be 570 mm in diameter and up to 30 mm thick. The main challenge for the filter fabrication is to achieve the expected homogeneity over the whole surface.

The shutter is a system based on an existing design developed by Bonn University, allowing fast opening and closing times.

2.3 CCD camera vessel

The vessel (C in Figure 1) holding the 70 CCD mosaic is closed by the last lens of the optical corrector. The closure is necessary to ensure vacuum inside the camera. The detectors must operate at cryogenic temperatures, of the order of -100 degrees Celsius. These temperatures are achieved using a re-circulating liquid nitrogen system connected to the focal plane support by copper straps. The size of the vessel is approximately 61 cm in diameter, and 84 cm long.

2.4 Detectors

In order to reach depths of the order of redshift $z = \sim 1.3$, specially-designed CCDs are being used in the focal plane, with increased sensitivity in the red and near-infrared regions of the spectrum. These have been developed by the Lawrence Berkeley National Laboratory and are fully depleted, with high resistivity and thickness (250 um).

Table 2 summarizes the most relevant parameters of these CCDs. Some smaller (2k x 2k) CCDs are used for focusing and guiding purposes.

Pixel array	2048x4096 pixels
Pixel size	15μm
Quantum efficiency(g,r,i,z)	70%,90%,90%,75%
Full well capacity	170000 electrons
Dark current	2 electrons/hr/pixel at 120K
Read noise	7 electrons at 250 kpixel/s
Charge Transfer Inefficiency	10^{-6}
Charge diffusion	6-7 μm
Linearity	Less than 1%

Table 2: LBNL CCD performance (ref. Diehl 2008)

2.5 Readout

Currently, a modified version of the National Optical Astronomical Observatory (NOAO) Monsoon architecture [3] is being used to read out the CCDs. Each DES CCD has two video readout channels and requires conection to 15 clock inputs and 7 bias voltages. The CCD readout crates will be located in thermally controlled housings around the camera vessel. Active cooling using water circulation will be used for the electronics.

3. Current developments and future

A first version of the mountaintop software has been tested successfully on-site, as well as some images taken by a prototype CCD. Detector fabrication is well underway. CCD testing and selection is taking place at Fermilab. Currently 33% of the CCDs have been calibrated and selected for the detector plane. The full mosaic will be available during the first semester of 2010. Electronic boards and crates are in production and will be finished by the end of 2009. Fermilab will also build a telescope simulator where the complete camera will be tested during 2010. Installation at CTIO will be carried out in early 2011. After the commissioning phase, science operations are expected to start in Fall 2011.

References

[1] A. Albrecht et al., *Report of the Dark Energy Task Force*, astro-ph/0609591

[2] I. Sevilla, *The Dark Energy Survey*, these proceedings.

[3] T.. Diehl et al., *Characterization of DECam focal plane detectors*, in Proceedings of SPIE 7012, 702107 (2008)

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