DECal: a spectrophotometric calibration system for DECam

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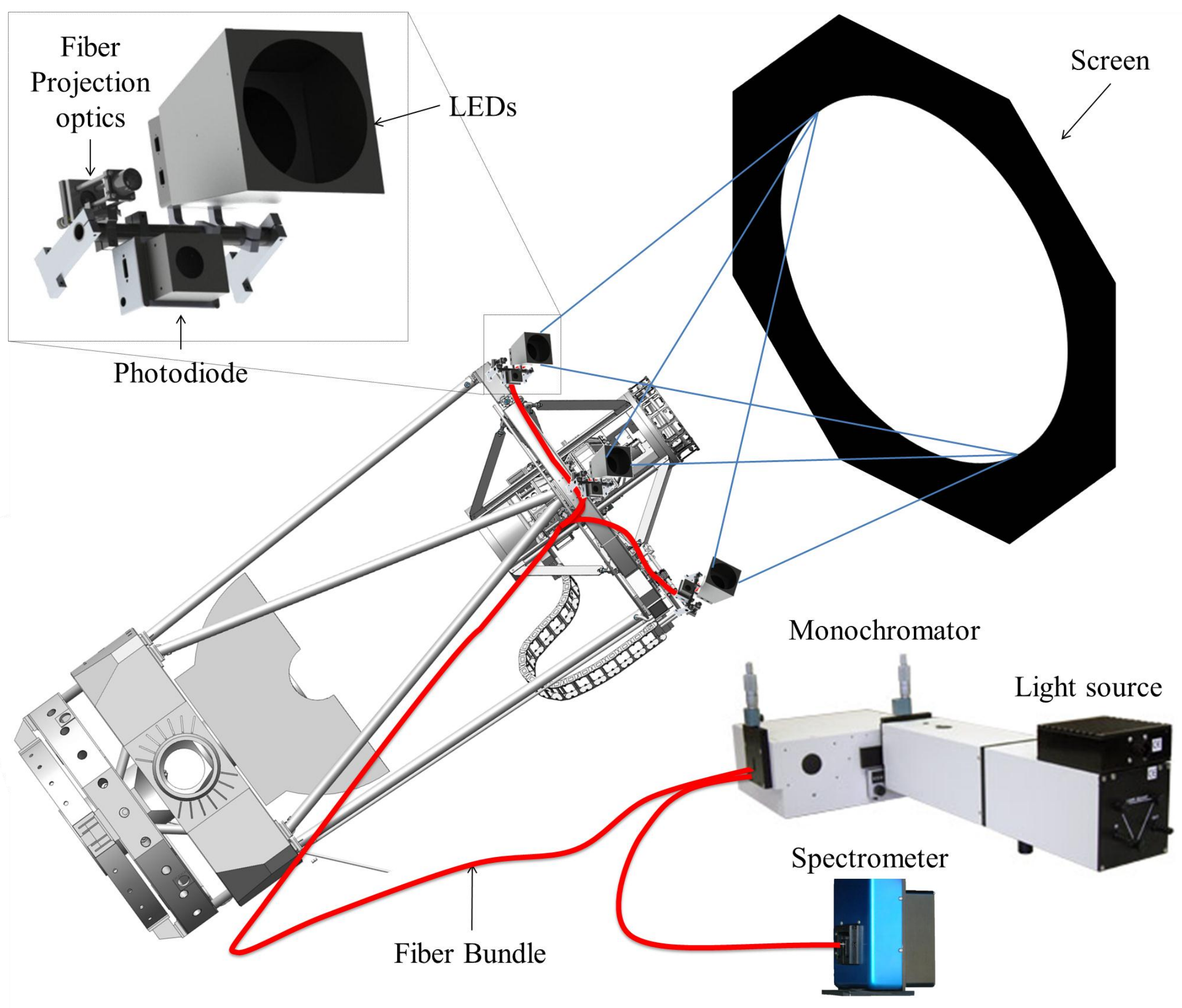
Introduction

Current and future generations of large scale cosmological surveys will rely heavily on precise calibration of astronomical datasets to produce precision results. Surveys such as Pan-STARRS, LSST, the Dark Energy Survey (DES), and others like them, will produce data that are capable of making high precision cosmological measurements of the Universe. These measurements are made possible in part by photometric datasets that are precise to better than 0.01 magnitude and are only achievable when properly calibrated. Carefully constructed calibration systems are being planned, constructed, and tested for these surveys. This poster describes recent progress on the calibration system that we have designed and constructed to calibrate the Dark Energy Survey data products.

Experimental setup

A schematic of the experimental setup is shown below. The experimental setup consists of a broadband light source from which we select a narrow bandwidth (e.g., 1 or 2 nm FWHM) using a monochromator. The monochromator output is coupled to a fiber bundle made of 87 fibers aligned in 3 rows. The fiber bundle brings the light to the top of the telescope where it splits into 4 equal branches around the top ring of the telescope. Light is projected onto the flat field screen from 4 different points using beam projection optics that ensure uniform illumination of the screen. 4 NIST-traceable calibrated photodiodes, also placed on the top ring of the telescope, measure the power on the screen. A sample of the illumination beam is fed to an echelle spectrometer that monitors in real time the illumination wavelength with an accuracy of ~0.1nm.



Light source

DECal operates continuously over a very wide wavelength range (300 nm < λ < 1100 nm). We had difficulty identifying a single light source to provide adequate signal over all required wavelengths. As a result, we use two light sources to cover the entire wavelength range. A 150W compact xenon arc lamp light source (Optical Building Blocs Corporation, PowerArc series) covers the region from 300 to 800nm. A 250W Quartz Tungsten Halogen lamp (Horiba, LSH-T250) is used to cover the infrared from 800nm to 1100nm. The xenon light source cannot easily be used redward of 800nm because of the presence of strong emission lines.

Monochromator

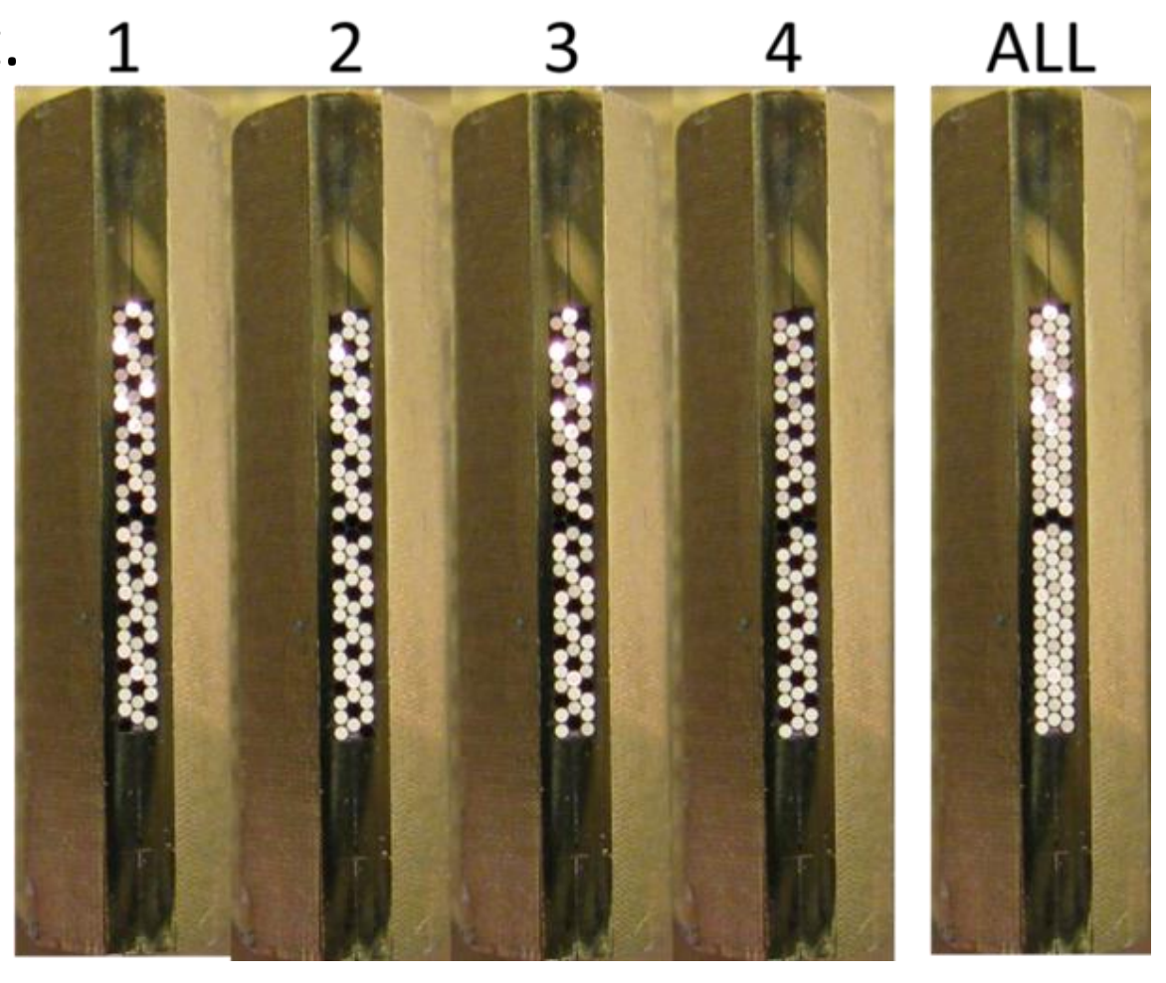
We use a fully automated f/4.1 Czerny-Turner monochromator (Horiba, iHR-320) having a high reciprocal dispersion of 2.3nm/mm when used with a 1200g/mm grating. The high dispersion is crucial in achieving a good throughput: for a constant output bandwidth, the throughput of a monochromator goes with the square of the dispersion. We adjust the bandwidth of the light by varying the input slit width. The output slit width is fixed to 900 microns, the width of the linear fiber bundle. The monochromator has two input ports that host the two lamps; a flip mirror allows us to change from one lamp to the other without interruption.

Abstract

We describe a spectrophotometric calibration system that is being implemented as part of the DES DECam project at the Blanco 4 meter at CTIO. Our calibration system uses a 1nm wide tunable source to measure the instrumental response function of the telescope optics and detector from 300nm up to 1100nm. This calibration will be performed regularly to monitor any change in the transmission function of the telescope during the 5 year survey. The system consists of a monochromator based tunable light source that provides illumination on a dome flat that is monitored by calibrated photodiodes that allow us to measure the telescope throughput as a function of wavelength. Our system has a peak output power of 2 mW, equivalent to a flux of approximately 800 photons/s/pixel on DECam.

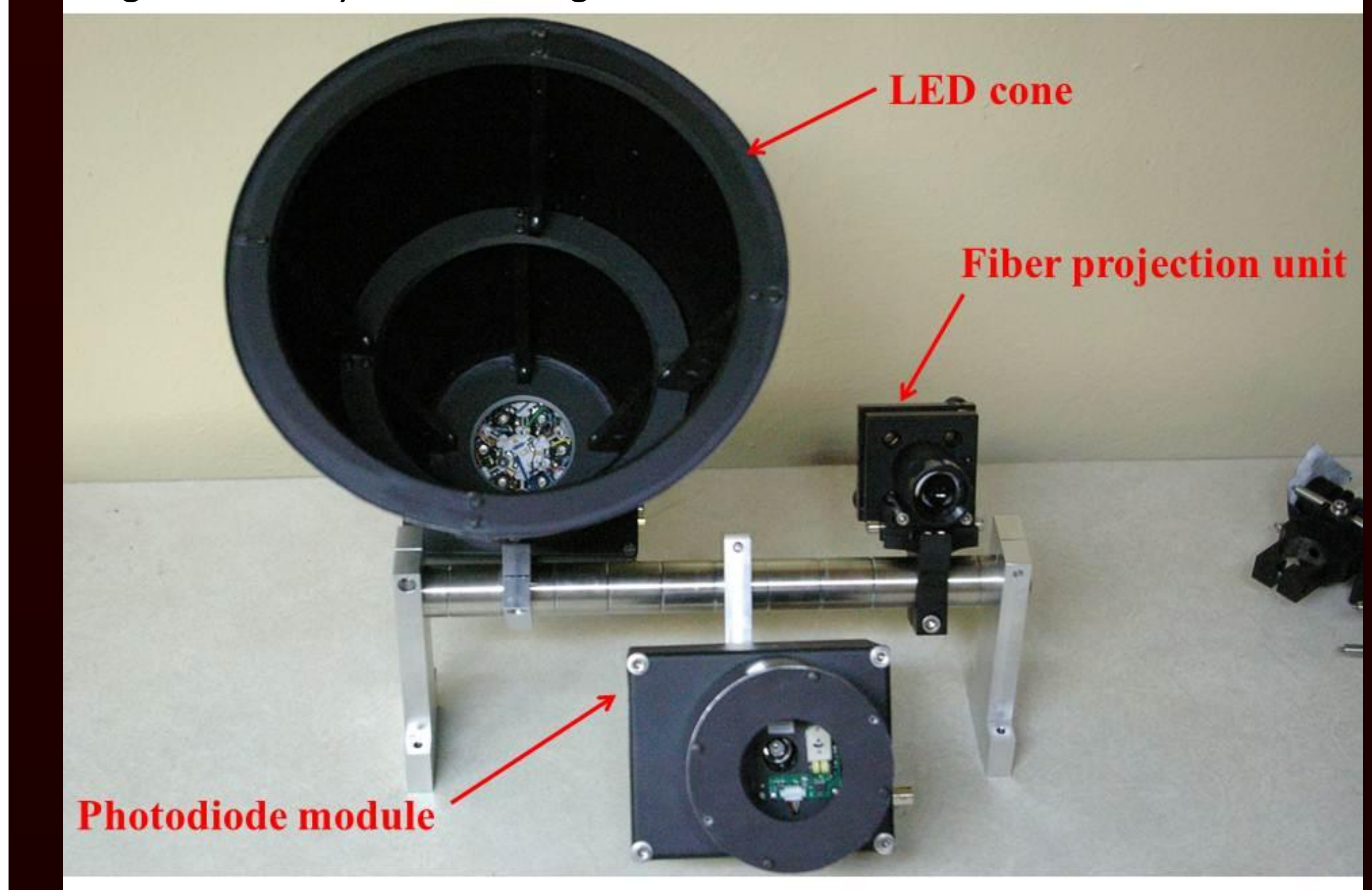
Fiber bundle

The bundle consists of 87 fibers with 300 micron cores. At the input end, the fibers are arranged in 3 parallel lines of 29 fibers. (See Figure below) The bundle brings the light from the calibration room (located under the telescope main floor) up to the telescope top ring. At a length of 65 meters, the fiber bundle splits into 4 branches, each 10 meters long and containing 21 fibers. These 21 fibers are placed in a compact circular arrangement and coupled to the projection system. Each of the 4 branches sample the monochromator slit evenly to ensure that the four projection units each have the same intensity and spectral content.



Projection system

A projection unit containing the fiber projection optics, the photodiodes and a LED cone for the daily flat field system was build specifically for DECal. (See picture below) 4 of these units will be installed on the top ring of the telescope and will allow us to illuminate the dome flat field screen in a uniform fashion.
The fiber projection unit uses an Engineered diffuser that projects the light uniformly into a 20 degree cone.

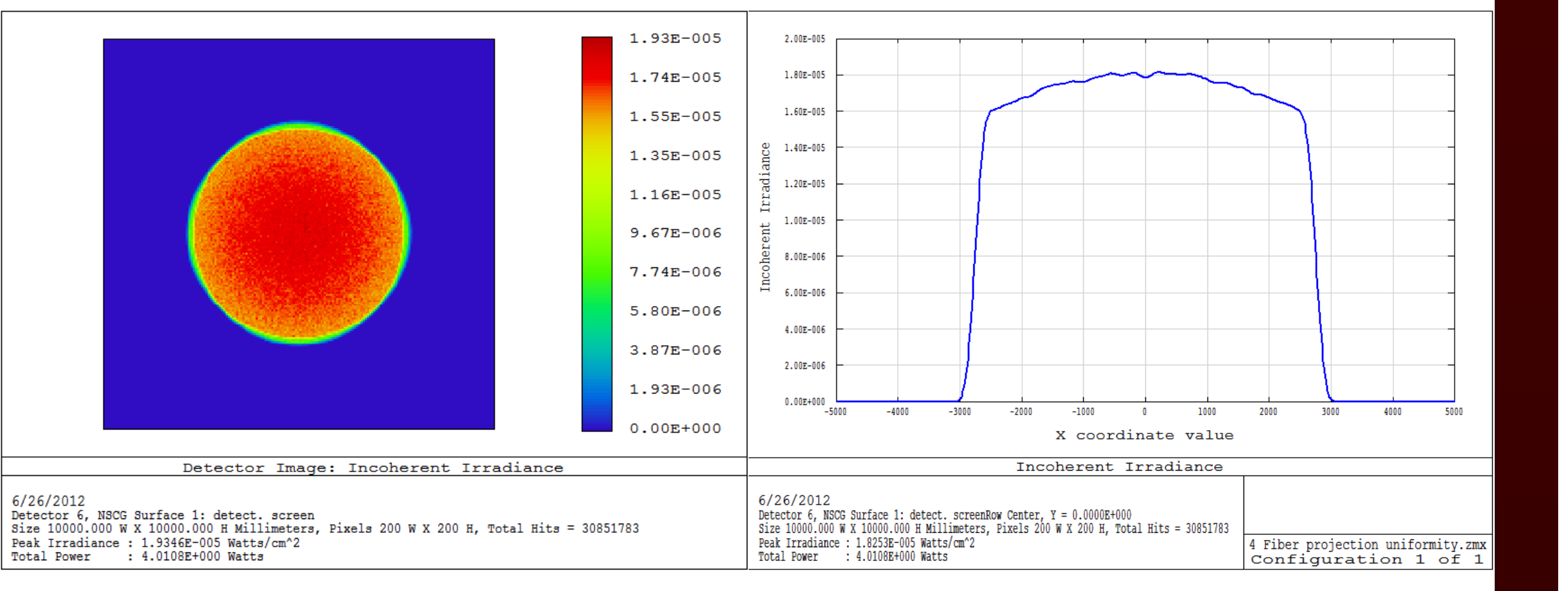


Photodiodes Modules

The 4 reference photodiodes are located in the photodiodes modules. We use 10mm diameter silicon photodiodes (Hamamatsu, S2281) to measure the light from 300nm to 1100nm. The photodiodes have a NIST-traceable calibration performed by Gentec-EO. We anticipate signals on the order of 1 nW on the photodiode. These signals will be amplified by a two-stage, low noise, trans-impedance amplifier with a variable gain from 10^8 to 10^{11}. The amplifier has a cut-off frequency around 20 Hz to reduce noise levels. The amplified signal is read by a 16-bit analog-to-digital converter (ADC, National Instruments, ENET-9215) acquiring signal at 100 kHz. The signal is averaged to 100Hz in the ADC and sent over Ethernet to the control computer where data are saved and analyzed.

Screen illumination uniformity

A ZEMAX non-sequential model of the illumination pattern from 4 fiber bundles using the 20° engineered diffusers was made to evaluate the illumination uniformity. In the model, the fibers are placed on the top ring of the telescope, 2.5 meters from the telescope axis; the distance from the flat field screen from the telescope ring is 7 meters. Figure below shows the results of the model. It confirms that the screen illumination should be uniform to 95% in the central 4 meters of the screen.



Detector Image: Incoherent Irradiance

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6/26/2012
Detector 6, NSCG Surface 1: detect. screen
Size 10000.000 W X 10000.000 H Millimeters, Pixels 200 W X 200 H, Total Hits = 30851783
Peak Irradiance : 1.9346E-005 Watts/cm^2
Total Power      : 4.0108E+000 Watts
```

Incoherent Irradiance

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6/26/2012
Detector 6, NSCG Surface 1: detect. screenRow Center, Y = 0.0000E+000
Size 10000.000 W X 10000.000 H Millimeters, Pixels 200 W X 200 H, Total Hits = 30851783
Peak Irradiance : 1.8253E-005 Watts/cm^2
Total Power      : 4.0108E+000 Watts
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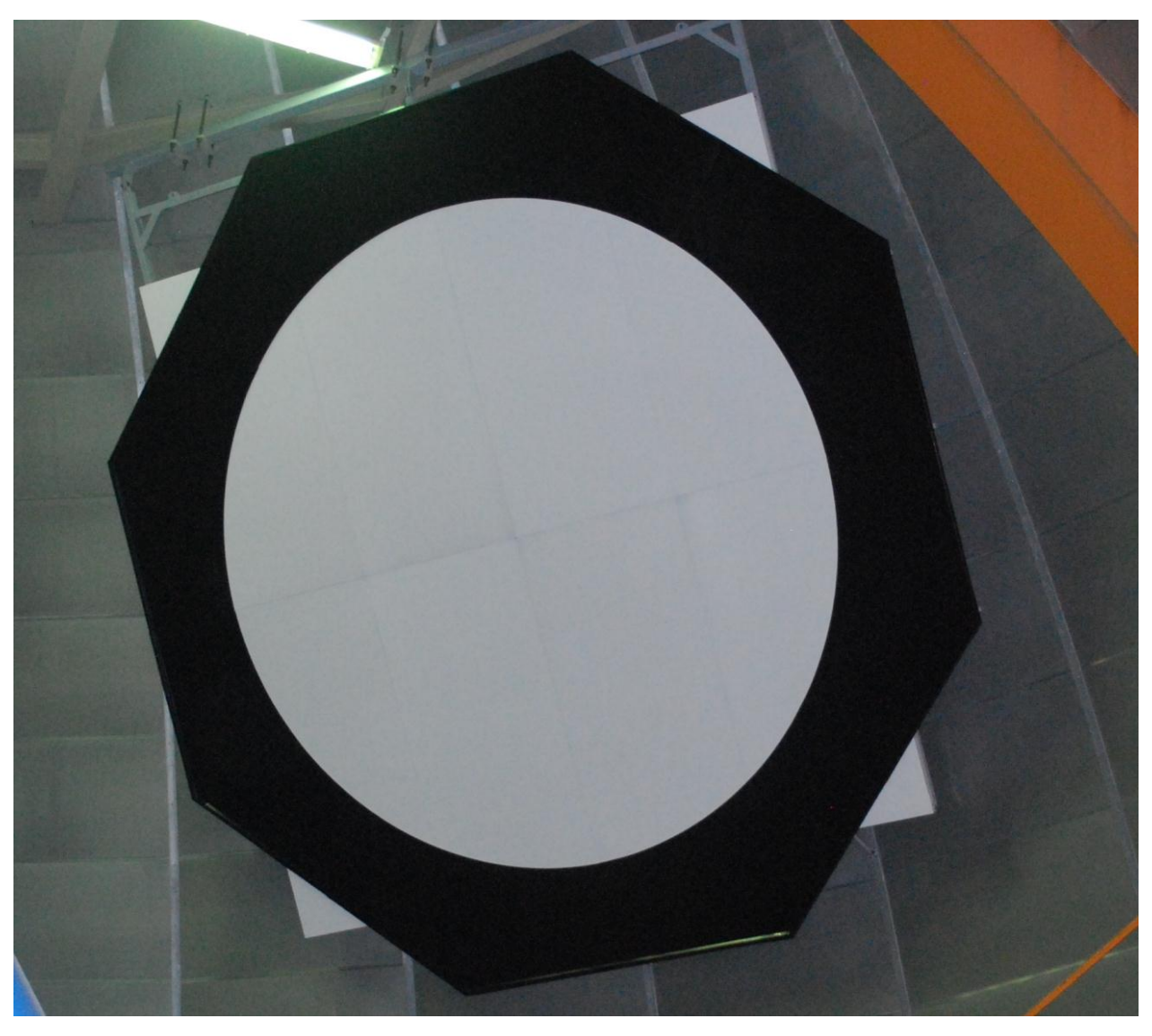
4 Fiber projection uniformity.zmx
Configuration 1 of 1

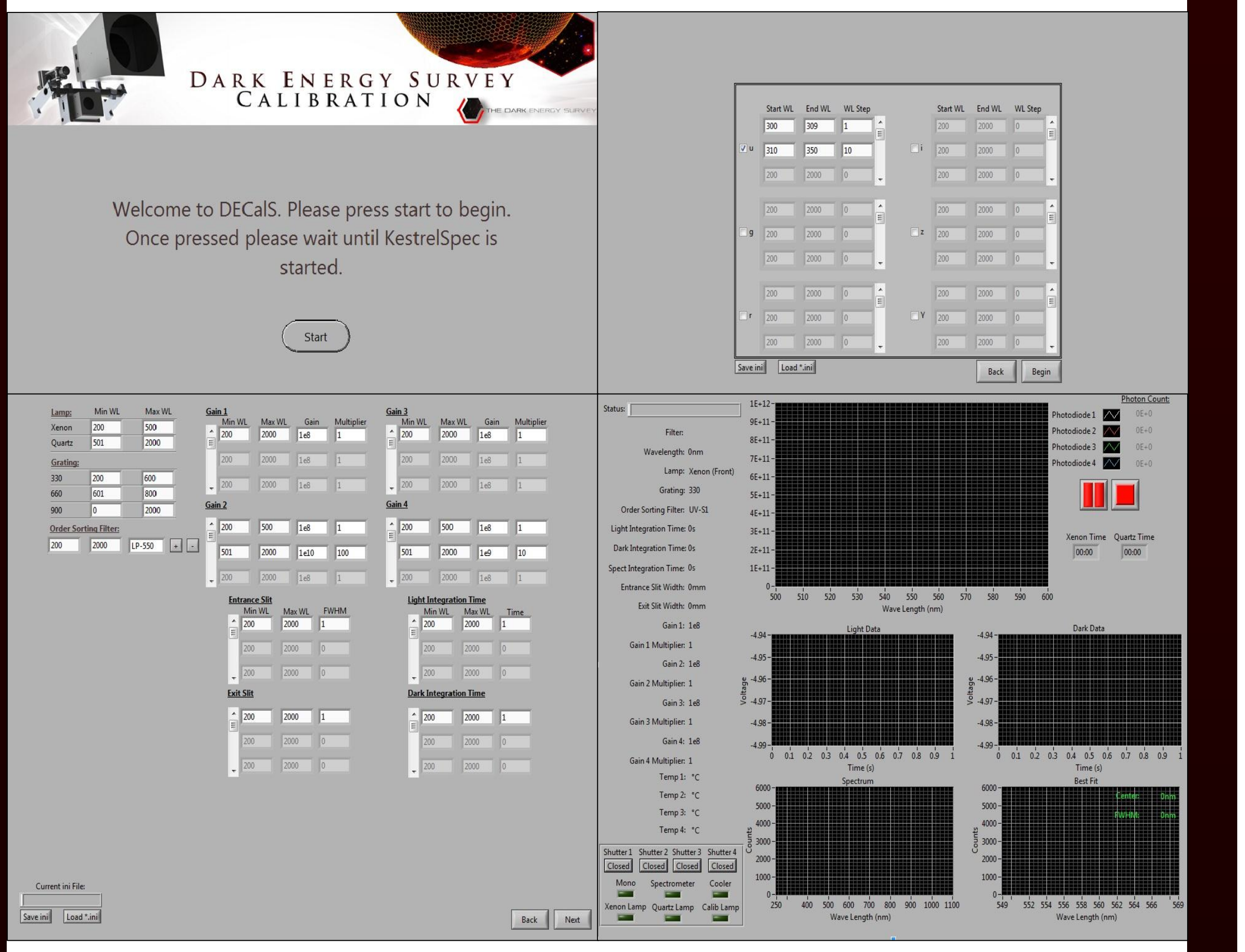
New flat field screen

A new flat field screen was installed in the CTIO Blanco telescope dome as part the DECam telescope upgrade. This was mainly done to ensure high reflectivity at all wavelengths including the UV as well as a nearly Lambertian reflectivity profile.



Software and automation

DECalS (Dark Energy camera CALibration Software) is a LabVIEW software that has a user-friendly interface that controls the different components of the system with minimal intervention required by the telescope operator or observer.



Welcome to DECalS. Please press start to begin. Once pressed please wait until KestrelSpec is started.

	Start WL	End WL	WL Step
☑ u	300	309	1
	310	350	10

Lamp: Xenon 200–500; Quartz 501–2000
Grating: 330 200–600; 660 601–800; 900 0–2000
Order Sorting Filter: 200 2000 LP-550

Status:
Filter:
Wavelength: 0nm
Lamp: Xenon (Front)
Grating: 330
Order Sorting Filter: UV-S1
Light Integration Time: 0s
Dark Integration Time: 0s
Spect Integration Time: 0s
Entrance Slit Width: 0mm
Exit Slit Width: 0mm
Gain 1: 1e8
Gain 1 Multiplier: 1
Gain 2: 1e8
Gain 2 Multiplier: 1
Gain 3: 1e8
Gain 3 Multiplier: 1
Gain 4: 1e8
Gain 4 Multiplier: 1

Conclusion

Building on the experience gained from previous prototypes we have maximized the system throughput and detector sensitivity to increase the signal-to-noise ratio and thus reduce the time required to scan each filter. This, coupled with the full automation of the system, will allow the operator to take a full measurement of the telescope+instrument system throughput as a function of wavelength in one night with minimal interaction. The system's simple operation also allows the possibility of using parts of a night during which bad weather prevents observing to perform the telescope calibration instead of reserving a full engineering night for calibration.

Texas A&M University Department of Physics and Astronomy is an institutional member of:

GMT
Munnerlyn Astronomical Instrumentation Lab Texas A&M University
HETDEX Hobby-Eberly Telescope Dark Energy Experiment — Illuminating the Darkness
LSST Large Synoptic Survey Telescope
DARK ENERGY SURVEY

Acknowledgments

Texas A&M University thanks Charles R. '62 and Judith G. Munnerlyn, George P. '40 and Cynthia Woods Mitchell, and their families for support of astronomical instrumentation activities in the Department of Physics and Astronomy.