The Dark Energy Spectrometer: A Potential Multi-Fiber Instrument for the Blanco 4-meter Telescope

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Introduction

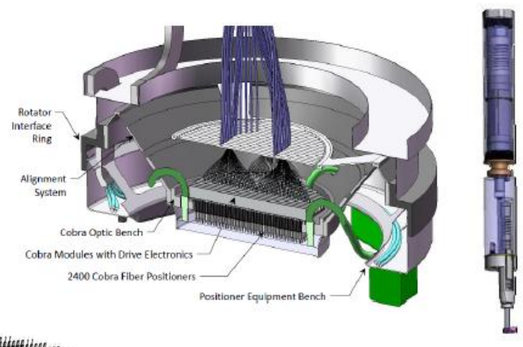
The discovery of dark energy is arguably the most important cosmological discovery in the past thirty years. New insights into the nature of dark energy will come soon from the Dark Energy Survey (DES), a deep, wide, multi-band imaging survey, spanning 525 nights over five years beginning in late 2012, that will use the new 570-Megapixel Dark Energy Camera (DECam) on the 4 meter Blanco telescope at CTIO.

As a result of the success to date of the DES project, we have conceived of a conceptual next-generation dark energy project. The observations would be made possible by a new multi-fiber optical instrument for the CTIO Blanco 4-meter telescope called the Dark Energy Spectrometer (DESpec). DESpec would provide a powerful spectroscopic follow-up system for the millions of Southern hemisphere sources discovered by DES (and later LSST), greatly enhancing the scientific return of both of these large-scale surveys.

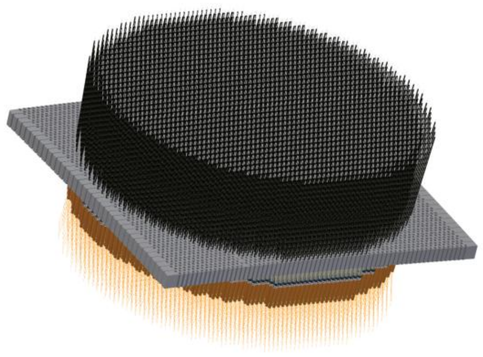
Fiber Positioner

The DESpec fiber positioner would house~4000 fibers at the telescope's prime focus. The fiber positioner must move the tips of the optical fibers to predetermined positions for each exposure and then hold them in place for the length of the exposure. It must also gather the fibers into bundles that optically feed the spectrographs. Since DESpec will reutilize the corrector optics of DECam, the focal plane will be about the same size, i.e., a diameter D~450 cm. This implies a separation between fibers (i.e., the pitch) of ~7 mm.

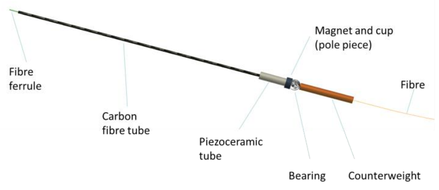
We are currently investigating two general classes of fiber positioners that could provide technical solutions for DESpec, shown below.



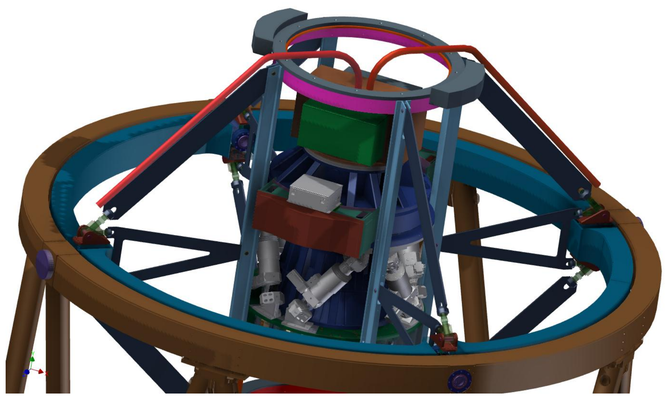
Right: The "Cobra" fiber positioner designed for WFMOS (left). The tip of the fiber is held at the bottom end of the unit positioner (right).



Left: A drawing of a MOHAWK fiber positioner with DESpec specifications, i.e., 4000 fibers with a 7mm pitch, placed in a 450mm diameter focal plane.



Right: The MOHAWK unit fiber positioner. The spines pivot from mounts at the base and are driven by piezo-electric actuators.



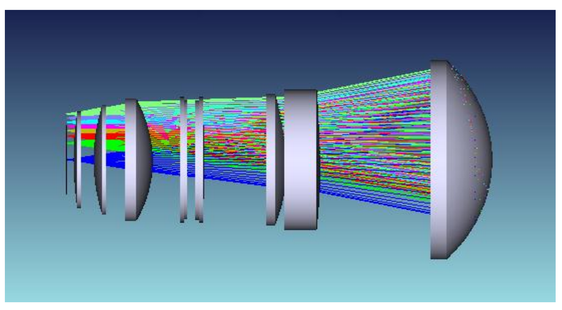
A schematic drawing of a MOHAWK-style fiber positioner positioned on top of the DESpec corrector optics, including the fiber bundles that would feed potential DESpec spectrographs.

Abstract

We describe the preliminary design of the Dark Energy Spectrometer (DESpec), a fiber-fed spectroscopic instrument concept for the Blanco 4-meter telescope at Cerro Tololo Inter-American Observatory (CTIO). DESpec would take advantage of the infrastructure recently deployed for the Dark Energy Camera (DECam). DESpec would be mounted in the new DECam prime focus cage, would be interchangeable with DECam, would share the DECam optical corrector, and would feature a focal plane with ~4000 robotically positioned optical fibers feeding multiple high-throughput spectrometers. The instrument would have a field of view of 3.8 square degrees, a wavelength range of approximately 500<λ<1000 nm, and a spectral resolution of R~3000. DESpec would provide a powerful spectroscopic follow-up system for sources in the Southern hemisphere discovered by the Dark Energy Survey and LSST.

Optical Corrector and ADC

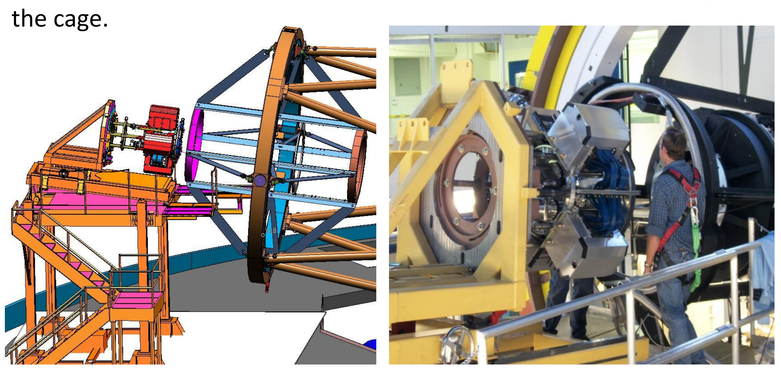
The DESpec optical corrector will benefit from previous experience with the DECam optical corrector; in fact we plan to share most of the elements of the DECam optical corrector with the DESpec instrument. C1 through C4 would remain in the prime focus cage during an instrument swap of DECam with DESpec. The assembled and aligned DECam corrector optics are now installed on the Blanco telescope.



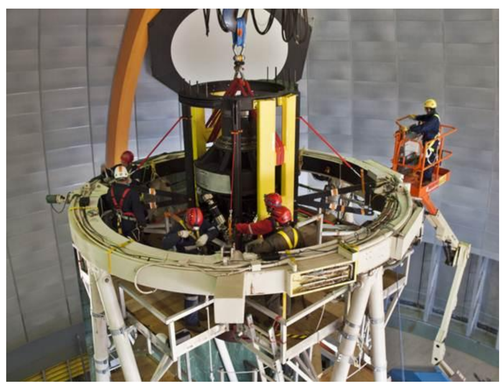
A potential optical design of the DESpec optical corrector. From right to left the optics are C1 to C3, the two-component ADC, C4, C5', and the field-flattener C6. The focal plane of fiber-ends would be just to the left of the new C6. "C1" is about 1m in diameter. The optical train is 1.9m long. C1, C2, C3, and C4 are already installed on the telescope as part of DECam.

Interchangeability with DECam

To change from DECam to DESpec, one would tilt the telescope to the northwest platform and use the camera installation fixture to remove DECam. DECam is then stowed off of the telescope with its Dewar window, the camera's final optical element (C5), in place. DESpec, which will have been stowed either off-telescope or on the telescope structure, is connected to a similar installation fixture for inserting into the cage.



The DECam camera installation fixture (schematic at left, in close-up at right) at Fermilab. Right image shows the installation fixture being used to mount the camera in the Prime Focus Cage (black, at right).



The new top end of the Blanco 4m telescope, during installation of the new prime focus cage to hold DECam.

Unit Spectrographs

A set of multiple identical DESpec unit spectrographs will produce and record spectra. The key elements driving the optical design of the spectrographs are the wavelength range, the required spectral resolution, and the diameter of the optical fibers carrying the light from the focal surface. To accommodate 4000 fibers, each of 10 spectrographs must accept ~400 fibers. There are several options for the physical location of the spectrographs: they could be mounted off-telescope or, if sufficiently small and light-weight, they could be mounted near the top of the telescope and arrayed around its upper ring in order to minimize fiber length and thereby increase the throughput of the instrument.

As we are currently continuing to develop the science and survey requirements, we are considering two spectrograph designs: a single-arm spectrograph with a wavelength range 550< λ <950 nm and a two-arm spectrograph in which the blue side has wavelength range 480<λ<780 nm and the red side covers 750< λ <1050 nm.

Parameter	Single-Arm Spectrograph
Fiber diameter	100 mm (1.75 arcsec)
Wavelength range (nm)	550<λ<950
CCD	DECam 2kx4k
Resolution (Δλ)	0.263 nm
# pixels/fiber	2.6
Spectral resolution	R~2850 at 750 nm
Camera *f*/#	*f*/1.3
Camera type	Reflective

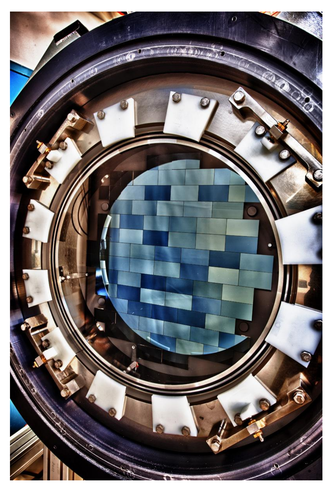
Left: parameters for a potential one-arm spectrograph design

Parameter	Blue Arm	Red Arm
Fiber diameter	100 mm (1.75 arcsec)	
Wavelength range (nm)	480<λ<780	750<λ<1050
CCD	Blue-sensitive 2kx4k	DECam 2kx4k
Resolution (Δλ)	0.228 nm	0.228 nm
# pixels/fiber	3	3
Spectral resolution	R~2760 at 630 nm	R~3950 @ 900 nm
Camera *f*/#	*f*/1.5	*f*/1.5
Camera type	Refractive	

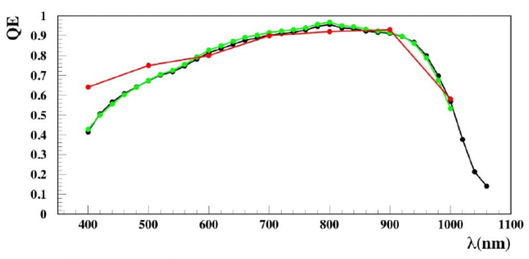
Right: parameters for a potential two-arm spectrograph design

Detectors

DESpec will use 2k x 4k backside-illuminated, red-sensitive CCDs designed by LBNL, for either the one-arm spectrograph or for the red arm of the two-arm spectrograph. These CCDs have high quantum efficiency (QE) at near infrared wavelengths. They are 250 microns thick and attain good (~5 micron) dispersion characteristics from a 40V substrate bias. The 4-side buttable CCD package is suitable, so existing spare, tested, packaged, science-grade DECam CCDs can be used on DESpec, providing a significant cost savings.



Above: The DECam focal plane populated with 70 2kx4k CCDs. DESpec will make use of the DECam spare CCD supply.



Right: The absolute quantum efficiency of three typical CCDs produced for the Dark Energy Camera. The blue side of the two-arm spectrographs could also use DECam 2kx4k CCDs.

Conclusion

We have described DESpec, a potential multi-fiber instrument for the CTIO Blanco 4m telescope. The instrument could be used to provide massive spectroscopic follow-up of dark energy sources discovered in the DES and LSST imaging surveys, and could be a CTIO facility instrument to be used for multiple science projects. The instrument design will continue to evolve along with the science case for the project. As a result, the instrument design described here does not represent final technical choices; however, it does represent feasible solutions that could be implemented at low risk and low cost were the project to move forward.

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

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