

A composite image at the top of the slide. On the left, there is a piece of white astronomical equipment, possibly a camera or spectrometer, with a large black circular opening. On the right, there is a large, glowing orange and red sphere with a hexagonal grid pattern, resembling a planet or a star. Below the sphere is a small black hexagon with a red outline, containing a white star. The text "DARK ENERGY SURVEY CALIBRATION" is centered in a serif font. To the right of the text is the logo for "THE DARK ENERGY SURVEY", which consists of a black hexagon with a red outline and a white star inside.

DARK ENERGY SURVEY  
CALIBRATION



# DECal: A Spectrophotometric Calibration System For DECam

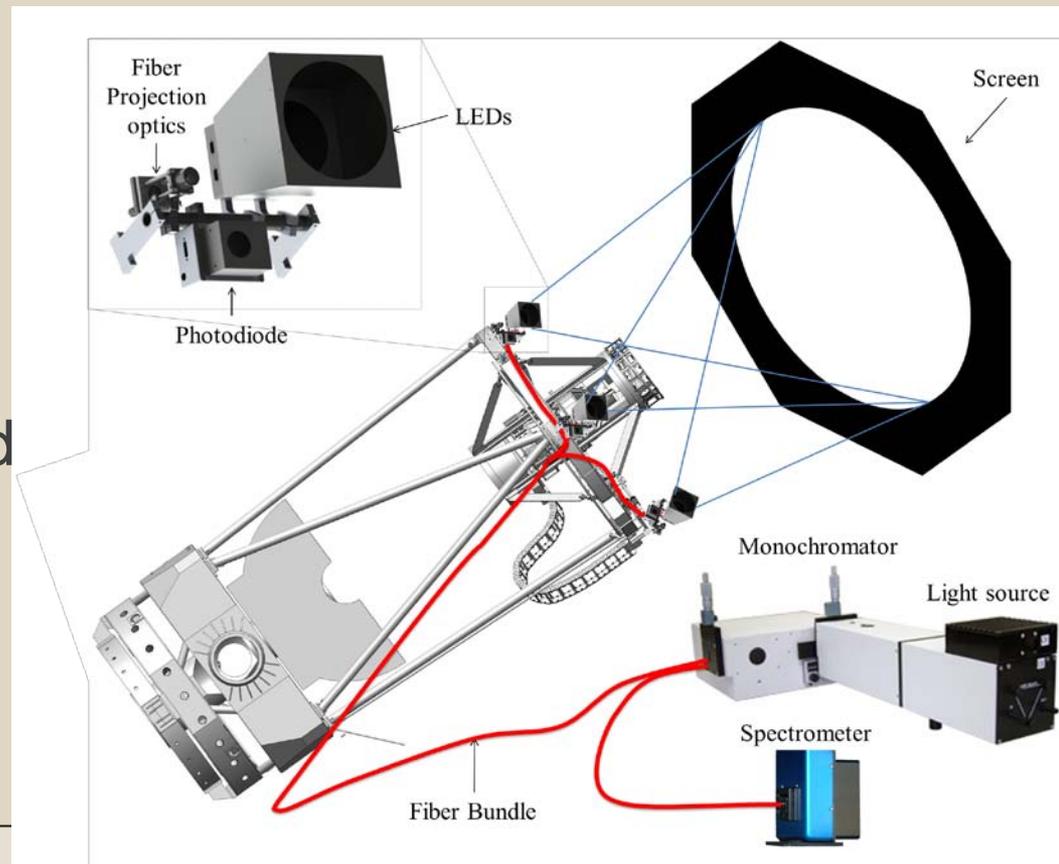
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# DECAL: a new spectrophotometric calibration system for the CTIO 4m

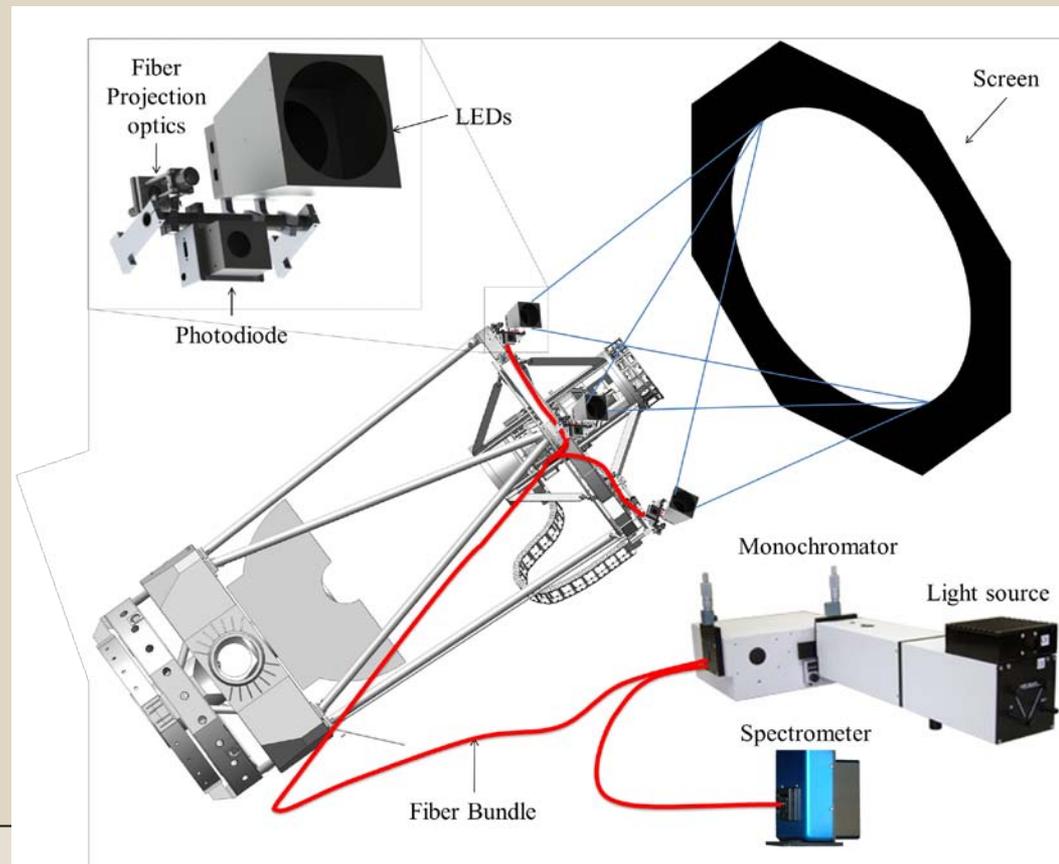


- Goal: calibrate DECam photometry to 1%
- Measure complete (relative) telescope+instrument system response vs. wavelength
- Especially useful for calibrating photo-zs and SN lightcurve k-corrections



# DECAL system summary

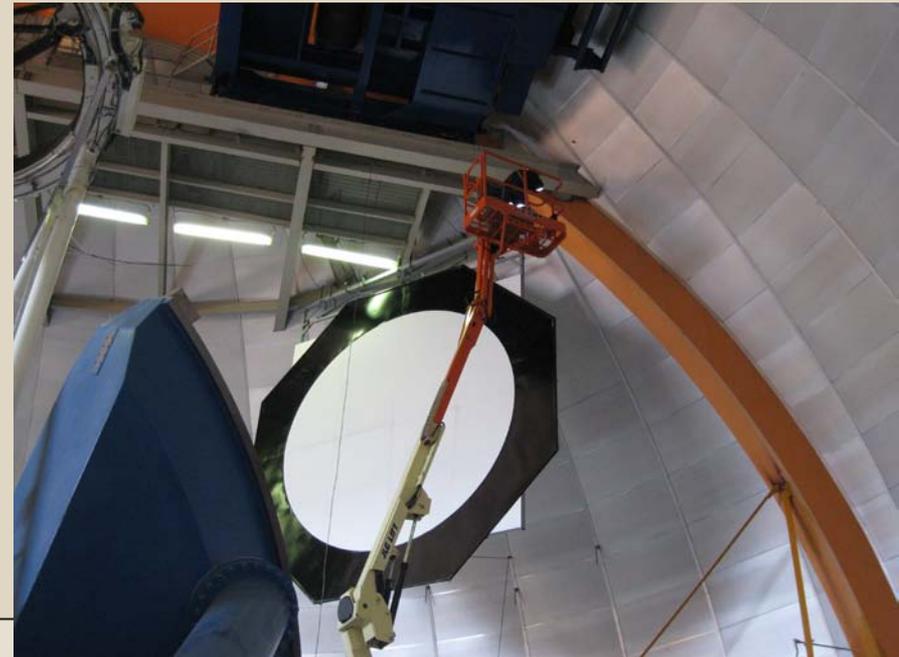
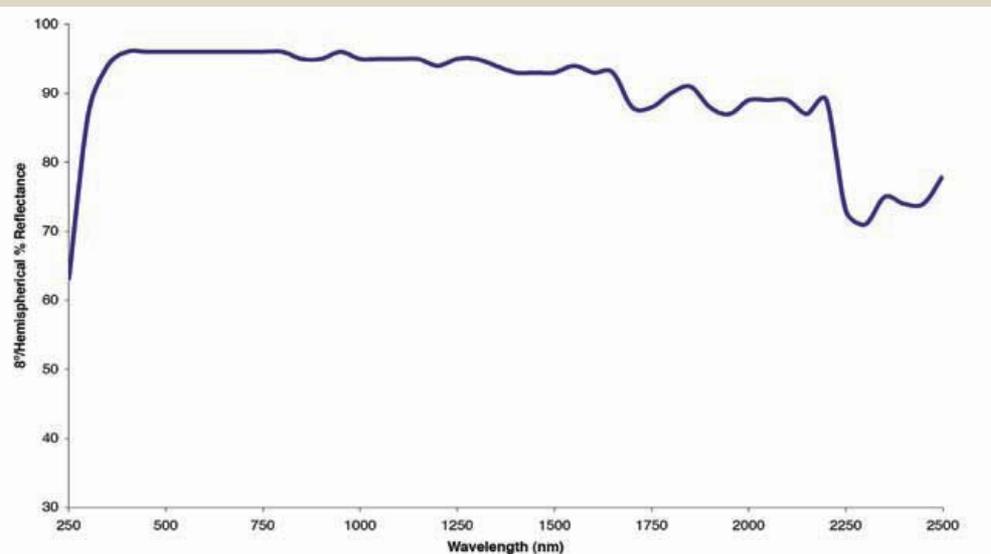
- Flat field screen
- Daily flat field system
  - LED flat field lamps
- Spectrophotometric calibration system
  - Monochromator (with spectrometer monitor)
  - Long fiber bundle
  - Monitor photodiodes



# Flat field screen

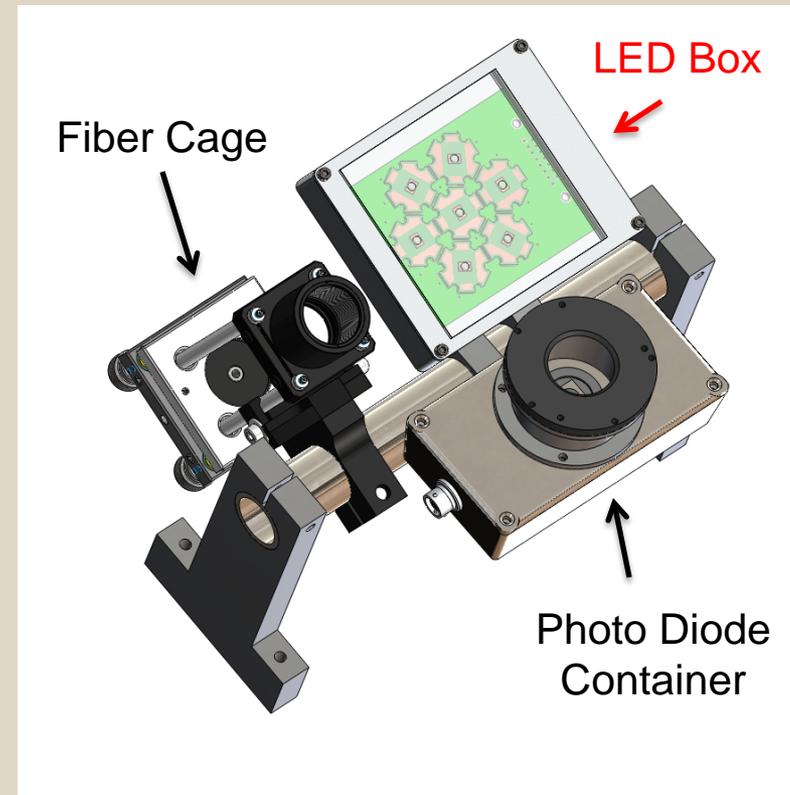
- 16 ft square lightweighted honeycomb aluminum panel
- Coated with Labsphere's Duraflect coating
  - Excellent reflectivity over wide range (300nm to 2400nm)
  - Almost a perfect Lambertian diffuser
  - Black circular baffle with 4m diameter

## Duraflect coating reflectivity

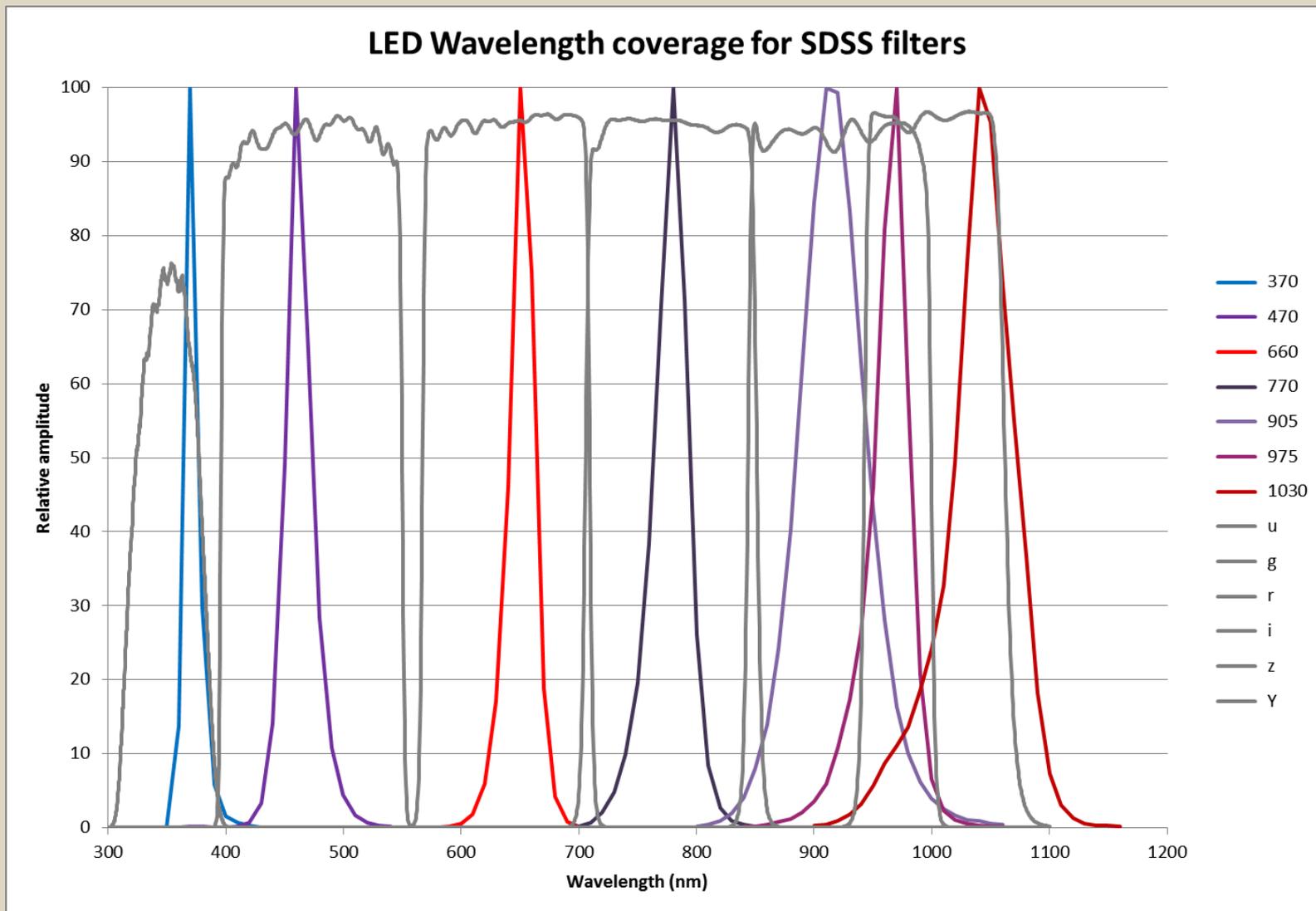


# Daily flat field system

- LEDs provide light in each filter to construct daily flat fields
  - Similar to system deployed at Curtis Schmidt
- Should be bright enough to take flats during the day



# LED spectra in each DES bandpass



# Spectrophotometric calibration system

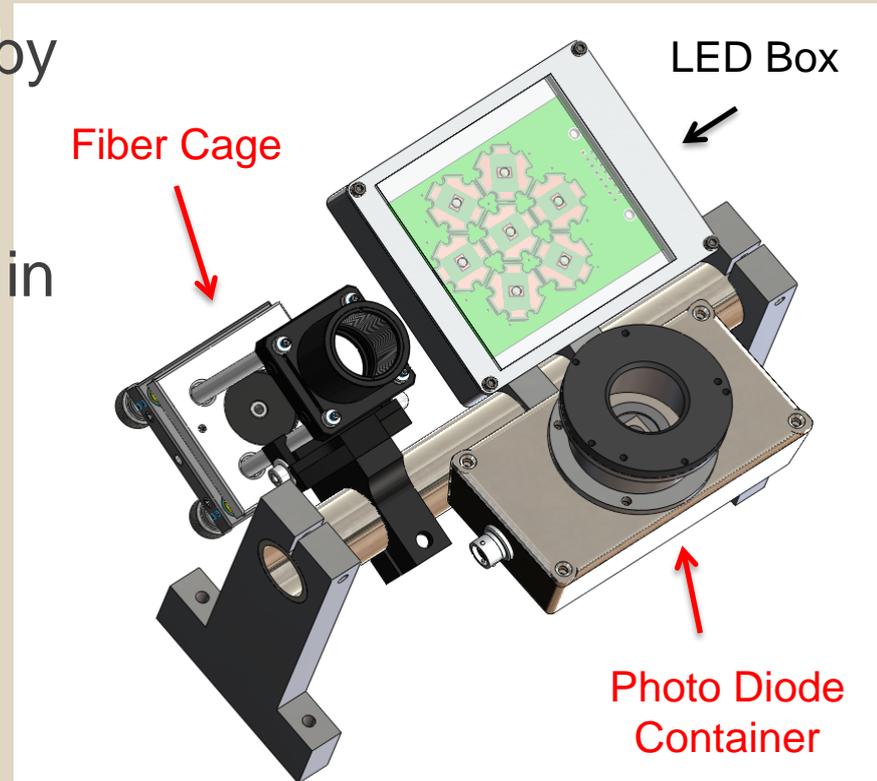


- Measure sensitivity of the complete telescope+optics+detector system as a function of wavelength
- Can sample every 1 nm over 310-1100nm
- Frequency of measurement will be determined once system is deployed
  - Probably about once a month on a cloudy night

# Spectrophotometric calibration system components

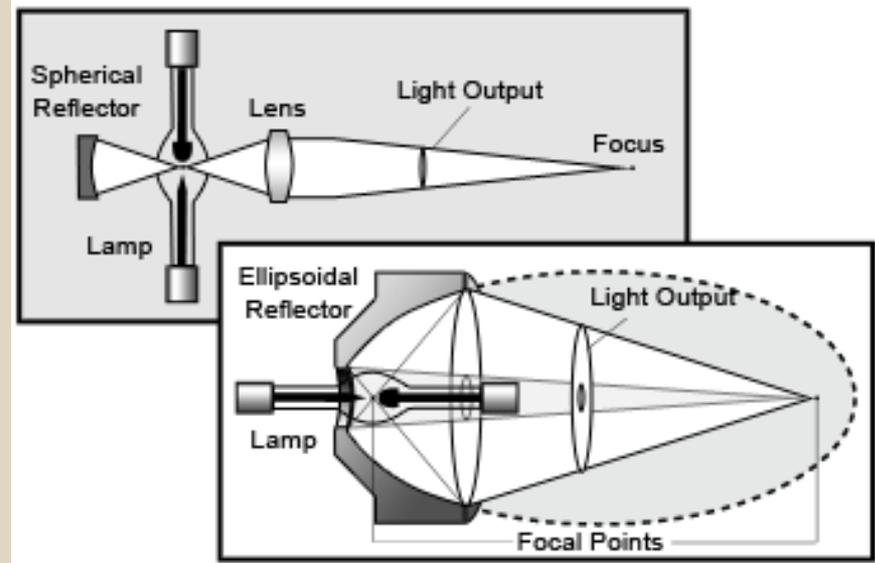


- Tunable light source
  - Monochromator
  - 250-1100 nm
  - Spectrometer monitor (fed by 3 fibers)
- 75m fiber bundle
  - 87 300  $\mu\text{m}$  fibers, 21 fibers in each of 4 locations around top of telescope
  - Optics project onto screen
- Monitor photodiodes



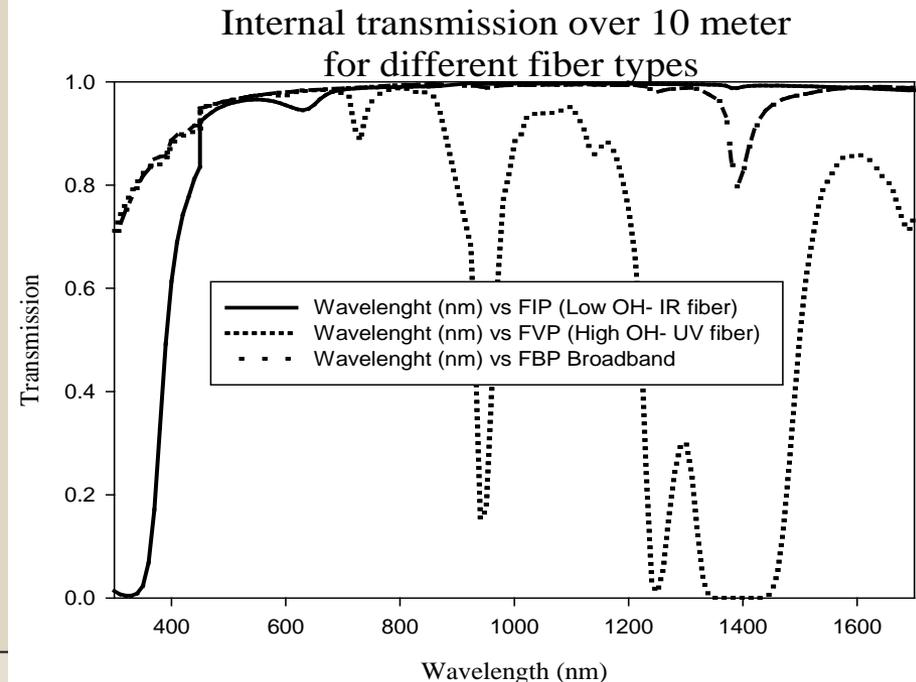
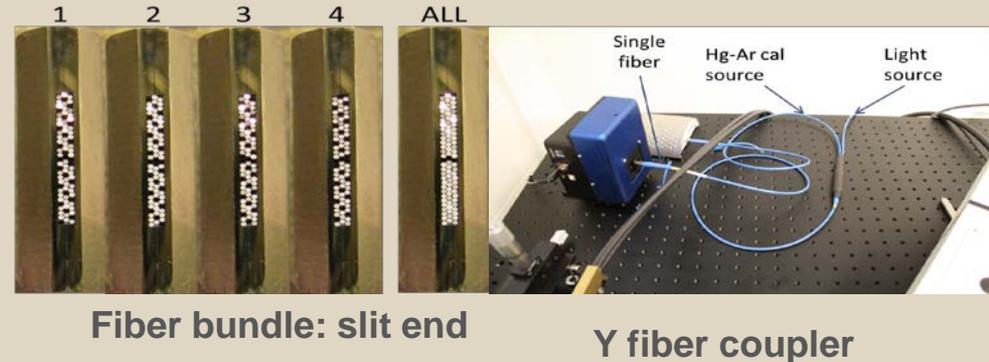
# Tunable light source

- Commercially available (Horiba) tunable light source
  - Inexpensive and versatile
  - Computer controlled wavelength selection
  - Input slit changes bandwidth (1-20nm)
  - Output slit is fixed by size of fibers
- Multiple light sources
  - Xenon lamp (250nm - 800nm)
  - Quartz Halogen lamp (800nm - 2500nm)



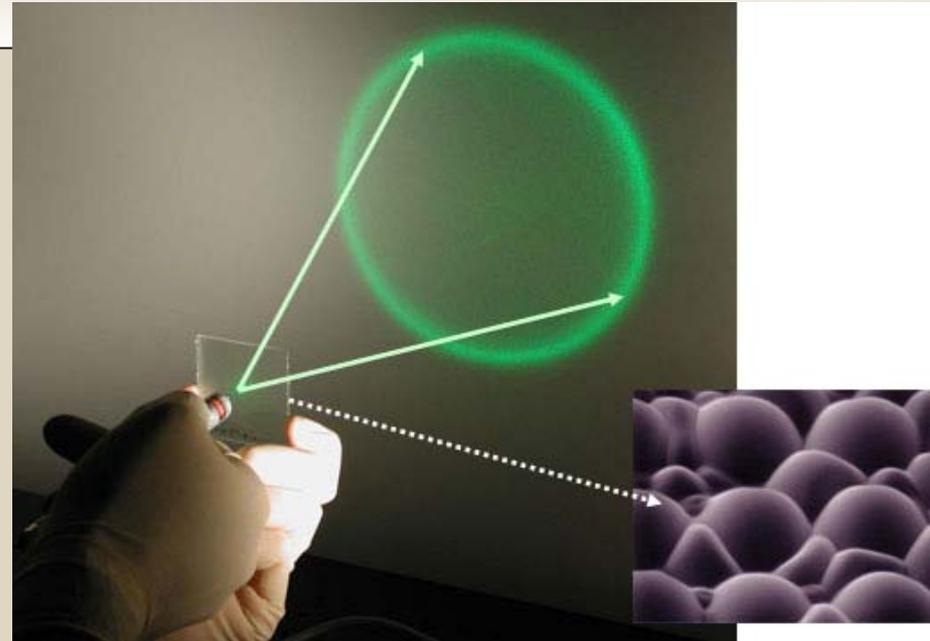
# Optical fiber bundles

- Fiber bundle carries the light to 4 locations at top of telescope
  - Three fibers feed a spectrometer to monitor power and wavelength in real time
- Broadband fibers
  - Good transmission over 10 meters from ~300nm to 2500nm
  - There are losses due to fiber length in UV

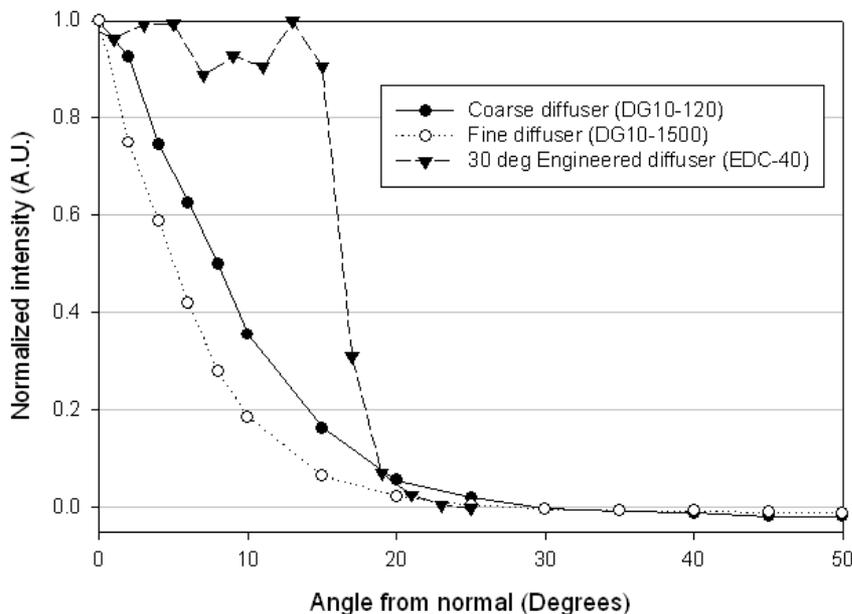


# Beam shaping optics

- Fiber output fed through special diffuser to provide uniform illumination of the screen
- Engineered diffusers shape the beam profile to a pre-determined shape.



Efficiency of 3 different diffusers



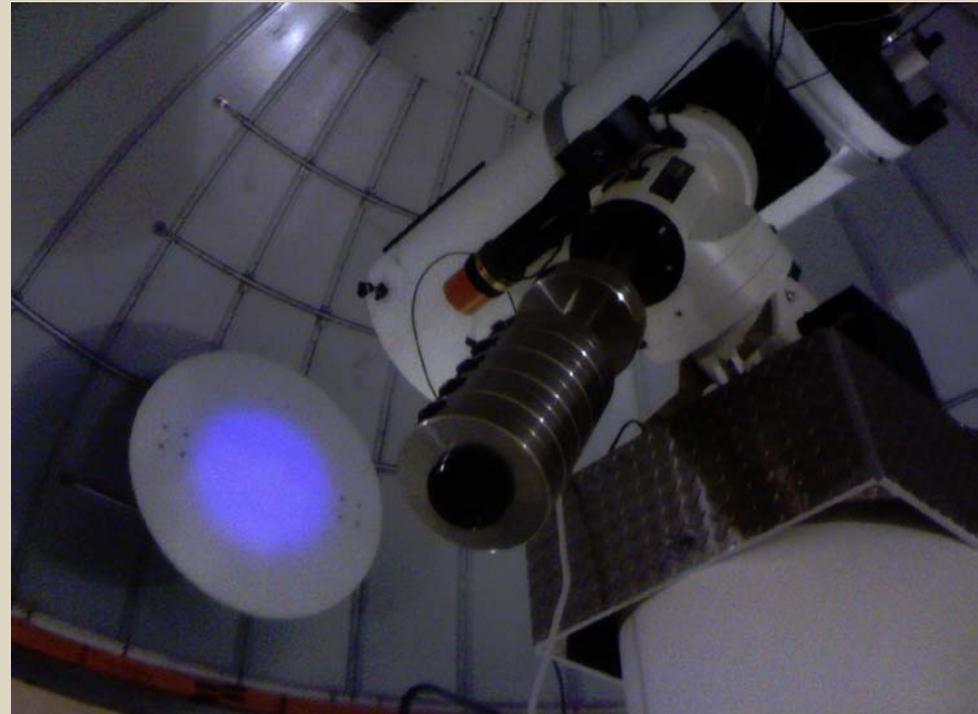
- Light illumination is uniform to ~10% in the 30 degree cone of light
- The cone contains more than 80% of the light incident on the diffuser
- Order of magnitude more efficient than regular diffusers

# Reference photodiodes

- Signal proportional to the light seen by the telescope
  - Relative calibration, not absolute
- Si photodiode sensitive from 300nm to 1100nm
- NIST calibrated

# Tests at TAMU 0.5 m telescope

- Early prototype of the illumination system
- Used an LED instead of monochromator as light source
- Goal was to test sensitivity of flatfield to:
  - Screen angle
  - Illumination uniformity
  - Presence of joints or screw heads in the screen
- Results indicate little dependence on any of these

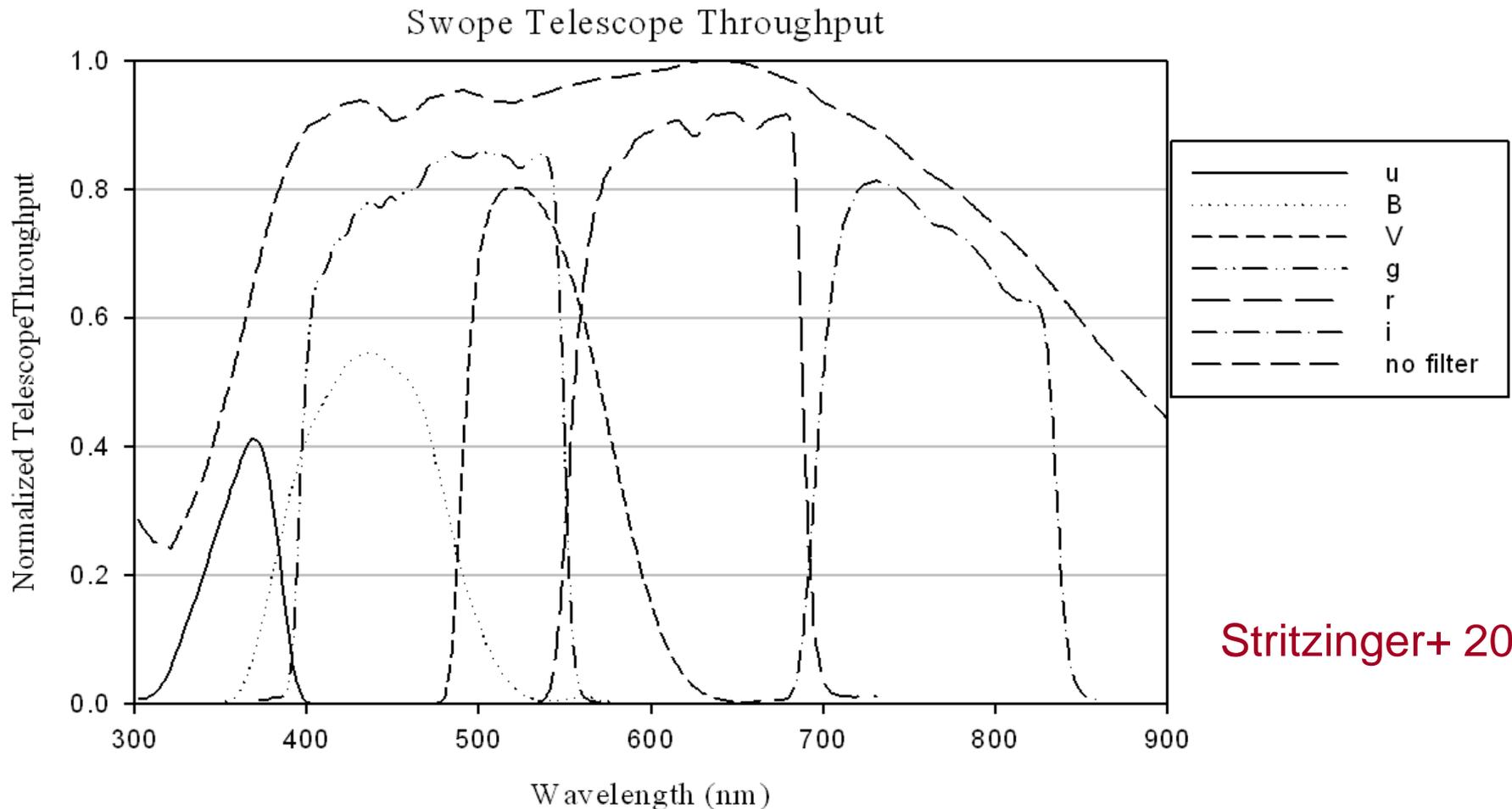


# Las Campanas prototype

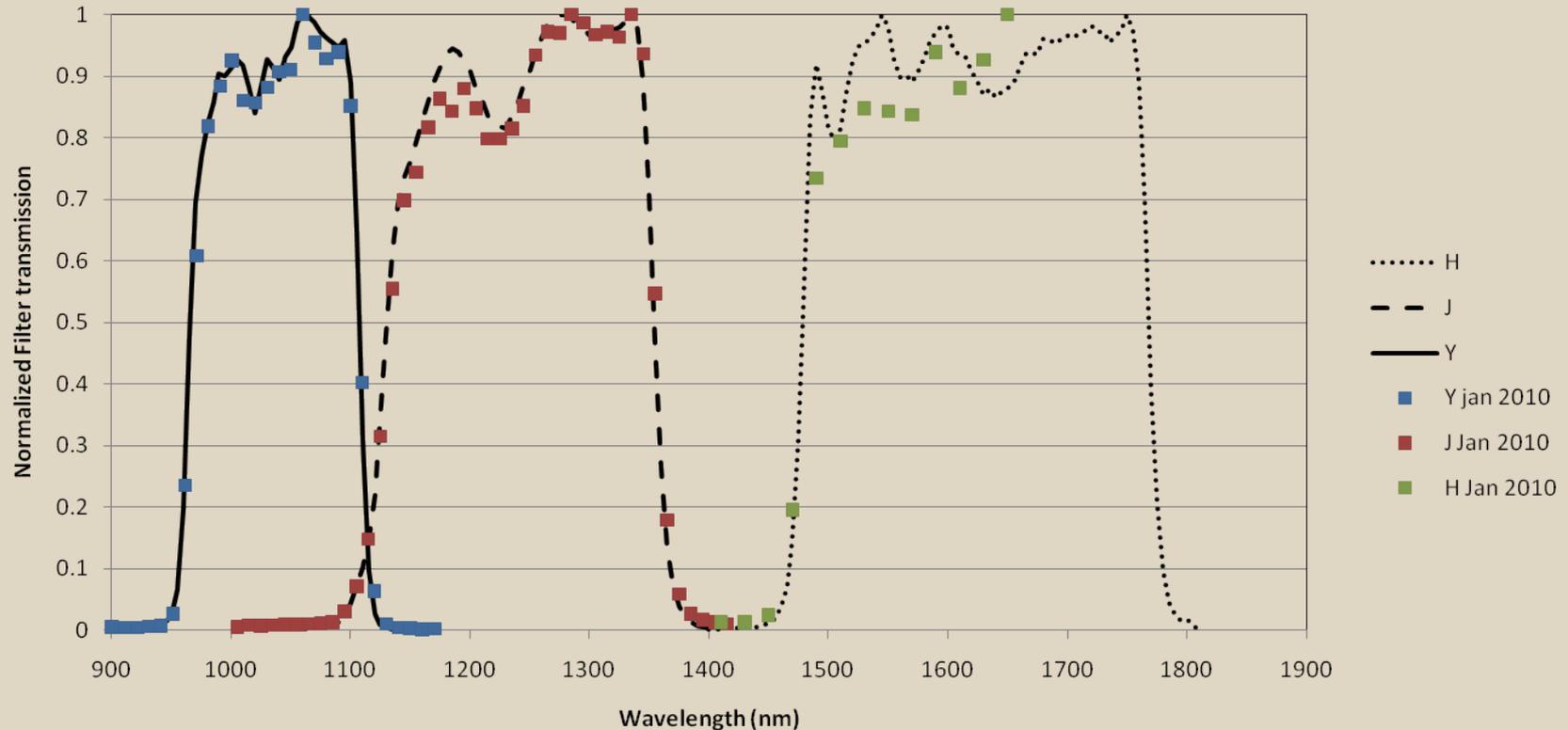


- 2010: Deployed a prototype of the system at the Las Campanas du Pont and Swope telescopes
  - Calibrated Carnegie Supernova Project data
- System works great!

# Swope optical filters

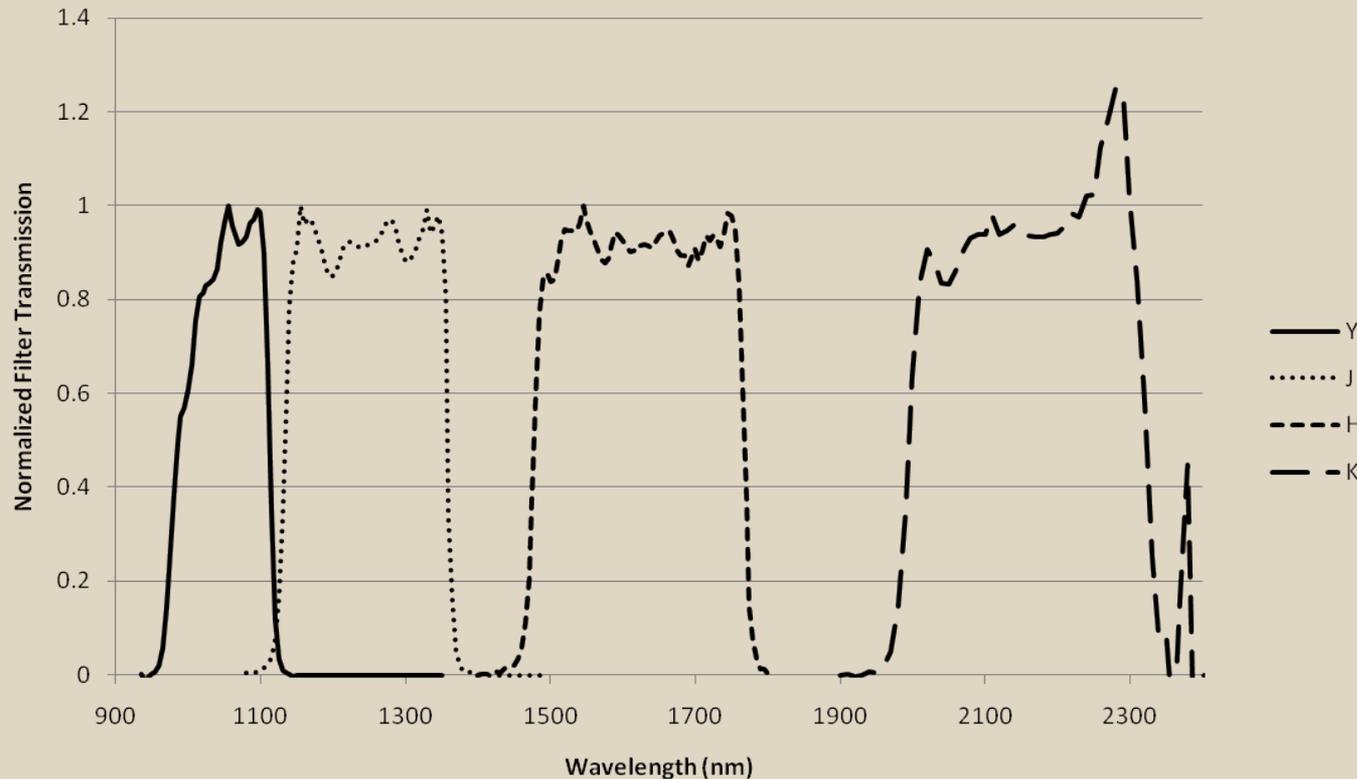


# Swope Infrared filters



- Jan 2010: Measured Y, J and H filters (points)
- July 2010: measured with InGaAs photodiode calibrated to 2400nm (lines)

# du Pont Infrared filters



- August 2010 measured with InGaAs photodiodes
- Light source intensity and InGaAs sensitivity drops beyond 2200nm, causing uncertainties to increase.

## DECaI status

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- Final system complete
  - Shipped to CTIO
- Software complete
  - Working with Klaus Honscheid to integrate into DECcam control software
- Final integration scheduled for early June 2012