LSST Filter Design Document –
DRAFT 3-8-05

This document specifies the requirements for the LSST filter set. The complete LSST filter set consists of six filters named **g, r, i, z, and y.**

There are two options for the **Y** filter and is a scientific trade-off between greater sensitivity to redder objects by means of a wider and redder band-pass (**y1**), and higher quality photometry by reducing the impact of chip-to-chip variations in the CCD quantum efficiencies (**y2**).

The LSST science goal for 1% photometry of the objects in LSST images defines the following general features of the LSST filter set:

1. No gaps should exist between filter band-passes, except in the spectral region between 930-960 nm where it is desirable to exclude a variable water vapor absorption feature.
2. Filter band-passes should not overlap.
3. Band-pass throughput should be as high possible
4. The transition between stop and pass band should be less than 10% of the filter band-pass.

Spectral band-passes

The science goals of the LSST project and the general filter requirements as specified in the SDSS and Pan-STARRS filter sets lead to the following half-maximum transmission wavelengths for each filter.

Table 1. Proposed LSST design HMTW

Band-pass Transition	**Half Maximum Transmission Wavelength (nm)**					
	g	**r**	**i**	**z**	**y1**	**y2**
Blue side	402	552	691	818	948	970
Red side	552	691	818	922	1060	1028

The data set below (Table 2 and Figure 1) show the LSST filter set values as proposed.

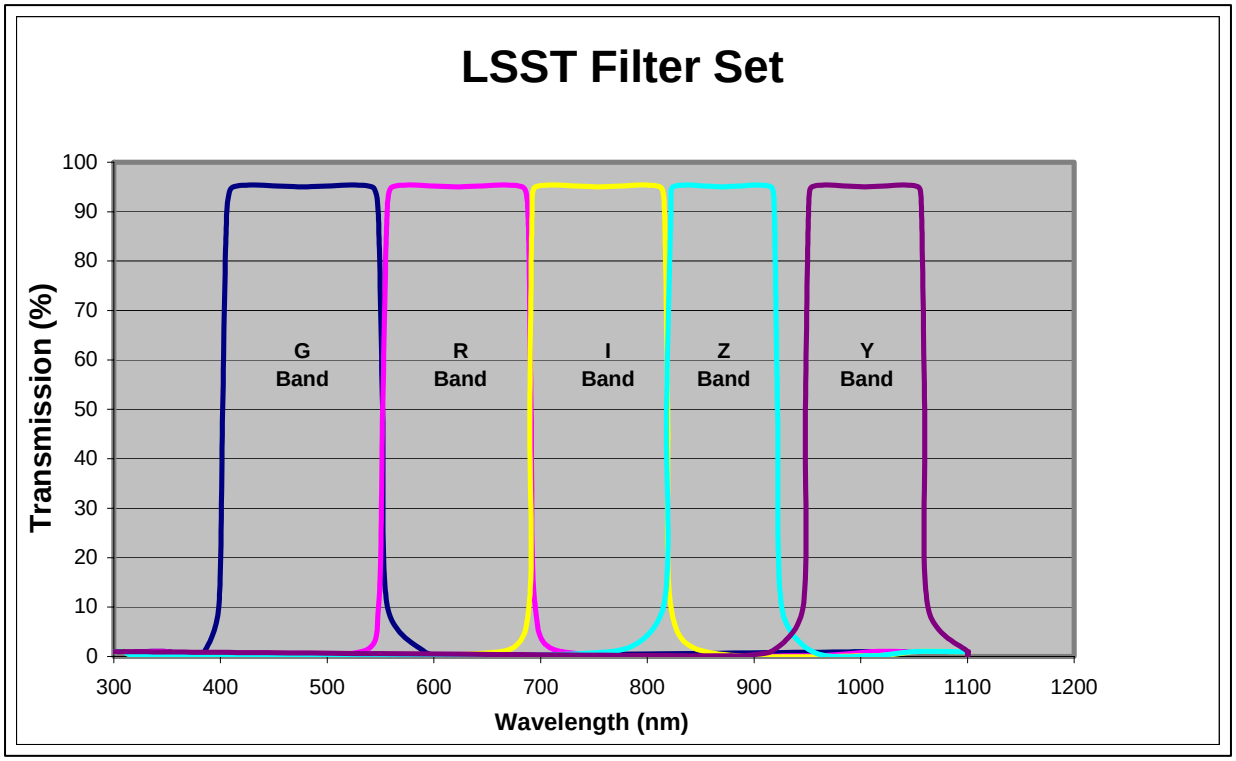

Figure 1. LSST Pass-Band Curves

Wavelength (nm)					Transmission %					
g	r	i	z	y	g	r	i	z	y	
320	320	300	300	300	1	1	1	1	1	
350	350	310	310	310	1	1	1	1	1	
370	370	320	320	878.4	0.1	0.1	0.1	0.1	0.1	
385	532.5	663.4	765.6	916.3	1	1	1	1	1	
398.4	548.5	688.7	815.3	945.9	10	10	10	10	10	
402	552	690	818	948	50	50	50	50	50	
406.3	555.5	692.1	821.6	951.2	90	90	90	90	90	
412	560.5	695	824	954	100	100	100	100	100	
477	621.5	754.5	870	1004	100	100	100	100	100	**Central Wavelength**
542	682.5	812.3	916	1054.2	100	100	100	100	100	
547.6	687.5	816.1	919.1	1057.5	90	90	90	90	90	
552	691.3	818.5	922.3	1060	50	50	50	50	50	
556.3	694.7	822.4	925.8	1063.3	10	10	10	10	10	
591.4	719.5	854.2	955.0	1100	1	1	1	1	1	
605.4	950	1010	1010		0.1	0.1	0.1	0.1	0.1	
1010	1010	1050	1050		1	1	1	1	1	
1050	1050	1100	1100		1	1	1	1	1	
1100	1100				1	1	1	1	1	

Table 2. Wavelength vs. Transmission for the LSST Filter Set

Specifications for the LSST Filter Set

All specifications in this document refer to the finished filter as delivered by the vendor.

Design Characteristics:

1. Beam that is incident on the filter has a focal ratio of f/1.25 with a 61.5% linear obscuration.
2. The filter is concentric about the chief ray so that all portions of the filter see the same angle of incidence range, about 14.2º to 23.6º.
3. At the filter, the sub aperture is about 100mm in diameter.

All measurements of filter transmission shall be calculated or measured using the above beam profile.

Detector Response Curve:
The detector response curve (QE) below is presented to allow calculations of out-of-band vs. in-band transmission. The goal shall be to have less than 1% out-of-band transmission.

400nm	600nm	800nm	900nm	1000nm
60%	85%	85%	85%	40%

Substrate Material: Fused Silica, round, parallel surfaces.
Note that if colored glass is available in 770 mm dimensions and is desirable for the definition of the filter band-pass, this is acceptable. But manufacturer must specify the composition of the glass chosen ahead of time since it will require small changes to our optical design. LSST may provide fused silica substrates if the vendor considers all dielectric solutions.

Transmittance:
Transmitted average should be 95%±3%

Spectral Cut-on/Cutoff Slopes:
<5% (slope between 90% and 10% points on filter edge-See Table 2)

Out of band transmission:
< 1% below cut-on/cut-off points

Spectral characteristics and coatings:
All of the filters should have good uniformity of transmission across their full clear apertures and should include anti-reflection layers to inhibit ghosting in the telescope.
AR coatings on filter [R <0.5%] should span region where T > 10%.

Aperture: 770cm
Clear Aperture: 750cm

All filters meniscus with equal radii of curvature of 5.9m

Angle of incidence: 14 – 23.6 degrees

Structure: Laminate or Single Layer.
Filters can be made of more than 1 substrate if this aids in manufacturing and/or cost reduction while maintaining optical quality.

Transmitted Wave-front Error After Coating: ≤ 0.33 λ PV over any 4 inch diameter at 610 nm.
The finished filter surface needs to be flat to better than 0.33 λ PV over any 4 inch diameter subaperture to preserve the optical quality of the telescope.

Surface Wedge (parallelism): ≤ 45 arc-seconds.
A wedge of 1.0 arcminutes will result in a change of about 5% in the telescope RMS spots before atmospheric distortion is considered. The specification is set to stay below this limit.

Surface Quality: 60/40
Inspection of the filter surfaces is to be consistent with MIL-O-13830A. This specification applies to all substrate surfaces before and after coating and for external surfaces for the case of a laminated filter. The argument for the relaxed surface quality specification here is similar to that given for the inclusion allowance. The filters are used far from focus.

Coating Durability: MIL-C-48497
Excluding tests for immersion in saline solution.

Operational Temperature Range for Filters: -5 to + 25 C

Total Thickness:
Thickness will be determined on a filter to filter basis and will be optimized for best PSF over entire filter (14-21mm thick filter).
Thickness tolerance shall be ±0.25mm.

Environmental Stability:
Coatings shall be stable from -20ºC to 50ºC, humidity range >24hr@98%, slow #600 tape pull
(no degradation in performance or λ shift.

Humidity Range: 5% to 95%

Lifetime: 10 years of use
Note that it is anticipated that the filters will reside in a dry air environment for more than 80% of this time.

Pinholes: 1/10 of 1% over total area

Vendor R&D Tasks

1. Establish procedures to distribute a uniform coating over the entire filter surface. This includes evaluating several coating techniques to determine the best method of coating.
2. Set-up test procedures to measure optical performance of filters.
3. Determine optical quality of glass and coatings necessary for rejecting out-of-band transmissions.
4. Develop techniques to ensure wavelengths of pass band are met.
5. Establish ability to coat on two sides for spectral performance.
6. Monitor and record techniques to reduced variations in coatings.
7. Examine spectrum shift with temperature. Characterize at different temperatures.

Vendor to Include:

1. Filter Procurement Process
   A. Design Study
      Define performance tradeoffs including shape coating designs, uniformity and
      repeatability.
      Define possible parameters to relax without compromising science.

   B. Risk Reduction Study
      Required uniformity and spectral performance developed and tested.
      Fabrication risks identified and addressed.
      Develop final cost/schedule estimates.
      Create witness samples.

2. Acceptance Test Reports
   A. Include interferometric measurements of filter transmitted wavefront over a number of 100mm subapertures and and spectrophometric

measurements of the filter transmission using an f/1.25 beam with a 61.5% linear obstruction. The transmitted wavefront specification may be ignored if vendor is supplied with finished uncoated substrates.

B. Manufacturing notes on the processing controls during the filter production should be provided.
C. Visual inspection of the filter conditions should be supplied.
D. Post Fabrication Documentation
   Total thickness.
   Wedge errors.
   Photometry measured at a minimum of 9 distributed places.
   Shipping containers
   Cleaning procedures

Filter Designs

Other current projects designing around the SDSS original filter specs are Pan-STARRS and WIYN. These projects have information on the web that may be of interest to LSST participants doing filter analysis. Some of the filter specifications are in .xls format. The websites containing filter parameters and specifications are listed below.

http://panstarrs.ifa.hawaii.edu/projects/people/siegmund/Telescope/20030523_Filters/
(keep in mind that most of the leaks seen are at or below the 1% level. These filters had not yet been tuned to reject out of band transmissions-kg).

http://www.wiyn.org/filters/