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A Performance Characterization System for Suprime-Cam Filters

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Abstract

We made a system which characterizes the performance of large glass filters for Suprime-Cam, prime focus camera for the Subaru telescope. We set up a standard format for the characterization based on a series of straightforward measurements. Characterization of Suprime-Cam filters has been made to be a routine work by this system. This paper describes the hardware of the system and format of the measurements. Transmittance curves of several filters measured with the system are also presented.

Key words: Suprime-Cam filters, Performance characterization.

1. Introduction

Suprime-Cam (Miyazaki et al. 2002) is a 80-Megapixel prime focus camera for the 8.2-m Subaru Telescope (Kaifu 1998). The wide field of view of Suprime-Cam, $34' \times 27'$, is a unique feature of Subaru among very large telescopes. Suprime-Cam is especially suited to surveys of various objects ranging from solar system objects to distant galaxies.

In addition to standard broad band filters, custom made narrow-band (NB) and intermediate-band (IB) filters would make it possible to design various interesting surveys with Suprime-Cam. Several NB filters were already used in surveys for high redshift galaxies and planetary nebulae (Ajiki et al. 2002; Okamura et al. 2002; Ouchi et al. 2003; Shimasaku et al. 2003; Kodaira et al. 2003). Band widths (BWs) of NB filters are between 70 Å and 120 Å. A unique set of 20 IB filters covering the wavelengths between 4,000 Å and 10,000 Å was manufactured for surveys of strong emission line objects such as QSOs/AGNs and $Ly\alpha$ galaxies as well as strong absorption objects such as damped $Ly\alpha$ systems and broad absorption line(BAL) QSOs. Their BWs range from 200 Å to 400 Å, giving the spectral resolution of $R \sim 23$ over the entire optical wavelengths. This set of filters will also improve the accuracy of photometric redshifts compared with those obtained from broad band filters only (Hayashino et al. 2000).

The physical size of the field of view is 158 mm $\times$ 124 mm. Filters to be used with Suprime-Cam, which are placed at 60 mm in front of the CCD detectors, should have the physical size of (205.0$\pm$0.5) mm$\times$(170.0$\pm$0.5) mm$\times$(15.0$\pm$0.2) mm and the clear aperture (CA) of at least 185.0mm$\times$150.0 mm. The specification is rather stringent because any Suprime-Cam filter should be mounted on a special frame which is loaded into the remotely controlled filter exchanger[1].

It is critical to any kind of surveys to maintain uniformity in the transmission characteristics of filters, that is, central wavelength (CW), band width (BW) and peak transmission (T_{peak}), over such a large area of 205 mm$\times$170 mm. This is the most serious concern with NB and IB filters, especially those whose CW/BWs are designed to target the low sky-background valleys (e.g., 8100 to 8250 Å and 9050 to 9300 Å) between the bundles of strong night-sky emission lines at long wavelengths.

Another concern with Suprime-Cam filters is the fast F ratio (F/1.86) at the prime focus. Transmission characteristics of an interference filter change with the incident angle of incoming light. For the beam of a fast F-ratio, CW shifts by several tens of Angstroms toward shorter wavelengths and, hence, BW also changes compared with the case when the filter is used in a parallel beam. Accordingly, it is important to measure filter characteristics over the entire clear aperture of large Suprime-Cam filters using the beam with the same F-ratio as the beam at the Subaru prime focus.

We made a system which can measure transmission characteristics of Suprime-Cam filters over the entire surface using a F/1.9 beam. We briefly describe its hardware and the format of the measurements, together with some examples of transmission curves of NB and IB filters.

2. Hardware

Hardware of the system consists of a usual spectrophotometer and an optics which generates a F/1.9 beam. We assembled the beam generator by ourselves and put it into a Shimadzu UV3100pc spectro-photometer. A schematic figure of the optical system is shown in Fig. 1. We use the almost parallel beam (F$\sim$15 in Fig. 1) of monochromatic light from Shimadzu UV3100pc as the light source. The F-ratio of the

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[1] see http://SubaruTelescope.org/Observing/Instruments/SCam/user_filters.html

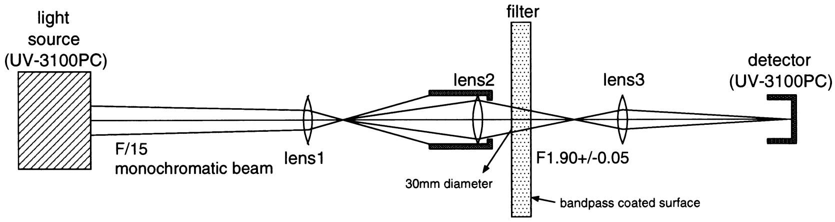


Fig. 1. Schematic figure of the F/1.9 beam generator.

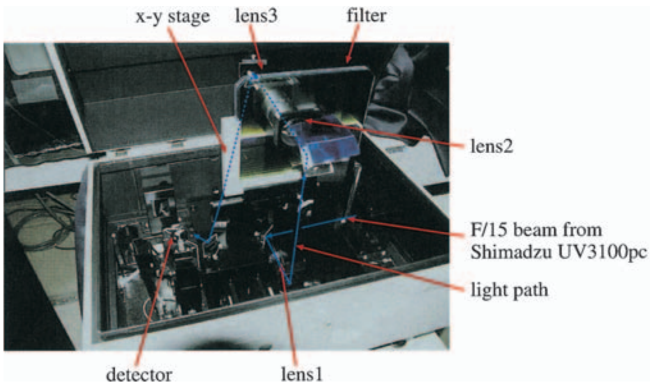
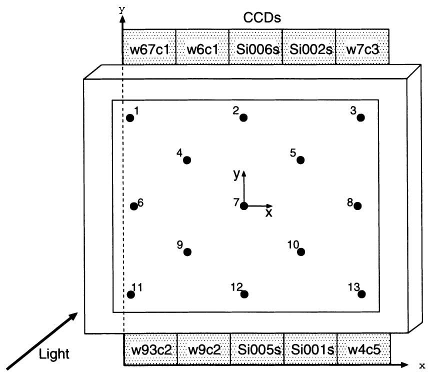


Fig. 2. A picture showing the F/1.9 beam generator and a filter put into Shimadzu UV3100pc spectro-photometer.



Positions X, Y (mm)

	X	Y
#1	−78	65
#2	0.0	65
#3	78	65
#4	−39	33
#5	39	33
#6	−75	0.0
#7	0.0	0.0
#8	75	0.0
#9	−39	−33
#10	39	−33
#11	−78	−65
#12	0.0	−65
#13	78	−65

Fig. 3. Positions where the transmittance curves are measured. IDs of the CCDs are also shown.

beam is converted to F/1.9 in the generator. The F/1.9 beam is then fed to a filter to be measured. The beam size on the surface of the filter is 30 mm in diameter, which is the same size as for the beam focusing on the Suprime-Cam. We set the filter so that the bandpass-coated surface of the filter does not face to the incoming beam, which is recommended in “Suprime-Cam filter acceptance policy” presented in the Subaru homepage, http://subarutelescope.org to reduce the reflected light going back to corrector lens and lighten Ghosts. The beam that passed through the filter is returned to the UV3100pc and the beam intensity is measured. Comparing the measured beam intensity with that for the reference beam without the filter, we obtain the transmittance of the filter.

A picture of the system is shown in Fig. 2. The filter is mounted on a manual X-Y stage, so that we can easily locate the position on the filter surface where the measurement is to be made, using template which indicates measuring points.

3. Format of Measurements

We measure transmittance curves at 13 positions distributed over the filter clear aperture(CA) of 185 mm$\times$150 mm as shown in Fig. 3. The focal plane of Suprime-Cam is covered by an 5$\times$2 array of 2k$\times$4K CCDs. IDs of the CCDs are also shown in Fig. 3 so that we can work out which position comes on which CCD.

To measure the transmittance curve at one position, it takes about five and ten minutes for NB filters and IB one’s respectively. At long wavelengths, i.e., λ >8000 Å, sensitivity of UV3100pc is very low. Therefore when we measure the filters used in this wavelength region, we repeat the measurements 3∼5 times at each position to increase the S/N ratio of the transmittance curve.

The measured data are sent to the control PC of UV3100pc and the transmittance curves at the 13 positions are plotted. Some examples are shown in the next section.

4. Transmittance Curves of Several NB/IB filters

Our specifications on the uniformity of CW, BW, and T_{peak} for the NB/IB filters are the followings,

- The differences in CW and BW from the respective targeted values should be less than 0.25% of the targeted central wavelength over the clear aperture. (e.g., 5985 Å$<CW<$6015 Å and 185 Å$<BW<$215 Å are acceptable for a filter with targeted values of CW=6000 Å and BW=200 Å.)
- $T_{peak}(min)$ should be larger than 70%, where $T_{peak}(min(max))$ means the minimum(maximum) value among the 13 measurements.
- $T_{peak}(max)$-$T_{peak}(min)$ should be less that 10%. (e.g., a filter with $T_{peak}(max) = 80\%$ and $T_{peak}(min) = 70\%$ is acceptable, while one with $T_{peak}(max) = 85\%$ and $T_{peak}(min) = 70\%$ is out of specifications.)

We show in Fig. 4 transmittance curves for seven NB filters, NB497, NB503, NB660, NB704, NB711, NB816, and NB921, together with five IB filters. They all satisfy the specifications. As shown in Fig. 4, transmittance curves for each NB filter exhibit sharp rising and IB filters have rectangular bandshapes in spite of the fast F ratio of F/1.9. It is also remarkable that all filters have few ripples in the plateau.

We have measured about thirty NB/IB filters which were already manufactured up to the present. During the course of our characterization process, a few filters turned out to be out of specifications. They were returned to the manufacturer and a new one was manufactured. Thus, this system has been found to play an important role to maintain performance of Suprime-Cam filters. Many kinds of unique surveys using custom made NB/IB filters will be carried out at the Subaru prime focus in future. We can now assure of the quality of Suprime-

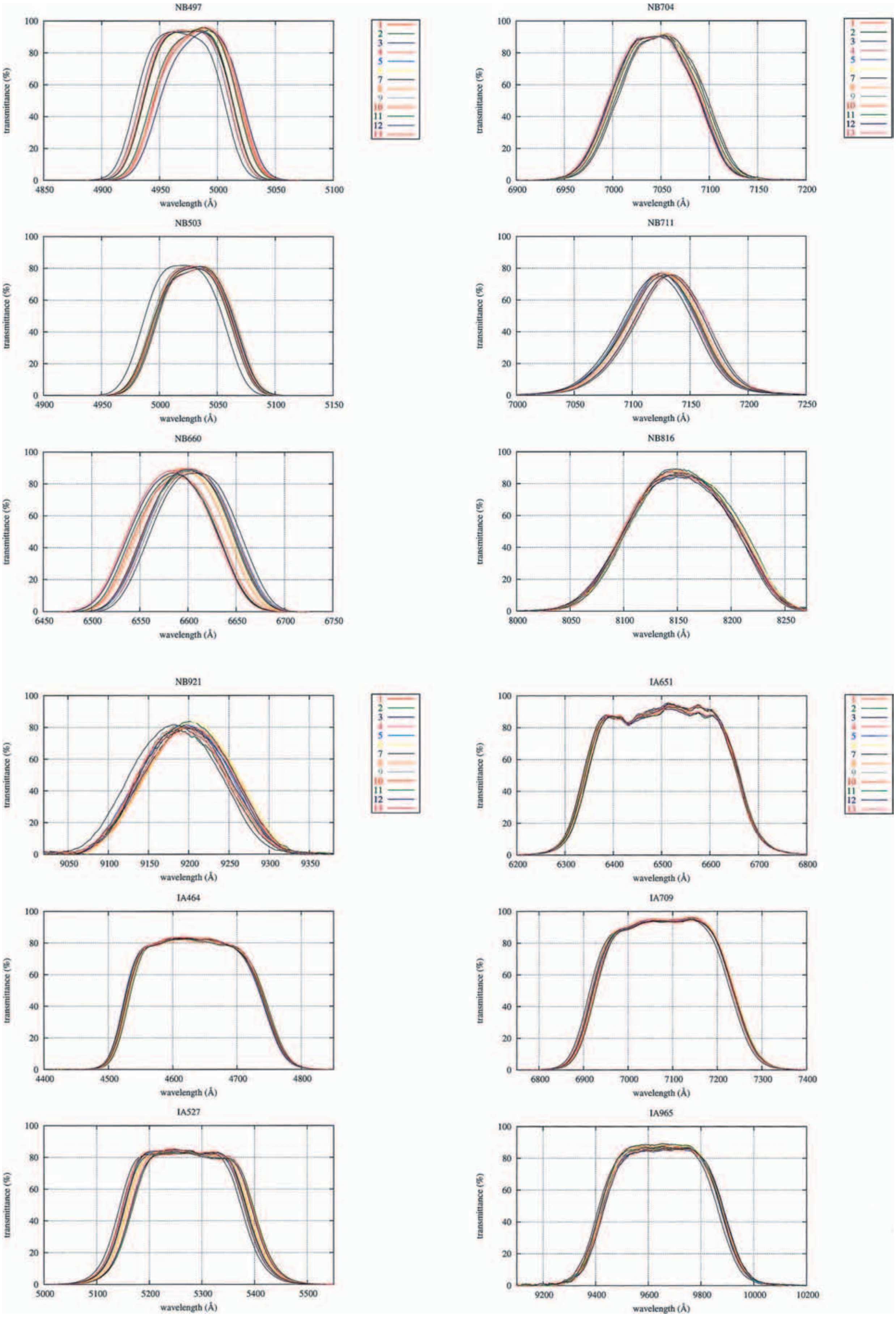


Fig. 4. Transmittance curves of NB497, NB503, NB660, NB704, NB711, NB816, NB921, IA464, IA527, IA651, IA709, and IA965 measured by our characterization system.

Cam filters by introducing this characterization system.

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