Date: September 7, 2015 Prepared by Kaye Vergel
Title: Diwata's Payload Calibration
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Timeline: 3/09/2015 - 4/09/2015: Initial Calibration
14/09/2015 - 15/09/2015: Re-measurement of HPT and SMI values

I. Introduction

The objective of this activity is to obtain the calibration constant that converts digital number to radiance. To do this we used the integrating sphere at the National Institute of Polar Research. The integrating sphere at NIPR has a radiance of 30 [$\mu W/m^2$/sr/nm] at 630 nm. Inside the integrating sphere, the radiance is constant.

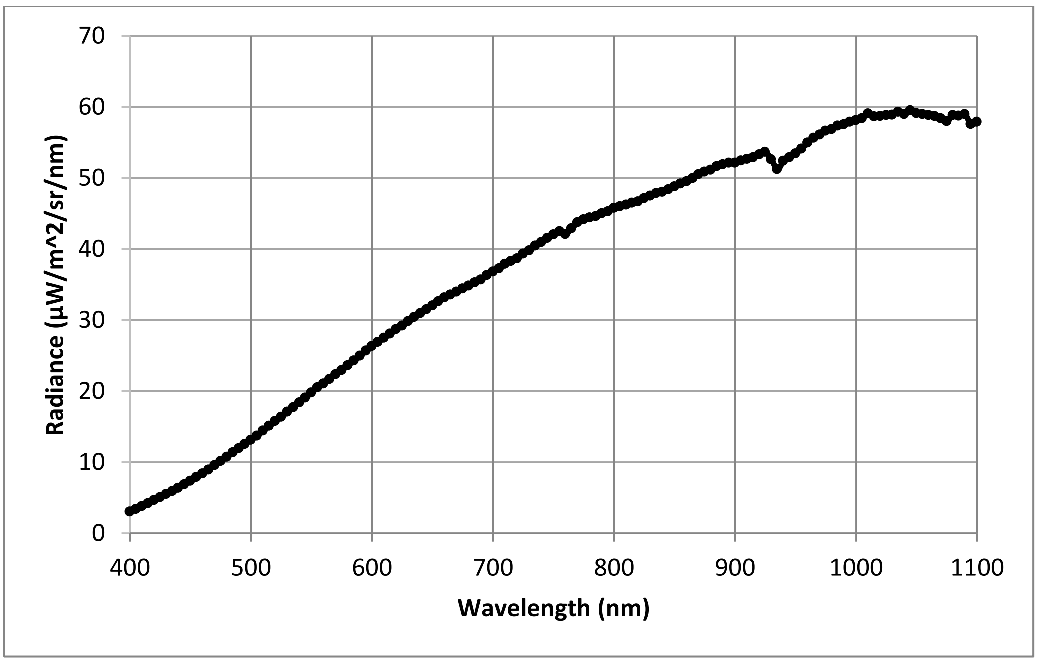


Figure 1. Radiance inside the integrating sphere

The calibration constant is given by the equation,

$$C(\lambda) = \frac{L(\lambda)}{DN*exposure\ time} \quad (1)$$

where:

$C(\lambda)$ *is the calibration constant at the specific wavelength*
$L(\lambda)$ *is the radiance at the specific wavelength*
DN is Digital Number

The calibration constant also varies with gain. Hence, images obtained at the same exposure time and wavelength but different gain values would have different calibration constants.

Therefore, we have to get images of the payload at different gain values. There is a wide range of gain values that can be used and it is time consuming to take images of all the possible values. Fortunately, we expect that there is a linear relationship between radiance and gain. Thus we can just get images at different gain values.

II. Procedure

A. HPT, WFC and MFC

The procedure done for obtaining the calibration constants for the three cameras, HPT, WFC and MFC are similar. For HPT, the following camera parameters were set.

Table 1. Gain and shutter speed values used in order to derive the calibration constants for HPT

Gain	Gain dB	Gain (amplitude ratio)	Shutter speed (V)	Shutter speed (s)
256	6	2.0	512	17.09
384	12	3.98	256	8.54
512	18	7.94	128	4.27
640	24	15.85	64	2.14
768	30	31.62	32	1.07
896	36	63.1	16	0.53
1023	41.95	125.21	8	0.27

The SCU emulator needs gain inputs in dec. Convertion from dec to decibel is given by Equation 2,

$$Gain[dB] = \frac{(Gain[dec] - 128)}{128} * 6 \qquad (2)$$

Equation 3 gives the conversion from decibel to amplitude ratio,

$$Gain[dB] = 20log_{10}(Amp) \qquad (3)$$

$$Amp = \frac{V_{out}}{V_{in}} \qquad (4)$$

$$Amp = 10^{\frac{Gain[dB]}{20}} \qquad (5)$$

The shutter speed is also given in dec in the SCU emulator. There are two speed types for the shutter speed: (1) normal speed; (2) double speed. Similarly, there are two modes, V and H modes. Normal speed in V and H modes are given by,

$$shutter\ speed[s] = shutter\ speed_{V\ mode}[dec] * 0.3337 \qquad (6)$$

$$shutter\ speed = (524 - shutter\ speed_{H\ mode}[dec]) * 6.356x10^{-5} + 3.97x10^{-5} (7)$$

Double speed in V and H modes are given by,

$$shutter\ speed[s] = shutter\ speed_{V\ mode}[dec] * 0.01668 \quad (8)$$

$$shutter\ speed = (524 - shutter\ speed_{H\ mode}[dec]) * 3.178x10^{-5} + 3.97x10^{-5} (9)$$

Images for the red, green, blue and near-infrared CCDs were taken using the parameters given by Table 1. The Data Processing Unit (DPU) used in taking images is that of Riseat. The DPU of Diwata is not yet available by the time that we were doing the calibration. Hence, we took images for each CCD of the HPT. The DPU of Riseat is not capable of taking images all at one.

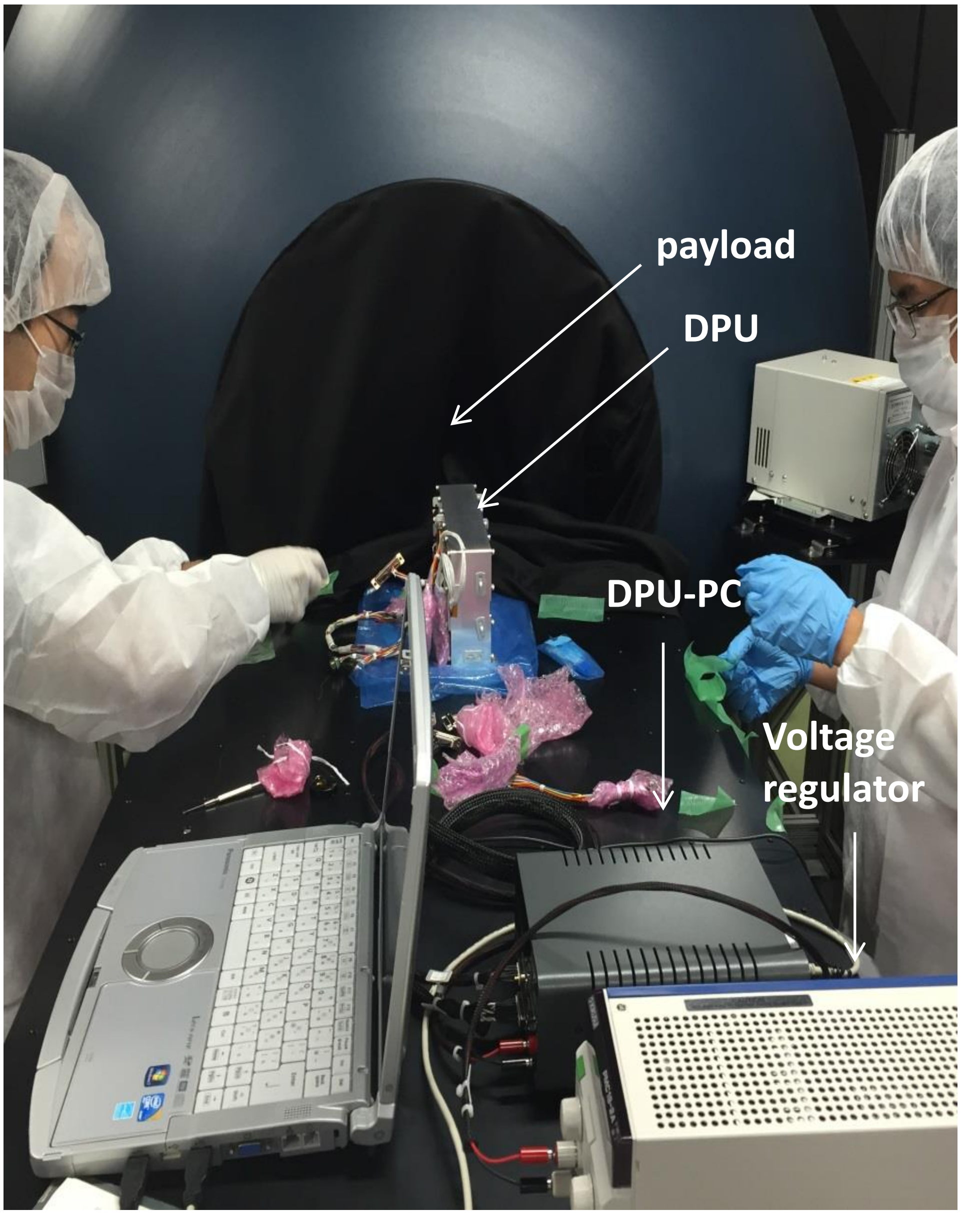


Figure 2. Calibration set-up

The following are the exposure-time-normalized vs gain curves obtained for each CCDs of the HPT.

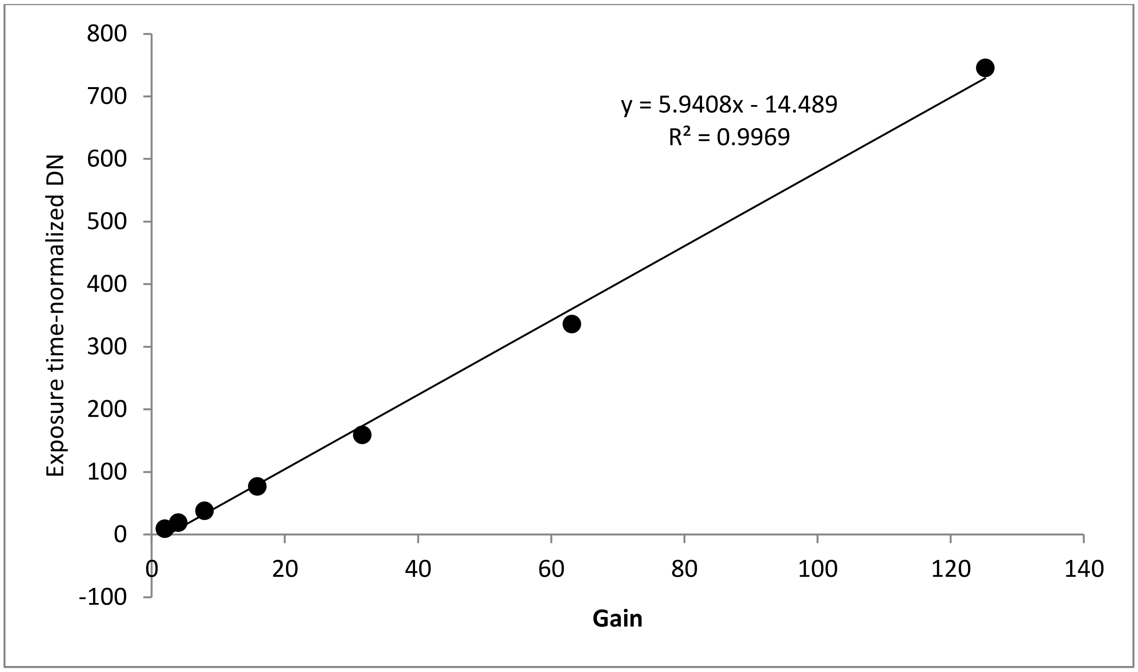


Figure 3. Exposure-time-normalized DN vs gain curve for the green CCD

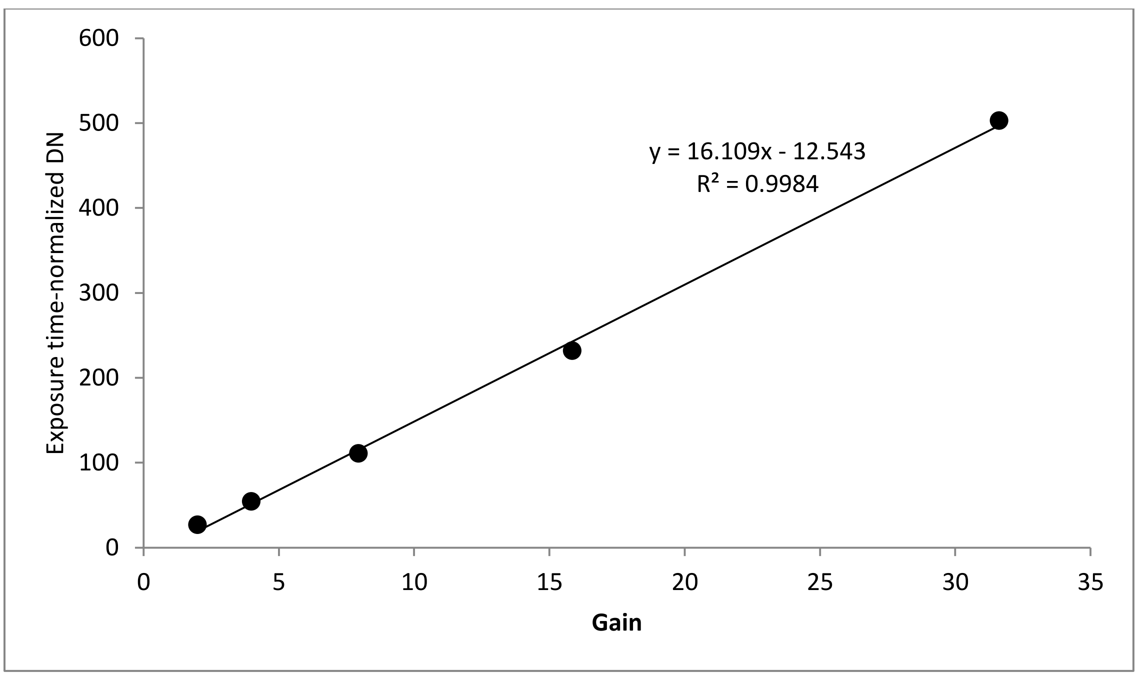


Figure 4. Exposure-time-normalized DN vs gain curve for the NIR CCD

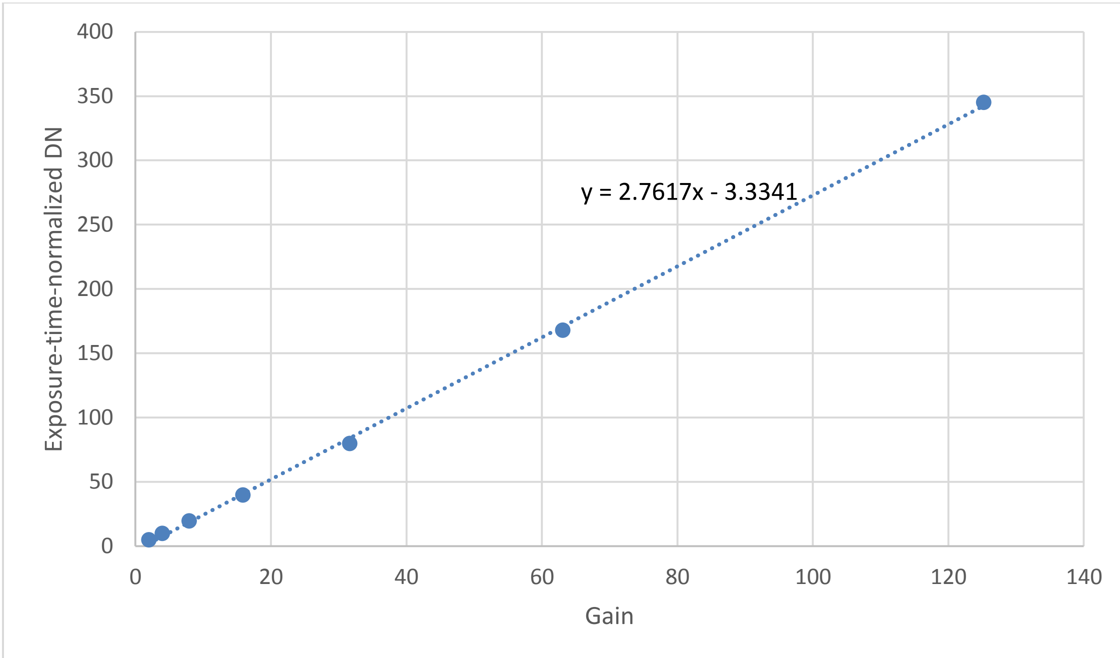


Figure 5. Exposure-time-normalized DN vs gain curve for the red CCD

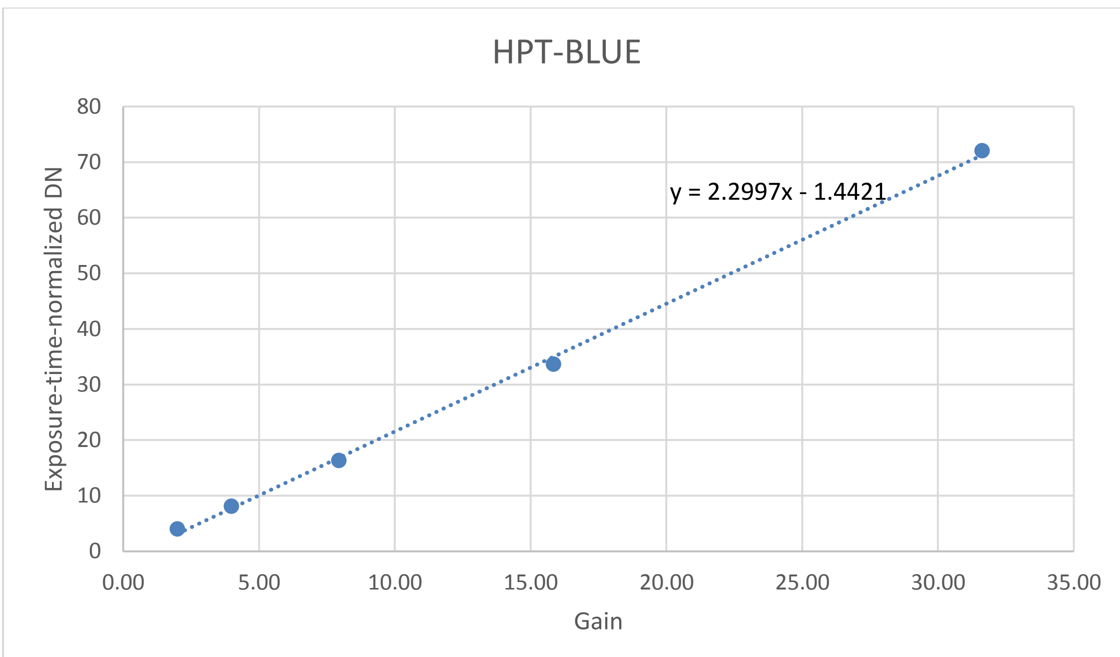


Figure 6. Exposure-time-normalized DN vs gain curve for the blue CCD

One can observe that the maximum gain values for all the CCDs are not the same. This is because we excluded the high gain points which make the plot non-linear. As the gain increases, the noise in the image also increases. The non-linearity of the curve when these points are included is due to the noise present in the image.

To get the digital number in an image, the average DN in a rectangular area located in the center of the image was used. The digital number is normalized by the exposure time because the exposure time changes as the gain is changed. As the gain increases, we had to decrease the exposure time in order for the image to not be over-exposed or under-exposed.

For the WFC and MFC, the parameters of the camera used are also the same as shown in Table 1. The exposure-tme-normalized DN vs gain curves are given by the following figures.

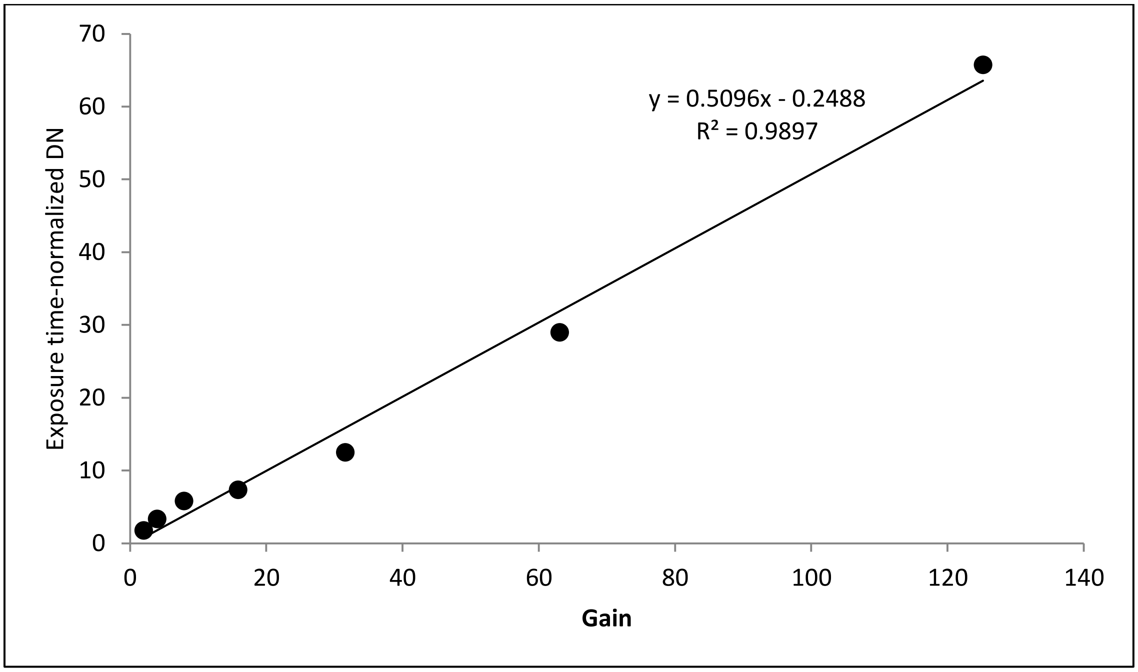


Figure 7. Exposure-time-normalized DN vs gain curve for the MFC

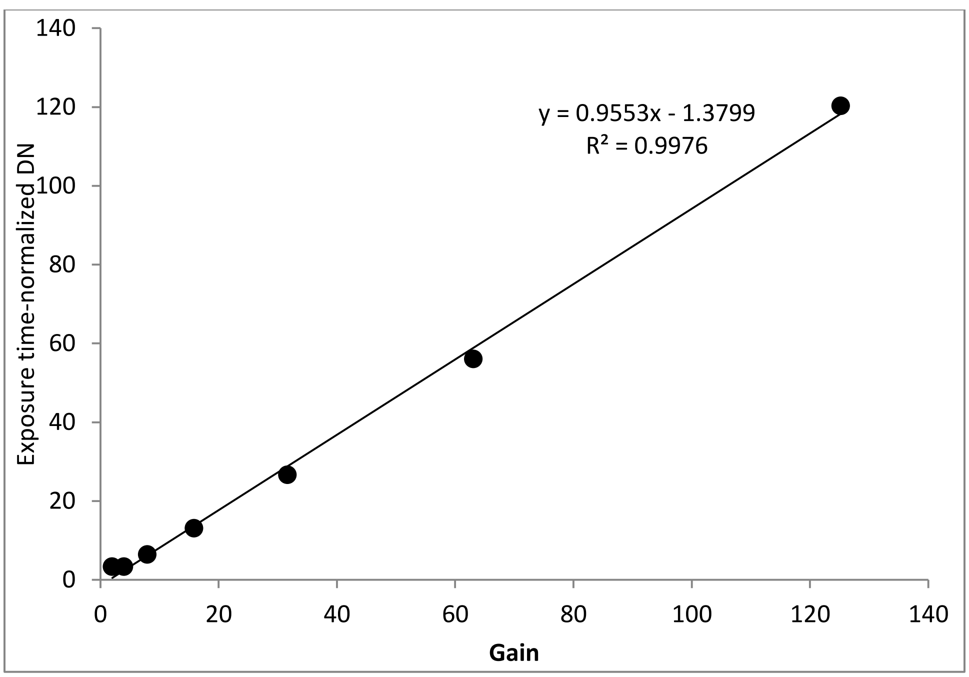


Figure 8. Exposure-time-normalized DN vs gain curve for the WFC

B. SMI with LCTF

For the SMI, aside from getting the curve for the gain, since there are two LCTF for visible (430 – 730 nm) and near-infrared (720 – 1020 nm) channels, we had to take images for each wavelength. This is because the calibration constant as given in Equation 1 is dependent on the digital number so we need to get images at a 1 nm interval.

Table 2. Gain and shutter speed values used in order to derive the exposure-time-normalized DN vs. gain curve for SMI-NIR.

Wavelength (nm)	Gain	Gain dB	Gain (amplitude ratio)	Shutter speed (V)	Shutter speed (s)
730	256	6	2.00	512	17.09
730	384	12	3.98	512	17.09
730	512	18	7.94	512	17.09
730	640	24	15.85	128	4.27
730	768	30	31.62	64	2.14
730	896	36	63.10	64	2.14
730	1023	41.953125	125.21	32	1.07

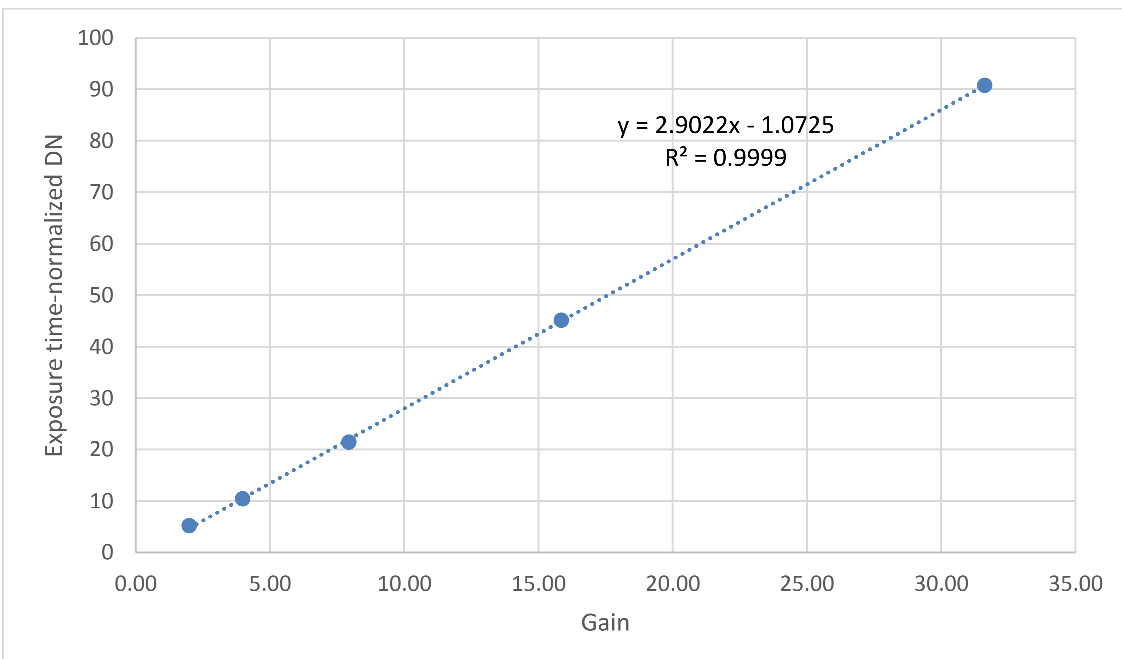


Figure 9. Exposure-time-normalized DN vs gain curve for the SMI-NIR

Table 3. Gain and shutter speed values used in order to derive the exposure-time-normalized DN vs. gain curve for SMI-VIS.

Wavelength (nm)	Gain	Gain dB	Gain (amplitude ratio)	Shutter speed (V)	Shutter speed (s)
450	256	6	2.00	512	17.09
450	384	12	3.98	512	17.09
450	512	18	7.94	512	17.09
450	640	24	15.85	128	4.27
450	768	30	31.62	64	2.14
450	896	36	63.10	64	2.14
450	1023	41.953125	125.21	32	1.07

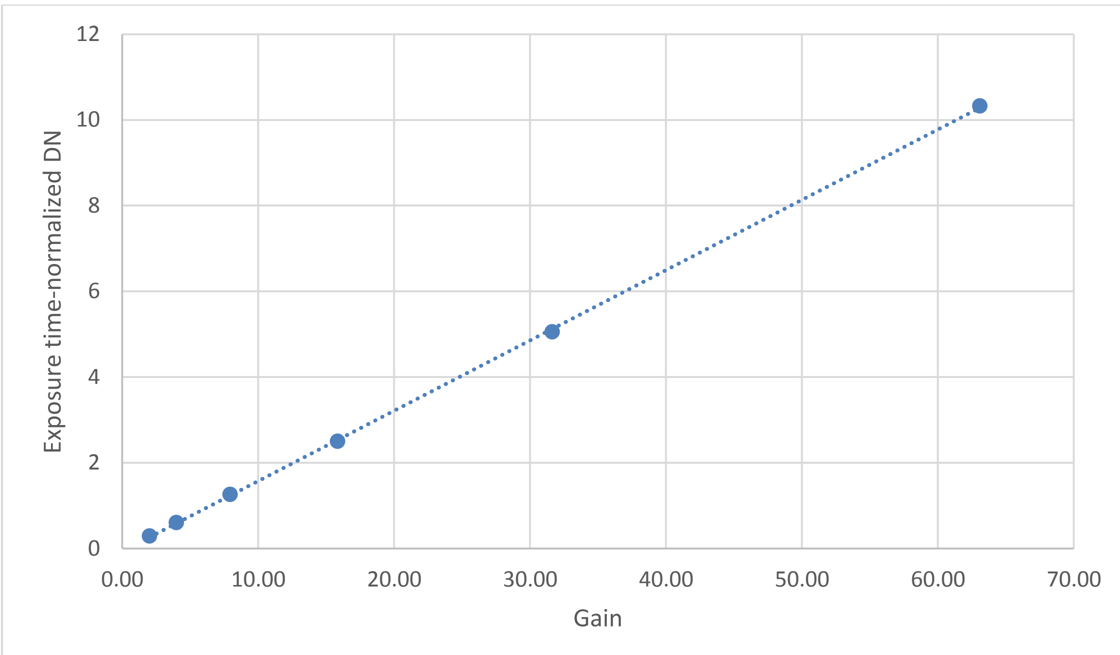


Figure 10. Exposure-time-normalized DN vs gain curve for the SMI-VIS

Below are the obtained curves per wavelength in both visible and near-infrared channels.

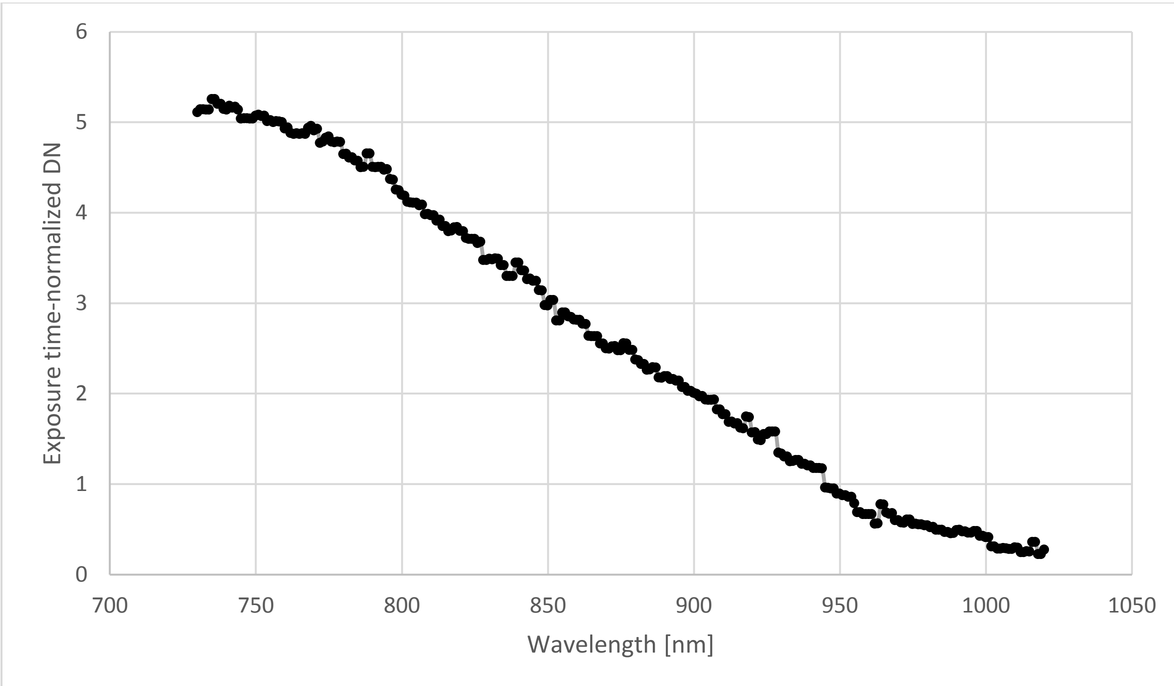
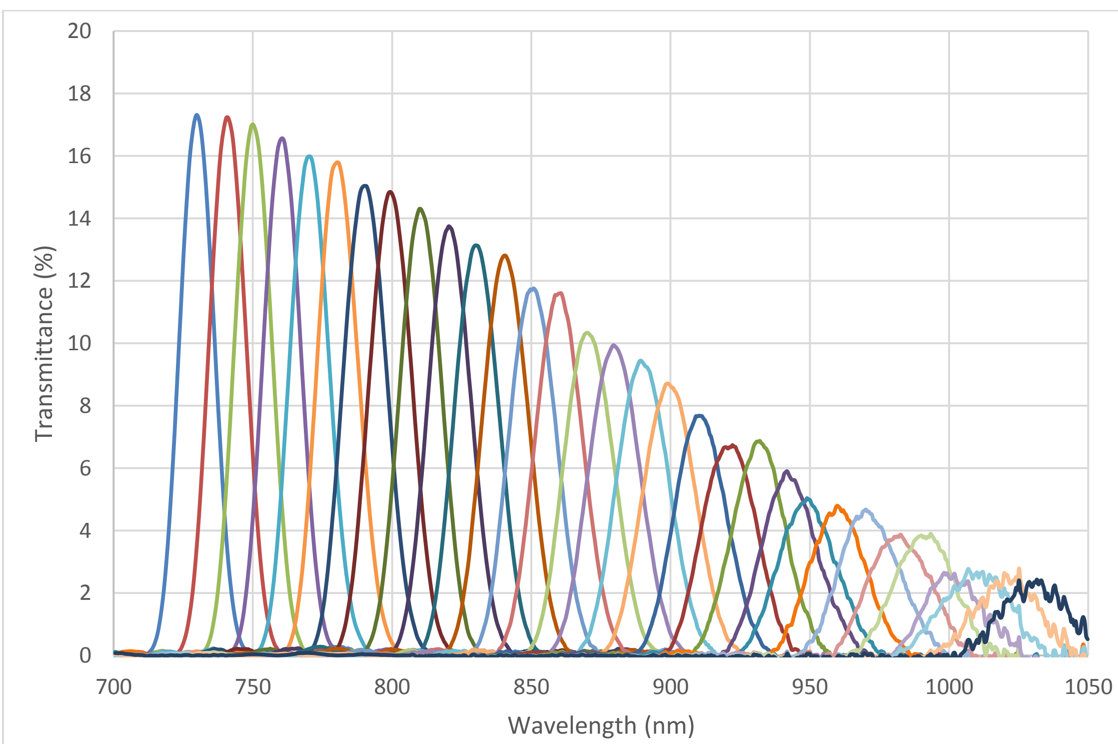


Figure 11. Exposure-time-normalized DN per wavelength taken for SMI-NIR

The curve of Figure 11 is what is expected since we're expecting a curve that is due to the radiance inside the calibrating sphere given by Figure 1 and the transmittance of the LCTF in the near-infrared given by Figure 12.



Fugure 12. Transmittance curve of LCTF in the near-infrared region

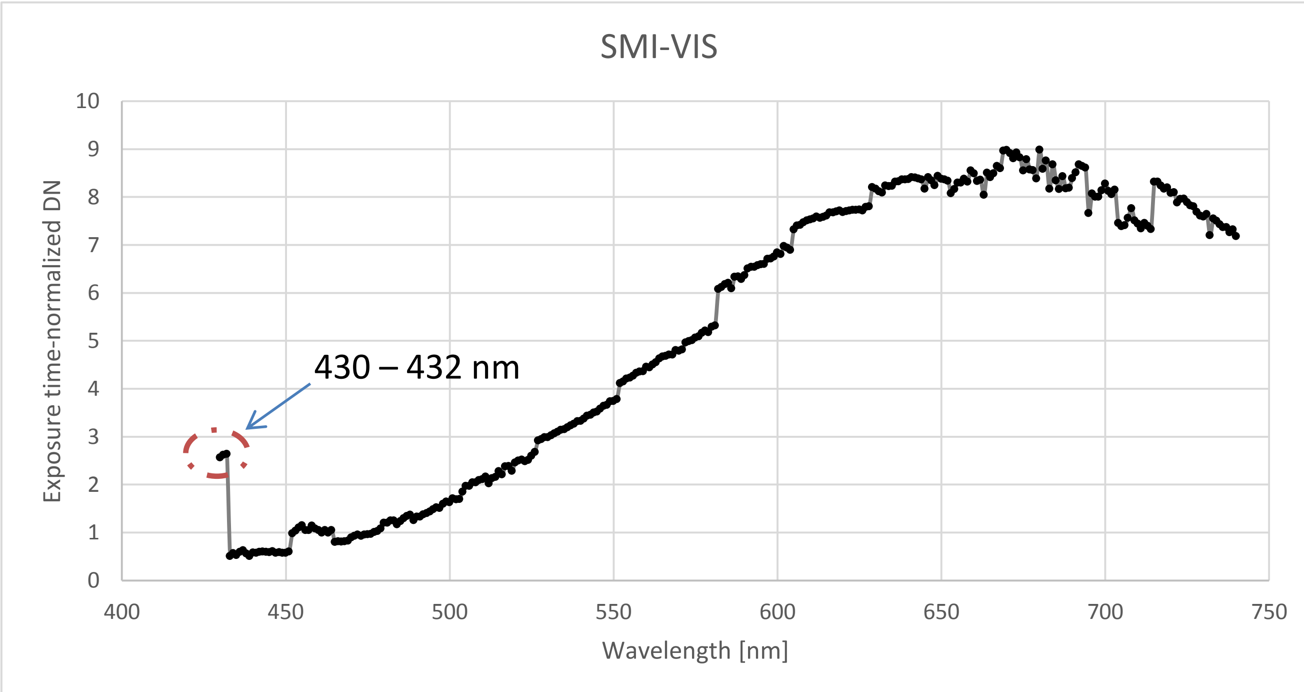
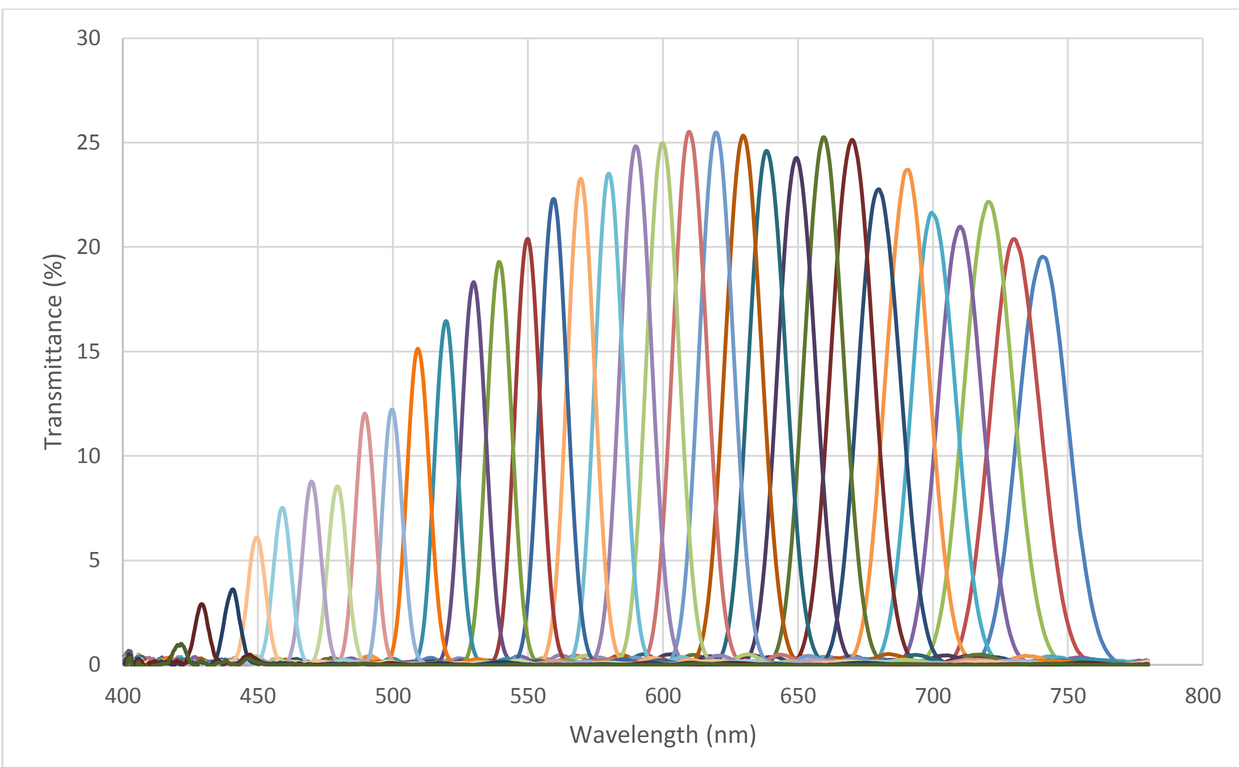


Figure 13. Exposure-time-normalized DN per wavelength taken for SMI-VIS



Fugure 14. Transmittance curve of LCTF in the visible region.

As one can observe in the Figure 13, there are peaks from 430-432 nm. These peaks don't follow the trend that we are expecting. We are not sure of the reason why these wavelengths don't follow the trend but this might be due to the smaller peaks of the filter (430 – 432 nm) in the higher wavelengths. The consequence of this is that we cannot use wavelengths of 430-432 nm.

C. SMI Patterns

Inside the calibrating sphere, we are expecting to observe a near-uniform brightness in the images that we capture. However, for the SMI we observed a wavelength dependent contrast difference.

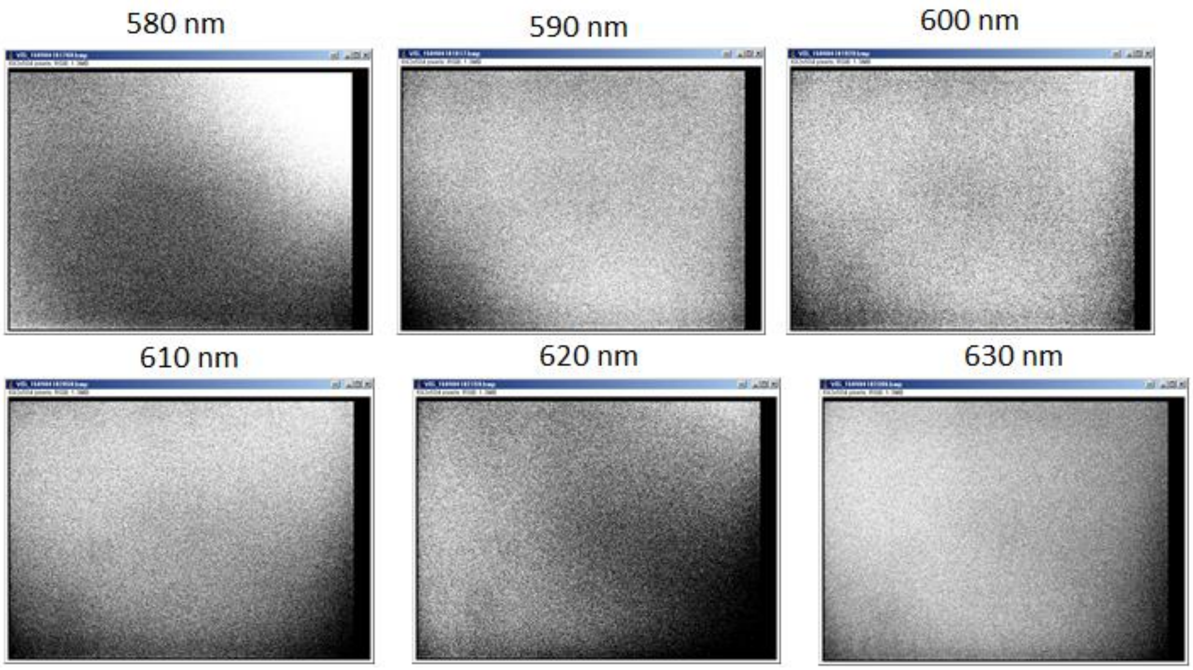


Figure 15. Contrast variation observed in the LCTF in the visible region

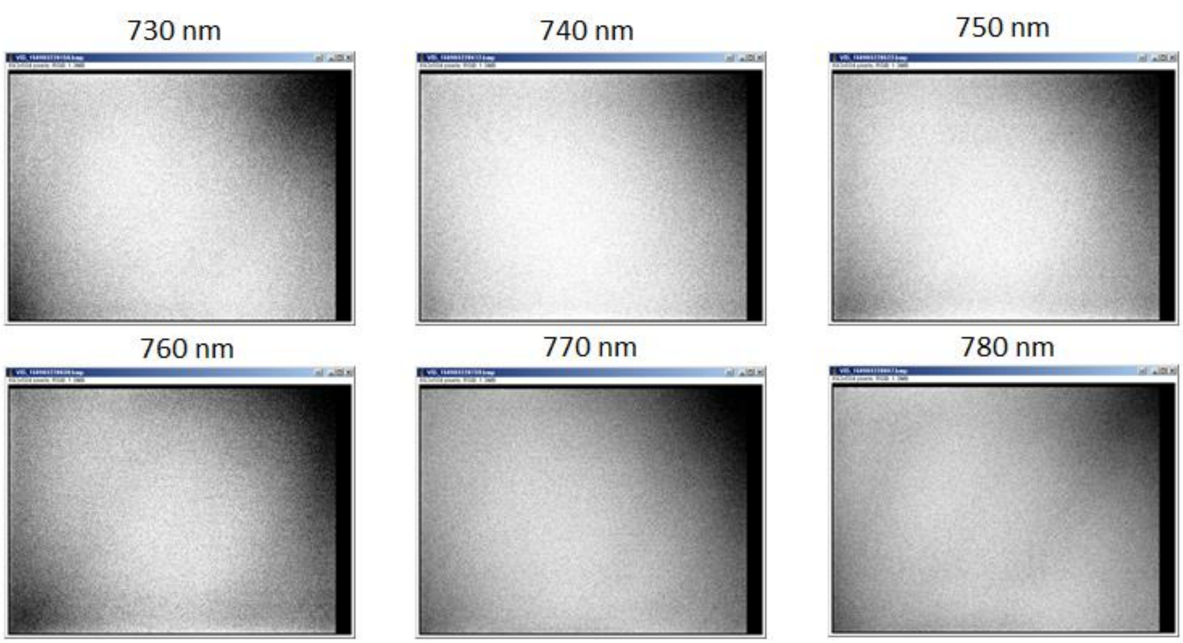


Figure 16. Contrast variation observed in the LCTF in the near-infrared region

As can be observed, the patterns are diagonal. This is a characteristic of the LCTF. The reason for the presence of these patterns is the placement of the LCTF in the SMI. The LCTF is placed before the optical system. Hence the light entering the LCTF is not collimated resulting to the observed patterns.

The implication of these patterns is we have to compensate for these in the post-processing. In order to do that, we are thinking of creating a mask for every wavelength. This mask would have to account for the observed spatial contrast variation.