Pre-Flight Calibration Results of Wide-Angle Polarimetric Camera as an Instrument for DANURI Lunar Orbiter. Minsup Jeong[1], Young-Jun Choi[1, 2], Sungsoo S. Kim[3], Bongkon Moon[1], Chae Kyung Sim[1], Kyung-In Kang[4], BonJu-Gu[4], [1]Korea Astronomy and Space Science Institute, [2]University of Science and Technology, Korea, [3]Kyung Hee University, Korea, [4]Korea Advanced Institute of Science and Technology, Korea (msjeong@kasi.re.kr).

Introduction: The Danuri lunar orbiter, launched on August 5th, 2022, includes the Wide-Angle Polarimetric Camera (PolCam) as one of its onboard instruments. The main objectives of this camera are to obtain polarization data across the lunar surface at two different wavelengths (430 nm, and 750 nm) over a range of phase angles from 0° to 135°, with a spatial resolution of approximately 81 meters, and to acquire a reflectance ratio at 320 nm and 430 nm for the lunar surface with a similar spatial resolution. Polarimetry data can provide information about the grain size, maturity, and porosity of the regolith on the Moon's surface [1, 2]. The ratio of 320 nm reflectance to 430 nm reflectance is useful to estimate the TiO_2 distribution across the Moon.

Table 1 Specifications of PolCam

Field of View	9.9°
GSD	81 m @ 100 km
Swath	35 km @ 100 km
Type of Sensor	CCD
Imaging Pixels	1024 x 6 /camera (Default 512 pixels w/ binning)
filters	320 nm, w/o polarization 430 nm, 0˚, 60˚, 120˚ 750 nm, 0˚, 90˚
# of Camera	2
Mounting Direction	45˚ with respect to nadir in the across-track direction.

Operation Concept: PolCam is a camera system that consists of two push-broom cameras that each have a 9.9° field-of-view centered at 45° from the nadir point, which allows them to view the track of the orbiter to the left and right [3]. It has three color bands: a 320 nm band for photometry and 430 and 750 nm bands for polarimetry. In the 430 nm band, reflectance is measured through three different polarization filters at 0°, 60°, and 120° to determine both the degree and angle of linear polarization. In the 750 nm band, reflectance is measured through two polarization filters at 0° and 90° to determine the degree of linear polarization. These filter combinations minimize the data transfer rate from the orbiter to Earth, assuming that the angle of linear polarization is the same at both the 430 and 750 nm bands. The Danuri orbit passes above both the north and south poles of the Moon at an altitude of 100 ± 30 km during its nominal one-year mission. It takes approximately 2 hours for Danuri to complete one orbit around the Moon. Each orbit shifts longitudinally by about 32.4 km or about 1°.07 at the equator, and the swath of each PolCam camera is approximately 38.9 km (1°.28) at this altitude, resulting in a slightly overlapped area between two sequential orbits.

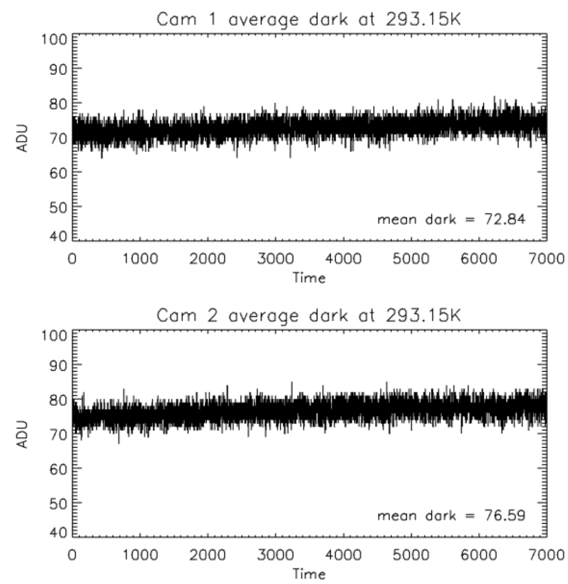

Figure 1 Dark values of PolCam Cam 1 and Cam 2.

Dark current: PolCam periodically captures images of the dark side of the Moon's orbit on a monthly basis in order to consider the impact of high-energy radiation from space, which can gradually change the dark current over time.

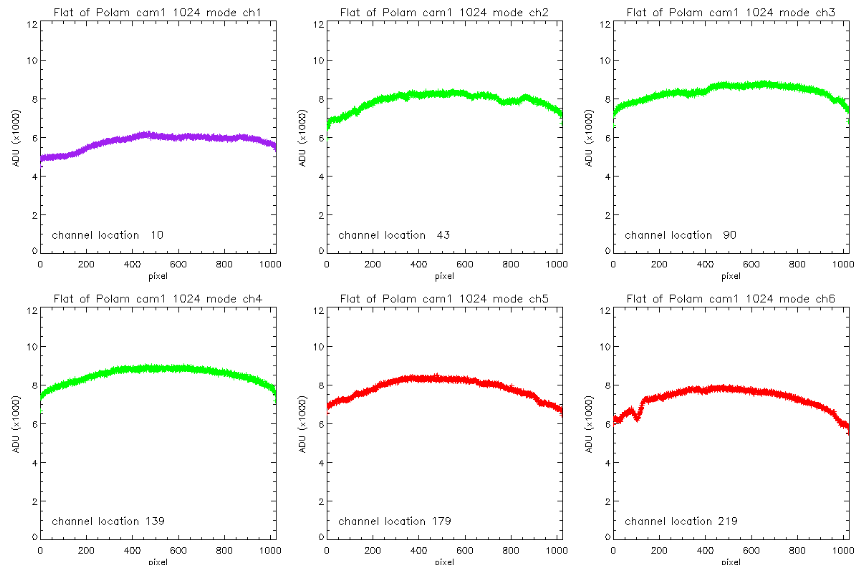

Figure 2 Flat field frame of PolCam Cam 1.

Unlike absolute photometry, polarization observations are less sensitive to dark and bias because they are differential photometry data with the same condition. In addition, the exposure time during PolCam's normal operation ranges from 5.676 msec to 33.66 msec, indicating that the impact of dark is quite small. Figure 1 shows the measurement of PolCam's dark at 293.15K in a vacuum chamber. The average dark value for Cam 1 is 72.84 ADU, while the average dark value for Cam 2 is 76.59, showing a tolerable difference of about 5%.

Flat Field Frame: In general,polarization observations are also relatively insensitive to flat field frames because they are differential observations. However, the observation results can still be affected by flat field frames, especially when using a different observation system than a typical polarization observation with a single optical system, polarizing filter, and sensor. PolCam uses a 2D CCD sensor (1K square) with three band-pass filters and polarizing filters to obtain five combined polarizing images at wavelengths of 320 nm (CH1, w/o polarizer), 430 nm 0° (CH2), 430 nm 60° (CH3), 430 nm 120° (CH4), 750 nm 0° (CH5), and 750 nm 90° (CH6). As a result, the six sets of observation images always have different optical paths and responsivities. In other words, while the optical system is shared, the color filters, polarizing filters, and detectors are all in different situations. Therefore, flat field correction is an important part of the data processing. PolCam's flat field frame was measured in a laboratory by positioning the camera over a collimator connected to a tungsten lamp and an integrating sphere, placed on the entrance pupil of the camera. Tungsten light sources typically have some degree of polarization on their own, but using an integrating sphere can further reduce this. PolCam's flat field frames measured in six channels at the same time are shown in Figure 2. The response of each channel is slightly different due to the different optical paths and responsivities mentioned above.

Focusing: PolCam's focus was adjusted using collimated light in a laboratory setting. After making adjustments, the final FWHM (Full Width at Half Maximum) value was measured to be 1.34 pixels in the center of the image and 1.38 pixels at the edge of the image.

References: [1] Jeong et al. (2015) ApJS, 221:16. [2] Shkuratov et al. 2007, ICAR., 187, 406-416, [3] Sim et al. 2020, PASP, 132:015004