THE RADIATION RESISTANCE OF THE IMAGING SENSOR INSTALLED ON THE MULTI-BAND CAMERA ON SLIM. Y. Nakauchi[1], K. Saiki[2], M. Ohtake[1], H. Shiraishi[1], C. Honda[3], H. Sato[1], Y. Ishihara[4], [1]Japan Aerospace Exploration Agency (3-1-1 Yoshinodai, Sagamihara, Kanagawa 252-5210, Japan; nakauchi@planeta.sci.isas.jaxa.jp), [2]Osaka University, [3]University of Aizu, [4]National Institute for Environmental Studies.

Introduction: **S**mart **L**ander for **I**nvestigating **M**oon (SLIM) project leaded by JAXA aim for "pin-point landing" to 100 meter-order error circle on the Moon. The spacecraft has a ~730 kg wet mass and ~200 kg class dry mass. It will be launched with a Japanese rocket H-IIA in 2021 or 2022. Landing around SHIOLI crater (25.2ºE, 13.3ºS) located in the west of Mare Nectaris is planned. After landing, SLIM project is planning to observe ejector from SHIOLI crater using **M**ulti-**B**and **C**amera (MBC). Based on "Kaguya" observation, there is a high possibility that the mantle material is exposed around SHIOLI crater [1]. Therefore, we expect to estimate Mg# (= Mg / (Mg + Fe) atomic ratio) of lunar mantle materials [2].

MBC is a compact VIS-NIR camera composed of an imaging sensor (Vis-InGaAs), a filter-wheel with 10 band-pass filters, a telephoto optical system, and a movable mirror for panning and tilting (Table 1). The sensor has sensitivity at wavelength from 700 to 1700 nm, which covers the characteristic absorption bands of lunar minerals. The housing of MBC is divided into a camera head unit (MBC-H) and an electric unit (MBC-E), which are connected with a harness cable (Figure 1). In order to estimate Mg# of lunar mantle materials, signal to noise ratio (S/N ratio) of MBC is required 100. However, MBC will be damaged by irradiation of high energy ions such as solar wind ions and cosmic ray during cruising phase. Irradiation of high energy ions is one of the main factors that lowers S/N ratio. We examined the radiation resistance of the Vis-InGaAs imaging sensor to be installed on the MBC.

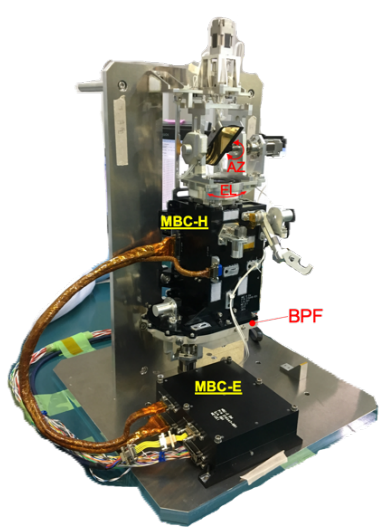

Figure 1) Image of MBC-EM

Table 1. MBC characteristics and performance

Item	Properties
Instrument characteristics	
spectrometer	band pass filters
sensor	Vis-InGaAs imaging sensor
temperature	0ºC ~ 40ºC at the sensor
observable area	~50º in azimuth ~70º in elevation
Observation performance	
wavelength of band pass filters	750 nm, 920 nm, 950 nm, 970 nm, 1000 nm, 1050 nm, 1100 nm, 1250 nm,1550 nm, 1650 nm
band width	30 nm
field of view	4º
spatial sampling	1.3 mm/pixel at 10 m

Experiment and Analysis:

We irradiated proton and heavy ions (Ar, Kr, Xe) to Vis-InGaAs imaging sensor: XFPA-1.7-640_TE1 (Xenics). Ion irradiation was achieved in a vacuumed chamber using Azimuthally-Varying-Field cyclotron and ring cyclotron at Osaka University. The experimental conditions of ion irradiation are summarized in Table 2. Linear Energy Transfer (LET) and stopping range was calculated by using SRIM code [3].

To assess the performance degradation of the sensor, the irradiated dose of proton was increased step by step and the 100 images of dark output were took after each irradiation step. Integrated total dose of proton was 8.68 $\times$ 10^{11} ions/cm^2. The analysis area in each image was 200 $\times$ 100 pixels. When calculating the dark current of each irradiation step, it was averaged the analysis area between 100 images. And to assess the occurrence frequency of single event latch-up (SEL), the dark output was monitored during irradiation of heavy ions.

Table 2. Experimental conditions of ion irradiation

Atom (mass number)	Charge	Energy (MeV)	Irradiation Rate (ions/cm^2/sec)	Total Dose (ions/cm^2)	LET※ (MeV/[g/cm^2])	Stopping Range
H(1)	1+	30	2.39E+08	8.68E+11	4.58E-03	2.83 mm
Ar(40)	17+	487	1.39E+11	7.53E+10	3.33E+00	110.81 um
Kr(86)	15+	250	1.25E+11	1.42E+11	4.29E+01	23.86 um
Xe(132)	23+	384	1.99E+08 ~2.08E+08	1.47E+11	9.47E+01	24.77 um

※ LET: Linear Energy Transfer

Result and Discussion: Figure 2 shows the average of dark current between 100 images and the standard deviation. The average of dark current in the analysis area increases with proton irradiation. After the proton irradiation of 8.68×10^{11} ions/cm^2, the average of dark current increased by 17 % compared to before proton irradiation. Considering the damage to the sensor based on Non Ionizing Energy Loss (NIEL), the amount of damage by that dose of proton is about seven times larger than the expected damage that the sensor of MBC will receive during the mission period. The average of dark current increase only 1.3 % with the amount of expected damage during the mission period. In Figure 3, we compared the dark current before and after proton irradiation. The dark current, which was increased by proton irradiation, decreased to the same level as before irradiation. This result suggest that the increase in dark current during proton irradiation was mainly caused by a temporary increase in leakage current in the sensor. On the other hand, during irradiation of heavy ions, no single event such as SEL occurred. These results indicate that the S/N ratio of MBC is not largely decreased by irradiation of solar wind and cosmic ray.

Conclusion: In this study, in order to investigate the radiation resistance of the Vis-InGaAs imaging sensor to be installed on MBC, we irradiated proton and heavy ions to the sensor. The increase in dark current due to proton irradiation was 1.3 % during actual the mission period. SEL due to irradiation of heavy ions was not occurred. It is indicated that the S/N ratio of MBC is not largely decreased by irradiation of solar wind and cosmic ray during SLIM mission period.

References:[1] Ohtake M. et al. (2019) 50th LPSC abstract #2342. [2] Saiki K. et al. (2020) 51st LPSC abstract. [3] Ziegler J.F. et al. (2010), Nuclear Instruments and Methods in Physics Research 268 (11-12), 1818-1823.

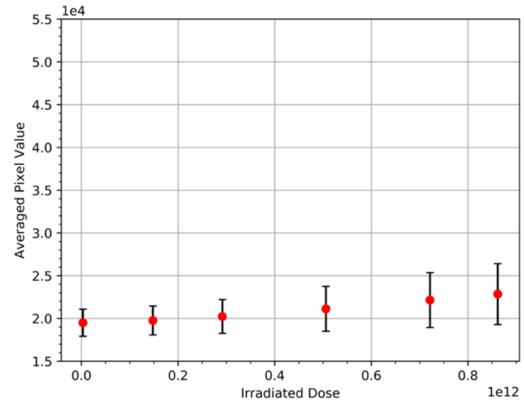

Figure 2) Averaged of dark current in analysis area against irradiated dose of proton. Error bar is standard deviation (1σ) of dark current between each image.

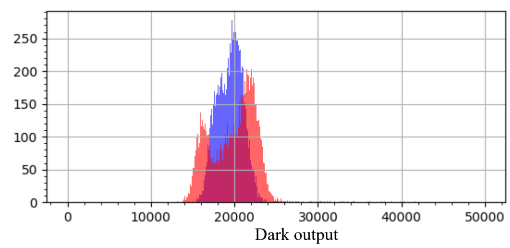

Figure 3) Dark current histogram of each pixels in analysis area. Blue is before irradiation and Red is after irradiation.