TID and SEE Response of the COTS LI-OV9712-USB-M8 Camera

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The LI-OV9712-USB-M8 camera was studied using low dose rate ^{60}Co irradiation and 105 MeV proton beams. Results revealed the camera presented high robustness against total ionizing dose but failed rapidly in proton irradiation.

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Abstract— **Performance degradation of the LI-OV9712-USB-M8 Camera was studied using a low dose rate ^{60}Co chamber and 105 MeV proton beams. Results revealed the camera present high robustness against total ionizing dose, however, failed rapidly in proton irradiation.**

Index Terms—**Total Ionizing Dose, ^{60}Co, Single Event Effect, Proton beam, COTS camera**

I. Introduction

ROBUST telemetric information and visual data have become an essential aspect to ensure accurate system monitoring and proper execution of robotic systems in space-based activities [1-4]. Visual information brings the possibility of having direct and concise information about execution of any mechanical device, and contrary to sensors, information can be obtained without requiring complex wiring or processing [5, 6].

The development of terrestrial devices makes commercial-of-the-shelf (COTS) cameras a suitable, inexpensive, and lightweight alternative for space environment. COTS cameras can be employed in somemonitoring tasks without compromising performance. However, due to the radiation in space environments, radiation assurance qualification of the COTS camara device is required to ensure optimal functionality [4-8].

Radiation in space can produce long term effects, including gradual functional degradation or even complete failure. Long term radiation effects are due to total ionizing dose (TID), are usually emulated at the ground level using high energy photons such as gamma rays from ^{60}Co sources [9]. Energetic particles in space can also generate transient effects presented as glitches in the normal functionality of a device. High energy particle beams, such as protons, are a common approach used to investigate SEL, SEU and SET caused by radiation [10][11].

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This work is dedicated to evaluating the long- and short-term effect of radiation on a COTS USB Camera. A low dose rate ^{60}Co chamber was used to emulate the total dose acquired in the space environment. In addition, a 105 MeV proton beam was used to test the single event effects response of the DUT.

II. Device under testing overview

Fig. 1. COTS LI-OV9712-USB-M8 Camera [13]

The DUT in this study is the COTS LI-OV9712-USB-M8 Camera shown in Fig 1. The specifications of this camera developed by Leopard Imaging are presented in Table I [13].

TABLE I
LI-OV9712-USB-M9 Camera specifications

Dimensions	22mm x 19.5mm x 14.7mm
Weight	2g
Supply Voltage	5V
Max Current consumption	140mA
Op Temperature	-20°C to 80°C
Lens	M8
F number	2.5
Focal Length	2.35mm

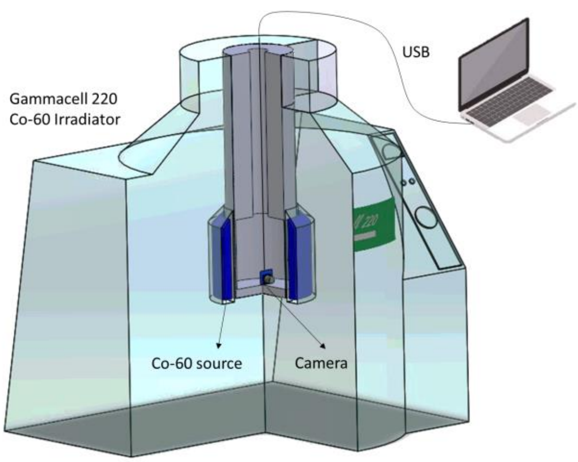
This camera offers an adjustable lens with shortest focus of 5mm, and comes with an OmniVision OV9712 sensor, and the communication interface is offered via USB 2.0 [13].

III. Total Ionizing Dose experiments

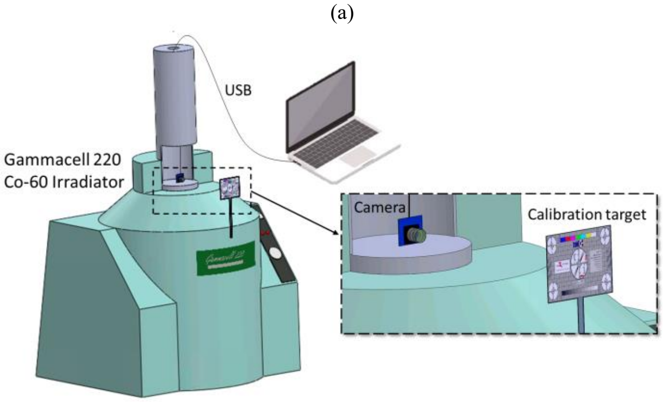
The Total Ionizing Dose effects experiments were studied using a low dose Cobalt-60 chamber located at the University of Saskatchewan. This Gammacell 220 shown in Fig. 2 has a dose rate of 2.51 rad/min. The target dose for this experiment was set to 120 krads. Two different setups were employed on this experiment aiming to find a relationship between percentage of hot pixels in dark images and color degradation caused by the total accumulated dose.

Fig. *2*. Low dose Co-60 chamber at the University of Saskatchewan.

The percentage of hot pixels was studied by taking pictures in complete darkness, while the DUT was placed inside the Cobal-60 chamber as shown in Fig 3a.



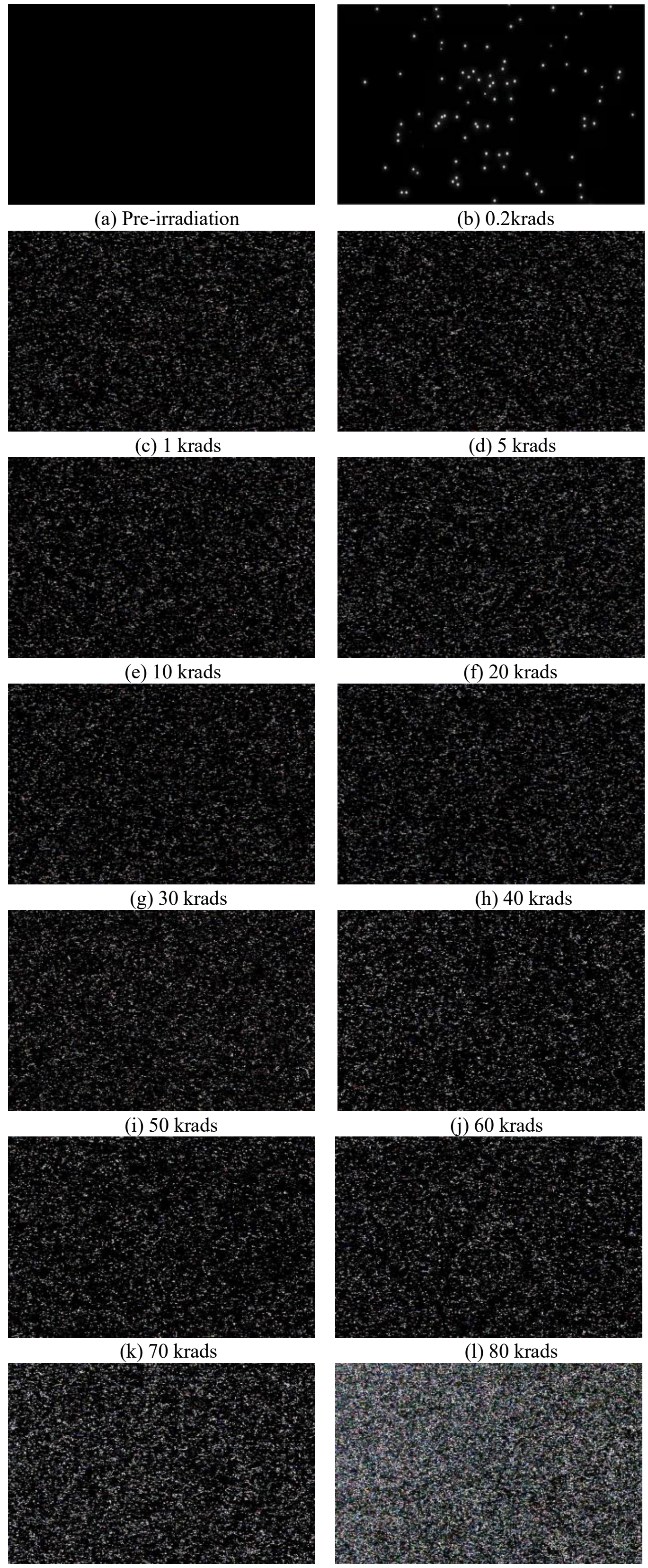
(a)



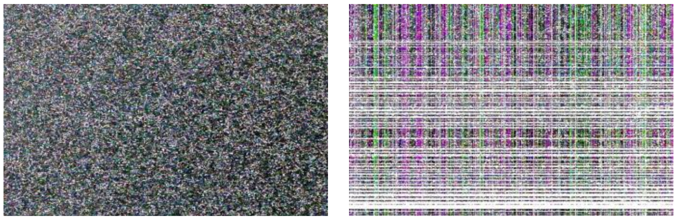
(b)

Fig. *3*. TID experiments setup for (a) hot pixels generation (full darkness), (b) Color degradation.

The response of the selected COTS camera along the TID experiment is presented in Fig. 4. A review of the test data showed a small degradation of individual pixels is produced from doses around 0.2 krads. This pixel degradation increases the leakage current which appears as hot pixels. As the total dose increased, the number of hot pixels is also increased, and hence the percentage of white spots in the dark image also rises.



(a) Pre-irradiation (b) 0.2krads
(c) 1 krads (d) 5 krads
(e) 10 krads (f) 20 krads
(g) 30 krads (h) 40 krads
(i) 50 krads (j) 60 krads
(k) 70 krads (l) 80 krads
(m) 90 krads (n) 100 krads



(o) 110 krads (p) 120 krads

Fig. *4*. Hot pixels generated on dark images caused by accumulated dose, images captured using COTS LI-OV9712-USB-M8 Camera

However, for doses above 90 krads, it is evident that the long exposure to radiation clearly altered the dark image. Fig. 5 depicts the relation between the percentage of hot pixels and the total dose increases.

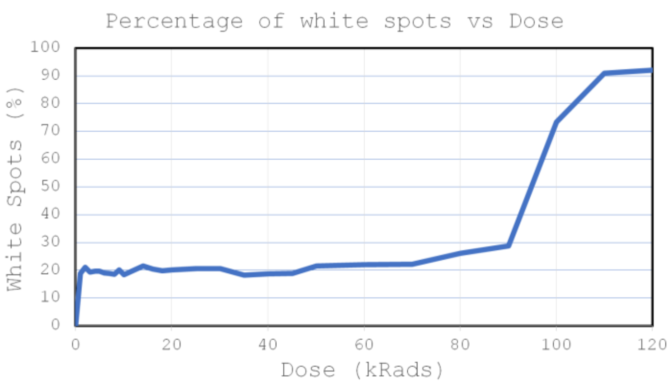


Fig. *5*. Percentage of hot pixels vs Dose in dark pictures captured using the COTS LI-OV9712-USB-M8 Camera

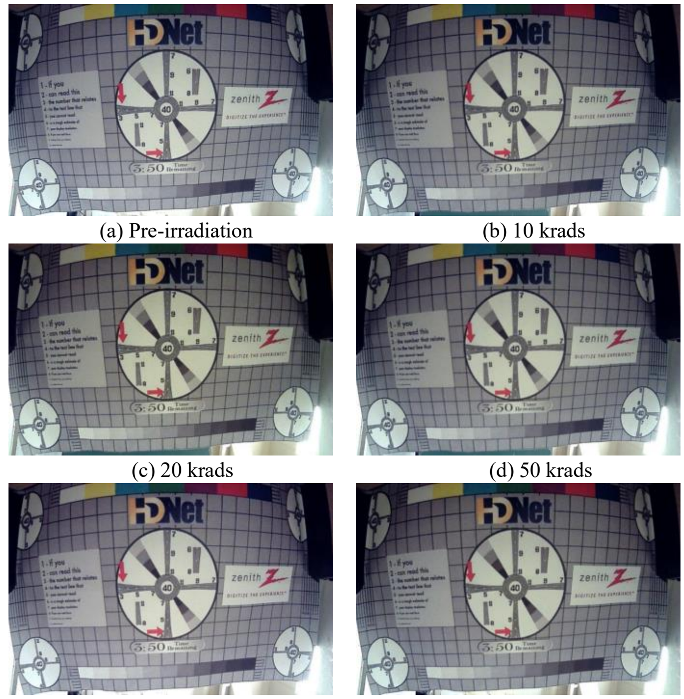
Upon reviewing the images, a very slow increase in the number of hot pixels in the dark image for doses between 1k and 80 krads, and beyond that point the number of hot pixels increases exponentially.

However, for doses above 90 krads, it is evident that the long exposure to radiation clearly altered the dark image. Fig. 5 depicts the relation between the percentage of hot pixels and the total dose increases.

To characterize the color image degradation (picture quality degradation), the DUT was temporarily removed from the radioactive environment, thus the selected camera was fixed inside the cavity of the Gamma cell, so that it can be easily removed from the radiation without changing its position with respect to the target object. As shown in Fig 3b the target calibration objective was placed at about 30cm from the camera.

Images presented in Fig. 6 reveal that there is no significant visual degradation of the color or quality of the images captured up to 95krads dose. Moreover, these pictures help to confirm that as stated before, for accumulated doses below 95 krads there is no presence of dead pixels and all the fixed pattern noise found in the dark pictures can be attributed to increase of the leakage current causing hot pixels.

The current consumption of the DUT was tracked along the experiment, results are presented in Fig. 7 showing there is no change in current consumption vs. dose, and the current consumption stays within the device specs.



(a) Pre-irradiation (b) 10 krads

(c) 20 krads (d) 50 krads

(e) 75 krads (f) 95 krads

Fig. *6*. Color pictures captured at different total doses using the DUT.

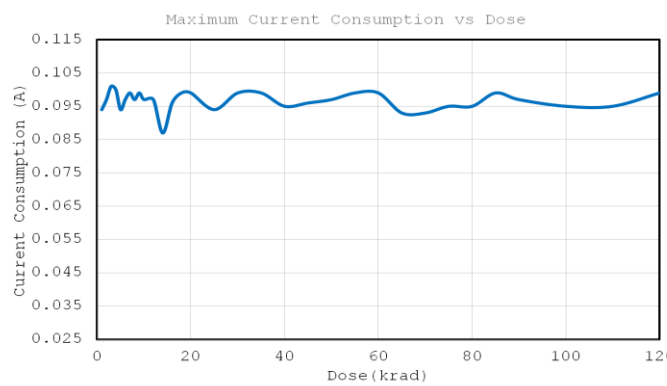


Fig. *7*. DUT current consumption vs total dose.

IV. SEE EXPERIMENTS USING PROTON BEAM

To investigate the SEE response of the DUT, radiation experiments were performed at the TRIUMF Proton Irradiation Facility (PIF) located on the University of British Columbia (UBC) campus. Proton beams with 105 MeV energy and 1 nA current were used to irradiate DUT. An analog/mechanic clock was employed as a moving target so that it was not affected by the interaction with protons. As shown in the setup in Fig. 8, the camera was irradiated from the back so that it can face the moving objective.

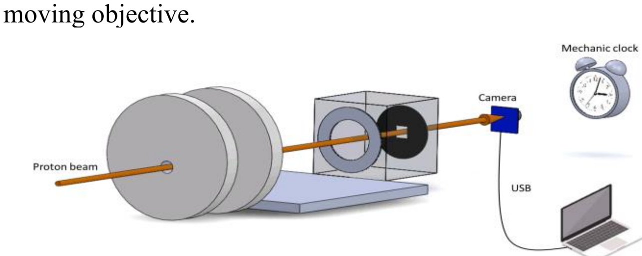
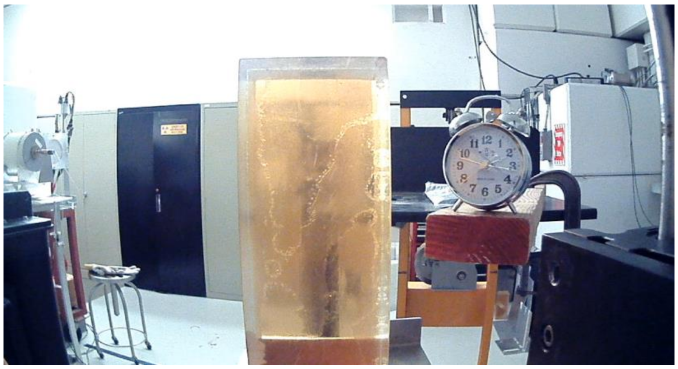


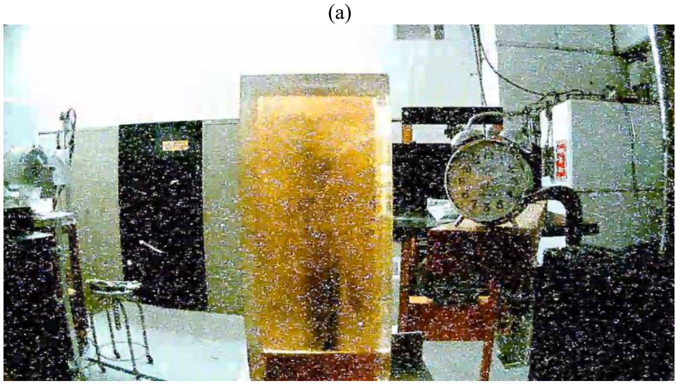
Fig. *8*. SEE experiment setup at TRIUMF for glitch detection on video recording of a moving target.

The selected USB camera was set in video recording mode. The target of this experiment was to detect glitches on the recorded video of the clock. Fig 9 presents some frames extracted from the recorded video.

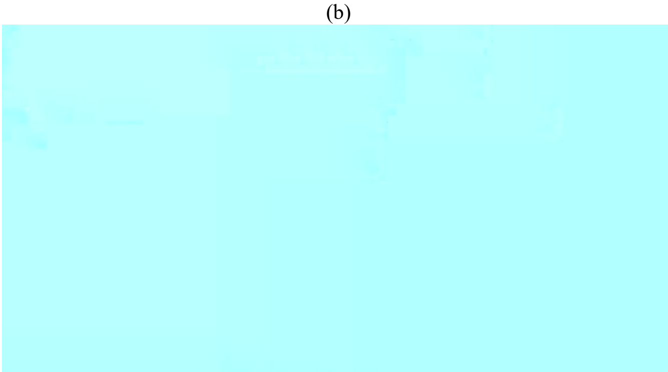
The response of pixels to the protons is shown in Fig 9b. After 6 seconds of the irradiation the connection with the DUT was lost, the current draw measured after irradiation revealed an increased value above the specs. The DUT suffered from a destructive effect caused by the interaction with protons and was not able to recover after irradiation.



(a)



(b)



(c)

Fig. *9*. Frames captured from the video recorded during proton experiment after (a) 0s/pre-irradiation, (b) 3s of irradiation, (c) 6 seconds of irradiation.

V. Discussion and Conclusion

While hot pixels accumulate with TID, the data collected revealed not significant degradation of the image quality of color, in conclusion the camera has a high total dose tolerance. However, when it comes to SEE response, the results revealed that it is quite likely that a component in the camera failed due to the proton interaction causing a destructive latchup.

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