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C30665L CD3740 Displacement Damage and Total Ionizing Dose Test Report

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July 2023

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1. INTRODUCTION

The purpose of this testing is to provide preliminary characterization of the displacement damage and total ionizing dose effects via 63 MeV protons on InGaAs PIN photodiodes fabricated and assembled by Excelitas for use in a LIDAR system. The testing is being conducted to determine the susceptibility of the component to the radiation environment that it will be exposed to during mission duration. The C30665L CD3740 is a custom designed InGaAs PIN photodiode (based upon the C30665EH [1]) that is packaged in a non-hermetic, open cavity QP-QFN28 package with a temporary window.

2. DEVICES TESTED

2.1.Part Background

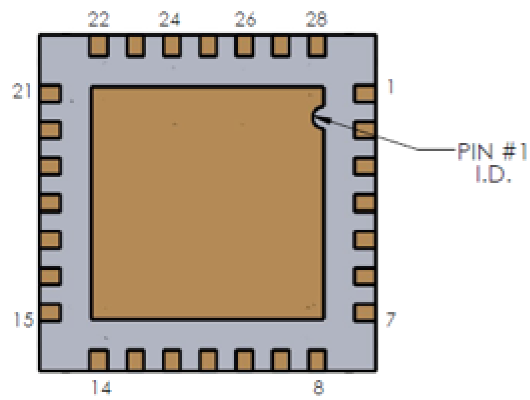
The devices examined in this test report is based on the C30665EH InGaAs photodiode from Excelitas in a custom, hermetically-sealed package. C30665EH is a 3mm diameter active area photodiode that can be operated in a spectral range of 800-1700nm with high responsivity and low capacitance.

Table 1: Part Identification Information

Qty	Part Number	REAG ID	LDC	Package
4	C30665L CD3740	21-029	05/21/20	QP-QFN28

2.2. Device Under Test (DUT) Information

Four engineering test units from the flight lot of C30665L CD3740 were selected for displacement damage and total ionizing dose testing via 63 MeV proton irradiation. The custom device package were mounted to printed circuit boards cut with in-house capabilities (Fig. 1-2). In order to reduce potential parasitic circuit contribution, a two conductive pad configuration was used to electrical contact the multiple pins corresponding to the photodiode anode and cathode. Three devices were mounted on test boards with SMA connectors and one device was mounted to test boards with BNC connectors. One randomly selected device was selected to be the control.



PIN #	Description
1,7,8,14,15,21,22,28	Cathode
24,26	Anode
2-6,9-13,16-20,23,25,27	No Connects

Figure 1: Pin out for C30665L CD3740.

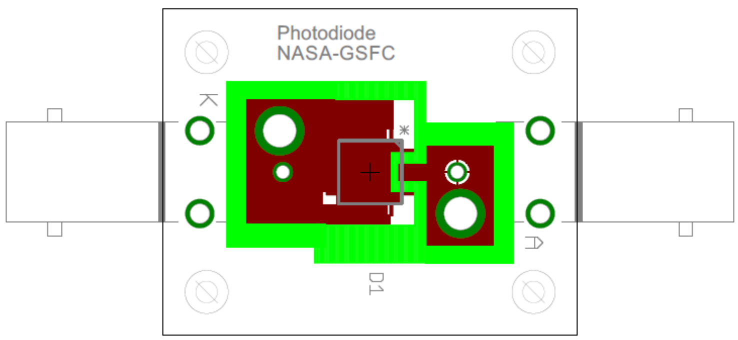


Figure 2: Test board layout. Note this layout is for the board with BNC connector. The test boards with SMA connectors are functionally equivalent.

3. Test Description

3.1. Test Setup

Test boards were attached to a single mounting board to irradiate multiple devices concurrently with consistent placement. Each test board was biased to 7V reverse bias via a power supply and BNC cable to the onboard SMA/BNC connectors (Fig.3). Electrostatic discharge (ESD) procedures were followed during test and transfer of the devices between irradiation chamber and characterization.

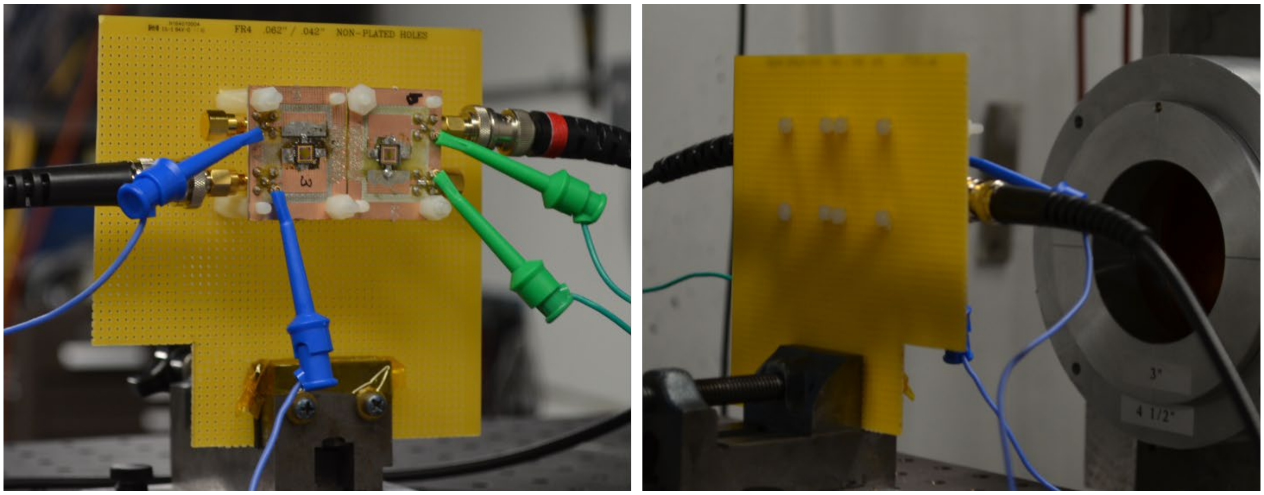


Figure 3: Test boards mounted for irradiation in the beam line.

Following each irradiation step, radiation-induced degradation was characterized via electrical capacitance measurements and optical photodiode linearity measurements. Electrical capacitance measurements were performed using a CV Analyzer that connects to the test board via BNC cables with SMA connectors. Measurements were taken at 100 kHz and 1 MHz frequencies at both 7V and 10V reverse biases. Optical photodiode linearity measurements were performed with a variable input optical power optical source operating at 1550nm and an integrating sphere to measure output current of the photodiode at 0V bias over a range of optical powers to capture the responsivity of the photodiode over a range of input powers. A list of test equipment used during irradiation and measurements is provided in Table 2.

Table 2: List of Equipment

Equipment Name	Functionality
Keithley 2230-30-1 Supply	Power supply during irradiation
Keithley 590 CV Analyzer	Capacitance measurements
Thorlabs TLX2	Optical source
300/330 fiber optic cables, 4 inch integrating sphere	Controlled illumination of the photodiode
Ophir PD300R-IR	Optical power meter
Keithley 2401 Sourcemeter	Photocurrent measurements

3.2. Irradiation Conditions

Testing was performed with 63 MeV protons at Crocker Nuclear Lab at the University of California – Davis. The test chamber during irradiation was room temperature (22.2 C˚) with a humidity of 37%. As the custom device packaging contains a temporary window, SRIM calculations were performed to confirm that the proton beam was minimally impacted when passing through the window. Pre-irradiation measurements were taken for each component to act as a baseline to evaluate radiation-induced degradation. After each dose step, each device (including controls) was characterized via electrical capacitance measurements and DC optical measurements. Irradiation steps were selected in accordance with mission dose requirements and to characterize device sensitivity for future applications (provided in Table 3). Measurements were taken at least fifteen minutes after irradiation to allow for short term annealing of defects.

Table 3: Irradiation Conditions

Group	Qty	Reverse Bias	63 MeV Proton Fluence [#/cm^2 ·10^{10}]	Equivalent Total Ionizing Dose Steps [krad(Si)]
1	2 (SN3, SN9)	7 V	0, 0.6, 1.9, 5.7, 13.2, 18.9, 34.0, 75.4	0, 0.8, 2.53, 7.54, 17.6, 25.1, 45.1, 100
2	1	7 V	Control	Control

4. Failure Criteria

Given the preliminary nature of these tests, failure criteria from a mission-perspective were not considered. For reference, manufacturer performance metrics representative of the measurements in this report are provided in Table 4. It should be noted that the capacitance measurements includes the parasitic capacitance introduced from connectors, cabling, soldering, and the test boards.

Table 4: List of Parameters Measured

Symbol	Parameter	Min	Max	Units	Test Conditions
R_λ	Responsivity	0.85		A/W	V_{op} = 0V at 1550nm
C	Capacitance		250	pF	V_{op} = 10V (Manufacturer) V_{op} = 7V

5. Results

While four devices were brought to the facility for testing, the device on the test board with BNC connectors was not functioning on the day of the test and was not irradiated or measured. Devices labelled as SN3 and SN9 were irradiated while the control device was labelled as “control”.

Electrical capacitance measurement were taken at 100 kHz and 1 MHz at 7V and 10V reverse bias and are summarized in Fig. 4-9. While the control sample remains constant, there is a small dependence on dose for the irradiated devices for all measurement conditions. For reference a total ionizing dose of 100 krads (Si) resulted in a capacitance shift of approximately -3pf.

Optical photodiode linearity measurements were conducted using a variable input optical power up to ~60nW for a 0V bias. For each linearity measurement, a linear regression routine was applied to the data to extract a slope that can be used as the responsivity of the photodiodes. The responsivity measurements normalized to pre-irradiation measurements are provided below (Fig. 10-11). Both the irradiated and control devices exhibit variability in the responsivity measurements that may be attributed to a lack of temperature control during optical measurements that could impact measurements. However, it can be seen that the irradiated devices consistently exhibit a reduced responsivity that would be indicative of radiation-induced degradation. Based on the baseline measurements, irradiated devices experienced an approximate -20% drop in responsivity from the pre-radiation measurements at a total ionizing dose of 100 krad(Si).

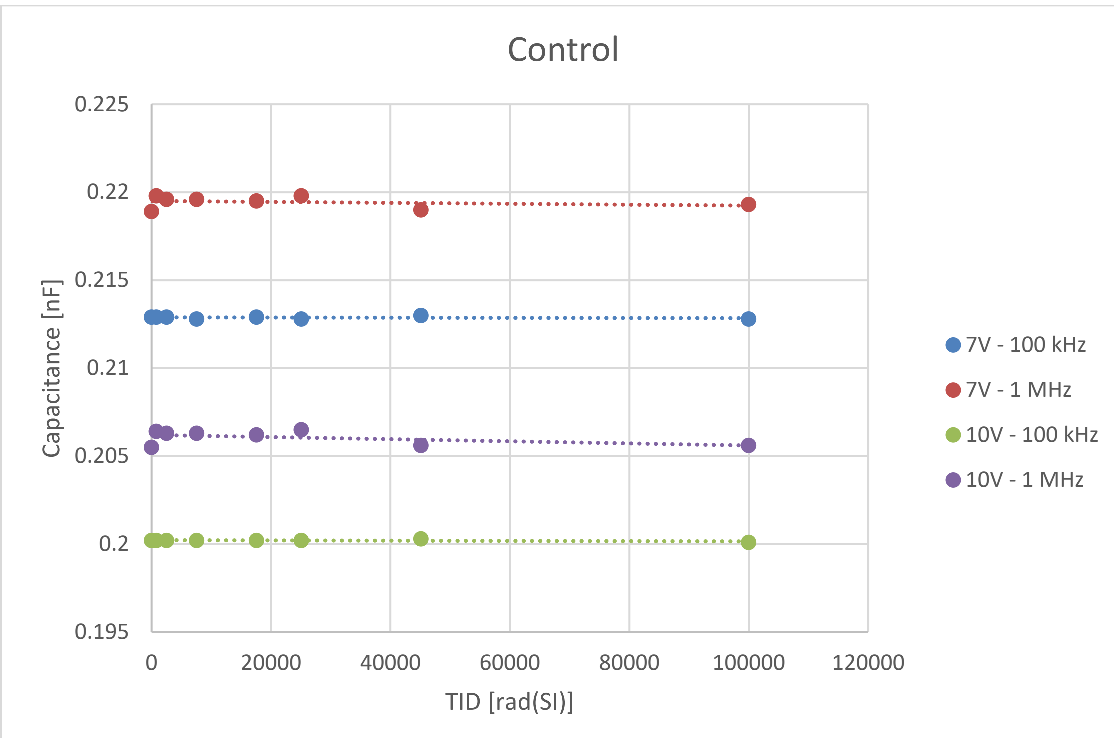


Figure 4: Electrical capacitance measurements as a function of dose for the control device. Dotted line is a guide for the eye.

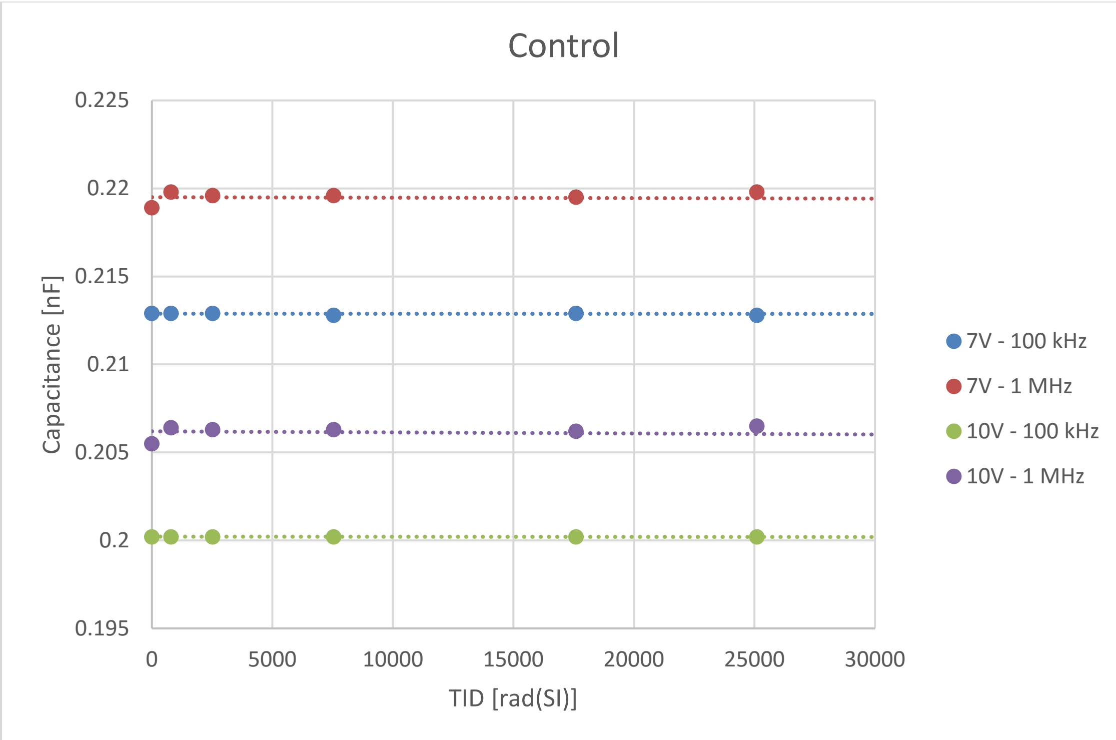


Figure 5: Zoomed in view of electrical capacitance measurements as a function of dose for the control device. Dotted line is a guide for the eye.

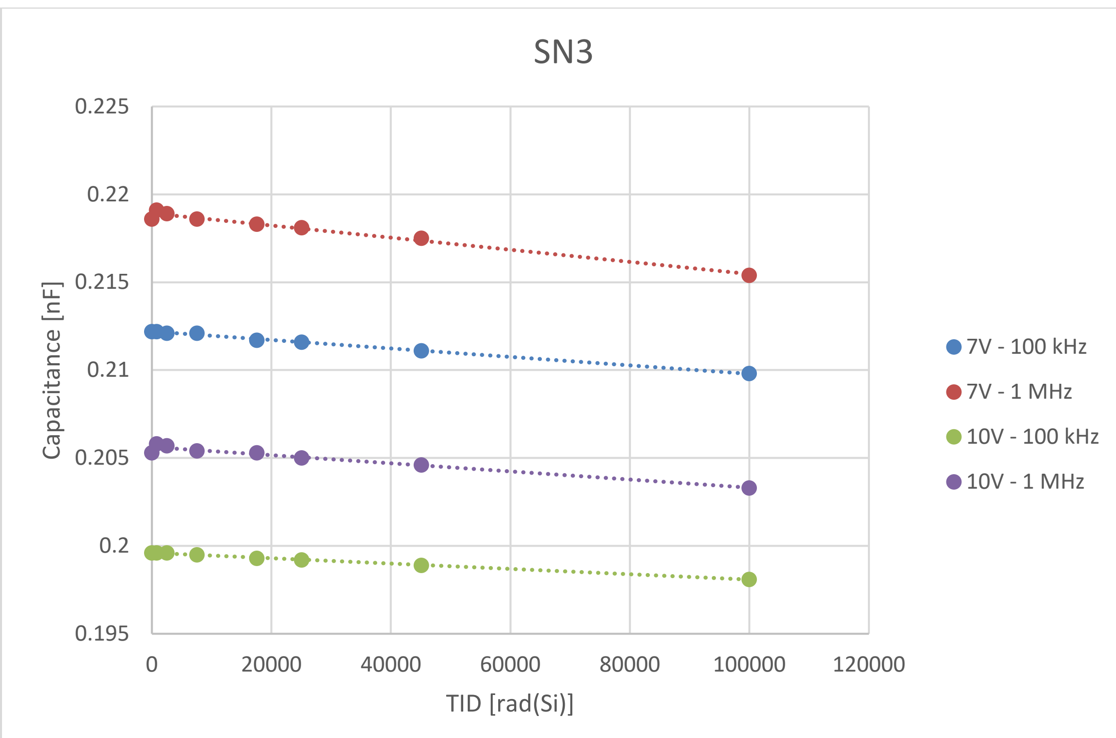


Figure 6: Electrical capacitance measurements as a function of dose for the SN3 device. Dotted line is a guide for the eye.

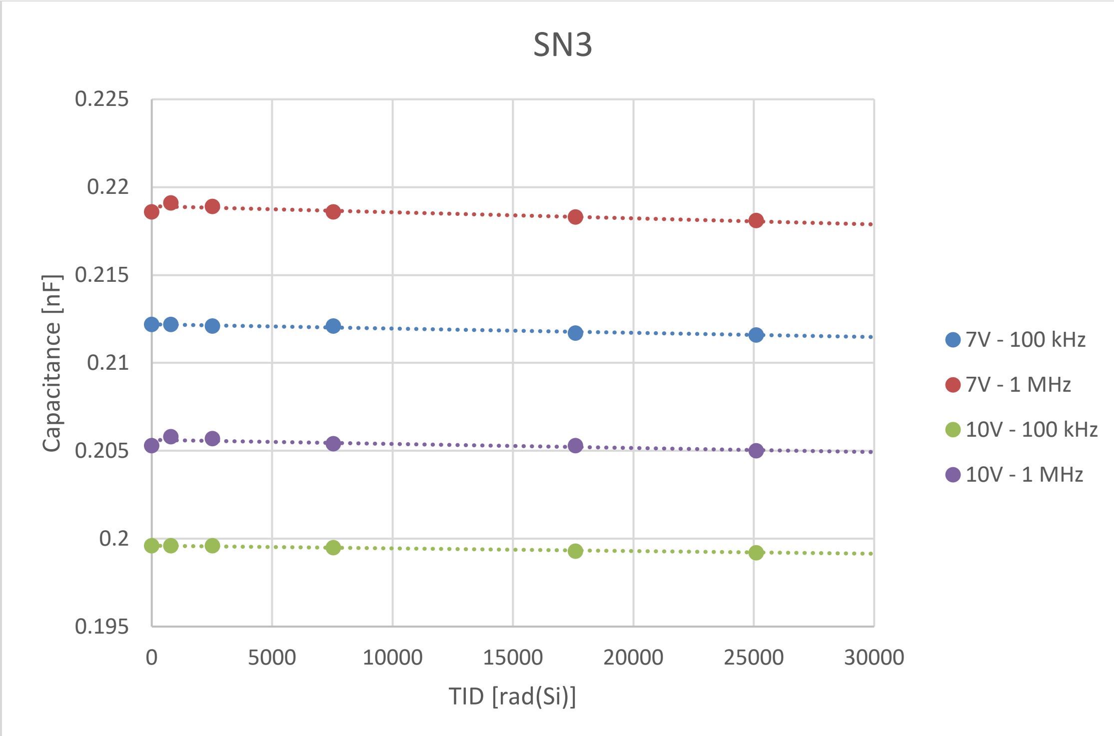


Figure 7: Zoomed in view of electrical capacitance measurements as a function of dose for the SN3 device. Dotted line is a guide for the eye.

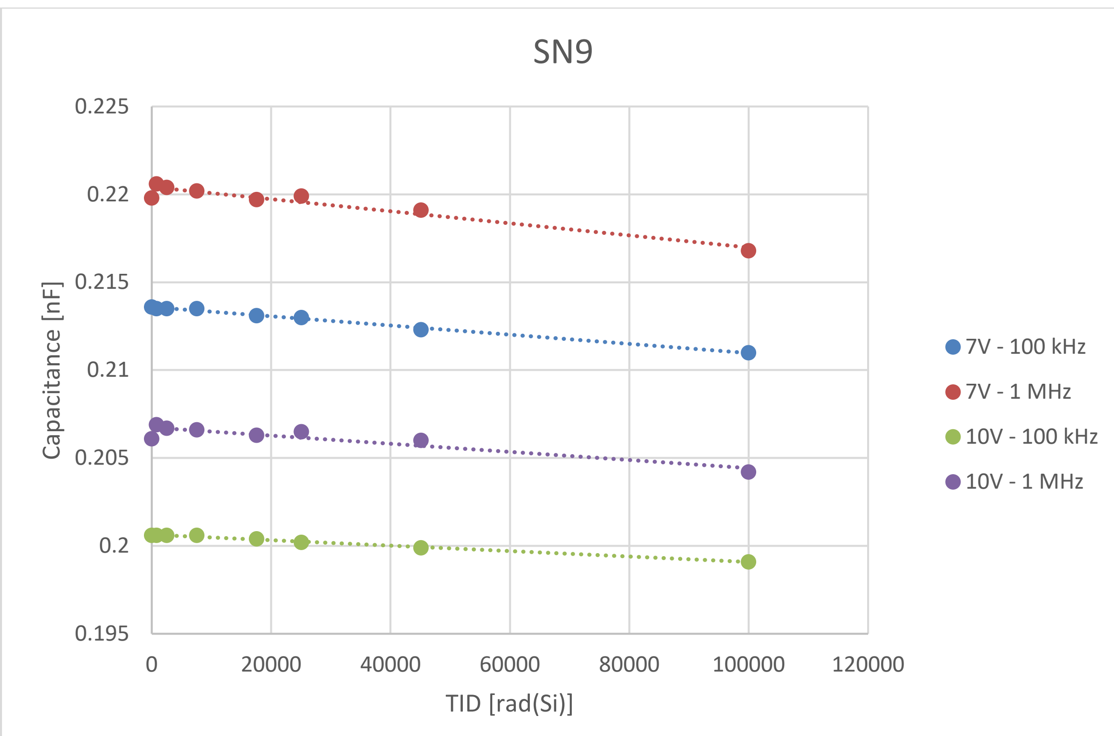


Figure 8: Electrical capacitance measurements as a function of dose for the SN9 device. Dotted line is a guide for the eye.

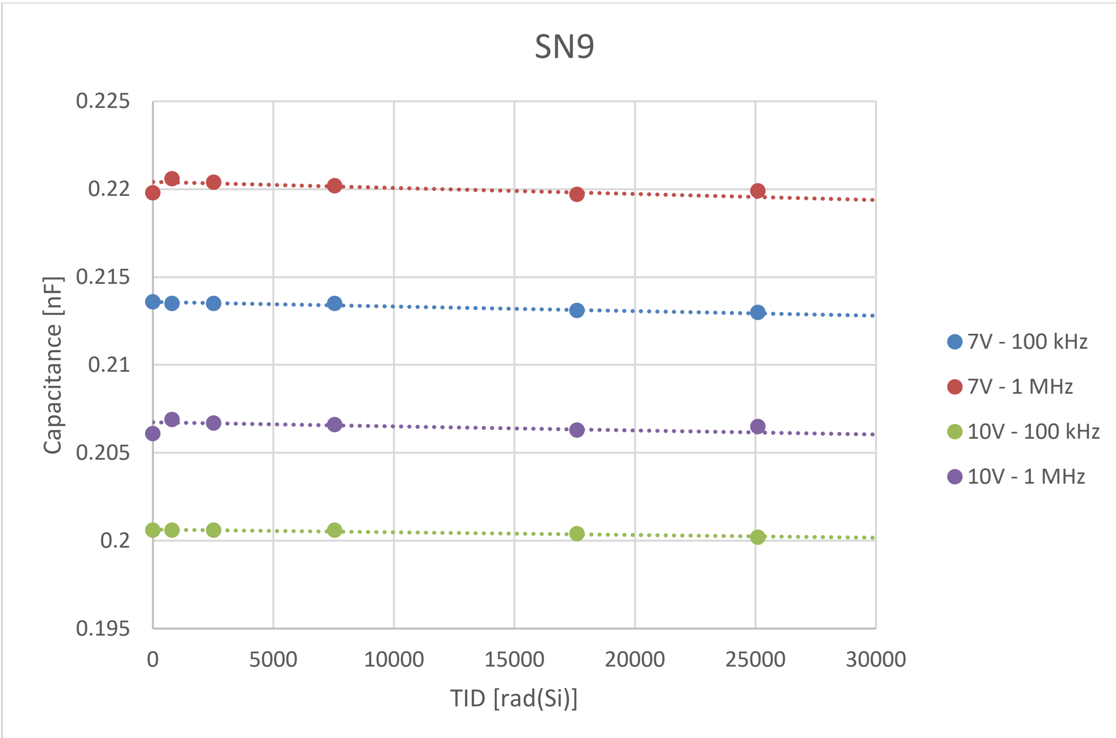


Figure 9: Zoomed in view of electrical capacitance measurements as a function of dose for the SN9 device. Dotted line is a guide for the eye.

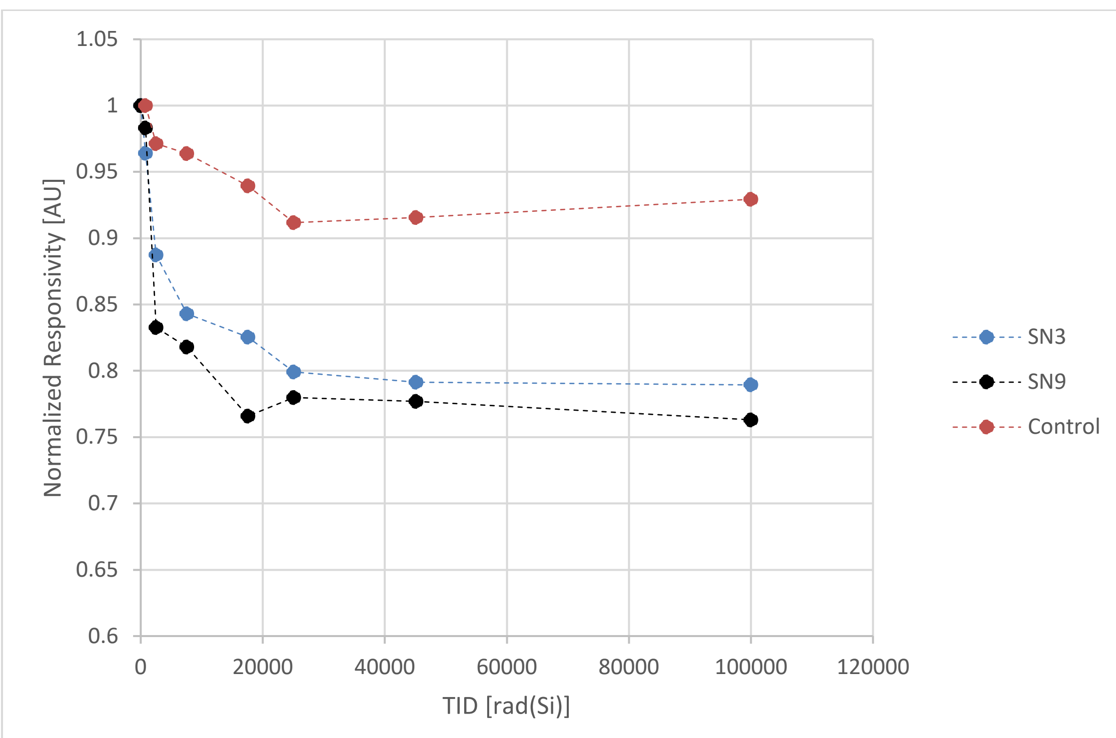


Figure 10: Normalized responsivity (normalized to first responsivity measurement) as a function of dose. Dotted line is a guide for the eye.

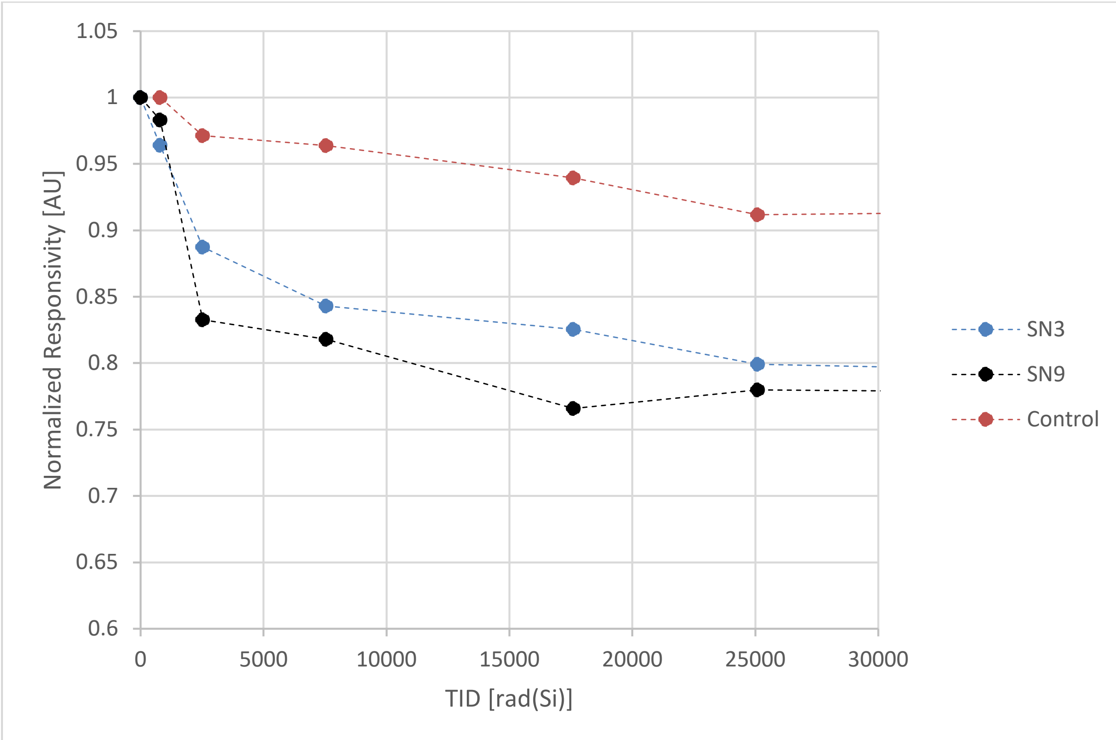


Figure 11: Zoomed in view of normalized responsivity (normalized to first responsivity measurement) as a function of dose. Dotted line is a guide for the eye.

6. Summary

Preliminary displacement damage and total ionizing dose measurements were performed with 63 MeV protons for a custom packaged InGaAs photodiode. Electrical capacitance measurements were performed to and showed minimal degradation up 1 MHz and optical photodiode linearity measurements showed ~20% decrease in responsivity at a dose of 100 krad (Si).

7. References

1) Excelitas, "Large Area InGaAs PIN Photodiodes," Accessed: May 2022. [Online]. Available: https://www.excelitas.com/file-download/download/public/62601?filename=C30665_Series_datasheet.pdf