CubeSat detector assembly for investigating in-orbit mitigation of radiation damage

Nigar Sultana,[1,2,*] Jin Gyu Lim,[1,2] Jean-Philippe Bourgoin,[1,3] Vadim Makarov,[3,2] and Thomas Jennewein[1,3,4]

[1] *Institute for Quantum Computing, University of Waterloo, Waterloo, ON, N2L 3G1 Canada*
[2] *Department of Electrical and Computer Engineering, University of Waterloo, Waterloo, ON, N2L 3G1 Canada*
[3] *Department of Physics and Astronomy, University of Waterloo, Waterloo, ON, N2L 3G1 Canada*
[4] *Quantum Information Science Program, Canadian Institute for Advanced Research, Toronto, ON, M5G 1Z8 Canada*

The most realistic choices for single photon detection in space-based quantum communication (QC) are silicon avalanche photodiodes (APDs) because of their high speed, low dark count rates, relatively high operating temperature, and high quantum efficiency in the 400-1100 nm wavelength range. However, they need to withstand damages in adverse conditions of space due to high energy proton radiation in lower-earth orbit to maintain functional lifetime. The radiation raises APDs' dark count rates over time. It is crucial to keep the dark count rate in the low 100's Hz for successful ground-to-satellite QC [1]. A previous study on APDs in satellite showed an increase of dark count rates by ∼30 Hz per day in orbit– this would make them unsuitable for QC within a few weeks [2]. Therefore, to continue QC for longer duration, mitigation of radiation damage is essential.

Recently, several ground-based radiation tests reported that thermal annealing the detectors at 100°C in a thermal chamber [3] and applying 1 W of focused optical illumination on APDs' active area (laser annealing) [4] are very effective solution to reduce dark count rates in irradiated APDs. Nonetheless, to our knowledge no in-orbit test has been attempted to examine the effectiveness of these annealing methods in mitigating the radiation damage. Hence, we are aiming to design and build a annealing payload (for cubesat) to execute periodic in-orbit laser and thermal annealing and study the effectiveness of these methods to mitigate the in-orbit radiation damage.

To implement the annealing processes for cubesat, the payload is divided into two sub-PCBs: one will contain the detector assembly (DA) and the other laser assembly (LA) and processor. Here we report the design and implementation of the DA. Figure 1 shows the 3D model of the DA. We choose the same APDs used in the other ground based tests– Excelitas C30902SH and Excelitas SLik– for our in-orbit test. These are the commercially available thick-junction silicon APDs having higher detection efficiencies at around 785 nm wavelength, which is the optical transmission wavelength for uplink QC [1]. For redundancy, the DA contains two of each APDs. All the four APDs have integrated thermoelectric cooler (TEC) and a thermistor sealed in a airtight glass package, and are fiber coupled. In order to reduce power, the DA can operate the APDs separately.

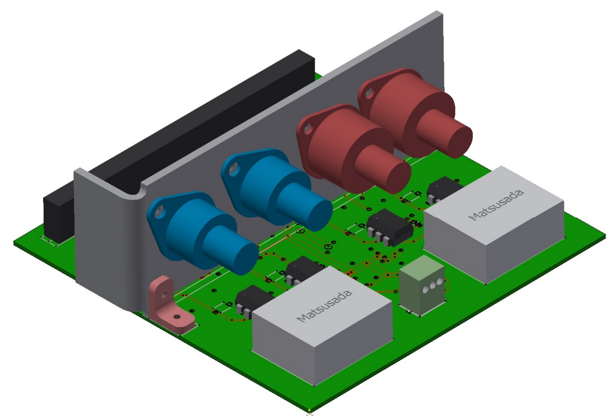

FIG. 1. **3D model of detector assembly (DA).** The PCB has the form factor of a cubesat and contains four APDs: two SLiKs and two C30902SHs from Excelitas, two high-voltage (HV) modules, two discriminators, one thermoelectric cooler (TEC) controller, two pulse processing circuitries, and several electrical switches to select HV supplies and TECs. The electrical platform is controllable by processor, which is interfaced through PC/104– a embedded computer standard connector. [Figure is by Shubham Singh[3]]

The DA performs the thermal annealing by controlling the integrated TECs. The TEC driver controls the heating and cooling temperature of TECs. To perform laser annealing, the APDs will be illuminated by high power laser from LA through the fiber connectors of the APDs. A processor (Cypress PSoC-3) controls the functionality of the DA which is interfaced by a PC/104 connector. The connector also provides the required power supply to the DA.

The DA, mass ∼120 g and consumes ∼1.2 W of power, and is contained in a volume of only 95 mm × 95 mm × 38 mm. APDs are essential element of both quantum receiver– to receive quantum information and source– for its characterization. This experiment is expected to have potential future impact on satellite QC, especially on quantum key distribution.

* n6sultan@uwaterloo.ca

[1] Bourgoin, JP *et al., New J Phys* 15:023006 (2013).
[2] Sun, X *et al., J Mod Opt* 51:1333 (2004).
[3] Anisimova, E *et al., EPJ Q Tech.* 4:10 (2017).
[4] Lim, JG *et al., EPJ Q Tech.* 4:11 (2017).