Compact nanosatellite design of a downlink platform for quantum communication

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Introduction

Quantum communication, leveraging the principles of quantum mechanics, has revolutionized the way information is encoded and transmitted. This cutting-edge technology promises unconditional security, shifting from resource-dependent approaches to nature-based security.

Quantum key distribution (QKD) is a prominent variant of quantum communication, providing unconditional security under specific assumptions. Recent advancements in quantum communication have led to the development of commercial systems, but their limited distance capabilities remain a challenge [1].

This project presents a novel approach to extend quantum communication to space-based applications using nanosatellites. The main focus is on implementing various protocols between a nanosatellite in Low-Earth Orbit (LEO) and a ground station.

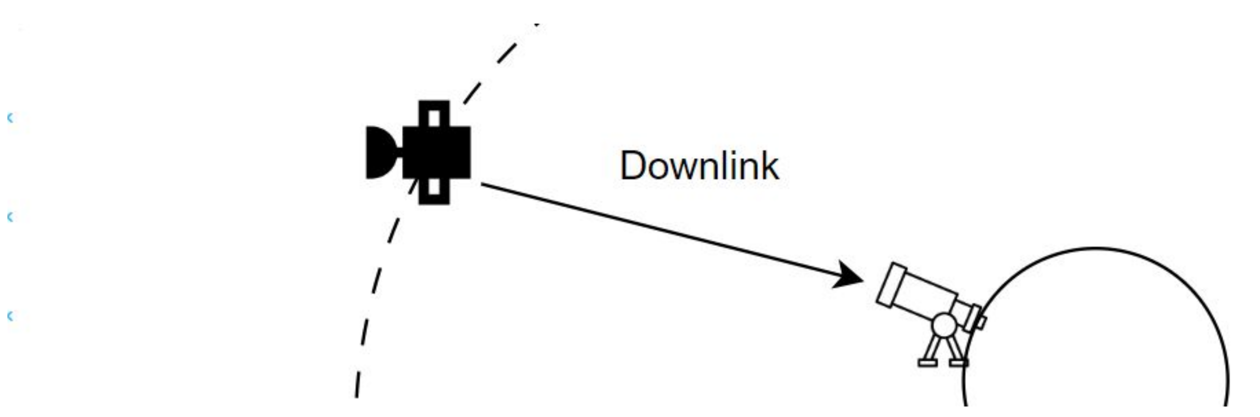

Figure 1: Mission diagram

Experimental concept

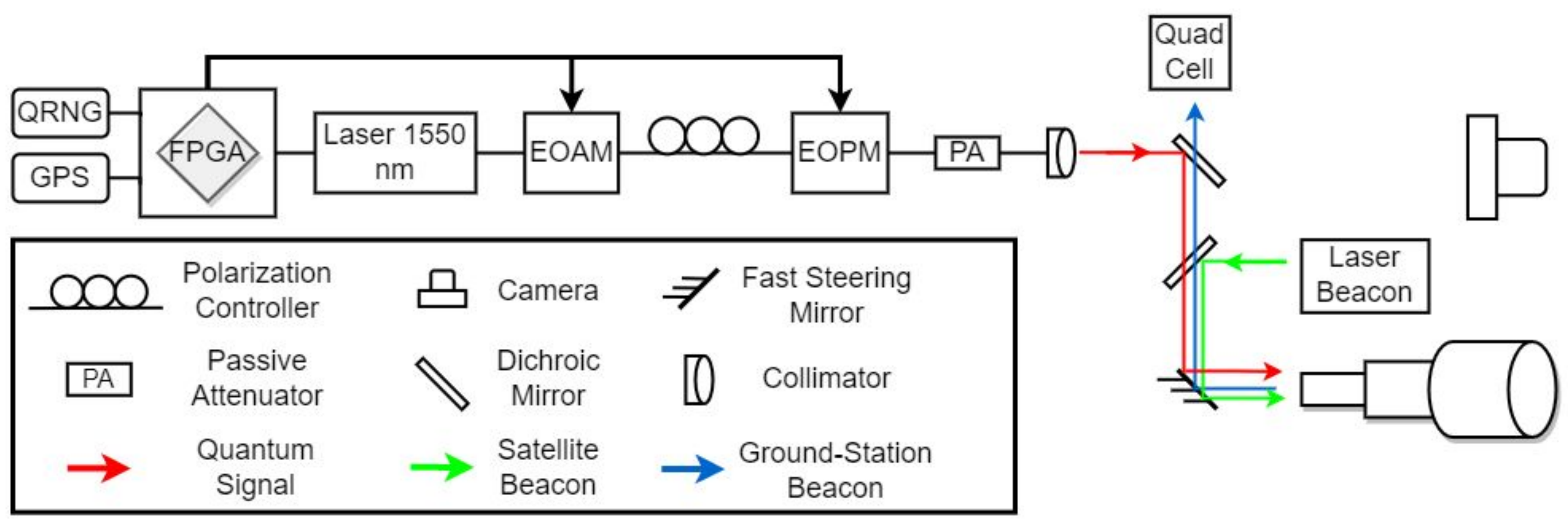

Figure 2: Experimental setup to perform quantum communication from a cubesat inspired from [2].

The setup consists of two parts, the quantum signal setup and the pointing and tracking setup.

The first one is responsible for the creation of the quantum states for a given protocol. These states are created by controlling the polarization degree of freedom of the qubits

The pointing part inspired by CLICK [3]. It is divided into a coarse pointing stage and fine pointing one. It makes use of ephemeris information, a wide field of view camera and a narrow field of view quad cell to keep the satellite aligned with the ground station with a few μrad precision.

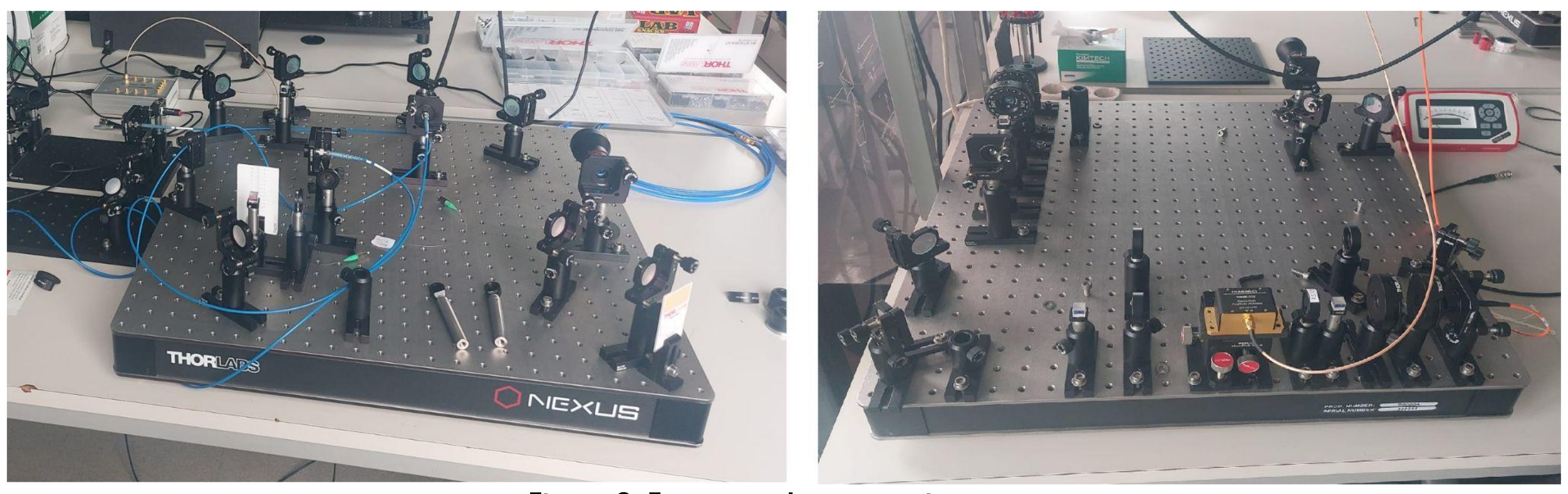

Figure 3: Free-spac demonstration setup.

To validate this setup, a free-space demonstration is being built. This demo will be used to test different protocols and showcase the setup.

In parallel, a fiber-based implementation is also being created using the commercial equipment proposed for the satellite. This will allow us to substantiate our design and characterize it. Both these setups are planned to be working later this year.

Preliminary design

Item	Size (ml)	Weight (g)	Power (mW)
Laser source	24	270	800
EOAM	19	180	650
EOPM	33	180	900
Variable Waveplate	2	150	700
FC/APC Collimator	13	60	-
Passive Attenuator x 2	4	20	-
Connector x 2	13	20	-
Alice payload	108	880	3400
Quad Cell	4	30	-
Camera + Lens	109	390	2500
Mems mirror	3	30	85
Laser source	24	270	800
Dichroic Mirror x 2	1	40	-
Tracking payload	141	760	3385
Telescope	119	950	-
Total	368	2590	6785
2U Maximum	2000	4000	

Table 1: Size, Weight, and Power (SWaP) analysis of the proposed preliminary design for a 3U CubeSat

Using commercial components, a preliminary design of the system was created that fulfills the size, weight and power requirements of the cubesat.

Following this, a mechanical design was created to highlight how this choice of components would fit inside the satellite and to perform vibrational and thermal tests to validate this design.

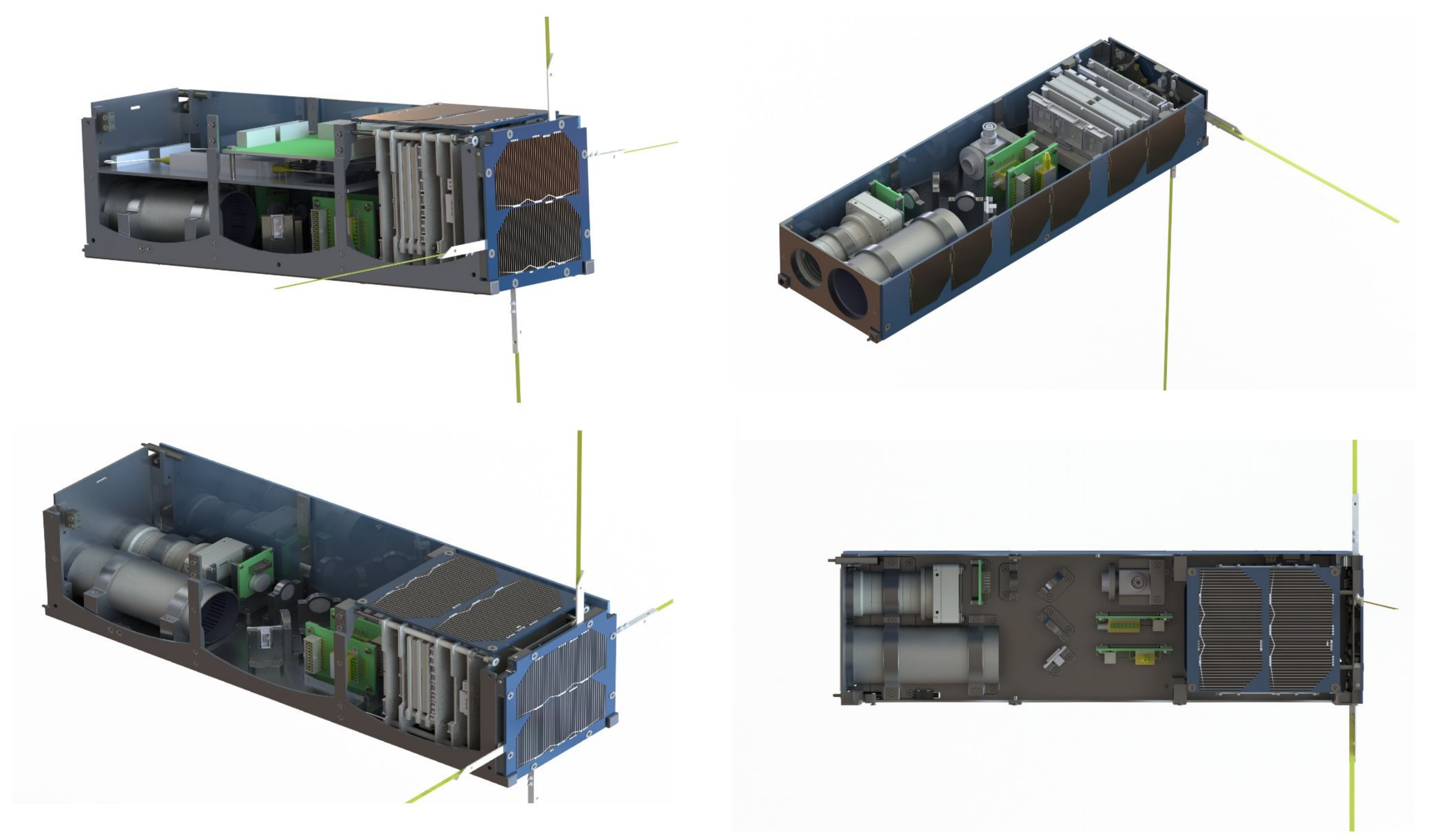

Figure 4: Four views of the 3D mechanical design.

Conclusion

This work presents our initial design of an optical payload for a 3U CubeSat. We have miniaturized the setup to fit the limited space inside the nanosatellite, considering optical, mechanical, electrical, and celestial mechanics aspects.

Our proposal demonstrates innovation by enabling various quantum communication protocols and his design serves as a platform for future space-based quantum communication research, sharing our findings and highlighting the compatibility of our quantum state emitter with a 3U CubeSat using readily available commercial components.

Contact

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References

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3. Kerri Cahoy, et al. The cubesat laser infrared crosslink mission (click). In International Conference on Space Optics—ICSO 2018, volume 11180, pages 358–369. SPIE, 2019

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