LUxembourg Quantum Communication Infrastructure lAb

Milestone 1 Report

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1. *General Status*

- The team has been working on WP2, particularly in in the WP2.1 “Equipment Procurement and Installation” and WP2.2 “Integration and Testing.”
- SNT Team finalized the provider selection for QKD equipment to be installed. The selection process included the request for equipment quotation from Toshiba Europe and Aurea technologies.
- Due to maturity, availability, and proofness, the team selected the Cerberis XCR platform provided by the company ID Quantique. Additionally, IDQ devices allow the user to perform research and his own developments in an open architecture.
- The procurement process started at the beginning of 2022, and due to the total amount, it took until the last week of June to retrieve the equipment at UniLu premises. The procurement process required a formal derogation process to avoid public tendering. The justification for the derogation was the lack of other providers of QKD equipment that allows performing development and research while at the same time providing a finalized prototype that can be used as a starting point for the custom developments.
- The current delays in the supplier’s chain have created a delay in finishing some procurements of auxiliary equipment related to the Lab.
- The team started the physical space request from the University Logistics to have the place to deploy the QKD experiments. The space in the JFK building is an underground room of around 70 square meters. The space on the MSO building in Esch-Sur-Alzette will be a standard office space with fibre optic connectivity.
- The team has been evaluating if installing a temperature control system in the JFK lab is required. For this purpose, we have been taking temperature measurements since the beginning of the year. In any case, the vendor specifications state that there are no

stringent requirements in terms of temperature control other than an average room temperature. (10 to 30 Degrees in specs).

- University Logistics accomplished maintenance activities in the Lab facilities on JFK, basically to the floor and the electrical and communication network. The JFK Quantum Lab settlement is accomplished: the deployment of optical network fibre from the Lab to the JFK Data centre, server installation and mount rack setup.
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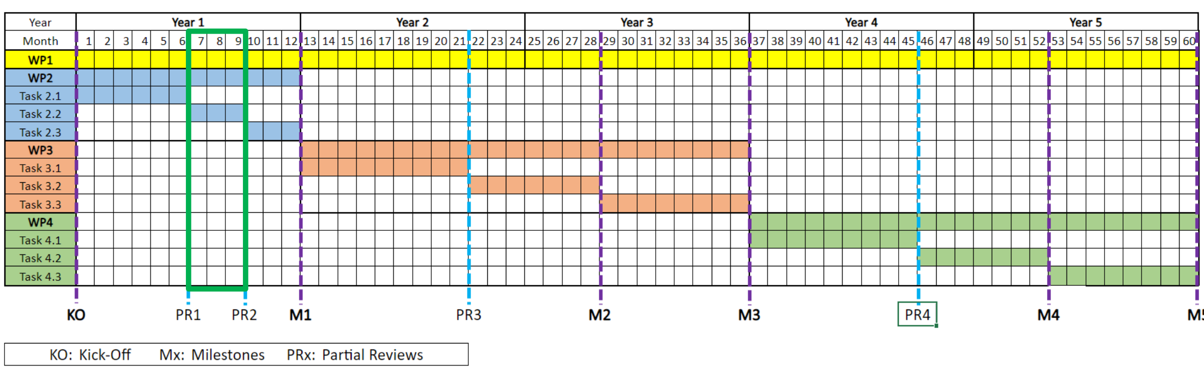
- The team is accomplishing the first experiments on the in-situ quantum link. The experiments include the basic setup of one pair of QKD devices, the “network setup,” and the “Quantum Channel Setup.”
- The team has accomplished the preliminary configuration and testing on 3 pairs of QKD devices and presented the testing report in Technical Report 1: Integration and testing results which include the initial device setting in the log file and statistic testing result.
- The second training provided by IDQ was presented physically in early November. The next milestone is implementing the Evedropping and provide the testing result.

2. *Ongoing WPS*

- WP2.2 **Integration and Testing**
- The following diagram includes a green rectangle to depict the current work package.



3. *Second IDQ training course*

The second IDQ training will take place in November 2022 and it will cover the following topics:

- Introduction to Eves drop fundamentals and implementation
- Introduction to ETSI command keys request via script (not RAW keys)
- Q&A – open discussion to topics related to QKD system implementation

4. *Lab Experiments*

Preliminary experiments have been accomplished with one set of Cerberis XGR-P2P-1551-18 shown in the figure. Both devices are connected to an internal network and configured with a PC in the same network.

Figure 1. QKD pair (ALICE01/BOB01) for network setting

The team proceeded with the initial configuration of the QKD network setting from the network IP port setting and QNET topology settings. For this task, we configure the USB to Serial port connection between the PC and the devices and the software used for the initial configuration of each QKD equipment.

Once this previous step was finished, we used the GUI settings for creating nodes, including KMS, Provider, and Consumer in a LuxQLab Group, part of the QKD topology shown in Figure 2. For a pair of QKD devices, this topology includes the Providers (in RED), the Nodes (in BLUE), and the Consumers (in YELLOW and GREEN); those last ones with different encryptor types, e.g., Cisco and ETSI.

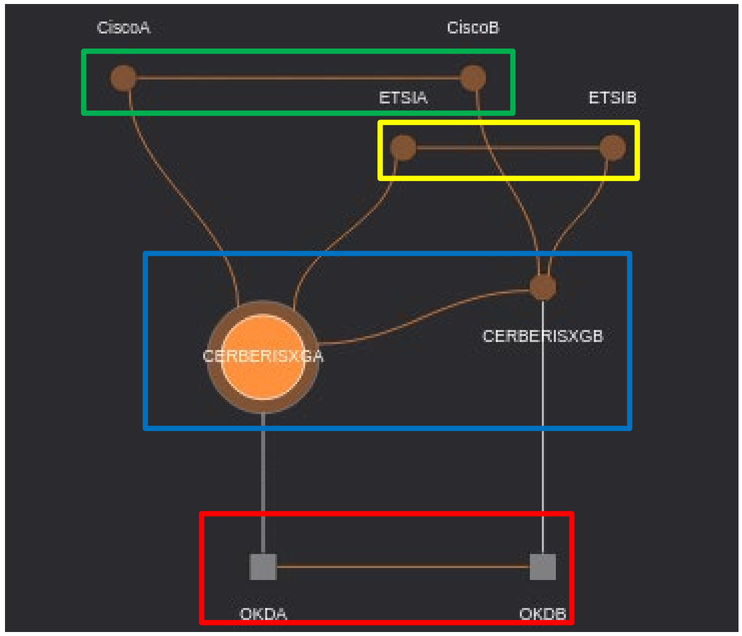


Figure 2. GUI illustration for QKD network topology for a pair of QKD devices.

After configuring the nodes, we successfully set up the QKD Network software but failed to deploy the quantum channel physically. The team worked within IDQ for a solution and finished the correct deployment.

Next experiments were accomplished with 3 sets of Cerberis XGR-P2P-1551-18 (ALICE01/BOB01) (ALICE02/BOB02) and Cerberis XGR-P2P-1310 (ALICE03/BOB03). As sown in Figure 3. The deployment of each pair of QKD network is implemented by QNET script and preliminary test 1 pair at one time. We test each pair of devices by connecting to a router and configuring the IP address with a PC within the local network. The AUX port and KMS port are connected to the router by RJ45. For the quantum channel, the SC-PC fibre cable with 9/125um and 2m length is connected. For the service channel, the 9/125 single-mode fibre patch cable is connected. Those 2 connections are appended with a 10 dB attenuator.

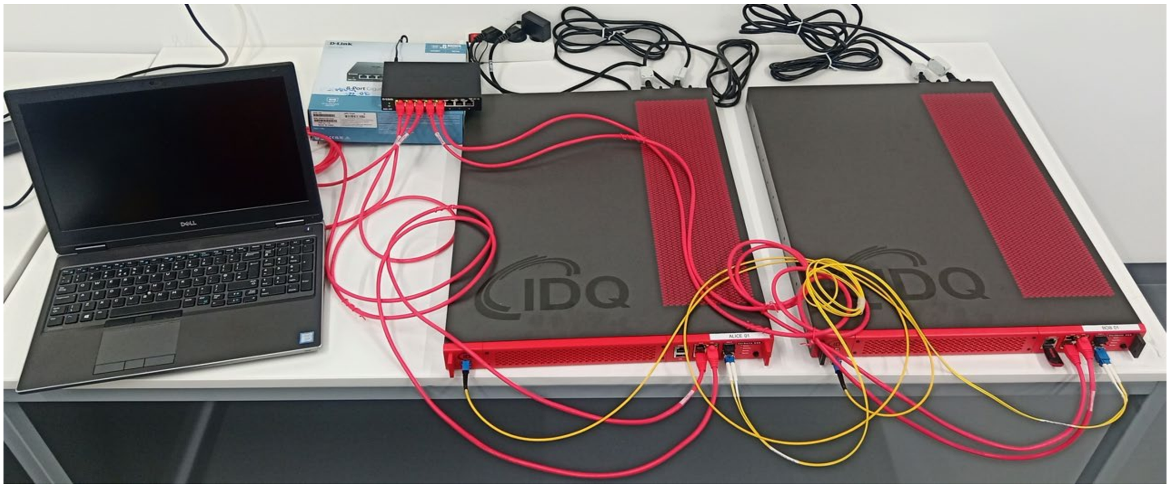


Figure 3 QKD pair (ALICE01/BOB01) for testing result

5. *Technical Report 1: Integration and testing results*

The encryptor has been configured to the devices by USB drive, and key load procedure is performed to ensure a pair of QKD networks has the same key. After the preliminary setting of network deployment, authkey generation and load, the QKD device starts to synchronize and perform the alignment procedure as shown in Figure 4. This procedure calibrates the fiber connection to reach the maximum visibility of QKD communication.

Figure 4 Synchronization and alignment procedure of QKD device

After this, the QKD device starts to perform the IDQ4P protocol to initial the key exchange as shown in Figure 5. We can see that the "Peer initial key set" demonstrates the correctness of the preliminary setting.

Figure 5 Starting the initial key exchange of IDQ4P protocol

After the initial key set, the following is the detail of IDQ4P protocol of setting each required channel of QKD network as shown in Figure 6. Next, we are going to wait for the device to start working functionally and collect the statistic data from the QNC interface to show on the GUI interface.

Figure 6 IDQ4P protocol setting

The static test result has been orginized as following. There are 3 parameters we need to check the functionality of QKD device. 1) QBER: The qubits error rate performance is considered to check the receiving digital bit stream on the quatum channel. A QBER value is measured by counting the probability of having an error in the exchange of qubits of the computational basis. 2) KEYRATE: Actual key rate transmits between ALICE and BOB. 3) VISIBILITY: The phase relation check is quantified by measuring the visibility of interferences occurring in the second basis analyzer. Based on both values, QBER and visibility, it is possible the estimate if it is possible to extract secret keys from the qubits exchanged between the emitter and the receiver stations.

- **Cerberis XG0R-P2P-1551-18 (ALICE01/BOB01)**

First, the QBER is illustrated in Figure 7. We can see the actual QBER from the initial setting to the moment after the calibration process is complete. The QBER is stable at around 0.02 after 1 hour.

Figure 7 QBER of ALICE01/BOB01

Second, the key rate is shown in Figure 8. After the QBER is getting lower, the key rate can be achieve up to 2kbps.

Figure 8 KeyRate of ALICE01/BOB01

The visibility is shown in Figure 9 and can reach up to 1.

Figure 9 Visibility of ALICE01/BOB01

After run time of 1 day, we show the testing result in Figure 10.

Figure 10 Testing result of 1 day for ALICE01/BOB01

- **Cerberis XGR-P2P-1551-18 (ALICE02/BOB02)**

The QBER for ALICE02/BOB02 is shown in Figure 11. We can see that is round 0.02.

Figure 11 QBER of ALICE02/BOB02

The key rate is shown in Figure 12. We can see that is around 2kbps. However, there is a drop happen around 8am. The drop of key rate is cause by some reasons which includes fiber remove or bumping. This malfunction can be investigated by log file recording in the device.

Figure 12 KeyRate of ALICE02/BOB02

The visibility is shown in Figure 13 and can reach up to 1. However, there is a visibility drop at 8am caused by excess losses, bad fiber, poor connections, dirty fiber, etc. This leads to the result of key rate drop.

Figure 13 Visibility of ALICE02/BOB02

- **Cerberis XGR-P2P-1310 (ALICE03/BOB03)**

For this device, the only diffence is the key rate which is higher than the above 2 pairs and can reach up to 2.5Kbps. The testing result is shown in Figure 14, Figure 15, Figure 16 and Figure 17.

Figure 14 QBER of ALICE03/BOB03

Figure 15 KeyRate of ALICE03/BOB03

Figure 16 Visibility of ALICE03/BOB03

Figure 17 One-day testing result of ALICE03/BOB03

6. *Next Milestones*

- PR2 (Partial Review 2), planned for month 9, with the expected deliverable: "2nd Draft of Technical Report 1: Integration and testing results."

7. *Purchased Equipment*

a. **2 Units** (pair): Cerberis XGR-P2P-1551-18- Point-to-point system for Research and Academia with a premium range of 18dB, 1551.72 nm
b. **1 Unit** (pair): Cerberis XGR-P2P-1310 - Point-to-point system for Research and Academia with a range of 16dB, 1310nm
c. **Accessories:**

- Attenuators UPC (2x 7dB and 2x 15dB)
- Attenuators SC/PC (3, 5 and 10dB)
- 2x SFPs
- Duplex UPC and simplex APC patch cords
- Rack mounting kit (rails and brackets)
- 4x Power cords
- Ethernet and console patch cords
- USB to Serial adaptor
- SC and LC Fiber cleaners
- Quantis-PCIe-40M PCIe card (PCI express base 1.0a compliant) 38.3Mbps entropy source and 9.6Mbps RNG data throughput
- Quantis-PCIe-240M PCIe card (PCI express base 1.0a compliant) 232Mbps entropy source and 58Mbps RNG data throughput
- SFP+-1550nm-10Gbps long range Single-mode Fiber Optic Transceiver Module SFP+ 10 Gpbs 1550nm - 80km

8. Auxiliary Purchased Equipment

a. **2 Units:** DELL PowerEdge R750xs Server, 2x Intel Xeon Gold 5315Y, 16x 16GB RDIMM 3200MT/s Dual Rank, 2x 1.6TB Enterprise NVMe (to deliver by September 14th)
b. **2 Units:** DELL 27" Monitor P2722H
c. **2 Units:** DELL Wireless Keyboard & Mouse KM5221W
d. **2 Units:** Dell Smart-UPS SRT 8000VA RM (to deliver by October 21st)
e. **1 Unit:** TP-LINK TL-SG1024 24 Port Gigabit Ethernet 19"-Switch
f. **1 Unit:** D-Link DGS-108 8-Port Layer2 Gigabit Switch

The following figures show the received QKD equipment.

Figure 18. IDQuantique packages received at JFK building

Figure 19. A Cerberis XGR 1551-18 Node (Alice)

Figure 20. - Quantis-PCIe-240M PCIe card

9. *Lab space diagrams*

The ellipse in red shows the LUQCIA lab at JFK building ((Old Robot Football field) S2 (-2 Floor)

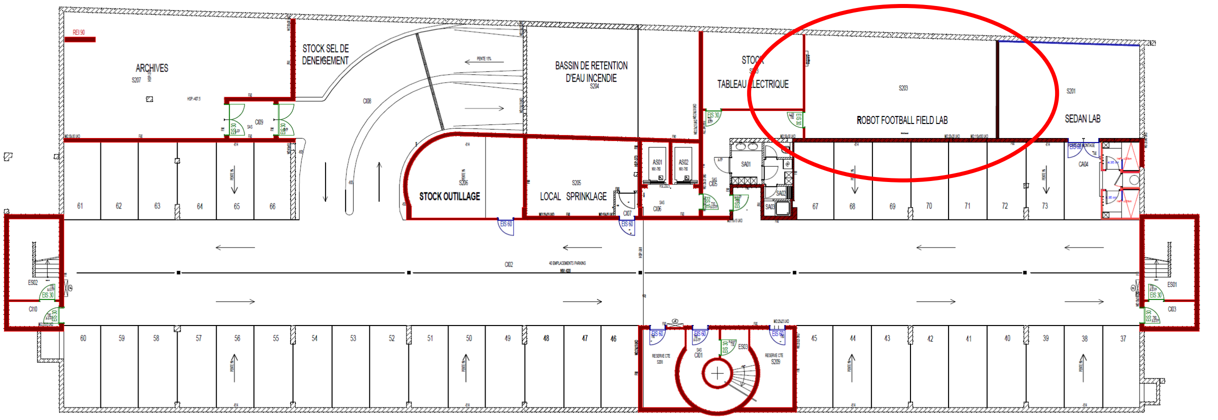


Figure 21. LUQCIA Lab Space within the JFK building plan

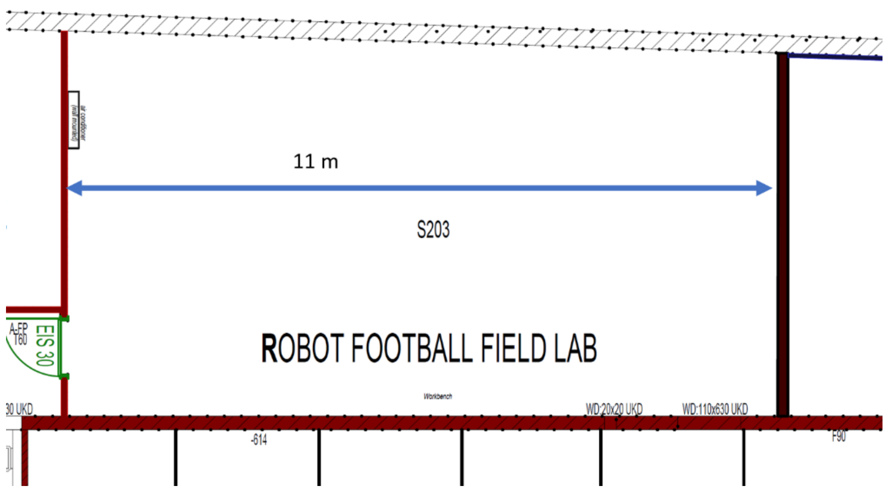


Figure 22. LUQCIA Lab Space dimensions

University Logistics finishes the maintenance activities in the Lab facility related mainly to removing the old carpet and creating an antistatic floor. The results of these activities can be seen in the following figures. In addition, the University Logistics also arranged the maintenance of the electric network and the ethernet communication network in the Lab, as well as the installation of the fiber optics in the Lab.

Figure 23. Lab floor after removing the old carpet.

Figure 24. Works in Lab floor finished.

Two racks are be placed in the Lab. The figure shows the proposed locations of both stands. Each one will be provided with a fiber optic and Ethernet connection to the JFK building.

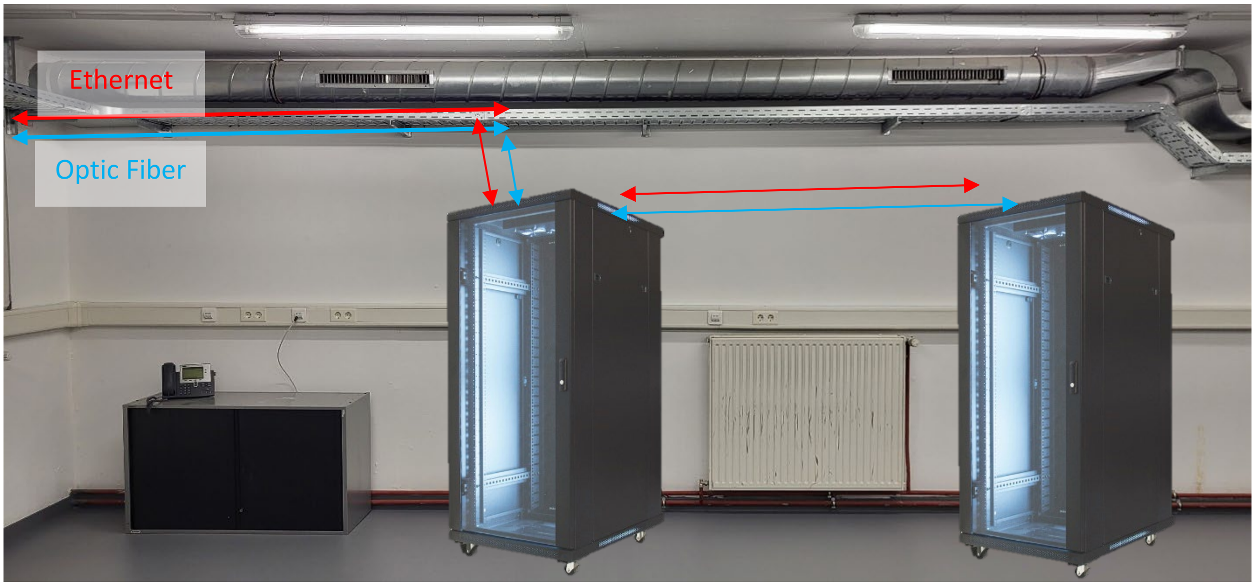


Figure 25. Locations where the racks will be installed in the Lab.

Figure 26. Rack placed in the Lab.

Figure 27. Lab setup.

Figure 28. RACK01 - ALICEs QKD Device. a) Front. b) Back.

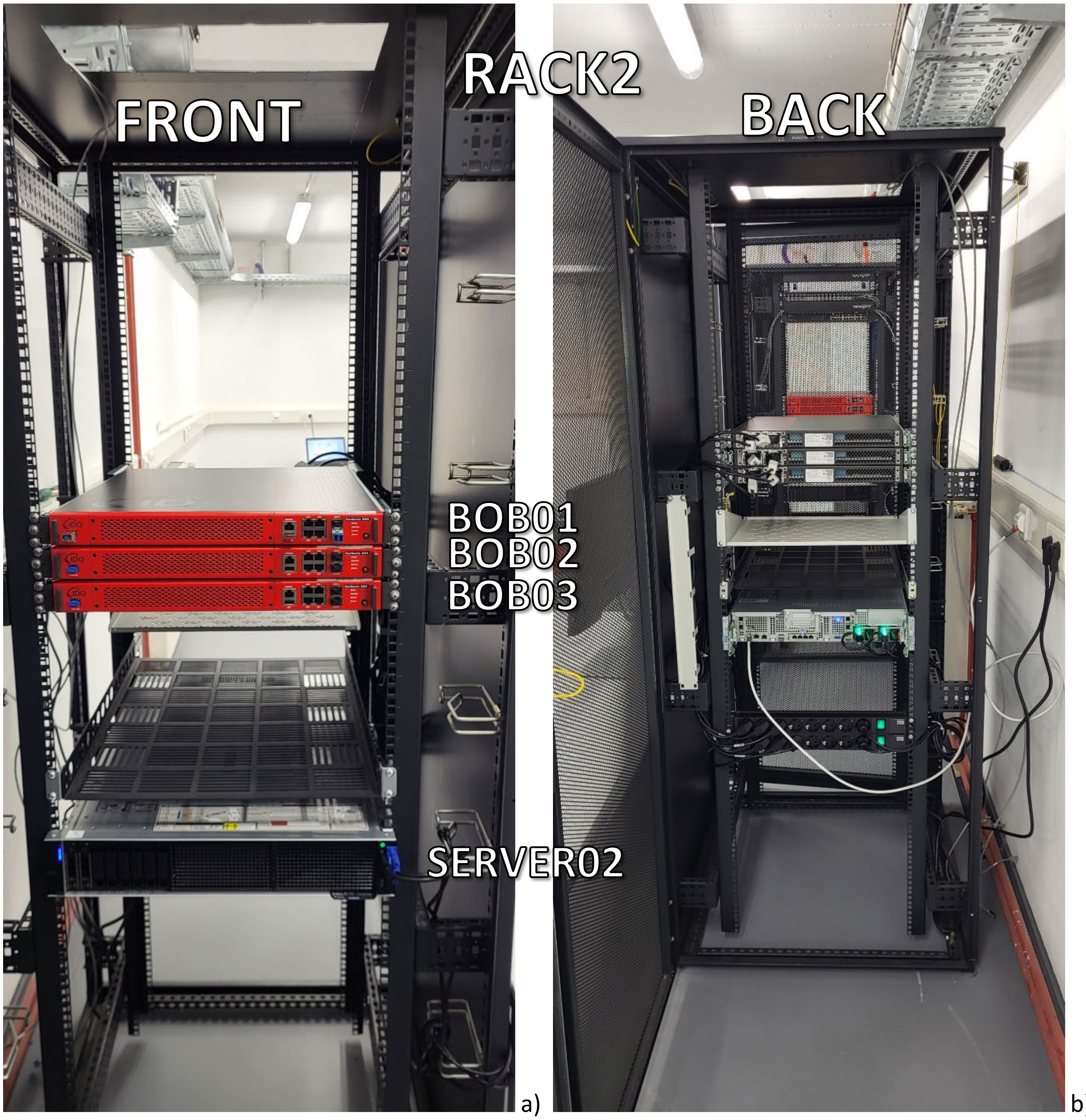


Figure 29. RACK02 - BOBs QKD Device. a) Front. b) Back.