# Building Trust in Quantum Technology

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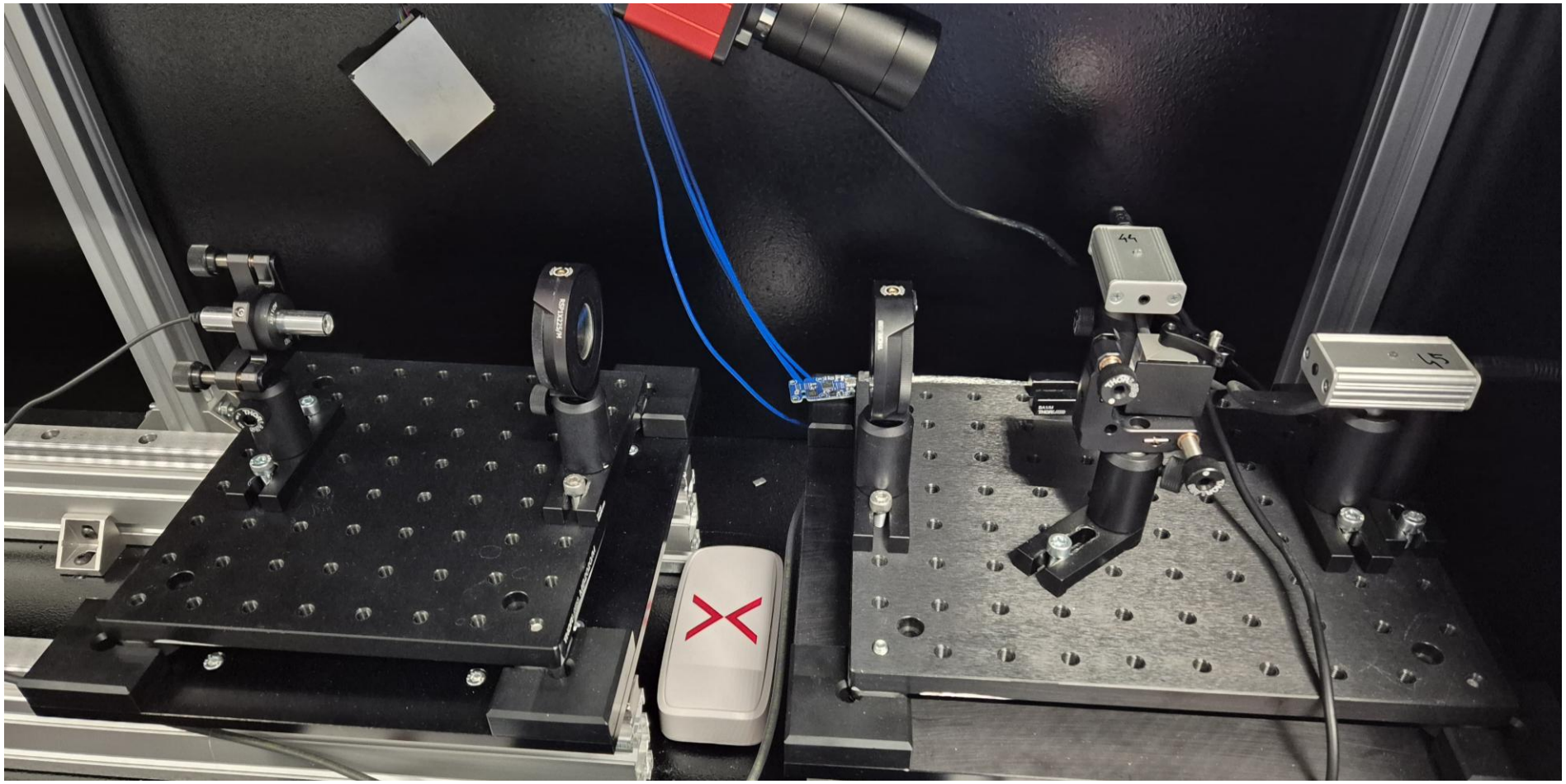
# Development, Testing, and Standardization

- We are at a turning point in the transition to the industrial application of quantum technology. Quantum communication, quantum encryption, and quantum computers are moving from laboratories into the real world.
- Today’s challenge is no longer whether quantum technology works, but how to ensure that results are comparable, reproducible, and trustworthy.
- As metrologists, this very question is what led us to quantum technology.

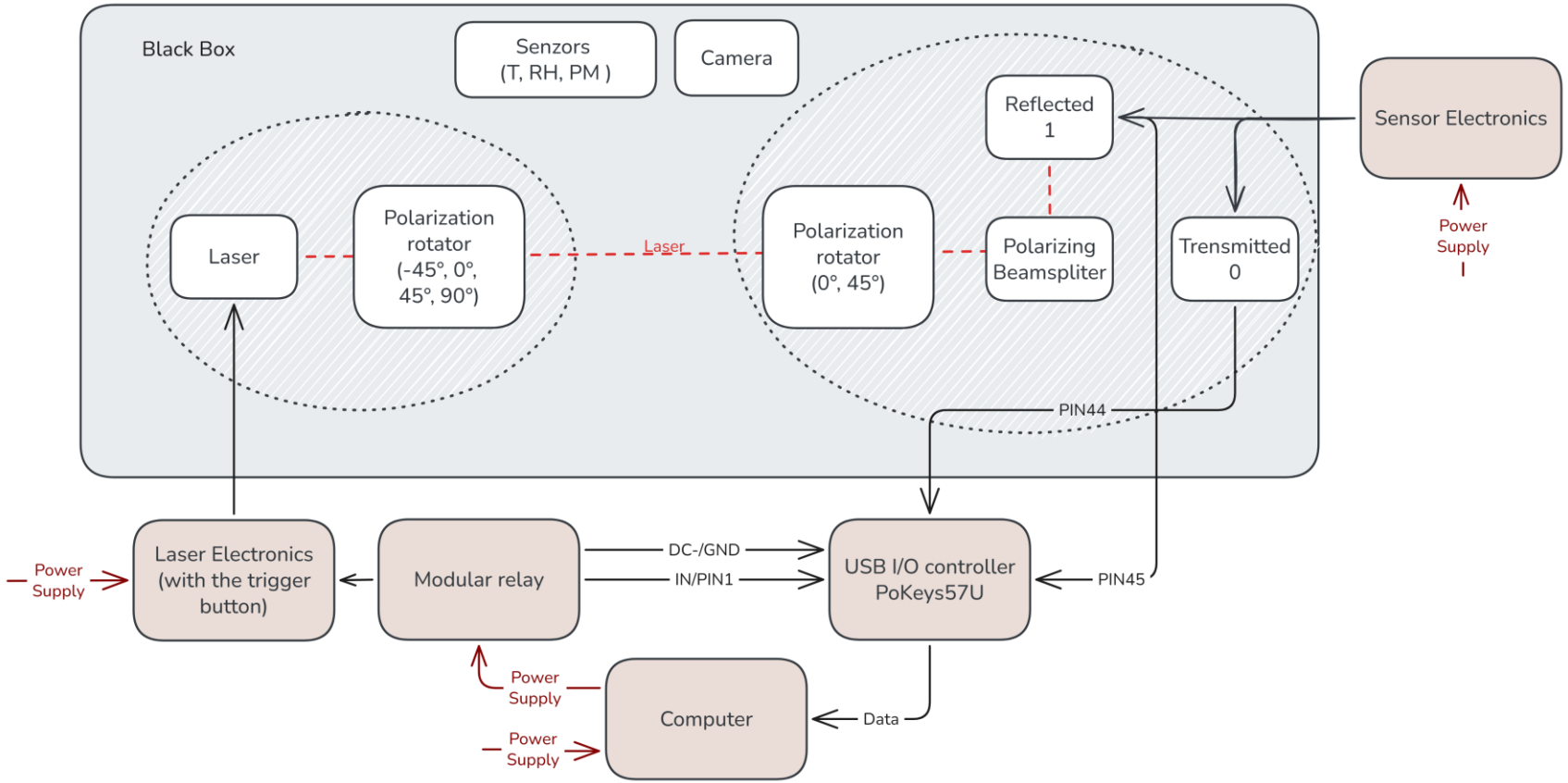
# First Step: Understanding the Impact of the Environment

- As part of the project “Mitigating Polarization Drift in Quantum Key Distribution,” we collaborated with ESA to investigate how environmental factors affect the performance of quantum communication systems in the atmosphere.
- We focused on: relative humidity, aerosols and dust particles, laser light polarization, and the reliability of information transmission.
- We set up a controlled experimental environment and performed more than five million measurements.

# Measurement System

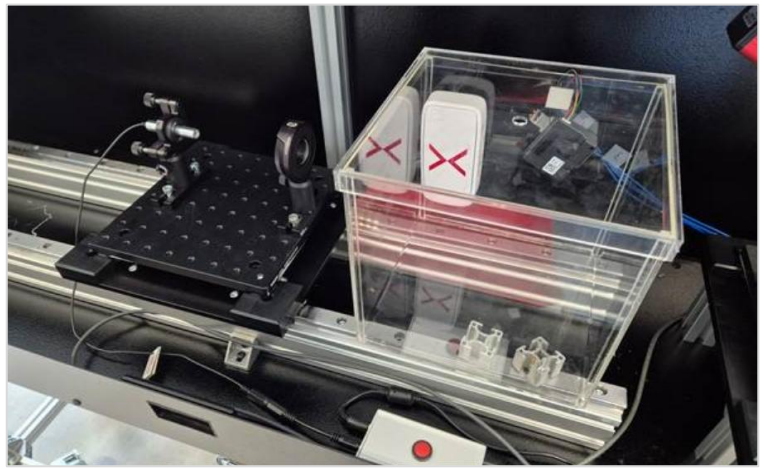


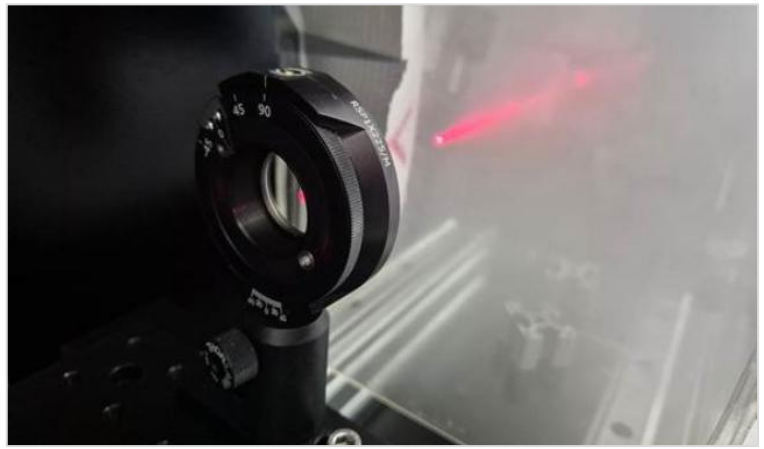
# Automation of the Measurement System



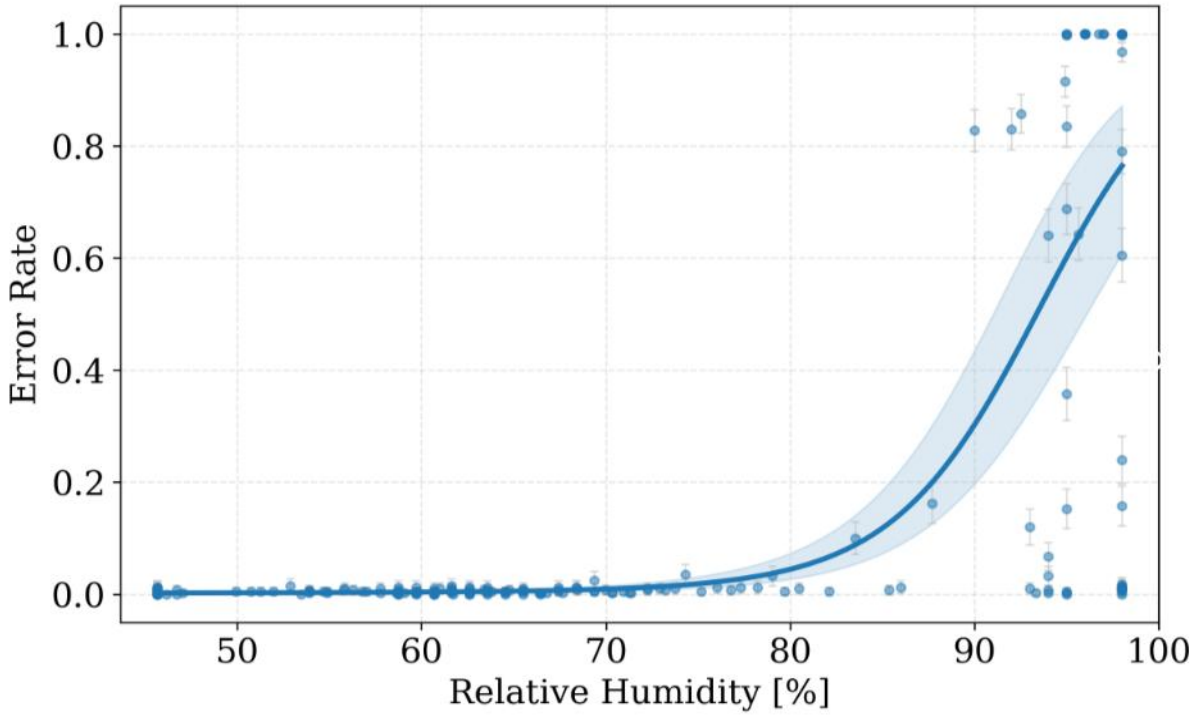
# Experiments in a Controlled Environment

| Experiment Code | Experiment Type | Polarization Basis | Optical Path Configuration | Environmental Condition | Distance A–B[1] [mm] |
|---|---|---|---|---|---|
| **EXP-BAS** | Baseline | Variable | Free space | Ambient laboratory conditions | 4250 |
| **EXP-PLX** | Plexiglass Control | Variable | Plexiglass chamber | Ambient laboratory conditions | 4250 |
| **EXP-HUM** | Humidity Variation | 90°, 0° | Water vapour inside plexiglass chamber | 30%–100% RH | 4250 |
| **EXP-AER** | Aerosol Scattering | 90°, 0° | Scattering medium inside plexiglass chamber | Smoke particles (0–6000 µg/m³) | 4250 |
| **EXP-TEM** | Temperature Observation | 90°, 0° | Free space | Heating / cooling the surroundings | 4250 |
| **EXP-LNG** | Optical Path Length | 90°, 0° | Free space | Ambient laboratory conditions | Variable |
| **EXP-ANG** | Optical Alignment / Misalignment | Variable | Free space | Ambient laboratory conditions | 4250 |



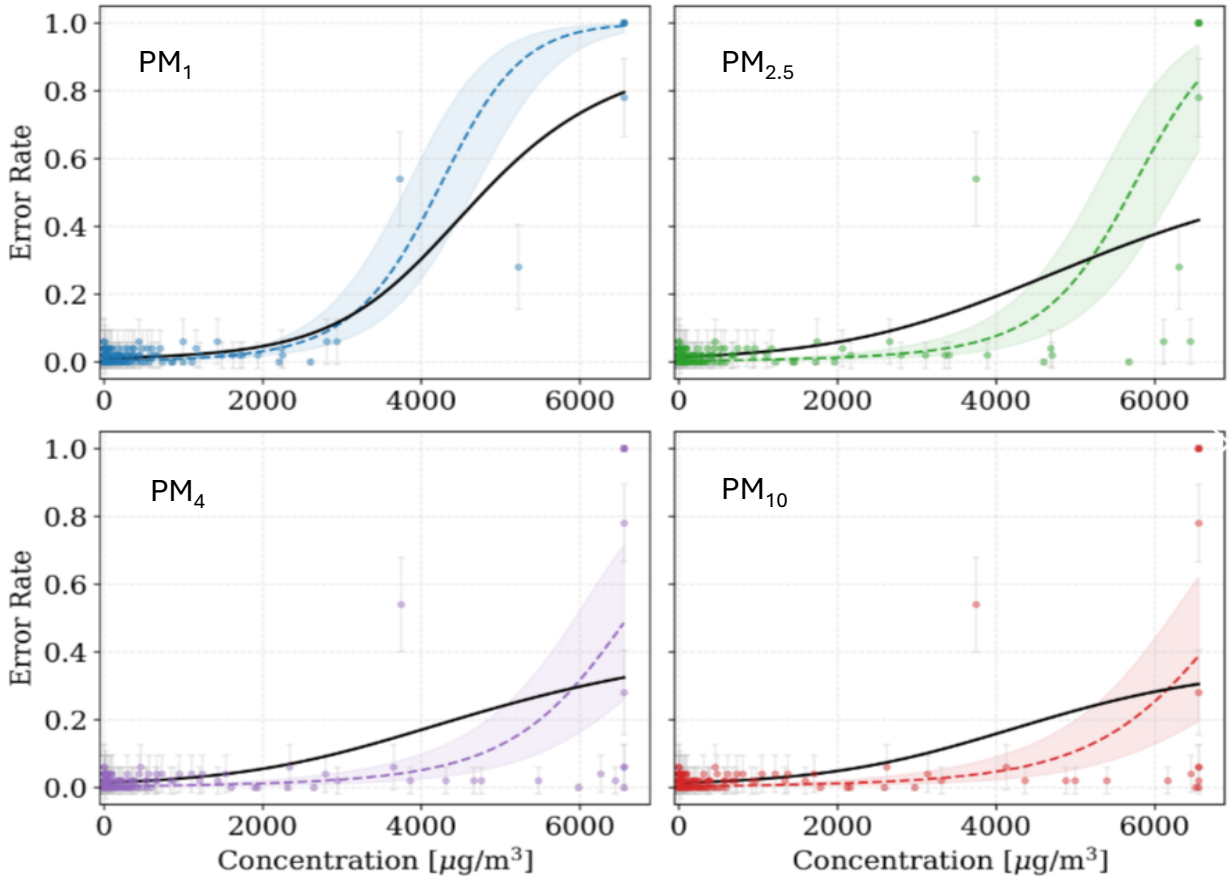


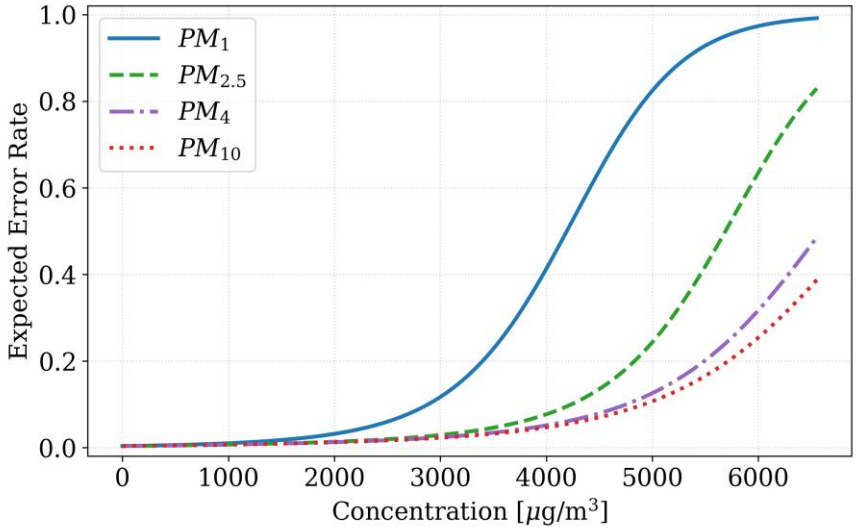
# The Effect of Relative Humidity on the Error Rate




- At lower relative humidity levels, the error rate remains relatively stable.
- Above 80% relative humidity, a pronounced nonlinear increase in the error rate is observed.

# The Effect of Particulate Matter Concentration on the Error Rate



# Next step: From the lab to the real world

- The next Esa project represents a logical continuation of our work.
- Instead of a laboratory system, we are establishing an approximately 10-kilometer-long optical link.
- The goal is no longer merely to observe individual effects in a controlled environment, but to collect long-term data in the real atmosphere.
- Such a link is also interesting because it provides a good approximation of some of the challenges we face in satellite-to-ground optical and quantum communication links.
- With this, we are moving from laboratory validation toward real-world operational conditions.

# Where does standardization begin?

- The problem today is not that we don’t know how to measure, but rather:
  - how do we compare the results of different systems?
  - If two laboratories report the same QBER, that does not necessarily mean that the systems operated under comparable conditions.
- This raises the following questions:
  - Which environmental parameters should we monitor?
  - Where do we measure them?
  - How often do we measure them?
  - How do we relate them to system performance?
  - Which models do we use to interpret the results?
  - Where do we draw the line between acceptable, risky, and unacceptable operation?

# Why Standards?

- Standardization, therefore, does not hinder development.
- Its role is to create a common framework for comparing results.
- It is a matter of agreement:
  - which parameters we consider important,
  - how we describe them,
  - how we evaluate them,
  - and how we compare the results of different systems in an objective manner.

# Standards in the Quantum Future

- The performance of quantum technologies must be measured objectively, independently of vendors, and focused on specific applications.
- Quantum applications must be compared with classical solutions.
- Standardized interfaces and performance measurement specifications are key to organizing supply chains and facilitating collaboration.
- Standardization makes quantum technologies more understandable, comparable, and verifiable.
- That is precisely why we are pleased to participate in the new SIST Technical Committee on Quantum Technologies, where we aim to bring practical experience from research and development projects into the discussion on future standards.

# Conclusion

- Our journey into quantum technology began with the question of which factors most influence the performance of quantum communication systems. Today, we are continuing this research in a real-world environment, while also seeking to contribute to the development of common metrics and standards that will enable the comparison of future quantum systems.
- The European Strategic Research and Industrial Agenda (SRIA 2030) aims to make Europe the global “Quantum Valley” by 2030.
- We want to be part of the mosaic of this future - a quantum Europe.

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Contact for Questions