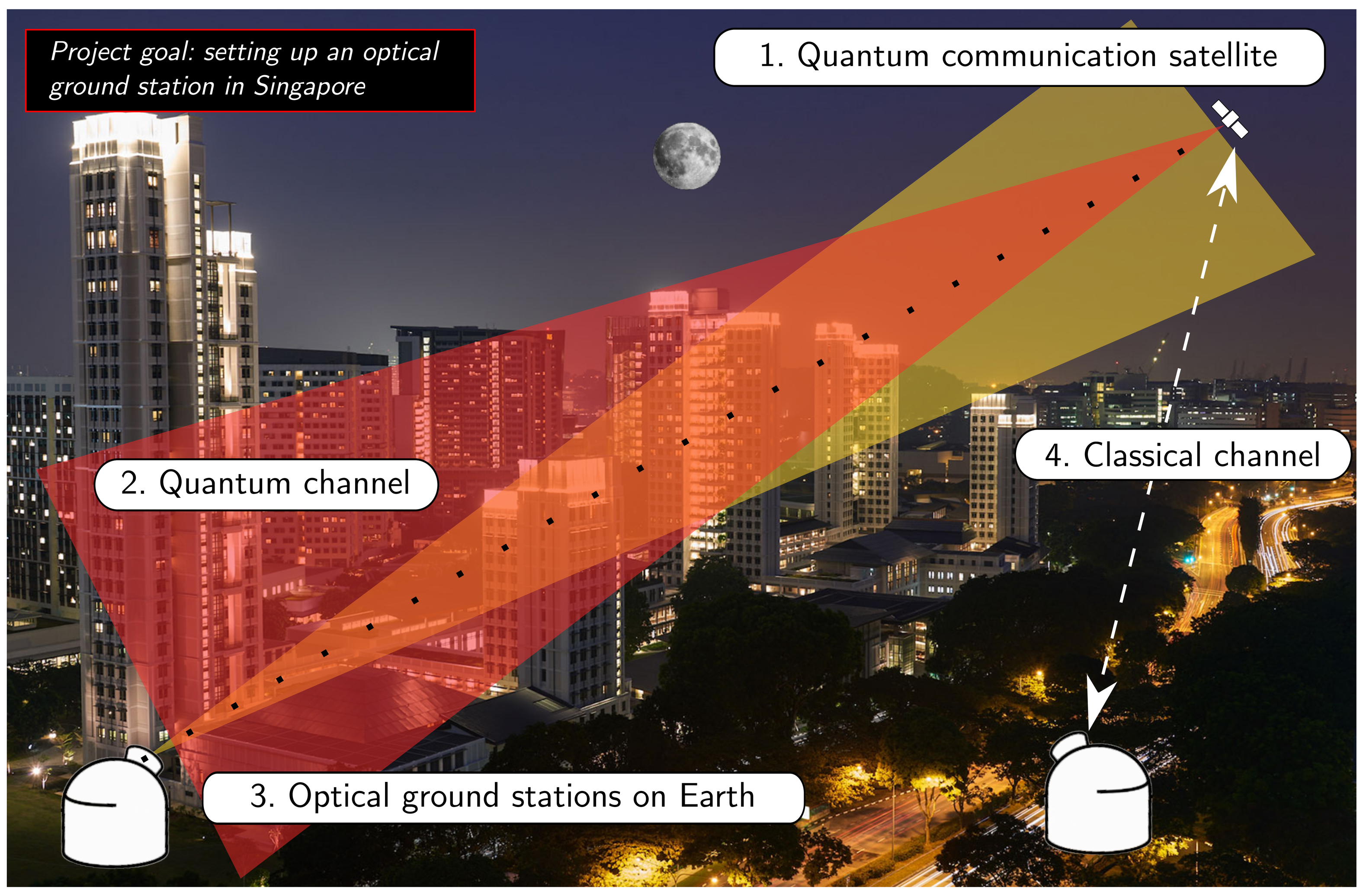
Designing an optical ground station in an urban environment for satellite-based quantum communication

Clarence Liu[1, 2], Srihari Sivasankaran[1], Esther Wong[1], Tan Peng Kian[1], Moritz Mihm[1], Christian Kurtsiefer[1, 2], Alexander Ling[1, 2]

clarenceliuh@nus.edu.sg

[1] Centre for Quantum Technologies, 3 Science Drive 2, National University of Singapore, 117543 Singapore,
[2] Department of Physics, National University of Singapore, 2 Science Drive 3, 117551 Singapore

Introduction: Satellite-based Quantum Communication

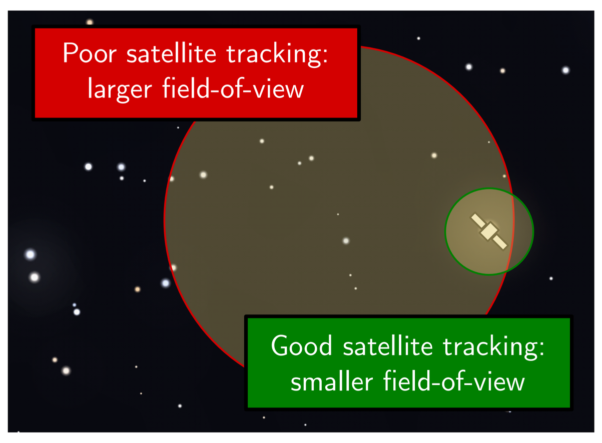


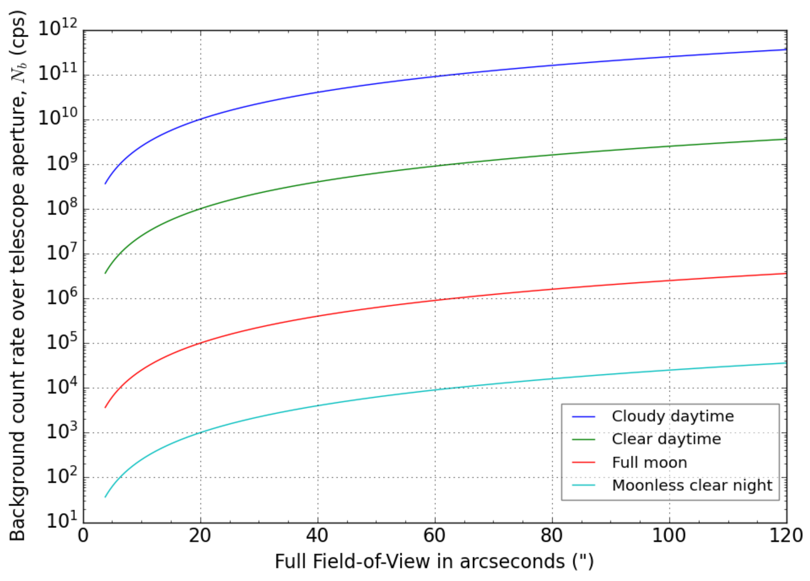
Quantum communication satellite | Quantum signal | Line-of-sight

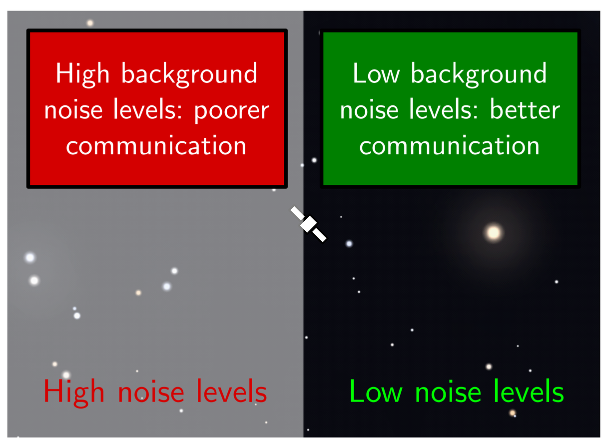
Optical ground station (OGS) | OGS field-of-view

OGS Field-of-View Design Considerations

Sizing of the OGS field-of-view is dependent on the satellite tracking capability of the OGS as well as the background noise level. By restricting the field-of-view, we reduce the amount of background noise over the same telescope aperture.







Environmental Challenges to Quantum Communication

- Vibrational environment
  - Sources of vibration
- Weather conditions
  - Cloud cover
- Atmospheric conditions
  - Atmospheric absorption
  - Atmospheric scattering
  - Atmospheric turbulence
- Background skylight
  - Presence of moon and clouds

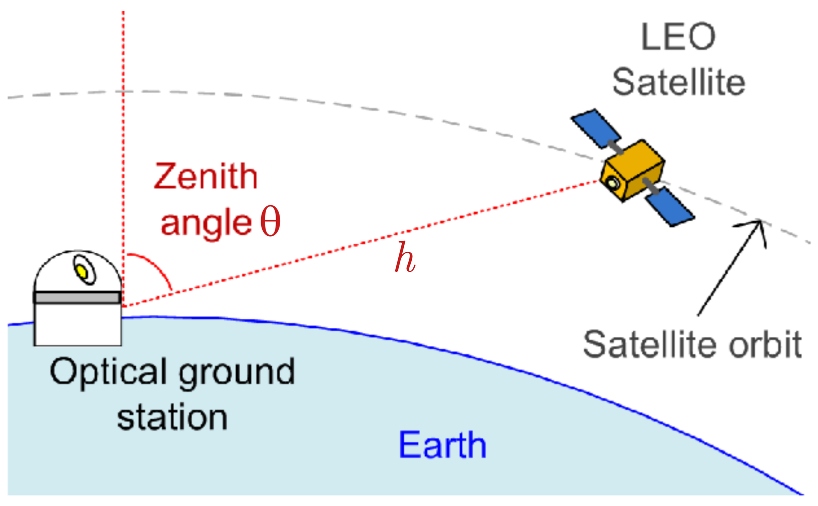
Atmospheric turbulence
Spatio-temporal fluctuations in the refractive index of atmosphere.

- Scintillation
  Intensity fluctuations.
- Beam spreading
  Broadened beam.
- Beam wandering
  Random deflection along path.
- **Angle-of-arrival fluctuations**
  Seeing limited spot size resolution.
  $\beta = \beta\left(\lambda, C_n, h(\theta)\right).$

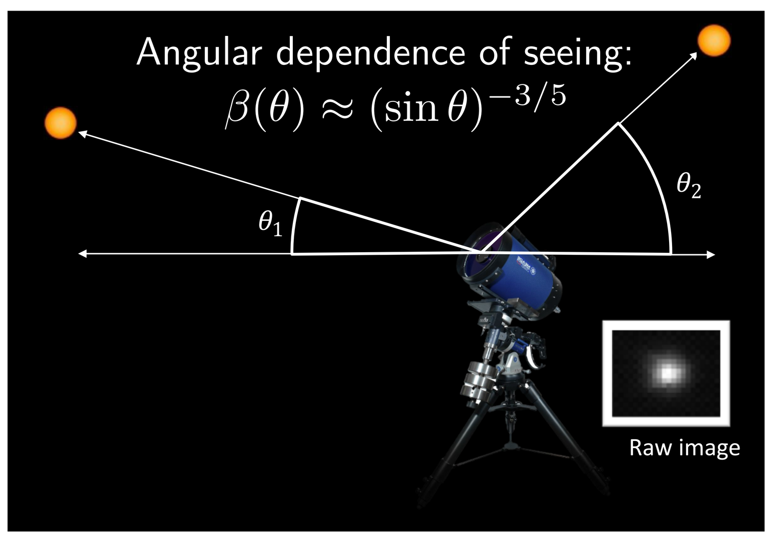
Characterising Atmospheric Turbulence in Singapore

We designed an experimental set-up for measuring and determining the seeing and scintillation conditions in Singapore during the late hours (past midnight).

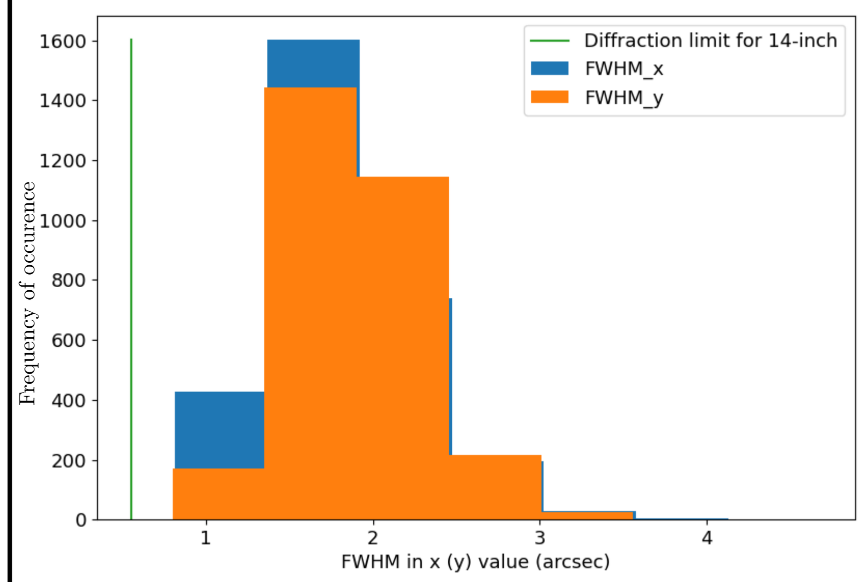
Dependencies

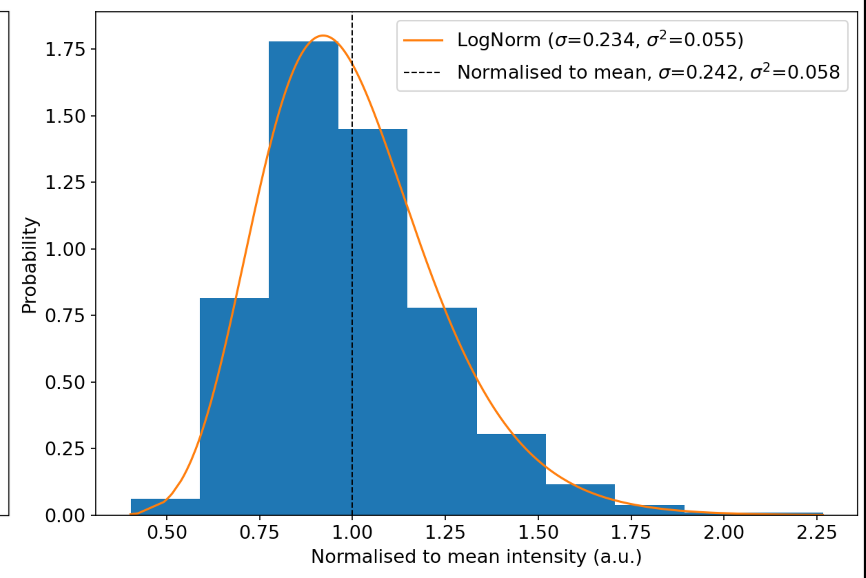


Measurement Set-up



Results and Analysis



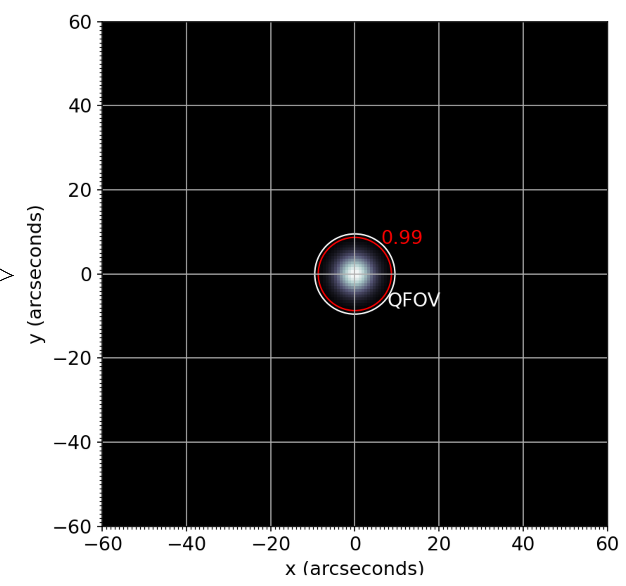


The maximum seeing is found to be about 4 arcseconds, the mode is found to be between 1.5 - 2 arcseconds. The scintillation index, a measure of scintillation, was also found to be less than one, signifying weak scintillation. In the seeing limited regime, the OGS would see the satellite as a spot of 4 arcseconds (max.) wide (FWHM).

Conclusion

The maximum seeing obtained from the measurements, and other factors, are then used as input into calculating a minimum field-of-view required for capturing the quantum communication satellite within a 99% probability.

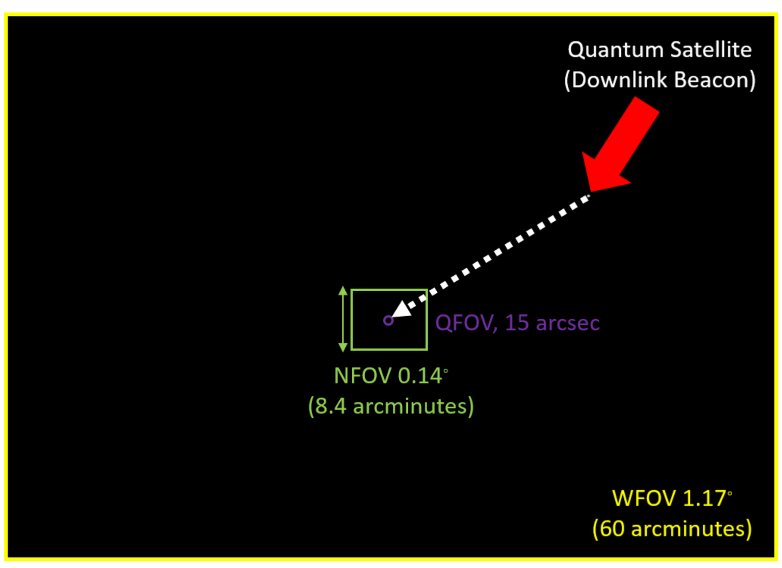
- Vibrational environment
- Atmospheric conditions
- Background skylight
- Satellite position knowledge
- Instrument tracking accuracy



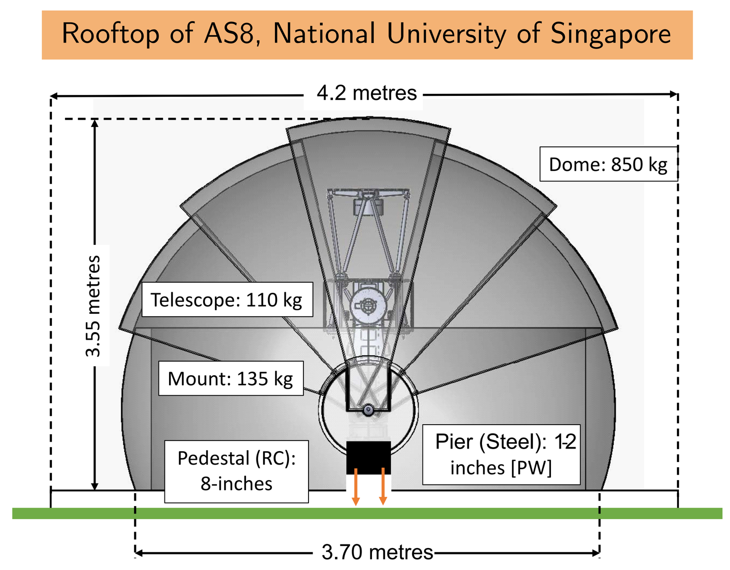
Minimum field-of-view (radius) required to capture the satellite within a 99% probability: 15 arcseconds.

QFOV: field-of-view of the OGS.
White blob: uncertainty distribution of the satellite.
Radius of red circle: cumulative distribution of uncertainty distribution at 99%.

Current Status



Rooftop of AS8, National University of Singapore



References

[1] R. Bedington et al., "Deploying quantum light sources on nanosatellites II: lessons and perspectives on CubeSat spacecraft", in Electro-Optical and Infrared Systems: Technology and Applications XII; and Quantum Information Science and Technology, Vol. 9648 (Oct. 22, 2015).
[2] Y. Takemoto and T. Sugihara, "A study of optical satellite communication systems employing rate-adaptive forward error correction", in 2015 IEEE International Conference on Space Optical Systems and Applications (ICSOS) (Oct. 2015).

Centre for Quantum Technologies

NUS National University of Singapore

Centre for Quantum Technologies
National University of Singapore
S15 #03-18 Science Drive 2 Singapore 117543
www.quantumlab.org