editorial

Quantum optics lifts off

The launch of the first space-based source of entangled photons and other ambitious plans are driving satellite-based quantum communications and fundamental physics tests in space.

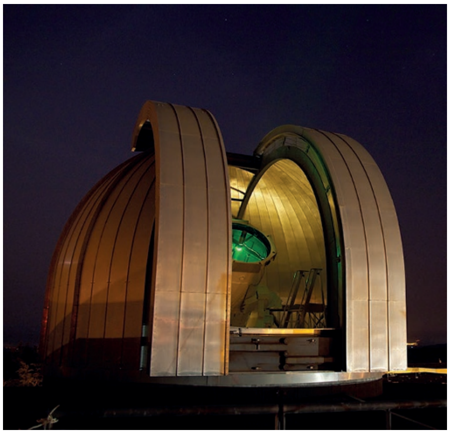
Will space be the final frontier of quantum optics? Only time will tell. Several groups worldwide have been making important progress in the area and reporting their latest results. One of the main research objectives is the realization of reliable satellite-to-ground quantum communications, which might eventually lead to a global quantum network. What is certain is that the classical satellite optical communication channels that are already in place would benefit from the secure data transmission afforded by quantum protocols.

In this context, the Chinese-led quantum experiments at space scale (QUESS) project, which launched its satellite in August[1], ticked an important box — carrying a source of entangled photons into space for the first time. Elsewhere, a collaboration between Singapore and the UK, and teams from Japan, Italy and Germany are all pursuing approaches for conducting quantum experiments between Earth and space.

From a general perspective, it might be argued that taking quantum optical technologies into space is a natural evolution. The quantum toolbox has been put to the test over many decades on Earth: researchers have refined schemes for entanglement generation and manipulation, achieved quantum teleportation and performed quantum key distribution (QKD) over long distances (up to around 300 km with optical fibres[2]). However, a terrestrial fibre-based global quantum network for communications would require quantum repeaters that are not available at present, and some experts believe that satellite-to-ground channels represent a promising alternative[3].

Despite the impressive progress with terrestrial quantum experiments, one should not be misled into thinking that space-based quantum protocols are trivial extensions of Earth-based research. Alexander Ling, assistant professor at the National University of Singapore, leads a research team that is currently operating a source of correlated photon pairs aboard a CubeSat (a common nanosatellite standard), and told *Nature Photonics* about some of the challenges they are facing.

Owing to weight and space limitations aboard the larger spacecraft that took the experiment into a low Earth orbit, Ling and collaborators knew that they would not be able to shield their set-up against ionizing radiation. "We had expected there to be radiation damage [to the equipment], and had modelled it," explains Ling. Nevertheless, the data showed that the background rate for the detectors was higher than in the simulations[4], indicating that "the radiation damage was accumulating at twice the predicted rate," states Ling. The discrepancies between simulated and observed phenomena are a major challenge for quantum experiments in space, where "the radiation environment is not fully understood, and the only way to mitigate [damage] is to shield, or to design the mission so that it operates within the lifetime of the electronics," comments Ling. Still, hope is not lost as radiation hardening is commonly used for scientific equipment in space when limitations on payloads are less strict. Ling was also positively surprised by the performance of their unshielded source, polarization rotators and photodetectors: "nine months after launch [we are still] fully operational," he notes.



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Another technical challenge is optical losses. Giuseppe Vallone, assistant professor at the University of Padua, is the lead author on a recent article reporting the experimental demonstration of single-photon interference originating from the coherent superposition of temporal modes reflected by a moving satellite 1,000 km away from a receiving ground telescope[5] (pictured). Vallone explains that imperfect satellite tracking, laser beam divergence and the size of the telescope are all sources of optical loss, which affect the quality of the received data and are especially damaging to fragile photon entanglement. As Vallone told *Nature Photonics* "to realize QKD ground-space experiments it will be necessary to minimize losses as much as possible."

Although the development of secure quantum communications based on a satellite network is widely recognized as one of the primary goals, there are other stimulating opportunities for this research. The realization of space-based quantum protocols would open the way to fundamental tests of physics in unexplored conditions, such as investigating the persistence of quantum correlations over long distances. Other studies could look at the effects of general relativity on quantum systems and entanglement.

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With such exciting scientific endeavours ahead, it might come as a surprise that research groups operate independently rather than joining forces. "Right now every team tries to be the first to demonstrate the feasibility of a given space-based experiment," comments Vallone. But he thinks that European or international collaborations will be set up in the future. A different question is whether a collaborative scheme will also be applied to 'sensitive' tasks such as building large QKD networks. Indeed, as Vallone points out "in a similar way as with global positioning systems, it may well be that Europe, the USA and China will opt for developing separate infrastructures." ❐

References

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