TUTORIAL

Entangled Photons in a CubeSat

Putting compact quantum science into space could support a next-gen internet.

As quantum communication moves forward, a few researchers are eyeing something much bigger: a quantum internet—a global network of quantum devices tied together by quantum-encrypted links. One route to that, some believe, could lie in space, using small, quantum-enabled nanosatellites, or CubeSats, as network nodes. OPN talked with Alexander Ling of the National University of Singapore about his team's efforts to pack quantum technology into CubeSats—most recently reported in *Optica* (doi: 10.1364/OPTICA.387306)—and what this might someday enable.

How to pack a space-ready quantum experiment into a nano-satellite.

1. Packing things in

CubeSats are tiny satellites built of modular cubes 10 cm on a side. The CubeSat hosting the experiment from Ling's group, dubbed SpooQy-1, is a three-unit (3U) construction, roughly 30 cm long, with the quantum experiment occupying the right-hand two-thirds of the spacecraft.

Packing a space-ready quantum experiment into that small volume entailed big challenges, Ling says—particularly keeping components aligned to the tiny tolerances required. To achieve that, the team borrowed a concept from "some of the big space telescopes," placing the quantum experiment on an isothermal mount. This metal structure takes up heat-related strain, keeping the experiment's components properly lined up.

The solar-powered SpooQy-1 weighs in at a mere 2.6 kg —compared with masses of anywhere from 50 to 600 kg for conventional satellites used in space-based communications experiments. The low mass could give CubeSats a big cost advantage for hosting quantum communication nodes, according to Ling. That's because any realistic use case would require an entire constellation of satellites for covering more than a small area of Earth's surface at a time.

2. Creating entanglement

Ling stresses that the recent experiment reported in *Optica* is "a very small step" toward such a quantum CubeSat constellation. The experiment aimed to establish that entangled photons—the linchpin of many quantum systems—could reliably be generated and detected in low-Earth orbit on such a small craft. To do so, Ling said, the team went "back to basics," and asked itself what were the essential elements of an entangled-photon light source. "Anything that was just 'nice to have', we left it off the drawing board."

The setup begins with a 405-nm laser diode pump, the light from which passes through two nonlinear BBO crystals; these create pairs of lower-wavelength signal and idler photons in each crystal, through the process of spontaneous parametric down-conversion (SPDC). A half-wave plate between the crystals rotates the polarization of the SPDC photons from the first crystal. An alignment of the BBO crystals' optical axes causes photon pairs from the first crystal to be "almost completely overlapped" with photon pairs from the second—substantially increasing the experiment's harvest of entangled photons, Ling says..

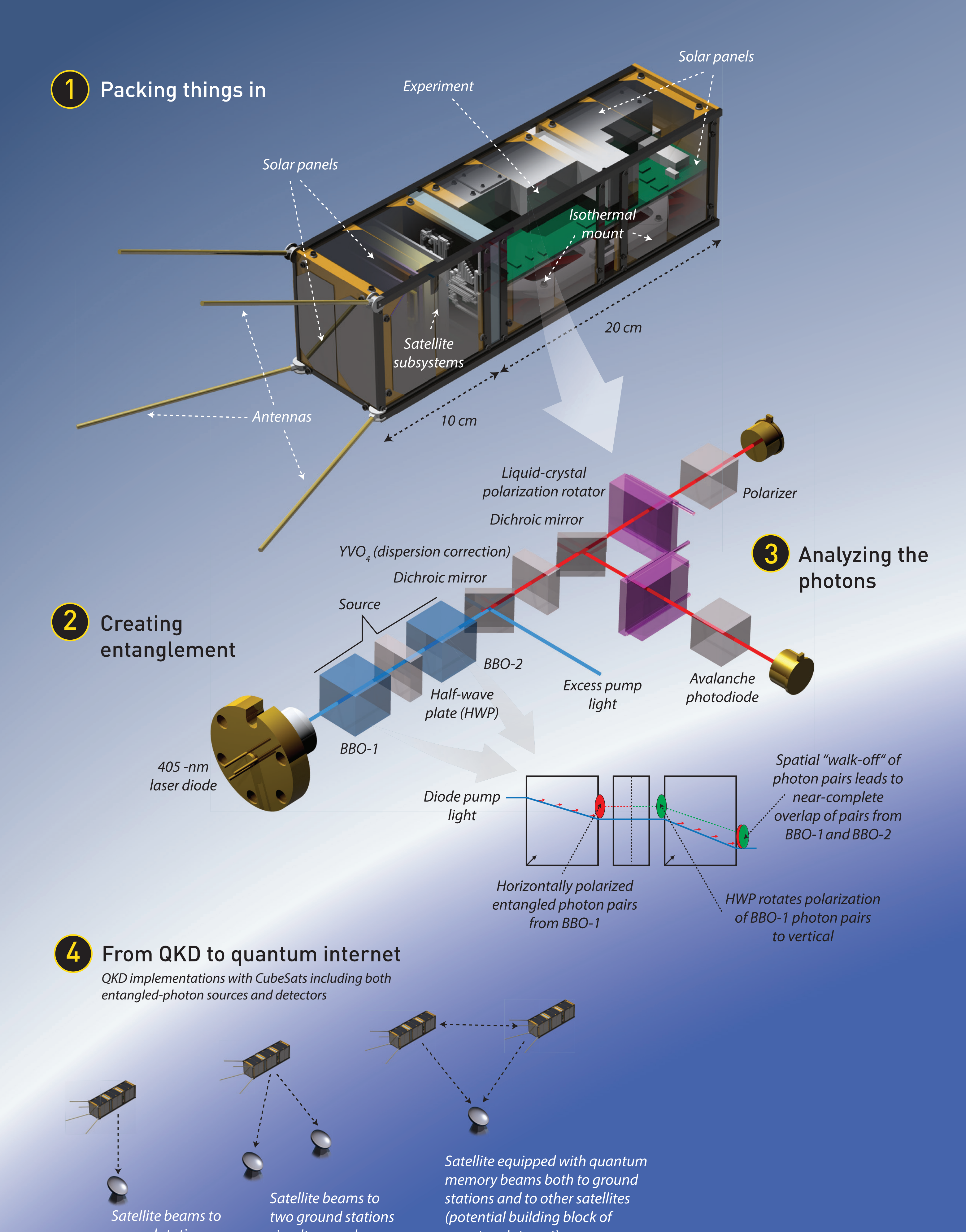
3. Analyzing the photons

After passing through a dichroic mirror and a dispersion-compensating YVO_4 crystal, the signal and idler photons from the BBO crystals are separated by another dichroic mirror. Because the experiment is designed to test for entanglement in polarization, a liquid-crystal polarization rotator (LCPR) and a polarizer are used to analyze different polarization states. An avalanche photodiode does the final detection and sends the signal back to Earth for analysis.

4. From QKD to quantum internet

SpooQy-1 was launched from the International Space Station on 17 June 2019. By sweeping through different polarization settings in the analyzer arms, the team created correlation curves that established a high degree of entanglement—indicating that "entanglement technology can be deployed with minimal resources" in CubeSats.

Ling notes that, for real applications, the nanosatellites may need to "grow slightly larger" to accommodate the telescope and pointing system needed for free-space communications—whether from satellite to ground for basic quantum key distribution, or between satellites in more advanced quantum internet schemes (which may also require putting some form of quantum memory on the spacecraft). The team hopes to launch a telescope-equipped test CubeSat in the next few years. OPN



Source: A. Villar et al., Optica **7**, 734 (2020) / Art by Phil Saunders