Distributing entanglement and single photons through an intra-city, free-space quantum channel

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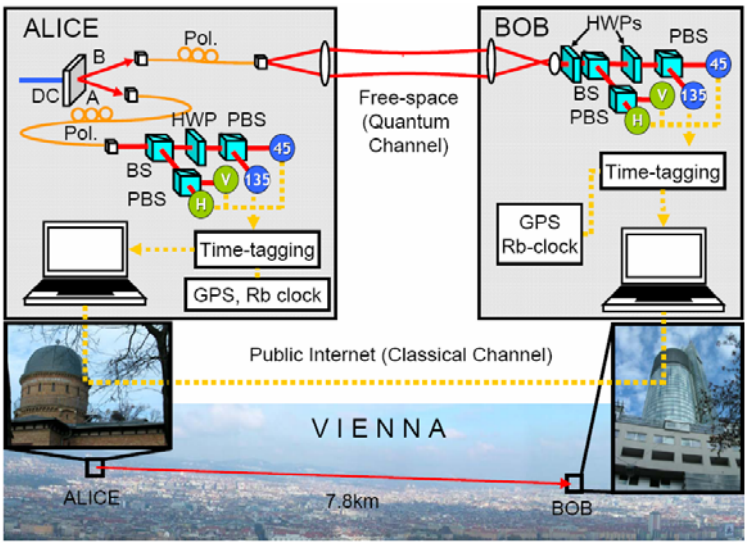
We have distributed entangled photons directly through the atmosphere to a receiver station 7.8 km away at night over the city center of Vienna, Austria [1]. Without a time-stable connection, the two stations found coincidence counts in the detection events through the cross-correlation of locally-recorded time stamps shared over a public internet channel. As such, the sending and receiver stations were completely independent. The polarization correlations contained in our measured time tags were sufficient to convincingly violate a CHSH-Bell inequality and demonstrate entanglement between our two city buildings.



Alice has the single-mode fibre coupled polarization-entangled photon source (DC) and sending telescope and is located in the 19th century observatory, Kuffner Sternwarte. Bob has a receiver telescope and is located on the 46th floor of the Millennium Tower skyscraper 7.8km away. Alice measures the photons in mode A from each entangled pair using a four-channel detector, made with a 50/50 beamsplitter (BS), a half-wave plate (HWP), and polarizing beamsplitters (PBS), which measures the photon polarization in either the *H/V* or +/- basis. She sends the other photon in mode B, after polarization compensation (Pol.), via her telescope and free-space link, to Bob. Bob's receiver telescope is equipped with a similar four-channel detector and can measure the polarizations in the same bases as Alice or, by rotating an extra HWP, measure another pair of complementary linear polarization bases. Alice and Bob are both equipped with time-tagging cards which record the times at which each detection event occurs. Rubidium atomic clocks provide good relative time stability. Both stations also imbed a 1pps signal from the global positioning system (GPS) into their time tag datastream to give a well-defined zero time offset. During accumulation, Bob transmits his time tags in blocks over a public internet channel to Alice. She finds the coincident photon pairs in real time by maximizing the cross-correlation of these time tags.

For this experiment, our quantum channel was maintained for 40 minutes during which we found approximately 60000 coincident detection events. The polarization correlations in those events yielded a Bell parameter, S=2.27 +/- 0.019, which violates the CHSH-Bell inequality by 14 standard deviations. We have extended the distance over which entangled photons have been distributed through free-space optical links by an order of magnitude. In doing so, we have surpassed the horizontal distance where the optical properties of the air are comparable to passing vertically through the entire atmosphere. Our results show that high-fidelity transfer of entangled photons is possible under these real-world conditions and are promising for future quantum communication using satellites.

[1] K. J. Resch et al, quant-ph/0501008 and accepted for publication in Optics Express