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RESEARCH BRIEF

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QUANTUM INFORMATION SCIENCE

QUANTUM TELEPORTATION ACROSS A METROPOLITAN FIBRE NETWORK

Quantum teleportation allows quantum states to be, in principle, teleported over arbitrarily long distances and has several applications in communication and cryptographic protocols. This work provided the first demonstration of quantum teleportation spanning several kilometers using telecommunication-wavelength photons.

BACKGROUND

Contrary to the classical realm, measuring quantum systems can significantly alter their evolution in time. In fact, measurements are often an integral part of quantum information processing protocols. An example of where measurement plays a key role is in entanglement, a pure quantum mechanical phenomena that has profound consequences. When two particles are entangled, measuring the state of one of the particles immediately affects the state of the other particle, regardless of the distance between them.

Quantum teleportation combines measurements and entanglement to teleport the state of a qubit (the quantum analogue of a classical bit) to a second qubit regardless of the distance between them. The receiver (by convention referred to as “Bob”) must prepare an entangled state (called a Bell state) and share one of his qubits with the sender “Alice,” who performs a Bell state measurement (BSM) on her joint system. Depending on the outcome of the measurement, Bob performs a local operation on his second qubit which effectively teleports Alice’s state to Bob.

In practice, noisy channels limit the distance photons (particles of light which can serve as a qubit) can be teleported. In this work, new teleportation protocols were implemented improving the distance over which teleportation takes place to 6.2 kilometres.

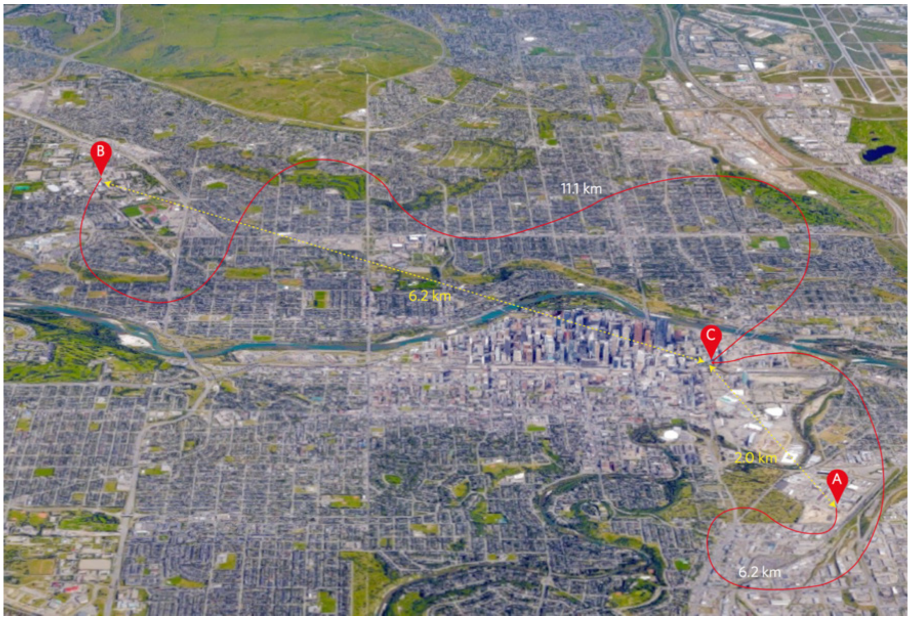
FINDINGS

The teleportation experiment was conducted by a team led by Wolfgang Tittel, a senior fellow in CIFAR’s Quantum Information Science program, and a physicist at the University of Calgary. For their experiment, they used Calgary’s municipal fiber optic network, which normally carries telephone calls and Internet traffic.

The experiment involved three locations. Alice was in the Calgary neighborhood of Manchester, and Bob was at the University of Calgary. The teleportation protocol involved a third party called Charlie, located in a building next to Calgary City Hall, who received photons from both Alice and Bob. Charlie performed certain measurements on both photons to successfully teleport Alice’s state.

The photons from Alice to Charlie needed to travel 6.2 km through fibres of the Calgary telecommunication network. The telecommunication photons from Bob to Charlie needed to travel 11.1 km through fibers. During transmission, the photons were subject to noise arising from varying environmental conditions impacting their state and arrival times. Despite these difficulties, it was shown that Alice’s photon state was teleported to Bob’s over a distance of 6.2 km with a fidelity of greater than 80 per cent.

It should be pointed out that throughout the protocol Bob only needed to send photons to Charlie, never receiving any photons from Alice. However, due to the strange and fascinating laws of quantum mechanics, Bob managed to receive Alice’s state.



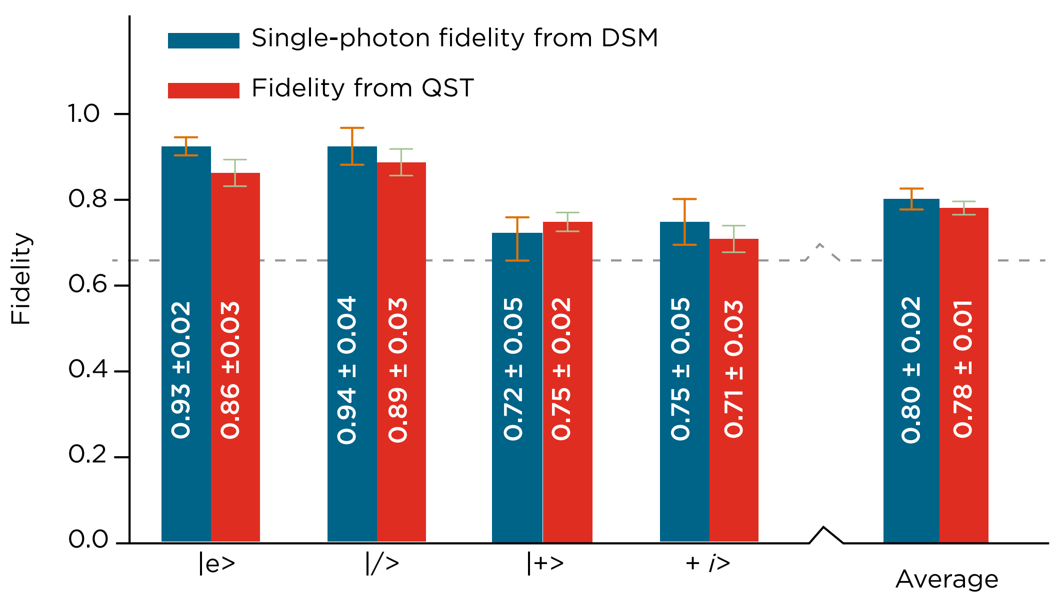
Arial view of Calgary showing the location of Alice (A) in Manchester, Bob (B) at the University of Calgary and Charlie (C) in a building next to Calgary City Hall.

METHODOLOGY

Alice prepared a series of telecommunication wavelength photons (1532 nm) to send to Charlie. Bob created an entangled pair of photons, one at 1532 nm and another at a wavelength of 795 nm. The telecommunication photon was sent to Charlie with the intent of having Alice's state teleported onto Bob's 795 nm photon. Charlie then performed a BSM projecting the pair of received photons onto a special entangled state effectively teleporting Alice's state to Bob.

To confirm that Bob received the correct teleported state, he performed a sequence of measurements on the 795 nm photon and the outcomes were analyzed using several approaches.

To overcome errors arising from the long distances travelled by the photons and unwanted environmental effects, the group employed a polarization tracker and a novel approach of quantum interference.



Fidelities of the teleported state using Quantum state tomography (QST) and a decoy-state method (DSM) to characterize how the environment and experimental imperfections affected the teleported state. For both methods, the average fidelity is above 2/3, the maximum value achievable by classical teleportation.

Quantum state tomography (QST) and a decoy-state method (DSM) where used to characterize how the environment and experimental imperfections impacted the teleported state. The fidelity (which indicates how close the final state is to the desired teleported state) was measured. Using QST the average fidelity was found to be roughly 78 per cent. Using DSM, the average fidelity was found to be greater than 80 per cent. In both cases, the fidelities were greater than 2/3, the maximum value than can be achieved using classical teleportation.

Deviations from ideal teleportation arose mostly due to the distinguishability in the photons prior to Charlie's BSM. For teleportation to work, the measured photons must be indistinguishable.

IMPLICATIONS

Optical amplifiers are used to amplify light signals in communication lines allowing information to be transferred across the globe. Quantum repeaters are the quantum analogue of optical amplifiers and extend the range of quantum communication between two parties. Quantum repeaters rely on the creation of entangled two-photon states in which one photon is absorbed, effectively performing a BSM. However, the entangled photon pairs must be created far apart and the BSM must take place halfway between the two photons to achieve optimal performance. The experiment in this study was performed fulfilling these requirements. Therefore, performing standard teleportation in a mid-point configuration could be used in the implementation of a quantum repeater achieving long distance (over 80 km) quantum communication.

REFERENCE

Quantum teleportation across a metropolitan fibre network, Raju Valivarthi, et al., *Nature Photonics* 10, 676–680 (2016).

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