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Images encoded with larger alphabets safely transferred over a quantum network

Researchers demonstrate the quantum transport of the highest dimensionality of information to date. Crucially, they use a teleportation-inspired configuration so that the information does not physically travel between the two communicating parties.

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Nature Communications has published research done by an international team of scientists from the University of the Witwatersrand (WITS, Johanesbourg, South Africa) and ICFO - The Institute of Photonic Sciences, which demonstrates the transport of an image imprinted on a beam of light across a network without physically sending the image, an important step towards realising a quantum network for the transmission of information written with a high-dimensional alphabet.

Quantum communication over long distances is integral to information security and has been demonstrated with two-dimensional states (qubits) over very long distances between satellites. This may seem enough if we compare it with its classical counterpart, i.e., sending bits that can be encoded in 1s (signal) and 0s (no signal), one at a time. However, quantum optics allow us to increase the alphabet and to securely describe more complex systems in a single shot, such as a unique fingerprint or a face.
ï¿½Traditionally, two communicating parties physically send the information from one to t
e other, even in the quantum realm,ï¿½ says Prof. Andrew Forbes, the lead PI from
its University. ï¿½Now, it is possible to teleport information so that it never physically
ravels across the connection - a ï¿½Star Trekï¿½ technology ma
e real.ï¿½ Teleportation has so far only been demonstrated between two parties using lo
 dimensional alphabets, which requires several entangled photons to send co
plex images. In this research, the team performed the first experimental demonstrati
n of quantum transport of high-dimensional states with just two entangled photons as a quan
um resource. To make the advance, the team used a nonlinear optical detector that circumv
nts the need for additional photons, yet works for any image that needs to be sent. **They report a new state-of-the-art communication protocol that can send information written in an alphabet of 15 dimensions, with the scheme scalable to even higher dimensions, paving the way for**

quantum network connections with higher information capacity.
In their experiment, the researchers came up with an elegant way of securely transferring high-dimensional spatial information between two parties, our famous Alice and Bob, using a teleportation-inspired scheme. Unlike previous experiments that had successfully teleported 3 dimensional states (using path entanglement), requiring unfortunately the help of extra entangled photons, here the team used three only two entangled photons, that form the quantum channel.
They first encoded the information to be teleported with an alphabet containing 15 elements. In parallel they created a photon pair entangled in all this 15 dimensions. From the pair of photons, the second entangled photon traveled from Bob to Alice and measured in nonlinear spatial detector by the interaction with the patterned light source in Alice, throug what is known as a Bell State Measurement (BSM). The effect of this measurement was to mi the states of the second and the light source photons in a second nonlinear crystal an perform a particular spatial projection on the resulting single photon. Thanks to the fact tha the first and second photons were entangled to begin with- i.e. their joint state was highl correlated- the result of the BSM was the transferring the information encoded from th coherent light source to the first photon, which had remained in Bob and had never been i contact with the source

Practical Applications in a Banking setting

The potential of this new quantum transport protocol is illustrated in the attached figure. Imagine a customer wishing to send sensitive information to a bank - a fingerprint perhaps. In traditional quantum communication the information must be physically sent from the customer to the bank, always with the risk of interception (even if it is secure). In the newly proposed quantum transport scheme, the bank sends a single photon (one of an entangled pair) with no information to the customer, who overlaps it on a nonlinear detector with the information that is to be sent. As a result, the information appears at the bank exactly as if it had been teleported there. No information is ever physically sent between the two parties, so interception is fruitless, while the quantum link connecting the parties is established by the exchange of quantum entangled photons.
ï¿½This protocol has all the hallmarks of teleportation except for one essential ingredient: t requires a bright laser beam to make the nonlinear detector efficient, so that the sender could know what is to be sent, but doesn't need to know,ï¿½ explains Forbes. ï¿½In this se se, it is not strictly teleportation, but could be in the future if the nonlinear detector coul be made more efficient.ï¿½ Even as it stands now, it opens a new pathway for conn cting quantum networks, ushering in nonlinear quantum optics as a res urce. ï¿½We hope that these results validating the feasibility of the process motivate further advances in the nonlinear optics field, pushing the limits towards a full quantum implementation,ï¿½ says Dr Adam Valles from ICFO (Barcelona), one of the le ds on the project who worked on the experiment during his postdoctoral fellowship at W

ts. ï¿½We have to be cautious now, as this configuration could not prevent a cheating sender from keeping better copies of the information to be teleported, which means we ould end up with many Mr Spock clones in the Star Trek world if that is what Scotty wa ted. From a practical point of view, the configuration that we currently demonstrate can alr ady be used to establish a high-dimensional secure channel for quantum communications between two parties, provided that the protocol does not need to be fed with single photons, as would be the case for quantum r

Acknowledging PhD research

Valles adds: ï¿½Performing such proof-of-concept experiments with currently availab e technology has been an interesting journey, and we have Dr Bereneice Sephton from Wits o thank for her determination and the comprehensive skills set needed to tame such n experimental beast. This is a true laboratory endeavour for which she should be lauded.ï ?½ Forbes echoes the sentiment: ï¿½This was an heroic experiment and Dr Bereneice S phton must be recognised as she is the one who got the system to work and performed t e key experimen

s.ï¿½ The team plan to continue working in this direction, with the next step focusing on quantum transport across an optical fibre network.

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Illustration of the scheme?s potential