



Quantum entanglement for designers

Description

The idea of the quantum Internet (QI) adds a new dimension to city infrastructures. Quantum physics is even more difficult to grasp than the [blockchain](#). But Iâ€™ll give it a shot, starting with lasers.

Lasers

A laser beam is a concentrated beam of coherent light within a narrow colour band (i.e., frequency range). You can point a laser beam at a sheet of card that has two slits cut close together into it. Some of the laser light will pass through the slits. A surface on the opposite side of the slits to the laser light source will show an interference pattern of light and dark bands. Thatâ€™s because light beams propagate in a wave pattern. The light waves are refracted by the two slits and spread out creating two wave patterns. The interference pattern appearing on the surface is brightest where the light waves reinforce one another, and will be darkest where they cancel each other out.

So light behaves as waves. It is also observable as individual particles, photons. Experiments that track the passage of low intensity laser light with countable numbers of photons shows that individual photons do in fact exhibit this wave characteristic when observed en masse. A sensor can count the photons and record their positions as they arrive on the surface in the two slit experiment.

Photons are discrete particles and donâ€™t exhibit degrees of luminance. Nor do they reinforce or cancel each other. The light patches on the screen are where the photons land in higher numbers. The dark patches have no photons. If one of the slits is covered over then the photons entering the open slit will fall on the screen without any interference banding. This experiment highlights one of the paradoxes in the behaviour of light.

Itâ€™s as if photons passing through one slit take account of the photons passing through the other slit so they decide where to fall if the light was moving as waves. The results of these experiments imply that under the right conditions photons from the same source coordinate with each other. That linkage is termed â€œquantum entanglement.â€•

The description I've just presented is standard fare in physics textbooks. The two-slit experiment establishes that photons exhibit "quantum entanglement." The behaviour of one particle depends on what happens to the other particle, even though they are observed at different times and places.

Everything spins

As well as the two-slit phenomenon, in quantum computing the characteristic of the photons of most interest is their spin, which physicists describe by convention as "up" or "down." The spin direction is measurable. Until the spin of a photon is measured, it is in both states (up and down) at once, simultaneously. I referred to this in my last post on the [quantum internet](#). Lab experiments can exploit the property of quantum entanglement to coordinate the measurement of a photon's spin state.

Exploiting the format of the two-slits experiment, it's possible to emit two photons from a lab device made up of a laser and refracting prisms. The photons will have the same initial quantum state. As they come from the same coherent light source they will exhibit quantum entanglement. The two photons remain entangled as long as nothing interferes with them. They will continue in this quantum state as they pass through space or a fibre optic cable. Experiments show that a pair of photons can retain quantum entanglement even though they travel away from each other "up to 100 km."

Even though the spin of the photons is indeterminate, were someone to measure the spin of one of them it would be either up or down with a probability of 50%. If someone were positioned with the other photon then they would get the same reading. As the photons are still entangled at a distance.

Qubit nets

Taking readings erases the photons' quantum entanglement. Once the two photons become disentangled then the ability to predict the state of one photon by knowing the state of other is broken. So a quantum network made up of photons coursing through a network requires a stream or steady pulse of photons.

Physicists have invented quantum repeaters that enable these networks to be extended.

One of the main advantages of widely distributed networks that support quantum communications is in connecting quantum computers together so that they can share processing of large scale problems (e.g. in bioengineering). The information contained in these photons are called "qubits."

The second advantage of a quantum approach to networking is security. The state of a qubit cannot be copied. The quantum entanglement between the photons would be severed were someone to take a reading of one of the photons while it's in transit. That is, interference would be detected at either end of the communication channel.

The third advantage is accurate synchronisation between equipment on earth and in satellites. GPS relies on accurately synchronised clocks on the satellite transmitters and the earth-bound GPS receiver to determine distance and hence triangulate your location. An article in *Nature* projects geolocational accuracies in the order of millimetres, improving on the 1 metre accuracy of current GPS.

The Quantum Internet in the built environment

The quantum internet suggests a new layer to communications infrastructures. Already, discussion about the QI involves network nodes positioned across cities.



I include some articles and videos in the reference list below. As it's a difficult and yet high profile field, there are three categories of output worth considering or watching on line: (1) Scientists in the lab and at their desks who teach this material and research it; (2) Heads of research units in universities and government departments motivated to promote their research in order to maintain support from governments and sponsors; (3) Journalistic output that translates some of the material for mass consumption.

Each outlet moderates its degree of technical explanation, metaphors, accuracy and predictions about applications to its audience. Some writers have carelessly projected that the quantum Internet will enable communication faster than the speed of light, or communication without radio waves or other communications media.

Thanks to the ubiquity and power of the Internet, the term "quantum Internet" has more caché than "quantum network". It's worth noting that competition to develop practical quantum computing internationally and commercially is intense and the stakes in leading in this technology are high. China has already launched a "quantum satellite" as reported in [New Scientist](#). I'll end with a restrained account from that article.

Entanglement can't directly transfer information, because that would mean data is travelling faster than light. But entangled particles can be used to create secret keys that enable extraordinarily secure communication.

I'm happy to be corrected on any of this.

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Date Created

April 3, 2021

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