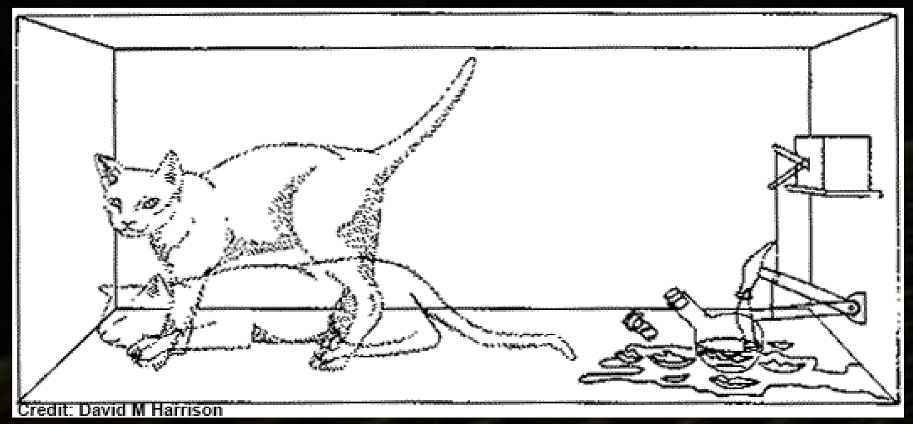


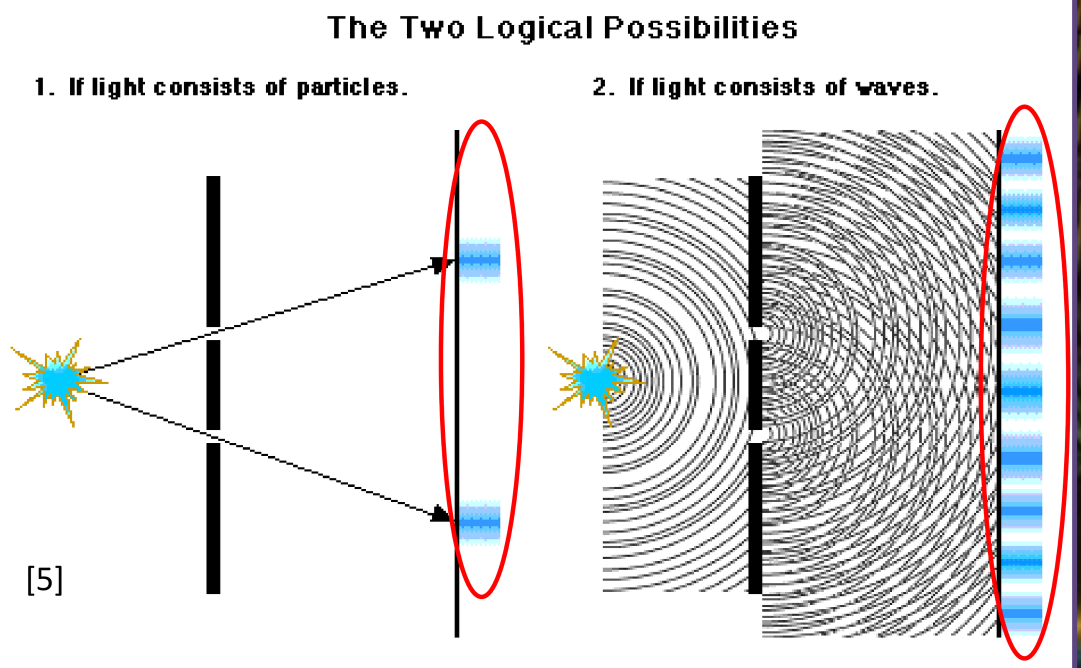

# Quantum Computing

## The Future of Information & The Possible Implications for Networks

"I think I can safely say that nobody understands quantum mechanics."
- Richard Feynman, The Character of Physical Law (MIT Press: Cambridge, Massachusetts, 1995)

## Understanding the Physics

Wave Particle Duality is a phenomena often seen at quantum levels in physics. This was first demonstrated in the early 1800s by Thomas Young. Particles (such as light), can be described as having particle properties, such as momentum, but can also be seen to behave like a wave. The double-slit experiment is one of the best ways to explain this.



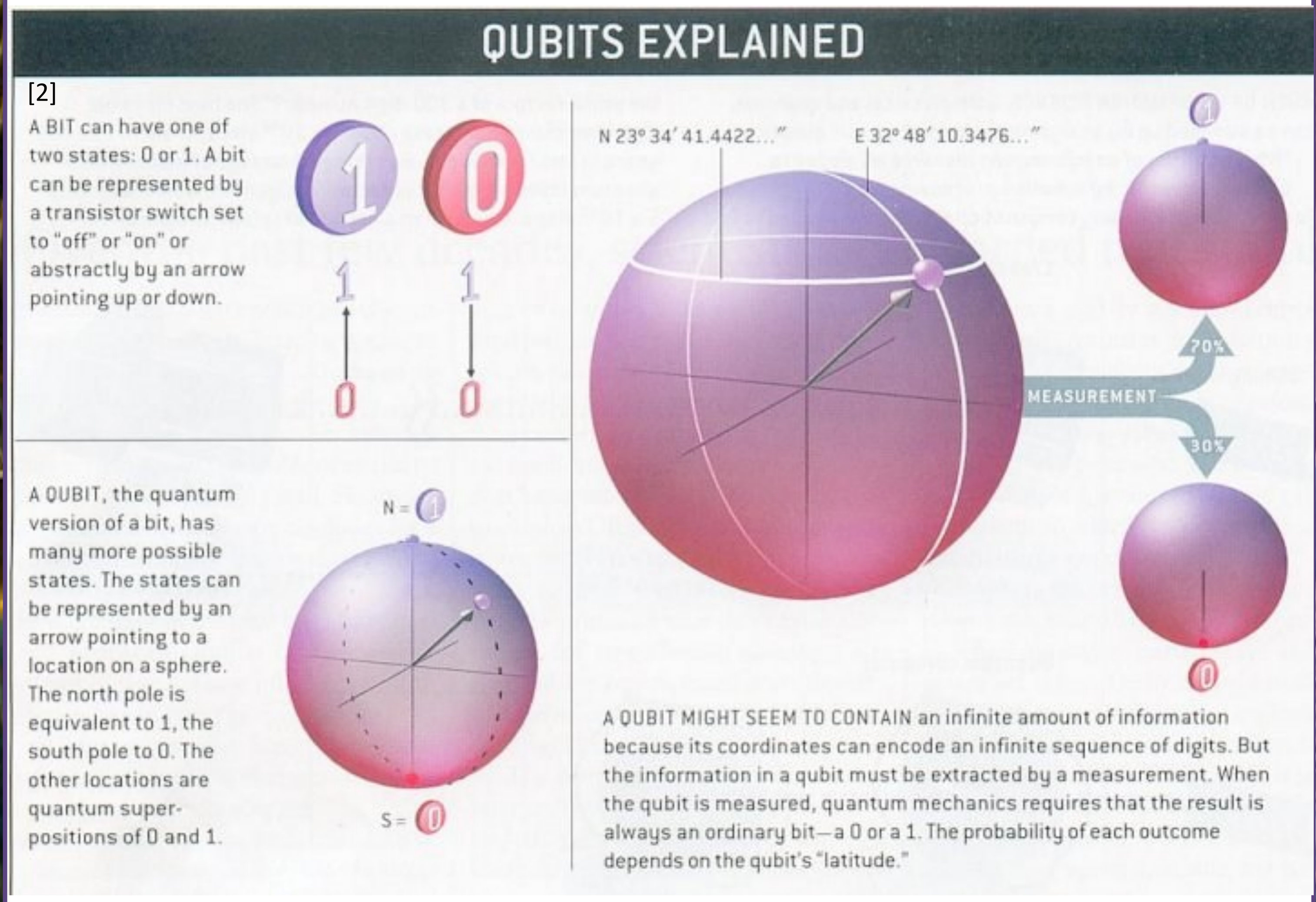

The experiment, pictured above, shows two possible results. Either light is a particle, and would show two impact bands, or it is a wave and would cause interference patterns. This experiment has been performed and adapted for 200 years, and each time it shows both cases to be true. The results seem to be dependent on if data is available from the slits.

The Superposition of States is a crucial quantum physics principle. It states that any two or more quantum states can be joined together and the result will be another quantum state and vice versa. The interference peaks of an electron wave in the double-slit experiment is an example of this superposition.

Quantum Entanglement is the concept that pairs or groups of particles can be generated or interacted with in such a way that the quantum state of each particle's properties cannot be independently described, regardless of distance. Measurements of physical properties on these entangled particles are found to be correlated. It appears that one particle of an entangled pair "knows" what measurement has been performed on the other and with what result, and is affected by it. So imagine you have two particles which are entangled. If you move these particles to opposite sides of the Earth, and change the property or properties of one of them, then the other particle will be influenced by that change, and will also undergo a change of its own.

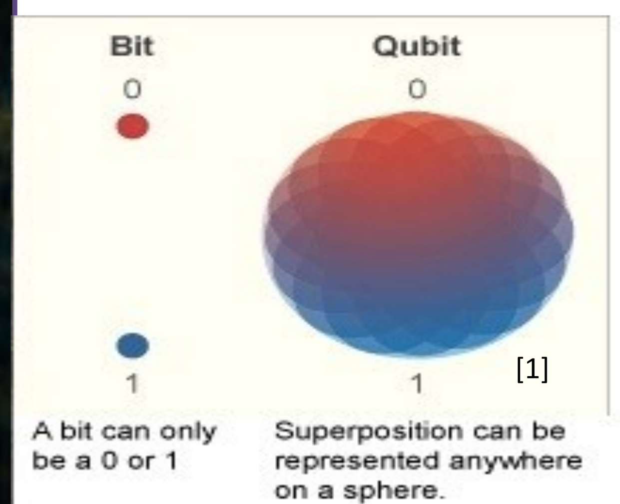
## Applying the Physics to Computing

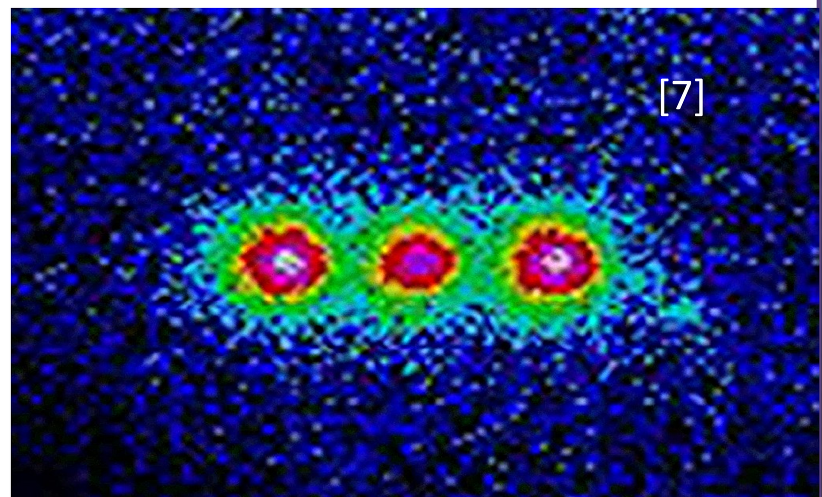
Quantum computing uses the fact that quantum particles can exist in multiple states at the same time & therefore can be used to carry out many calculations in parallel. Quantum computing exploits two resources offered by the laws of quantum mechanics: the principle of superposition of states and the concept of entanglement. Superposition is a "one-particle" property; while entanglement is a characteristic of two or more particles.




Normal computers process binary information – this means that something is either on or off, or in shorthand 1 or 0. Alan Turing proved that one can do any calculation provided enough switches exist. Quantum computers let us undertake a new kind of calculation by having switches that can be on or off, 1 or 0 at the same time. These are known as qubits (quantum bits). This means that for a particular calculation, a normal computer may go through all the different combinations of zeroes and ones whereas a quantum computer could perform all those combinations at once as it is in all of the states at once. This is incredibly useful as it would allows us to solve intractable problems.

In a conventional computer, algorithms are performed in order to solve calculations. All of this takes place using voltages to send signals and logic gates to handle the problem solving. Similarly, in a quantum computer one would find quantum gates. The term 'quantum gates' is used to describe the manipulation of qubits (currently that means shining a laser light on them or interacting them with other atoms). A series of these manipulations is what would make up the quantum computer.



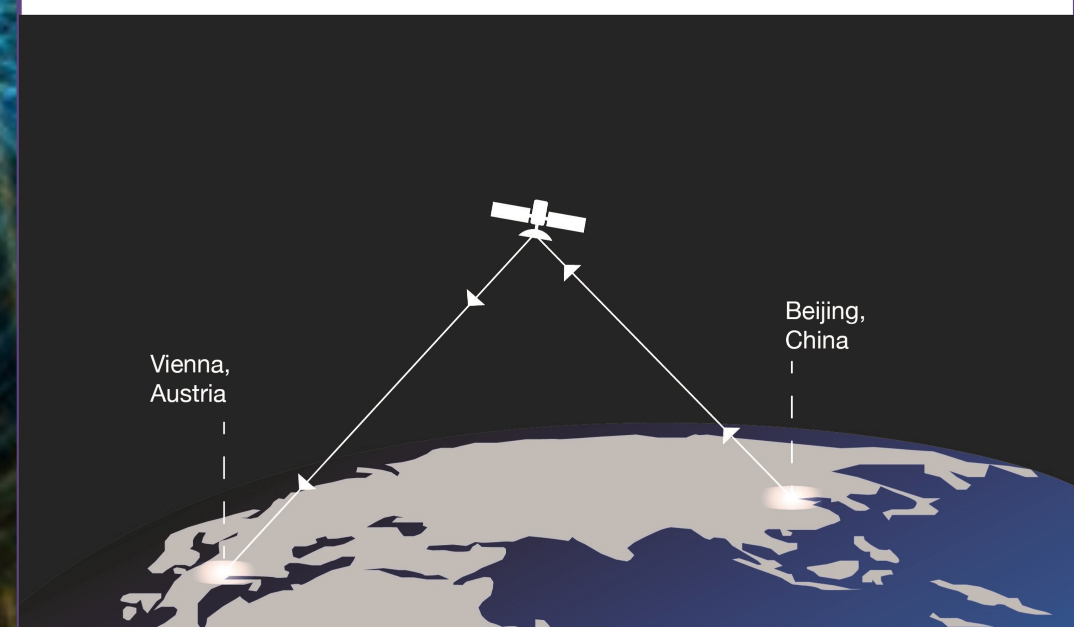

## Current Quantum Computing Technologies & Research

In 2012, Nobel Prize for Physics was jointly awarded to Serge Haroche and David J. Wineland "for ground-breaking experimental methods that enable measuring and manipulation of individual quantum systems."[4] Haroche captured microwaves and probed them with atoms, whereas Wineland captured ions and probed them with laser pulses.

One of the newest bits of research regarding quantum computing is the establishing of ultimate performance of quantum secure communications, i.e. knowing the limit of performance of the QKD (Quantum Key Distribution) - the main form of Quantum Encryption.

The D-Wave System is the "world's first quantum computing company and the leader in development and delivery of quantum computing systems and software"[6]. This is a company that worries less about the academic research prospects of quantum computing, and more about the scalability and design and manufacture of quantum computing systems, mainly for commercial use Their newest system, the D-Wave 2000Q, is set to be released in 2017.

In August of 2016, the Chinese Academy of Sciences launched the world's first 'quantum' satellite, named "Mozi". The satellite had two purposes. The first was to create direct communications between Beijing and Vienna, and using the satellite to establish a QKD between the two ground stations. The other purpose of the satellite was to enable testing of Quantum Entanglement on particles separated by distances of 1200km. Previous tests of the same kind were done on distances with a magnitude of 100km, so this would be a huge leap forward.




## What awaits in the Future?

The future is not set in stone. Technologies and trends come and go, and so it is difficult to think about what could possibly come next. However, there are a few things that are certain.

Moore's Law is the prediction that every two years, "the number of transistors on an integrated circuit will double". This has been a continuing exponential trend since the 70s. Although the field of Quantum Computing was exclusively theoretical up until quite recently, the current advancements in technology follow Moore's Law, and even overtake the trend line.

Google recently said that large quantum computers are only five years away from commercial exploitability, meaning that by 2022 we could be facing the beginning of an era where these new technologies are integrated into our lives, and slowly take over usage from the conventional computers we understand today.

These emerging technologies open up a vast avenue of possibilities. Encryption, designing of pharmaceutical drugs, machine learning, object detection and simulating our universe are just some of the possible applications of quantum computing.

While quantum computing may be just around the corner, it is important to realise that just as it was with conventional computers, understanding how they work will take a long time, and successfully implementing them in a way that is available to the general public will be challenging and time consuming.

There are many challenges that must be overcome before quantum computers can be used on a large scale. One of these main issues is the capture of atoms for use as qubits for longer periods of time, and capturing a greater number of them at once. Currently we are able to capture these particles for fractions of a second, and the most widely established record for the number of qubits held together at once is 14. This is not adequate enough for widespread use. Another challenge to overcome are results from these quantum computers. While we are starting to understand the basics of how these computers may work, scientists are having some trouble in interpreting the results reliably. This stems from the superposition of states. If the qubits are in every state (combination) at once, and you attempt to measure one state, the superposition of states and uncertainty principle states that the other states will be destroyed.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