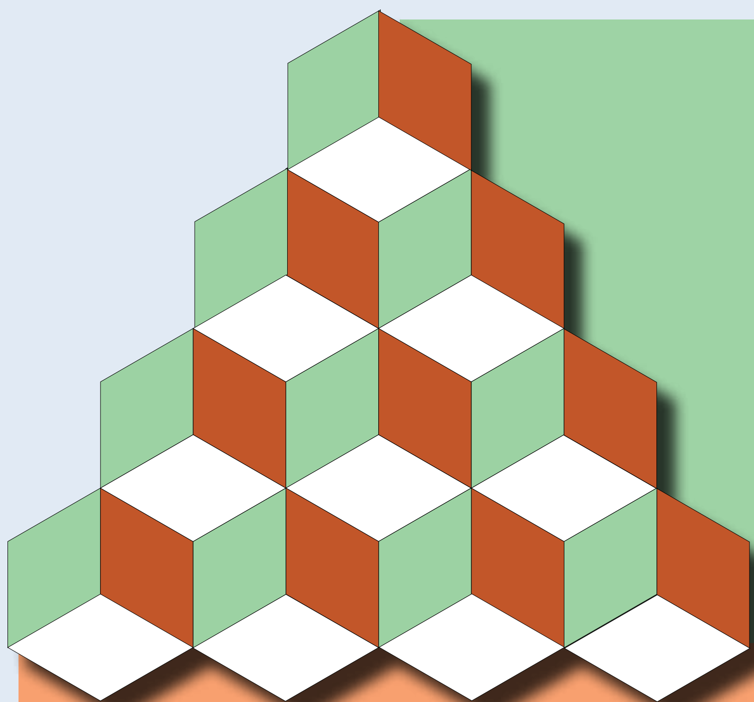
9 2 9 3 2 6 1 2 8 4 0 0 1 0 7 6 0 9 3 4 5 6 7 1 0 5 2 9 5 5 3 6 0 8 5 6 0 6 1 8 2 2 3 5 1 9 1 0 9 5 1 3 6 5 7 8 8 6 3 7 1 0 5 9 5 4 4 8 2 0 0 6 5 7 6 7 7 5 0 9 8 5 8 0 5 5 7 6 1 3 5 7 9 0 9 8 7 3

QUANTUM INFORMATION

Atoms on a small scale behave like nothing on a large scale, for they satisfy the laws of quantum mechanics... - Richard Feynman

A century ago, quantum mechanics changed our understanding of the building blocks of our universe. Today, scientists are using quantum physics to teleport information, create unbreakable codes, and build powerful new computers. We are on the verge of a new technological revolution...



How many cubes do you see?

Information

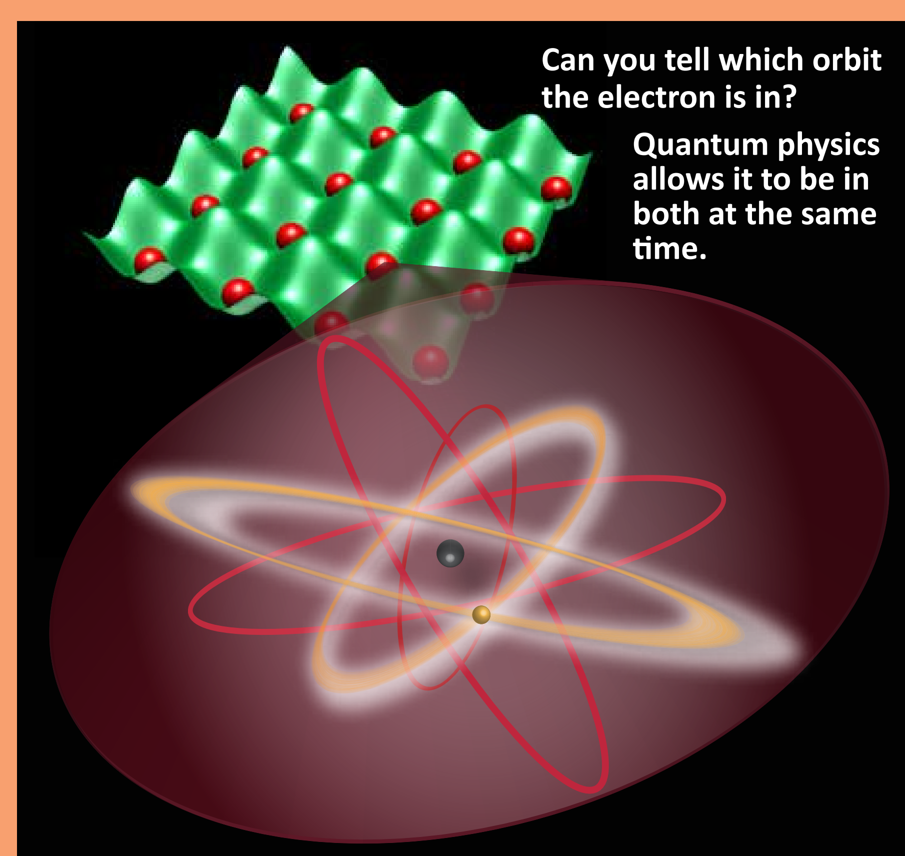
Information is everywhere–in books, text messages, DNA, computers. Quantum physics doesn't usually play a role in these storage formats. But information can also be packed into tiny structures like atoms, where quantum physics rules.

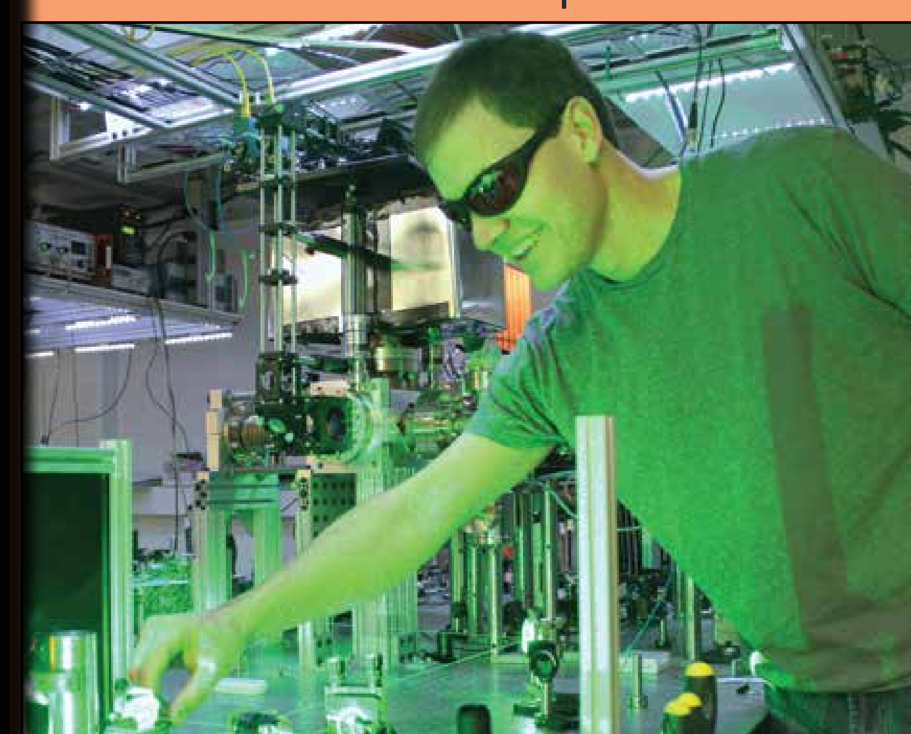
The quantum world is strange. Consider the picture at left: do you see 6 cubes, or 10? Just as your mind can interpret the image in two different ways, quantum systems can be in multiple states at once. This is called a *superposition*.

Look again: at any instant your mind picks a cube orientation, and the contradiction vanishes. Quantum superpositions are similarly fragile. *Measurement*, meaning an interaction with the outside world, causes a quantum system to "collapse" to one of its component states.

Physicists use lasers, like the green beams shown at right, to make egg carton-like patterns where atoms (shown as red spheres) can be trapped. These atoms are examples of qubits. Each atom has an outer electron (shown close-up as yellow sphere) that can be manipulated with laser light.

Images courtesy of Emily Edwards and Trey Porto



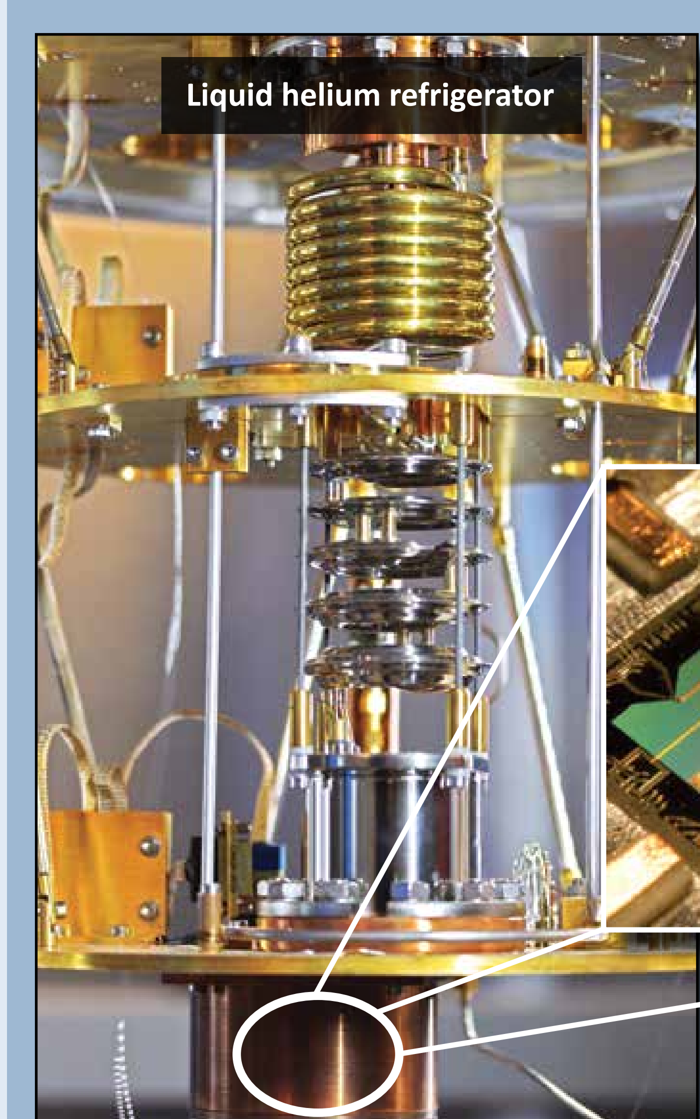


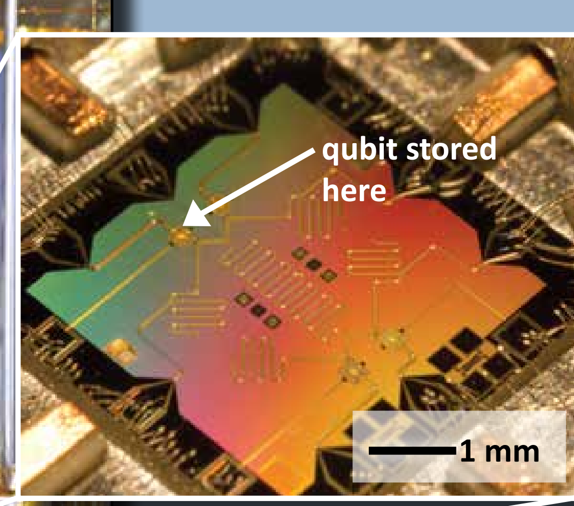
Qubits

Qubits are quantum information carriers, similar to how the "bits" 0 and 1 carry information in regular computers. Qubits can be made from any quantum system that has two states. In the picture at left, these states are depicted as electron orbits in an atom.

Quantum computers

Quantum **computers** will harness superpositions to quickly solve problems that would take today's computers years. With each added qubit, the processing power of a quantum computer doubles. Through massive parallel processing, quantum computers are expected to easily crack popular encryption schemes and offer faster ways of searching vast databases.

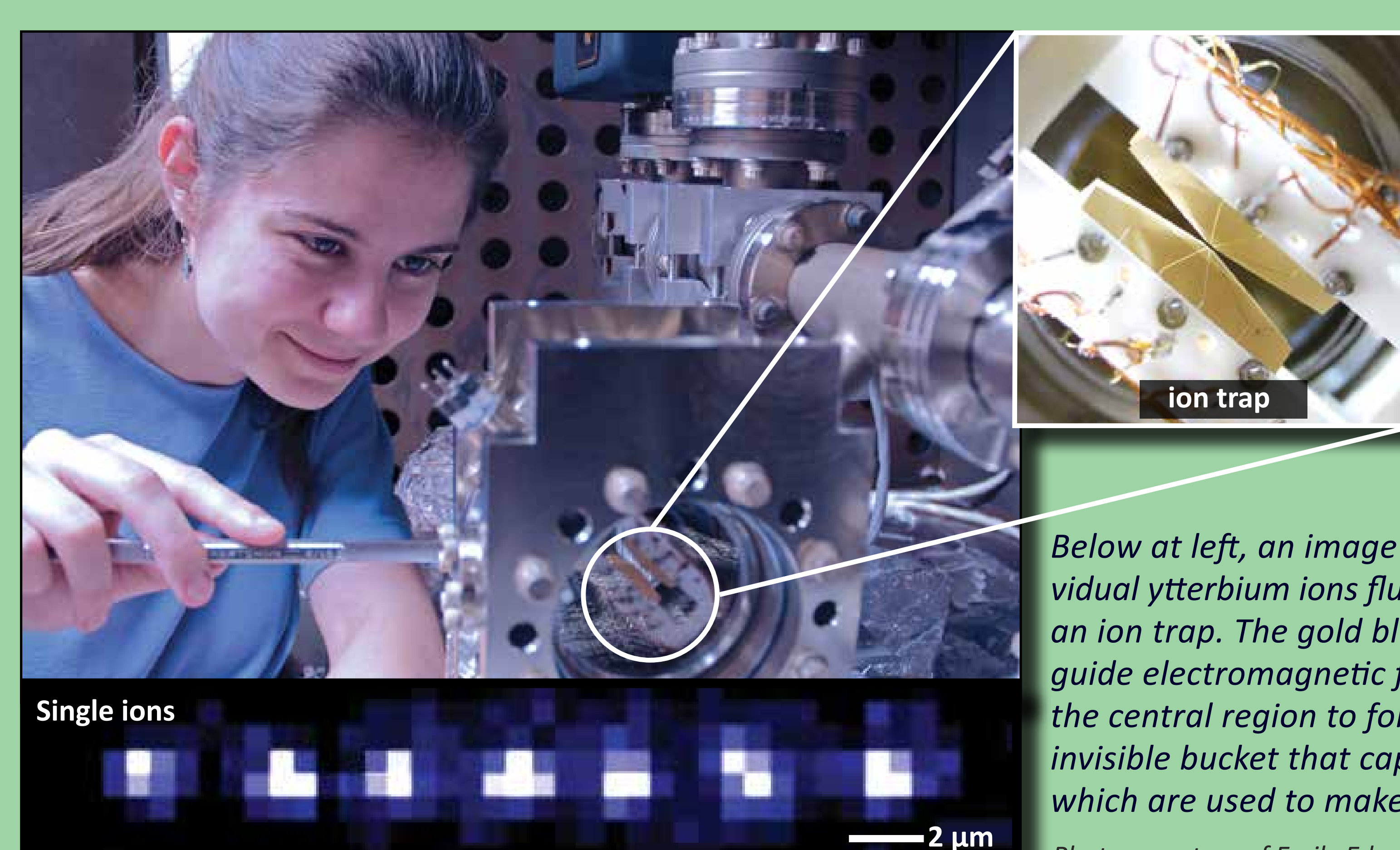




Superconducting qubit devices used for quantum computers are housed in ultracold refrigerators (left). Here, the qubit is stored in superconducting circuit elements and is manipulated by microwaves.

Photo courtesy of Erik Lucero

Photo courtesy of Emily Edwards



Below at left, an image of 7 individual ytterbium ions fluorescing in an ion trap. The gold blades above guide electromagnetic fields into the central region to form an invisible bucket that captures ions, which are used to make qubits.

Photos courtesy of Emily Edwards

Teleportation

In **teleportation**, information is transferred from one particle to another. These particles must be entangled, meaning they share a quantum state, even if they are separated in space. Scientists then make measurements on the entangled system, which allows them to teleport the quantum state from one place to another. Ion traps like the one shown above have been used to teleport information a distance of up to one meter.

Cryptography and the poster border: Encryption relies on how hard it is to factor large numbers. The border is one of the largest numbers that has been factored.

Quantum cryptography

Quantum **cryptography** is spy-proof. When an eavesdropper attempts to intercept a message encoded using quantum cryptography, the message is altered by the eavesdropper's measurement. Unlike with "classical" information (e.g. emails and phone calls), senders can reliably detect snooping.

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www.jqi.umd.edu
www.aps.org/programs/education/highschool/teachers/quantum.cfm

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Get the Factors

4 9 5 0 1 4 4 1 7 8 8 9 6 3 1 7 8 6 9 4 6 2 9 5 1 8 7 2 7 3 7 8 9 6 2 2 1 8 2 3 6 9 8 3

2 7 9 9 7 8 3 3 9 1 1 2 2 1 3 2 7 8 7 0 8 2 9 4 6 7 6 3 8 7 2 2 6 0 1 6 2 1 0 7 0 4 4 8 5 3 7 5 6 0 0 0 9