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# HOW IS AN ACTUAL QUANTUM COMPUTER IMPLEMENTED?

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Our future may see us living on Mars, paying for everything with crypto currency , and relaxing or workingas we travel in our driverless cars. But there is an even bigger transformation coming our way and that isthe gradual arrival of quantum computing and the potential impact it will have on our ways we conduct research as well as business.

People in the tech industry are used to hearing about quantum computing, because the effects quantumhas or will have when it is delivered at scale will be massive. At the same time, some businesses tend to put quantum into the same folder as fusion energy, a technology with huge potential but always like 5 years away from being really available.

The reality though is that quantum computing is actually here in the real world, in 2021, granted, on a smaller scale, but it is available from giants such as IBM, Google, Microsoft, or Amazon as well as from startups like Rigetti or Xanadu.

So how does an actual quantum computer look like in 2021? Well, the actual implementation various fromcompany to company.

Trapped-ion qubits were used to implement the first quantum logic gates in 1995, and the proposal for a quantum charged coupled device, a type of quantum computer with actions controlled by shuffling the ions around, was first made in 2002 by researchers at the US National Institute of Standards and Technology. That work went on to win the 2012 Nobel Prize for Physics.

Quantum gates have later been demonstrated in various platforms, ranging from Rydberg atoms to defects in diamonds. The quantum computing technology of choice that was 1$^{st}$ used by quantum titans was solid state qubits. In these systems, the qubits are superconducting circuits that can be mounted directly onto a chip. That technology rapidly topped the benchmarks set by trapped ions and are used these days in quantum systems from IBM and Google.

Recently though, progress made by utilizing superconducting circuits appears to be slowing as quantum computers integrate more and more qubits. To interact properly, the qubits have to be the same and whereas 2 copies of the same ion are guaranteed by quantum mechanics to be identical, fabricating identical circuits is in the vicinity of being impossible. Fabrication directly onto a chip places superconducting circuits in thermal equilibrium with the chip. So, if you develop a superconducting qubit-based quantum computer, you have to cool that system down to close to absolute 0. That approach worksOK with maybe a couple 1,000 qubits but that will be truly challenging while really scaling the number ofqubits. So, some companies have recently shown interest in the trapped ion platform again, among themHoneywell that in 2020 formed Honeywell Quantum Systems to focus exclusively on that technology.

Another company in the quantum computing field is Xanadu. Xanadu is developing photonic chips for quantum computers. They label the chips the x-series, and they are made out of silicon and silicon nitride and consists of 3 primary modules. 1$^{st}$, squeezers, the input to the computer. 2nd interferometer, basicallythe logic gates and 3d, the photon detectors, the actual measurement output.

So let us briefly describe each module in more detail.

Classical laser light is first distributed to an array of squeezers, these microscopic devices are made of small ring resonators that when driven by bright classical laser pulses, generate a special quantum state of light that is labeled as a squeezed state and that is Xanadu's version of a qubit. These states involve a quantum superposition of different numbers of photons. And once generated are coupled into an array of bus waveguides that carry them to the next stage. The squeezed states now enter a network of beam splitters and face shifters called an interferometer.

To program the interferometer, the users' instructions are loaded into the chip electronically. The controlsystem translates these instructions into a set of electrical voltages that are applied to the different components on the chip. The squeezed states interact with one another and are entangled, a prerequisite for quantum computing. The interferometer can be thought of as a sequence of quantum gates acting onthe inputs.

In general, the output of the interferometer is a highly entangled quantum state that is encoding the processed quantum information. The quantum state is now ready for read out. Each output of the chip isdirected to a special photon detector called a transition edge sensor. These detectors count how many photons are present in each output, yielding an array of integers that are reported back to the user. The results of the computation or algorithm are encoded in the statistics of this photon number data.

The Xanadu quantum computing solution discussed here is useful for solving complex problems in the domain of graph theory and so is relevant for finance, chemistry, and logistics related problems.

This short presentation basically shows that the state of quantum computing technologies is definitely ina state of flux, with no clear winner yet on what technology will ultimately prevail while scaling the numberof qubits. Nevertheless, quantum computers are available in 2021 and they are already used to solve complex real-world problems that are difficult to solve on classical computers.