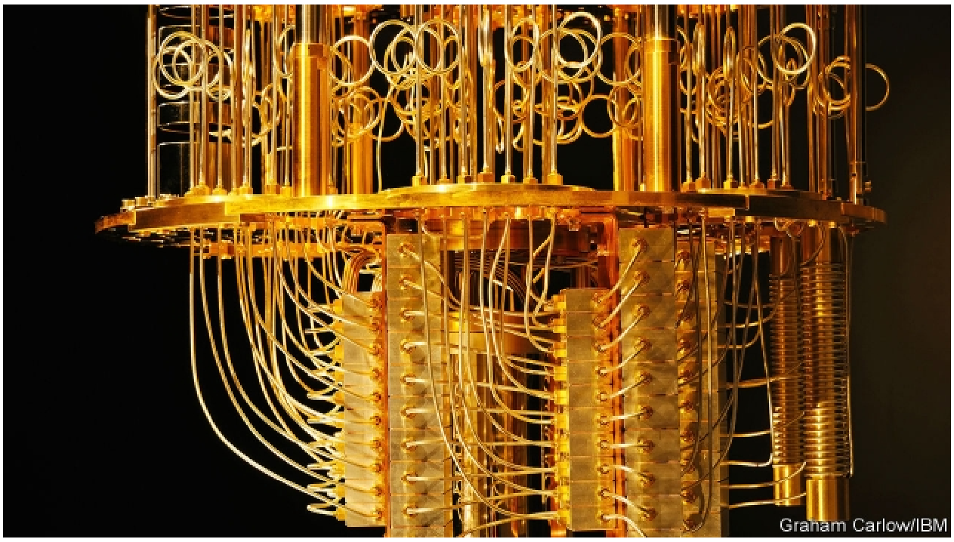
Quantum spring

The race is on to dominate quantum computing

But the technology may face a winter before it enters its summer


Graham Carlow/IBM

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COMPUTING was probably always destined to be electronic. Yet even as late as the 1930s, this was not entirely clear. Early in that decade Vannevar Bush, an American engineer, built a mechanical computer with gears, pulleys and shafts rotated by electric motors. His "Differential Analyser", which took up a small room, could solve equations with up to 18 variables.

Quantum computing, which holds the promise of outclassing even the world's fastest supercomputers, at least for certain types of problems, is now at a similar stage in its development. Prototypes are functioning but it is not clear what shape the machines will eventually take. One big question, for example, is whether "qubits", which are the quantum equivalent of transistors, will live in

Even as quantum computers inch forward, a lively ecosystem of software startups has sprung up. Big corporations, venture capitalists and national governments are investing, providing the money for a growing number of new firms. "The Quantum Computing Report", a website, recently listed more than 70 of them, many of which aim to write software for the new machines (more than a third of them have names starting with Q).

This fledgling industry is seeing the beginnings of a battle between tech giants such as Google, IBM and Microsoft, which are vying with each other to attract developers onto their respective quantum platforms. Some insiders have already started to warn that the sector is getting ahead of itself, predicting a "quantum winter" brought on by unfulfilled promise.

It would be easy to dismiss excitement about quantum computing as the start of another hype cycle. But the technology has huge potential, so it needs to be taken seriously. Classical computers think in "bits", which can have a value of either 0 or 1. Qubits are capable of "superposition", meaning they can be in both "states" at the same time. Another key quantum concept is "entanglement". Qubits can be connected, so that operating on one has an impact on the entangled ones, allowing their processing power to be harnessed in parallel.

The first feature makes for computers that have a huge memory. Superposition means that the capacity to store data doubles with each qubit. A 64-qubit computer has enough memory for 18 quintillion numbers. Entanglement then allows operations at lightning speed. Qubits are set up according to an algorithm suitable for a chosen problem; the system applies the rules of quantum mechanics until it reaches a state that represents the answer.

Reaching this point will be fiendishly difficult. Although researchers have mastered the art of setting up qubits, getting them to operate flawlessly is still an unsolved problem. Since any outside influence, such as vibration or heat, can make these delicate beasts lose their one-and-zero-ness, or "decohere", they have to be kept in complete isolation (hence the ultra-low temperatures, which slow atoms' movement).

Errors also need to be detected and corrected with the help of many other qubits.

This pace of development recently won the blessing of a luminary of the quantum field, John Preskill of the California Institute of Technology. "Quantum computers with 50-100 qubits may be able to perform tasks which surpass the capabilities of today's classical digital computers," he wrote in a paper, calling such devices "noisy intermediate-scale quantum" (or NISQ, with "noisy" meaning that the qubits will remain error-prone for some time to come).

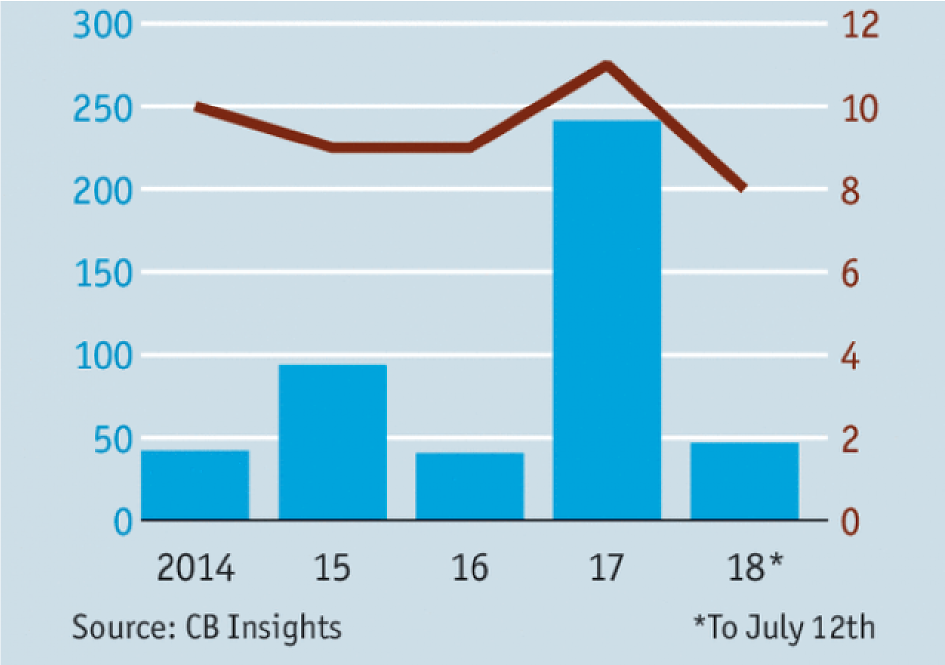
Big firms are trying to work out what quantum computing might mean for them, says Michael Brett of QxBranch, a startup. Chemicals giants such as BASF and DowDuPont want to understand whether the technology could help them "compute" the structures of useful new materials, such as catalysts to reduce the energy used to make fertilisers. Banks, including Barclays and JPMorgan Chase, hope to use them for tasks such as adjusting portfolio risk. Games-makers are also interested in using quantum computing to get videogames to behave more like the real world.

Since quantum talent is in very short supply, companies often enrol the help of startups, which play the role of consultancies. This brings in money for the new firms and also allows them to acquire the intellectual property to develop real software later. Zapata Computing is typical: spun out of MIT, its PhD-equipped employees develop programs on paper, which "look much like sheet music", in the words of Christopher Savoie, its boss.

Quantum harvest

The field has been well-funded by venture capitalists, with capital inflows reaching nearly $250m last year. Tech firms, too, are putting in resources. IBM has been working in the area longest. Arvind Krishna, global director of its research arm, compares its efforts to how IBM created a market for mainframe computers in the 1960s. It started quantum research in the 1970s; in 2016 it put its 5-qubit quantum computer online so others could use it and start writing programs (something it calls Q Experience). It has since designed tools for programmers, helped MIT to develop online quantum classes and created a network of firms as well as other universities to explore practical applications.

The competition is not far behind. Last month Google released Cirq, a kit of software tools. Rigetti has put a machine with a 16-qubit QPU online. IonQ, another hardware startup, has built a trapped-ion machine, which is easier to program. And then there is Microsoft. Like IBM, it wants to build an "end-to-end system", in the words of Todd Holmdahl, head of its quantum arm. Again like IBM, it offers a "quantum development kit" and even a special programming language called Q#. But any code written in it will have to run on simulation



The Economist

IBM, Google and Microsoft are spending heavily to lure developers and applications to their respective platforms. IBM emphasises the heavy usage of Q Experience: it now has more than 90,000 users, who have run 5m experiments and published 110 papers. Hartmut Neven, who heads quantum efforts at Google, says its toolkit is targeted at "professional programmers". He insists that his team will soon achieve "quantum supremacy", meaning it will show that its quantum computer is able to solve a problem faster than a classical one (a feat critics already call a stunt, because the problem is unlikely to be one of practical relevance). Microsoft, for its part, has tightly integrated its quantum tools with other programming software to make it easier for classical developers to use them.

Whatever the outcome, none of the hardware will end up in other firms' data centres, let alone on people's desktops, in the near future. Instead, quantum computers will find a home in computing clouds operated by Google, IBM and Microsoft (and also by Amazon and China's Alibaba, which have smaller quantum programmes). Since the machines will be good only at very specific tasks for many years to come, the firms intend to use them mostly as "accelerators", which will take over when specifically needed, much like computers with superfast artificial-intelligence (AI) chips today.

Other than these firms, only government agencies are likely to have their own quantum computers within the next few decades. National armed forces and to America's nuclear programme of the 1940s. The European Union launched a quantum-research initiative in 2016 and backed it with more than $1bn.

The flow of government money is already such that some venture capitalists are complaining about being crowded out. But rising excitement about all things quantum has also fuelled fears that the field is getting overhyped and that—much like AI in the 1970s and 1980s, after it did not live up to its promises—it is headed for a "winter"; a long period of reduced financing and interest.

Some startups are certain that there will be a retreat in a few years and are hedging their bets. Michael Marthaler, co-founder of Heisenberg Quantum Simulations, hopes that his firm will be established enough to be able to "hibernate". Other observers of the quantum-computing scene warn that much of the software written today may become obsolete should quantum technology take an unexpected turn.

But even if quantum's spring turns to winter, the chances are high that there will eventually be a summer. That has happened often enough in the past. To use a concept developed by Carlota Perez, an economic historian, revolutionary technologies always go through a "gilded age", often accompanied by an investment bubble that pops, before entering a "golden age" of widespread deployment. There is little reason to believe that quantum computing will deviate from that path.

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