Light-stopping technology key breakthrough for quantum computing

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Video:

In their quest to develop an optical quantum computer, physicists at the Australian National University have brought light to a standstill inside a cloud of ultra-cold atoms, an important prerequisite for carrying out quantum calculations using photons of light.

Tags
- Innovator
- Inventor
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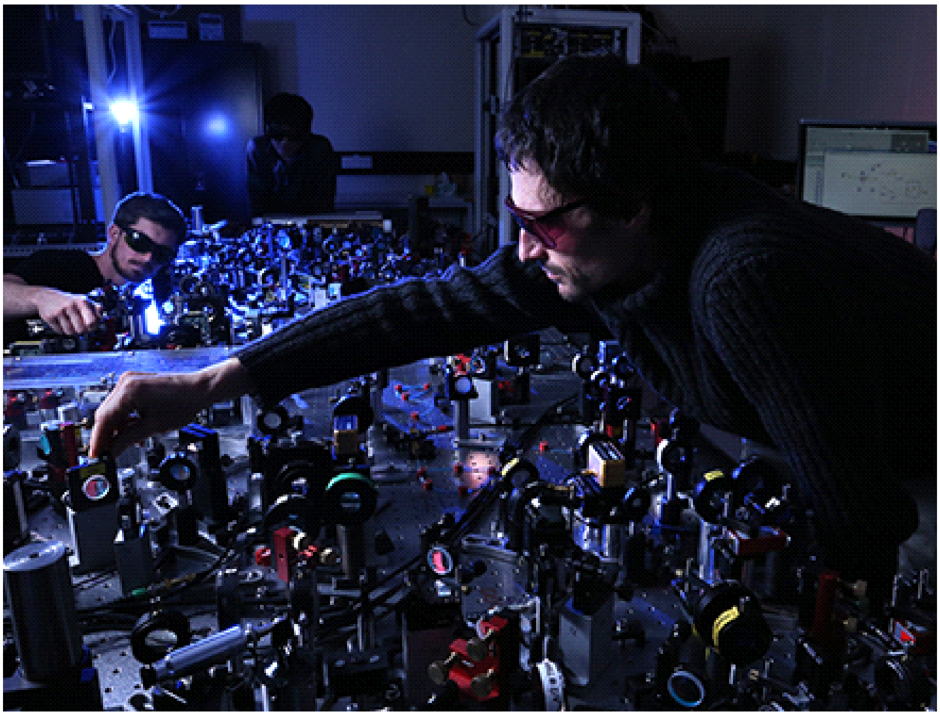

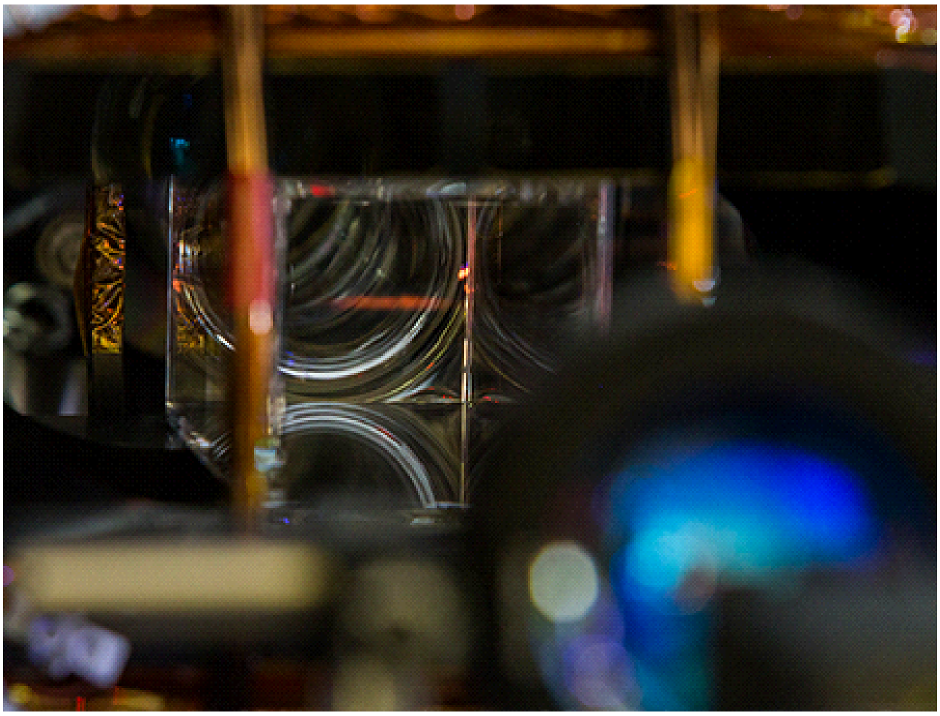

Travelling at nearly 300 million metres per second, light is the fastest phenomenon in the universe. Australian physicist Ben Buchler is intent on bringing it to a grinding halt.

At his lab at the Australian National University (ANU) in Canberra, Buchler is investigating whether tiny particles of light, called photons, can form the building blocks of quantum computers – machines that promise to revolutionise information processing.

In September 2016, his team reported a significant breakthrough in the prestigious journal *Nature Physics*. They brought a pulse of laser light to a standstill, trapping the photons inside a four-centimetre-wide cloud comprising billions of super-cold rubidium atoms – a phenomenon called 'stationary light'.

Buchler and lead author Jesse Everett, a PhD candidate, have compared their accomplishment to a scene from *Star Wars: The Force Awakens*, when character Kylo Ren uses The Force to halt a laser blast mid-flight.

If they can confine the photons for long enough, they hope they can trigger the strong photon-photon interactions necessary for quantum computing.

> “It is possible to encode information onto photons and ‘entangle’ these particles to perform quantum calculations,” Buchler says.

Light is an intriguing candidate for quantum computing because it can rapidly transfer data between two points along optical fibre networks and because photons interact very weakly with the outside environment. This virtual immunity to disturbances keeps information being transmitted intact.

However, to harness the potential of light, scientists need to make photons interact *more* strongly with *each other*, which they do not naturally do.

“We are trying to figure out ways of convincing two particles of light – two photons – to talk to each other in a way that allows us to do quantum computing,” says Buchler.

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Quantum computers a new way of solving problems

The extraordinary power of quantum computing lies in its ability to perform massive sets of operations simultaneously, whereas classical systems powering our laptops and smartphones can only carry out one operation at a time.

“If you take the classical computers we have now and imagine them 100 years into the future, they still wouldn’t be able to do what quantum computers could do,” he says.

> “They offer a completely new way of solving problems.”

Buchler says quantum computers will be “incredible enablers for learning” and suggests they could help solve the big mysteries in science.

It’s predicted they’ll be useful for rapidly scouring databases, and for modelling, analysing and optimising complex systems, including transport networks, financial markets and biological molecules.

Buchler is a Chief Investigator at the Australian Research Council (ARC) Centre of Excellence for Quantum Computation and Communication Technology (CQC2T), a consortium of 200 researchers at nine different universities.

The Centre is leading the world in the race to develop scalable quantum computers. One approach, championed by Centre director Michelle Simmons, uses silicon as the base material. The fundamental components, where information is encoded (known as quantum bits, or qubits), will be the subatomic particles (electrons and nuclei) of phosphorus atoms embedded in the silicon.

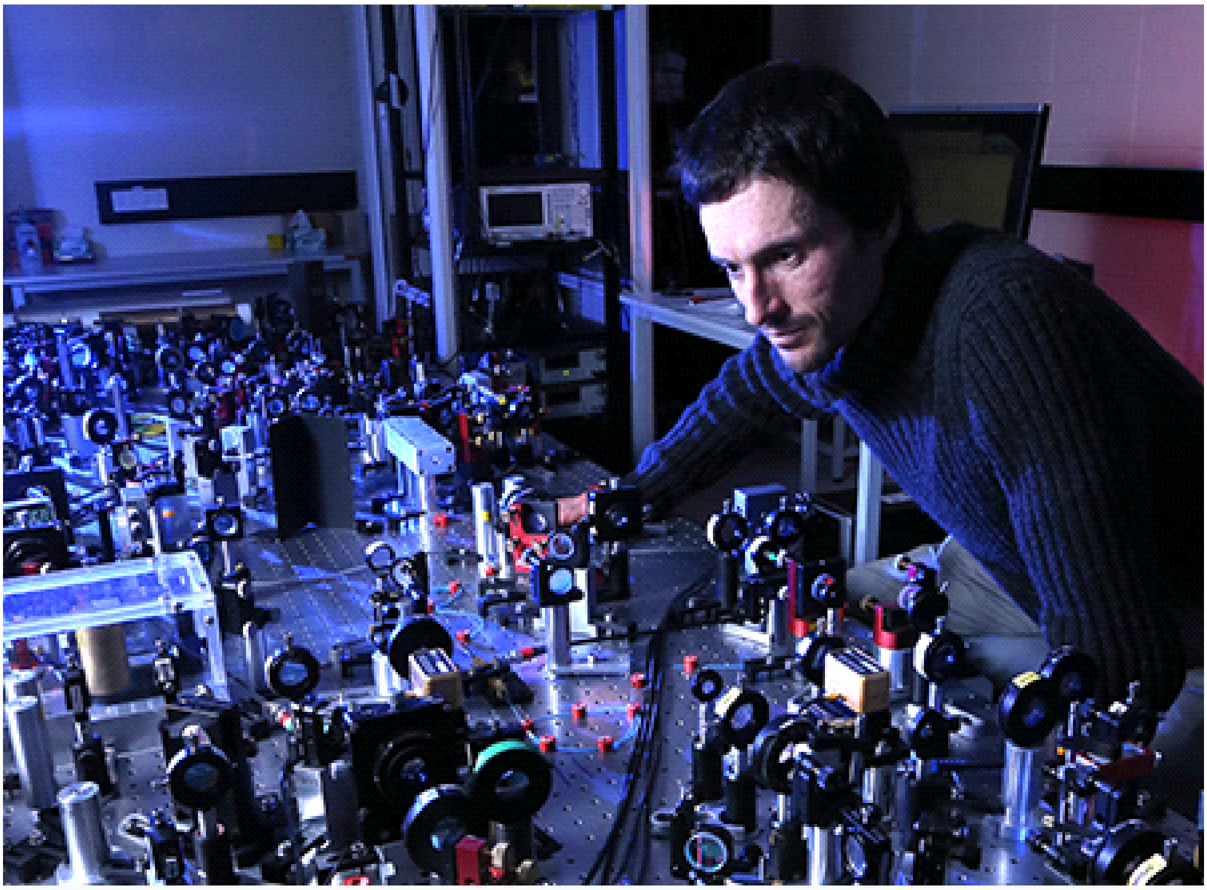
Buchler is central to the Centre's two other objectives: developing an ultra-secure system to communicate quantum information over long distances via optical fibres (and possibly satellites), and developing optical quantum computers, where information is encoded onto photons.

The latter, he says, will be needed to facilitate the former, the so-called quantum internet, working as 'repeaters' to extend the range of communication and to correct errors.

Some optical quantum computer prototypes have been built, says Buchler, but they are probabilistic, meaning the calculation works only some of the time. This means as the calculations get more complicated, the chances of getting an answer reduces.

His goal is 100 per cent reliability in calculation accuracy.

Buchler says ultra-secure citywide quantum communications are already achievable, but intercity networks between Sydney–Canberra–Melbourne, for instance, could take at least 10 years to realise with the technologies the Centre is developing.



Associate Professor Ben Buchler aligning a quantum memory experiment at ANU. Credit: The Australian National University.

From 'dark' quantum memory to 'bright'

stationary light

Buchler’s group previously developed a “quantum memory” system where light was temporarily stored inside supercooled atoms. However, during this storage period, the system is "dark". In other words, the photons can be regenerated from the information stored in the atoms, but the photons themselves are not trapped in the atomic cloud.

“If you want photons to interact with each other, using the atoms as an intermediary, then at least one of the photons has to be present during the process,” he explains.

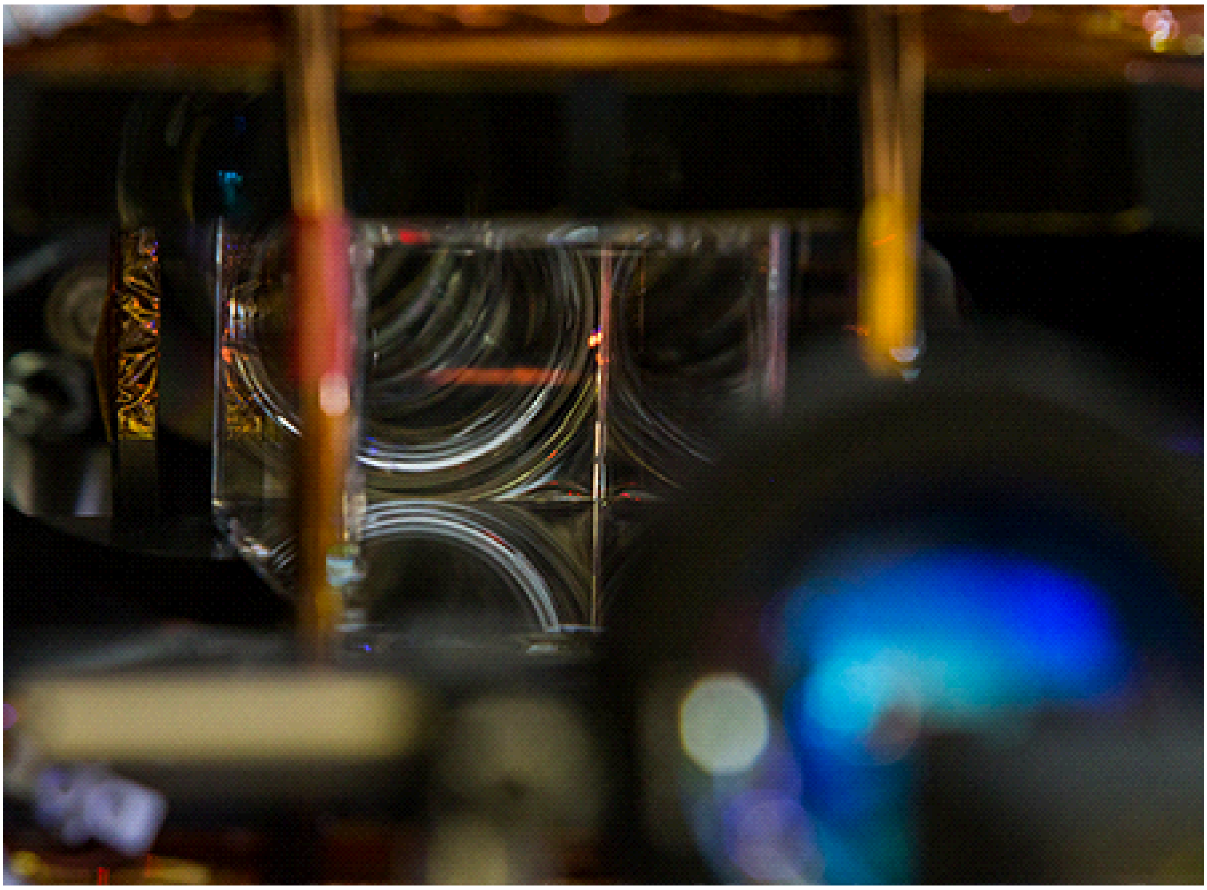
Importantly, in creating stationary light, Buchler and his team managed to keep the photons circulating inside the atomic cloud. This light changes the energy levels of the atoms, which allows the circulating photons to communicate with the absorbed photons.

The ANU team made another important innovation, developing a system for imaging the atoms as they respond to the absorbed light.

Stationary light is an ‘unobservable’ phenomenon because we can only see light when it moves towards our eyes. In the past, researchers indirectly inferred its presence by comparing the properties of the released light to predictive mathematical models.

But this new system offers a major upgrade: “With these photos we can get a much clearer idea of what the light is doing inside the atoms,” he says.

“The fact that we see the atoms evolve in the presence of stationary light in exactly the way the models predict gives us enormous confidence that this stuff is actually there and it’s working the way we think it does.”



The machine that bought a pulse of laser light to a standstill, trapping the photons inside a four-centimetre-wide cloud comprising billions of super-cold rubidium atoms – a phenomenon called ‘stationary light’.

Australia leading the quantum revolution

Born and raised in Canberra, Buchler did an honours degree in physics and a PhD at the ANU. In 2006, after completing a postdoctoral position at the Swiss Federal Institute of Technology (ETH Zurich), he returned to Australia with his wife, also a physicist, via the Trans-Siberian Railway and took up his current academic post.

His passion for science is motivated by a “fundamental interest in quantum mechanics and how the universe works” rather than developing new technologies. Nevertheless, Buchler says the prospect of quantum computers is exciting.

“If you can build a new tool that calculates things that you couldn’t calculate any other way before, then you’ve built this incredible machine for enabling science,” he says. “These machines will have an enormous impact on our lives in the future.”

Buchler says Australia and New Zealand are “anomalies” in the world of quantum research, leading globally thanks largely to the work of some trailblazing theoretical physicists working in both countries in the 1980s. “That momentum has only snowballed,” he says.

The field is undergoing “extraordinary growth” globally due to vast sums of public research funding and private investment from the likes of Google, IBM and Microsoft, Buchler says.

“Australia is well positioned to take advantage of the quantum revolution.”

Find out more about Ben Buchler's work at The Australian National University.
