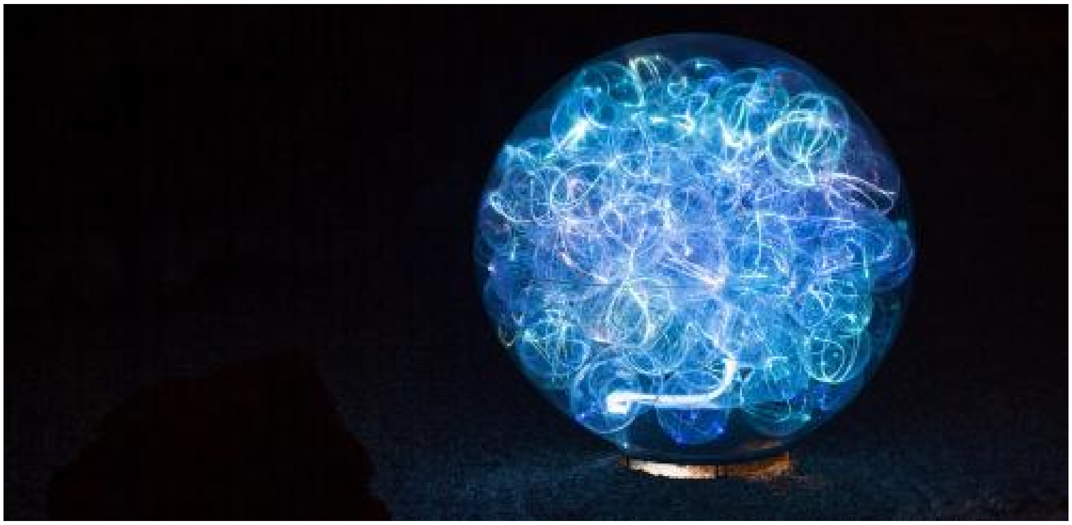
The power of one: Single photons illuminate quantum technology

October 11 2013, by Matt Collins



No photon bunches, please. Credit: derekbruff

Quantum mechanics, which aims to describe the nano-scale world around us, has already led to the development of many technologies ubiquitous in modern life, including broadband optical fibre communication and smartphone displays.

These devices operate using billions and billions of photons, the smallest indivisible quanta of light – but many powerful quantum effects (such as enabling quantum secure communication) can only be harnessed when working with a single photon.

The quantum science community has been waiting for more than a decade for a compact optical chip that delivers exactly one photon at a time at very high rates.

With international and local collaborators, I reported today in *Nature Communications* the ability to combine single photon-generating devices on a single silicon chip, a breakthrough for next generation quantum technologies.

Photons as qubits

In 1982, American physicist and Nobel Prize laureate Richard Feynman proposed the idea of building a new type of computer based on the principles of quantum mechanics.

While a regular computer represents information as a bit with a value of either 0 or 1, the quantum equivalent is the qubit, a quantum particle that has two clear binary states.

Due to its quantum nature a qubit can be in either state 0, or state 1 or superposition of them both at the same time.

Computations performed using a qubit follow a different set of rules to a regular computer – and this allows certain problems to be solved exponentially faster.

A photon is one example of a quantum particle that can be used as a qubit, and ideally researchers would like to be able to generate photons one by one, as two or more photons in a bunch no longer act as a qubit.

Credit: Photon

It is easy to generate many photons, but much harder to ensure they come out one by one – photons are gregarious by nature – and a high generation rate is desired, similar to a high central processing unit clock speed.

The creation of single photons has been possible for some years, but with poor performance and often bulky implementation. We showed that by combining multiple imperfect devices, all on a single silicon chip, we can produce a much higher quality and compact source of single photons, opening a number of new applications.

Fishing for photons

The challenge in our research was within the physical mechanism behind photon generation. There is an intrinsic link between the rate of useful single photons creation and how often two or more photons are generated instead: these bunches are unwanted.

Generating higher rates of single photons is thus accompanied by a higher proportion of unwanted additional photons, so we wanted to reduce that to a more favourable ratio.

Think about it in terms of fishing – instead of generating photons, we want to catch fish. An easy option is to send a fisherman out on a boat to cast a net; this will result in a lot of good fish, but also a lot of unwanted garbage.

This is analogous to using a conventional photon source, which generates many photons, but also a lot of unwanted photon bunches.

Alternatively, we can send two people out with fishing rods. With some luck, they could collectively catch the same number of fish in the same amount of time, but because the method is more selective, the chance of collecting garbage has been vastly reduced.

A single device for generating single photons (one fisherman) when operating at a high rate (casting a large net) generated unwanted photon bunches. By combining two single photon sources (two fishermen on a boat) on a single silicon chip (the boat), the proportion of 'garbage' photon bunches was significantly reduced. In the future we will combine many photon sources on one chip (we want many fishermen!). Credit: SevenPixelz

This is analogous to the work done here: two single photon sources (the fishermen) were combined on a single silicon chip (the boat), with the proportion of "garbage" photon bunches significantly reduced.

More fishermen

In the future we will extend this idea and combine many more devices onto a single silicon optical chip. Even though each individual source operates at a lower rate, they can be combined to give much higher rates – you just need more fishermen!

This will allow us to generate a large number of useful single photons, which can act as optical qubits, a fundamental ingredient of complex quantum processors.

The impact of this work opens the potential for more advanced single photon technologies, including secure communication where improved single photon generation directly increases the distance and bit-rate of a quantum secure communication link.

This an active area of research at the Centre for Ultrahigh Bandwidth Devices for Optical Systems (CUDOS) within the University of Sydney.

Still more applications include metrology (the science of measurement), simulation of biological and chemical systems, and – of course – quantum computing.

More information: www.nature.com/ncomms/2013/131 … full/ncomms3582.html

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