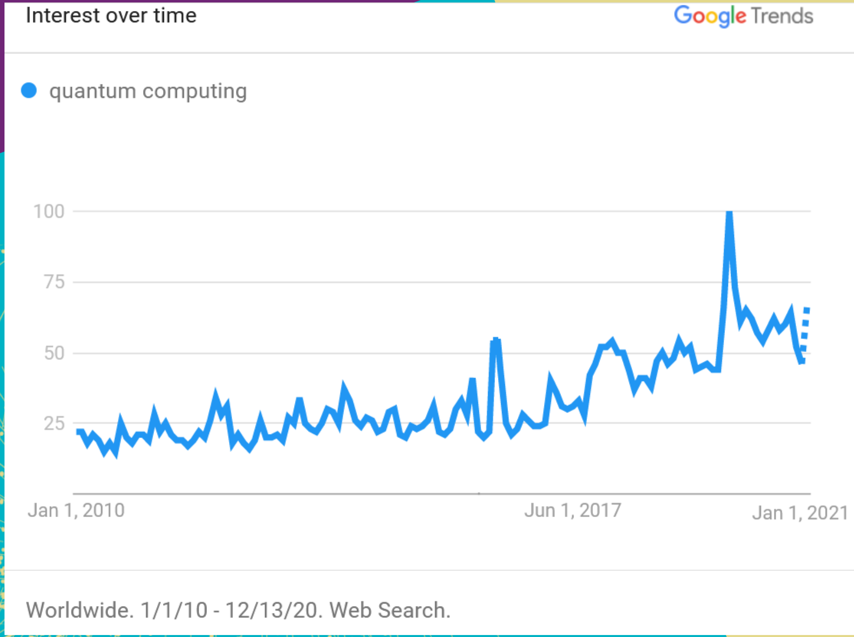


Nikhef Jamboree 2020

Quantum Computing

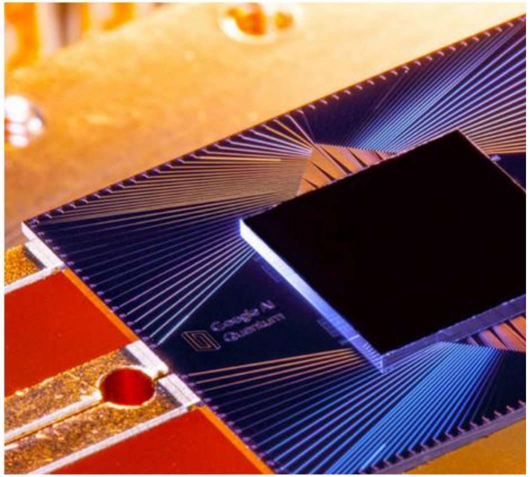
both ready and not ready for us
all at the very same time

David Groep
Physics Data Processing

NEWS QUANTUM PHYSICS

Google officially lays claim to quantum supremacy

A quantum computer reportedly beat the most powerf
type of calculation



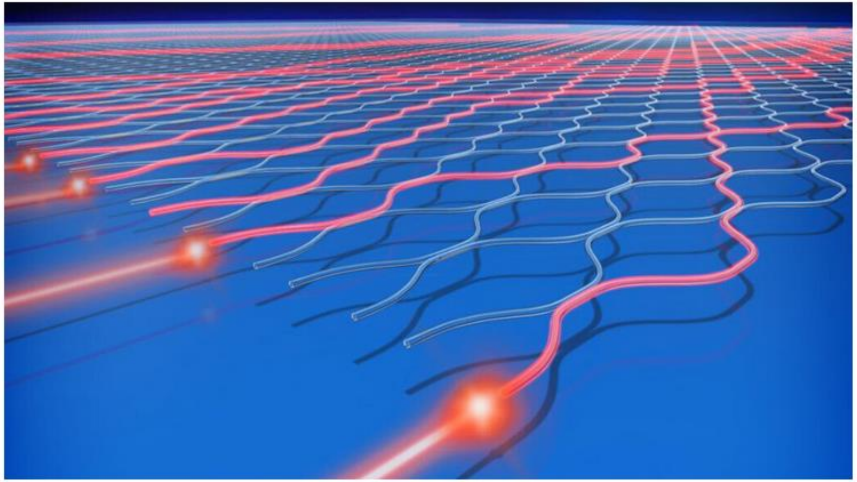
Google researchers report that their quantum computer, Sycamore, has performed a calculation that c
chip (shown) must be cooled to near absolute zero to function.

F. ARUTE *ET AL*/*NATURE* 2019

NEWS QUANTUM PHYSICS

The new light-based quantum computer Jiuzhang has achieved quantum supremacy

A second type of quantum device performed a calculation impossible for a traditional computer



The quantum computer Jiuzhang works by sending particles of light (illustrated in red) into a network of channels and then measuring the photons at the other end.

YIHAN LUO

Screen captures: sciencenews.org

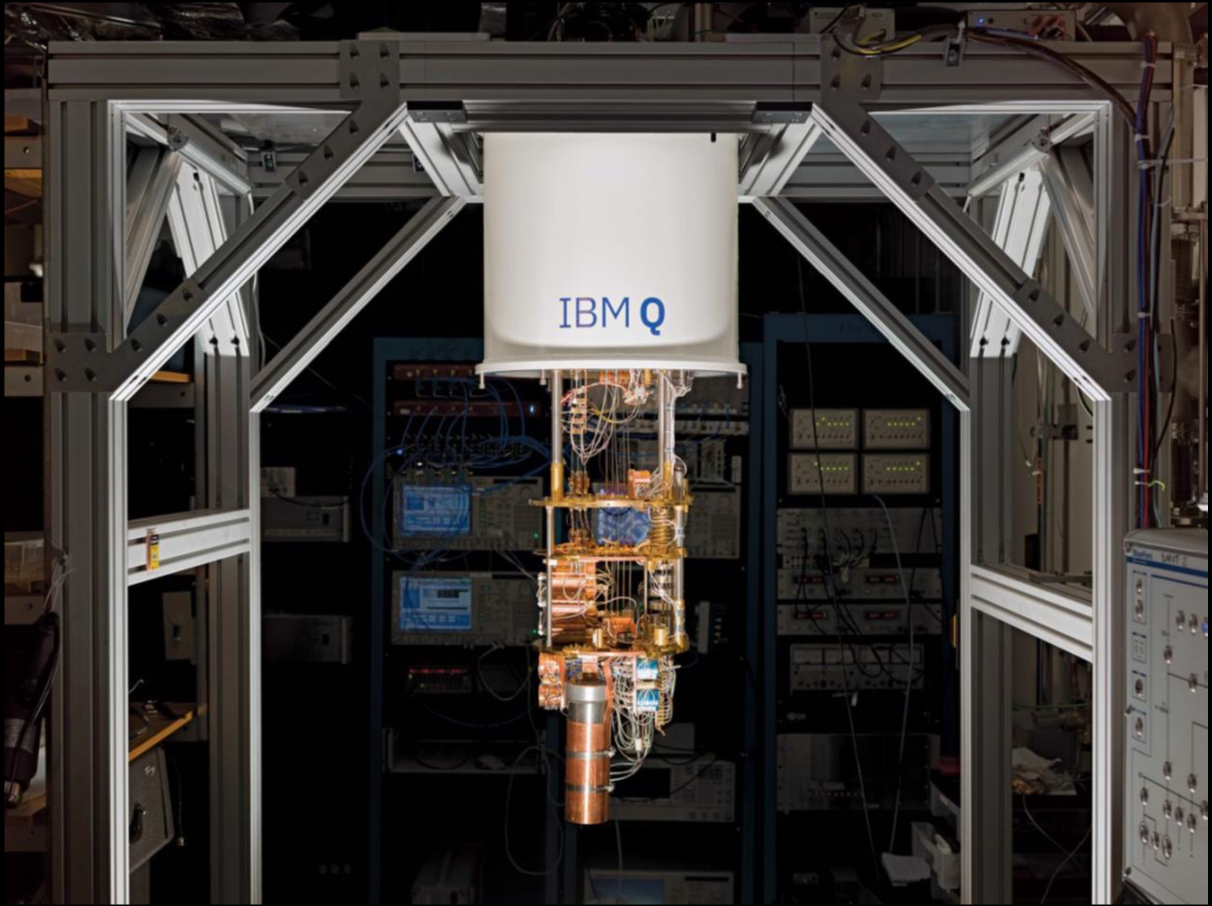
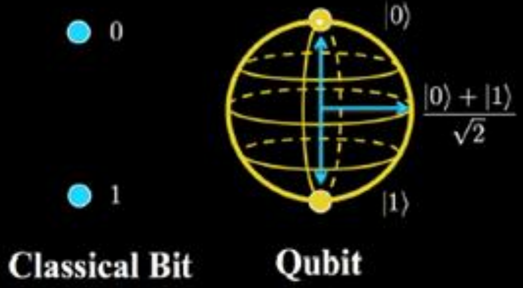


Image: IBM

What's in it … for the machine …



$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

$$|\alpha|^2 + |\beta|^2 = 1$$

and a rotation over π is immaterial

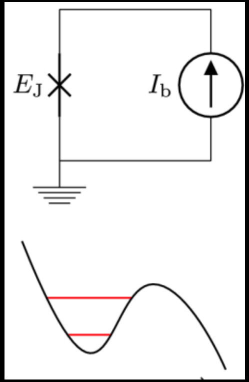
a classical bit can be either 0 or 1

typical implementation:
a charge in a MOS capacitor

a 'qubit' does have two basis states

$|0\rangle$ typically a ground state *and also* $|1\rangle$ (maybe higher-energy) state

typical implementations: Josephson junction, spin, photon polarization, a hole, …



and you can manipulate a qubit through unitary transformation of its state ('gates')

although in fact there are only 2 free parameters

image E_J: Anton Frisk Kockum & Franco Nori
Quantum Bits with Josephson Junctions https://link.springer.com/chapter/10.1007/978-3-030-20726-7_17

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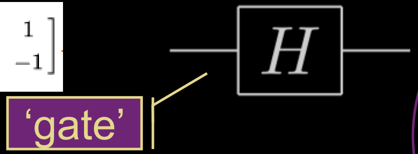
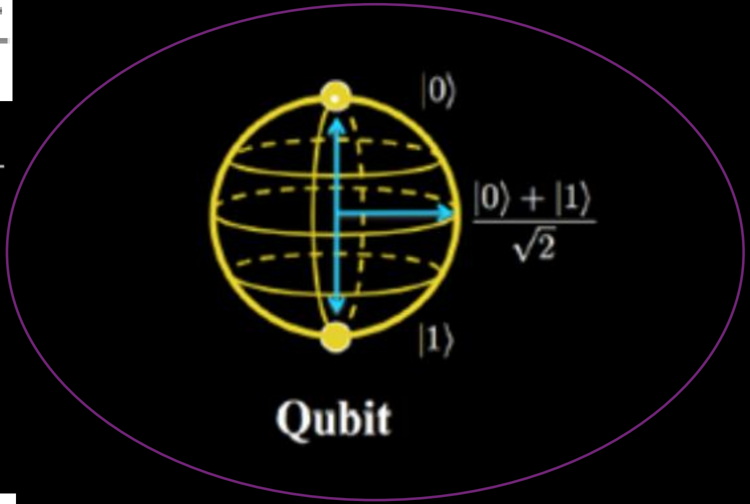
Things to do with a qubit when you’re bored

you can make it a superposition

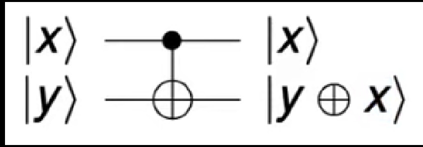
$|0\rangle$ to $\frac{|0\rangle + |1\rangle}{\sqrt{2}}$ and $|1\rangle$ to $\frac{|0\rangle - |1\rangle}{\sqrt{2}}$

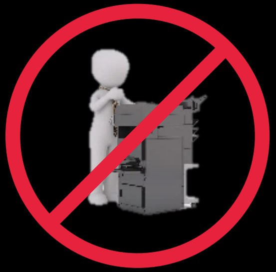
$H = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$

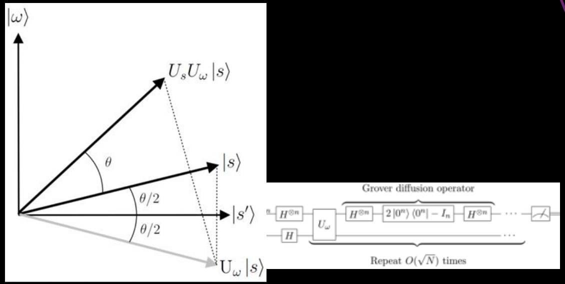




you can entangle it





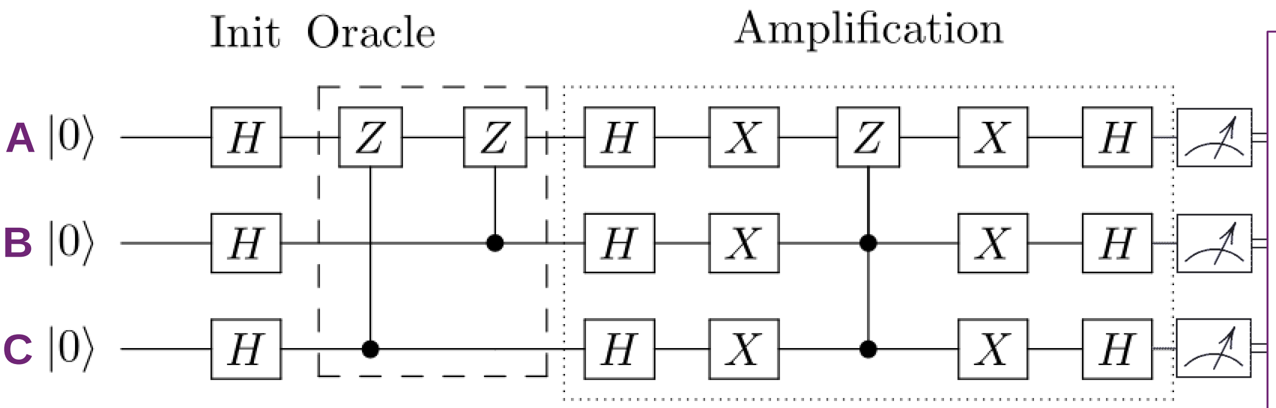


you can interfere with it

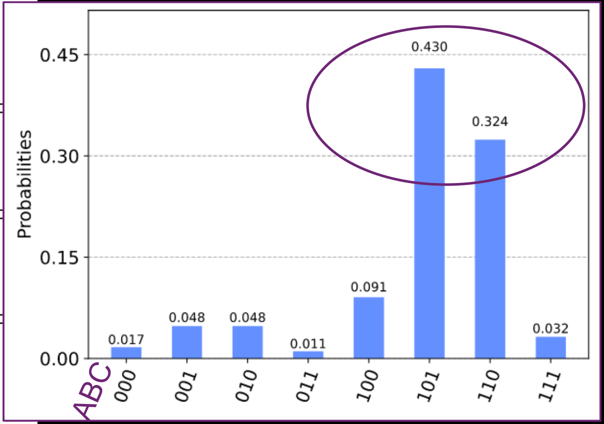
Image credits Bloch sphere: https://prateekvjoshi.com/
gates: wikipedia.org

More fun with more qubits … and a bunch of gates

create maximal-mix initial state | ***'function'*** *acts on ABC* | processing needed to determine 'action of the oracle' (function) **enhancing the real solution** – suppressing FAKE answers



'if A is |1⟩, *only* keep it there is either B xor C is |1⟩'



'a general purpose Quantum Computer feels a bit like programming an FPGA … that has a bad hair day'

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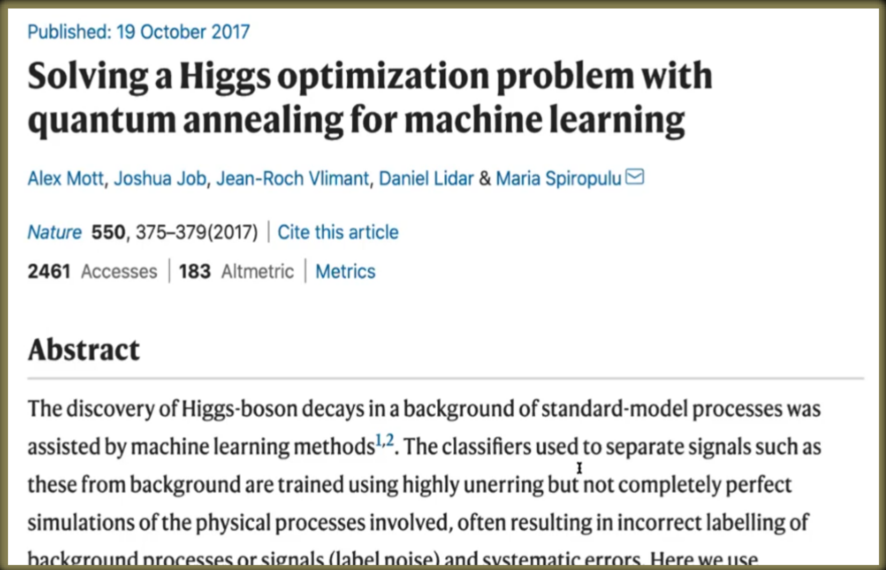
images: https://qiskit.org/textbook/ch-algorithms/grover.html

What’s in it … for us?



Published: 19 October 2017

Solving a Higgs optimization problem with quantum annealing for machine learning

Alex Mott, Joshua Job, Jean-Roch Vlimant, Daniel Lidar & Maria Spiropulu

Nature **550**, 375–379(2017) | Cite this article

2461 Accesses | **183** Altmetric | Metrics

Abstract

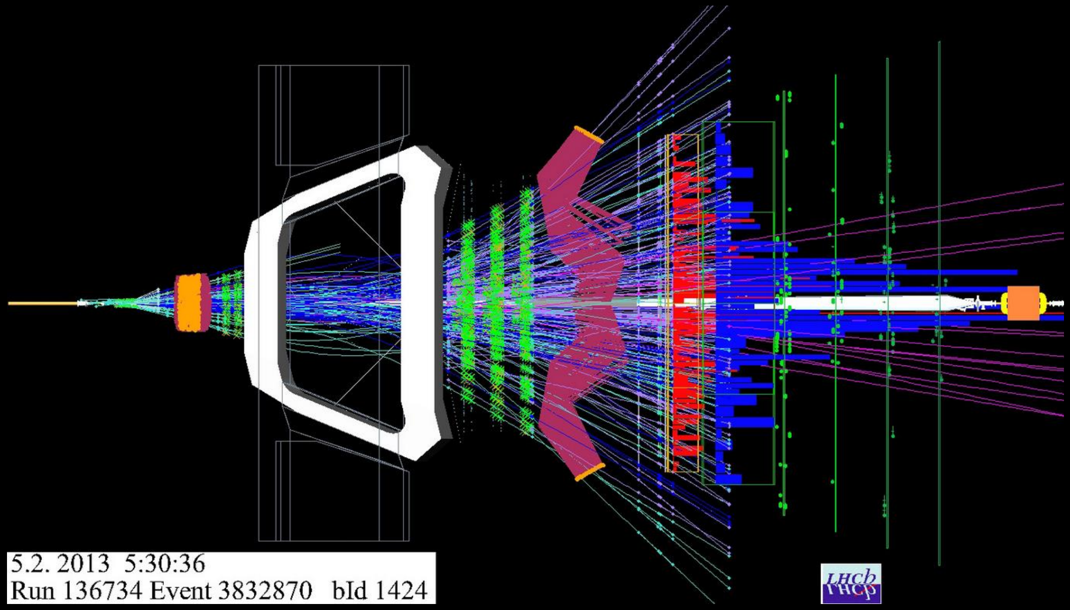
The discovery of Higgs-boson decays in a background of standard-model processes was assisted by machine learning methods[1,2]. The classifiers used to separate signals such as these from background are trained using highly unerring but not completely perfect simulations of the physical processes involved, often resulting in incorrect labelling of background processes or signals (label noise) and systematic errors. Here we use

‘an annealing Quantum Computer can do one thing (minimization) well, with *lots* of qubits, but is more like an ASIC …’

so can we also scale a general purpose QC like IBM’s to our problem sizes?

images D-Wave via: Elías F. Combarro, CERN QC lecture #5, https://indico.cern.ch/event/970903/

What's in it … for us



now if we could only obtain quantum supremacy …
… to make sense of this, for example

'just a few steps to take?'

- work on potential algorithms
- it's a minimization challenge with many inputs
  … but you need *a lot* of qubits
- and a way to boost the desired result, and suppress fake news
- *quantify* its efficiency in finding the right tracks

and it would be jolly nice if

- our quantum computer did not suffer from amnesia all the time
- not suffer *that* many errors

so: don't hold your breath,
it may take quite a while yet!

So now, be both convinced and confused …
… at the same time

Nikhef

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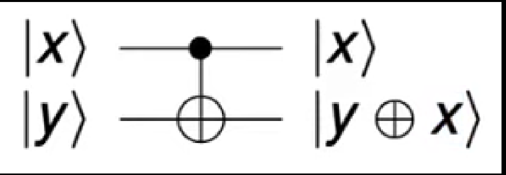
https://orcid.org/0000-0003-1026-6606

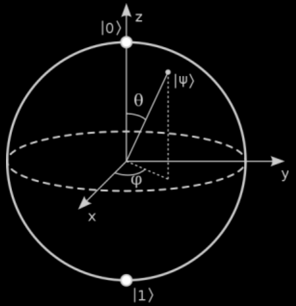
go and watch the CERN QC lecture series by Elías F. Combarro at https://indico.cern.ch/event/970903/

Nature always interferes slightly with our desires …

example gate:
a “controlled NOT”

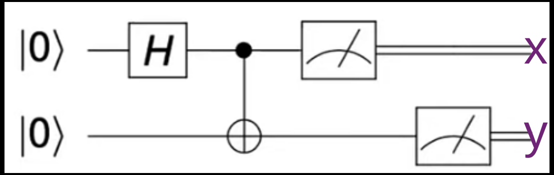


rotates $|y\rangle$ over π
around x-axis *if* $|x\rangle = |1\rangle$

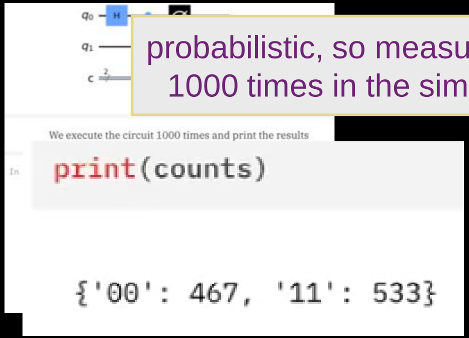


$$|00\rangle \rightarrow |00\rangle$$
$$|10\rangle \rightarrow |11\rangle$$

create superposition $\frac{|0\rangle+|1\rangle}{\sqrt{2}}$ (“H”)
and have it control a $|0\rangle$ qubit

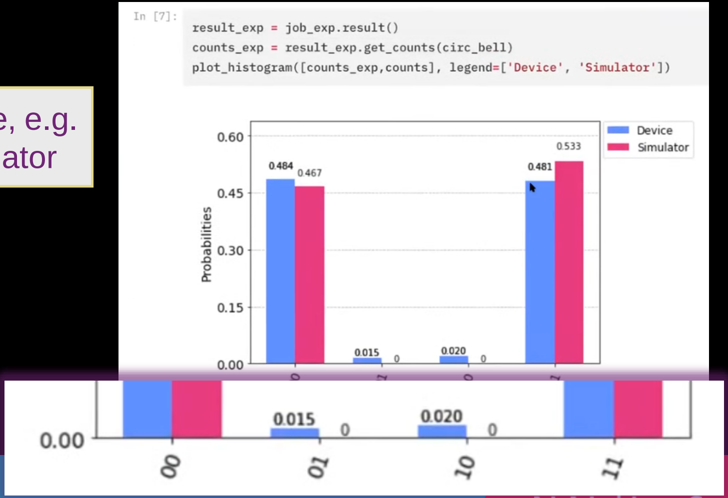


what you expect:
(and what the simulator gives)



probabilistic, so measure, e.g.
1000 times in the simulator

what you really get is:



result graphics from: Elías F. Combarro, CERN QC lecture #3, https://indico.cern.ch/event/970903/

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Image source: https://www.sciencenews.org/article/new-light-based-quantum-computer-jiuzhang-supremacy