The Quantum Blockchain Cloud

(or: buzzword compliance in the age of quantum computing)

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The H-word

Quantum Computing Hype Cycle Just Getting Started

Quantum computing could be to the 2020s what cloud computing was to the 2010s

By **Dana Blankenhorn, InvestorPlace Contributor** Jul 25, 2018, 1:24 pm EST

April 18, 2019 | Contributor: Kasey Panetta

Quantum Computing Under Hype Cycle and Market Clock Scrutiny

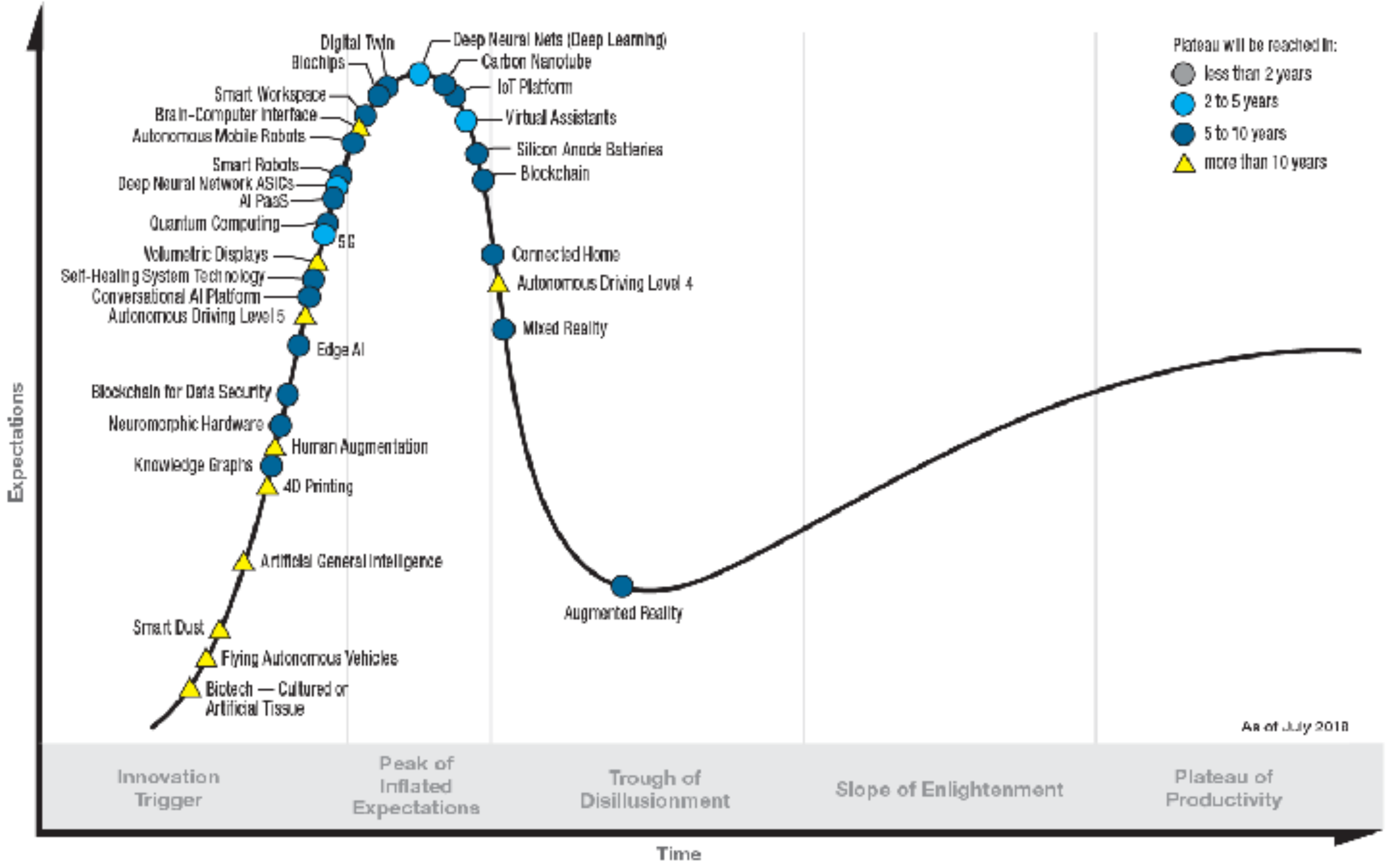
With new technology come the plaudits and the critics. Quantum computing is no different from any other sector

By **James Dargan** - August 1, 2019 46 0

Quantum computing is not a cure-all for business computing challenges

by **James Sanders** in **Innovation**
on May 16, 2019, 11:05 AM PST

Hype Cycle for Emerging Technologies, 2018



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Article

Quantum supremacy using a programmable superconducting processor

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QUANTUMSUPREMACY
10.23.19

The hype isn't helpful!

- The **amount of hyperbole** is mind boggling
  - Google's "quantum supremacy" was compared to the Wright brothers' first flight moment
- **How can we know what is true or not?**
- Is quantum computing really happening? Is our public key cryptography really no longer safe? **Hopefully this talk will help.**

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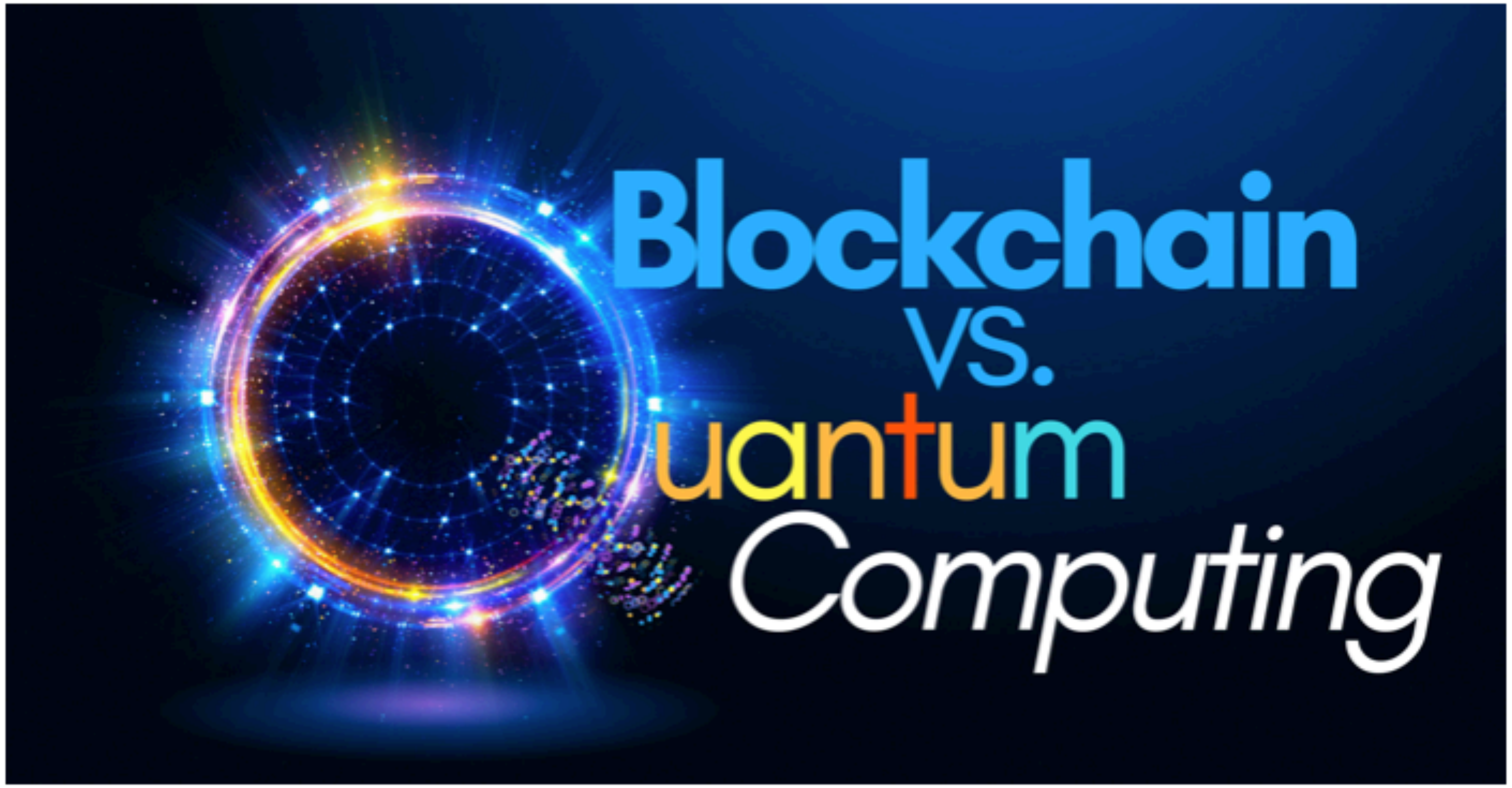
Hackernoon sez it better...

Quantum Computing: Is it the end of blockchain?

June 3rd 2018

TWEET THIS



Is this the end of blockchain?

Some facts

- Quantum computers have *qubits*, which - as many of you may already know - can simultaneously encode any value between 0 and 1 at the same time (in superposition)

- The trick with *qubits* is that they can be *entangled*, that is: their quantum states can be linked

    - This leads to some weird properties, such as "quantum teleportation"

    - It also plays a role in breaking classic public key cryptography

Building a qubit

- It turns out there are many ways in which qubits can be created
- Think of this as "hard drive" vs. "tape drive" vs. "flash drive"
- Many of these methods have some extreme requirements (very very cold environments, diamonds, powerful lasers, ...)
- The holy grail is keeping qubits stable; current records are in the order of a minute

Physical vs. logical qubit

- It turns out quantum computers are inherently noisy and unreliable; consequently, you need many *physical* qubits to create one *logical* qubit
- To perform error-free computations on a quantum computer, you need quantum error correction, to get from physical unreliable qubits to reliable logical qubits
- This can cause serious confusion; when the claims start flying that we need hundreds or millions or billions of qubits to break cryptography, **what type of qubits are they talking about?**

OK, but what about D-Wave?

- D-Wave regularly shows up in discussion about quantum computing
- Current model is claimed to have 2048 qubits, with a new model claiming 5000 qubits by mid-2020
- So are we done by mid-2020? No more RSA or Elliptic Curves? Some news outlets seem to think so (the picture on the right is from a scare-tactic Forbes article on quantum)

Not so fast (after all)

- D-Wave is not a general purpose QC, instead it does something called "adiabatic quantum computing"
- The jury is still out on whether this provides a real speed-up over classic computing, experts disagree
- The documentation is also unclear, but it appears that the 2048/5000 qubit claim talks about *physical* qubits
- Most importantly, though, D-Wave's systems cannot run Shor's algorithm (more about that in a minute)

Time for a quick summary

- Making stable qubits is really hard
- Qubits are highly unreliable
- You need orders more physical qubits to create logical qubits
- The state of the art are machines with some 50-ish logical qubits with limited stability

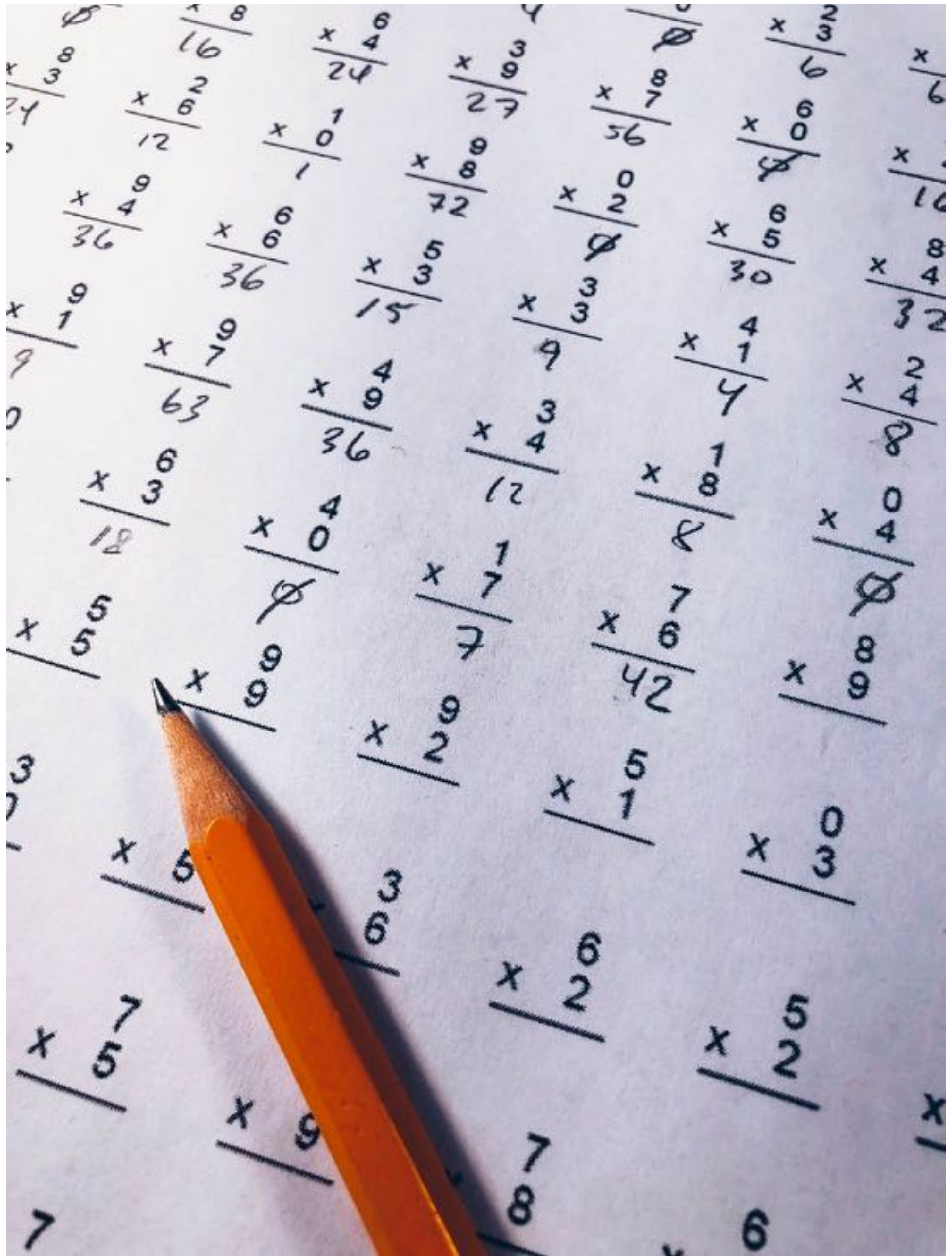


Photo by Chris Liverani on Unsplash

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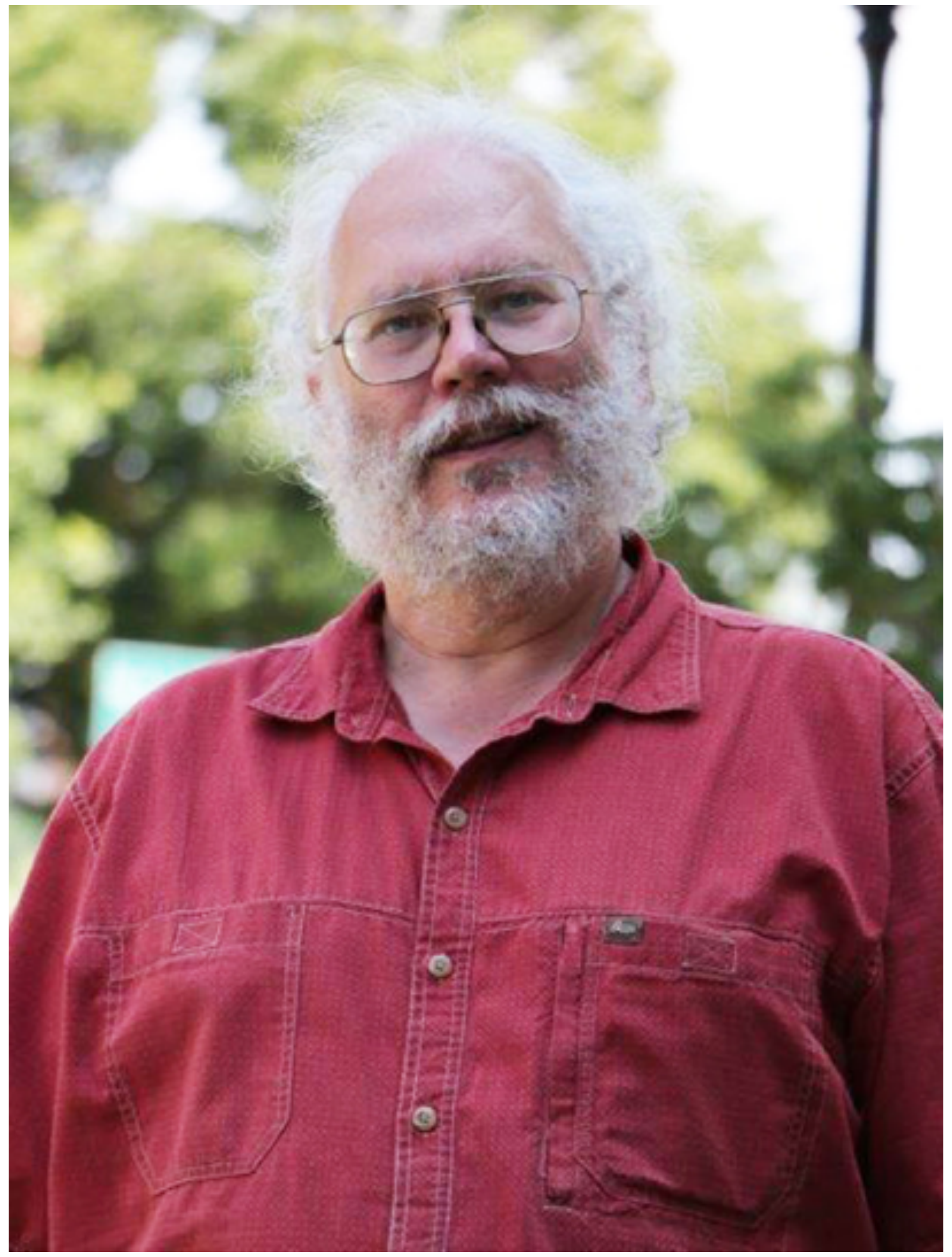
Shor's algorithm

- In 1994 prof. Peter Shor (see picture) devised an algorithm to factor very large numbers (think: RSA) much more efficiently on quantum computers

- This was touted as the "killer app" for quantum computers (which many claim had been a niche interest until then)

- His algorithm requires a stable general purpose quantum computer to execute; let's assume that exists for the sake of argument



Research to improve Shor

- Researchers are trying to improve Shor's algorithm
- To drive down the requirements to break common public key algorithms
- They do this without actual access to a working QC (awesome!)
- Take, for example, this table from [6] (references at end of deck):

	Physical assumptions				Approach		Estimated costs		
Historical cost estimate at $n = 2048$	Physical gate error rate	Cycle time (microseconds)	Reaction time (microseconds)	Physical connectivity	Distillation strategy	Execution strategy	Physical qubits (millions)	Expected runtime (days)	Expected volume (megaqubitdays)
Fowler et al. 2012 [9]	0.1%	1	0.1	planar	1200 T	single threaded	1000	1.1	1100
O'Gorman et al. 2017 [18]	0.1%	10	1	arbitrary	block CCZ	single threaded	230	3.7	850
Gheorghiu et al. 2019 [19]	0.1%	0.2	0.1	planar	1100 T	single threaded	170	1	170
(ours) 2019 (1 factory)	0.1%	1	10	planar	1 CCZ	serial distillation	16	6	90
(ours) 2019 (1 thread)	0.1%	1	10	planar	14 CCZ	single threaded	19	0.36	6.6
(ours) 2019 (parallel)	**0.1%**	**1**	**10**	**planar**	**28 CCZ**	**double threaded**	**20**	**0.31**	**5.9**

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Research to improve QECC

- Researchers are not just trying to improve Shor
- More fundamentally (because it is required for other quantum algorithms) they are trying to improve error correction
- One of the latest developments is called "surface codes"; these purportedly work better on "noisy" qubits
- In the context of Shor: they require approximately 15,000 physical qubits per logical qubit for qubits with an error rate of 10^{-3} (state of the art)

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So where are we with Shor?

Public Key System	Key size	Security	Logical qubits required	Physical qubits required	Running time
RSA	1024 bits	80 bits	2,050	8.05×10^6	3.58h
	2048 bits	**112 bits**	**4,098**	$\mathbf{8.56 \times 10^6}$	**28.63h**
	4096 bits	128 bits	8,194	1.12×10^7	229h
ECC	**256 bits**	**128 bits**	**2,330**	$\mathbf{8.56 \times 10^6}$	**10.5h**
	384 bits	192 bits	3,484	9.05×10^6	37.67h
	512 bits	256 bits	4,719	1.13×10^7	55h

Source: [2] -- terms and conditions apply 🤪

That previous slide...

- Has a *lot* of assumptions, none of which hold today
- So the $64 million question is: when, if ever, will these assumptions hold?
- An oft-quoted person is Michele Mosca, whose most recent prediction puts the likelihood of a quantum computer that can break RSA 2048 in the next decade at **one in six**

picture source: represent.com

So what do the experts agree on?

- **Nobody** really **knows if a quantum computer** good enough **to run Shor will ever be built**
- *Equally*, **nobody claims** that **it can never be built**
- There is **lots and lots of parallel research** going on, all of **which requires major breakthroughs** to get there
- *The best thing you can do*: **keep a keen eye on post-quantum crypto!**

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Mosca's Inequality

- A handy way to reason about when you should really take action is what is often referred to as "*Mosca's Inequality*": **X + Y > Z**

  where: **X** = *the amount of time you want to keep your data secret*
  Y = *the amount of time you take to transition to PQC*
  Z = *when we expect QC's to be able to run Shor*

- The problem, again, here is that **nobody really knows a sensible value for Z** in this equation

The experts are on it

President Donald J. Trump signs the "National Quantum Initiative" into law

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More hyperbowl...^H^H^H^H...bole

picture source: Wikipedia

Quantum Key Distribution

- I assume most (if not all?) of you are familiar with One-Time Pads?

From: A History of U.S. Communications Security (Vols. I and II);
the David G. Boak Lectures, National Security Agency, 1973
https://www.governmentattic.org/18docs/Hist_US_COMSEC_Boak_NSA_1973u.pdf

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QKD relies on the observer effect

- QKD is used to distribute a one-time pad from A to B
- Security relies on the fact that you can tell if the message was observed
- Common implementation: polarised light through a fibre-optic cable

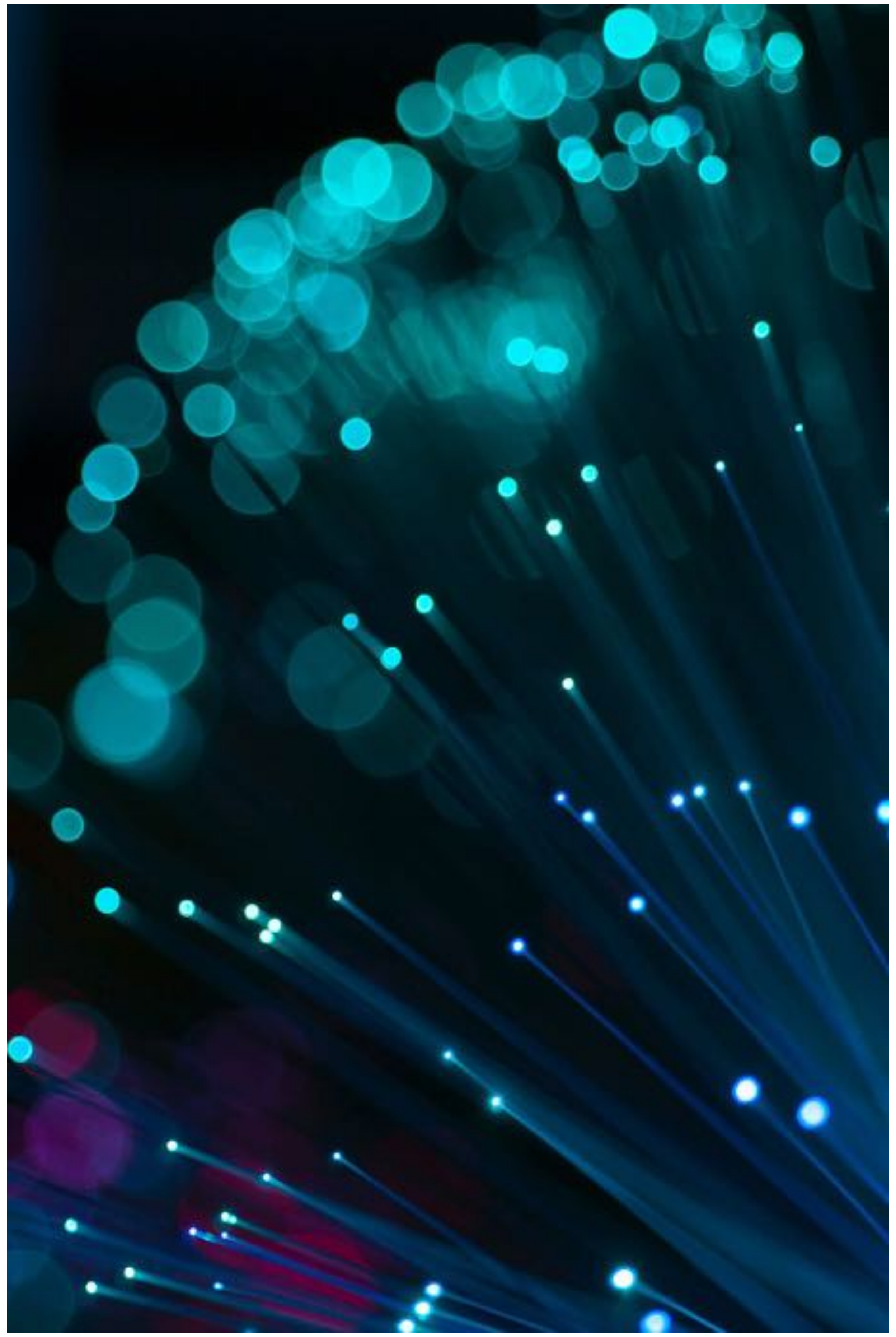

Photo by Umberto on Unsplash

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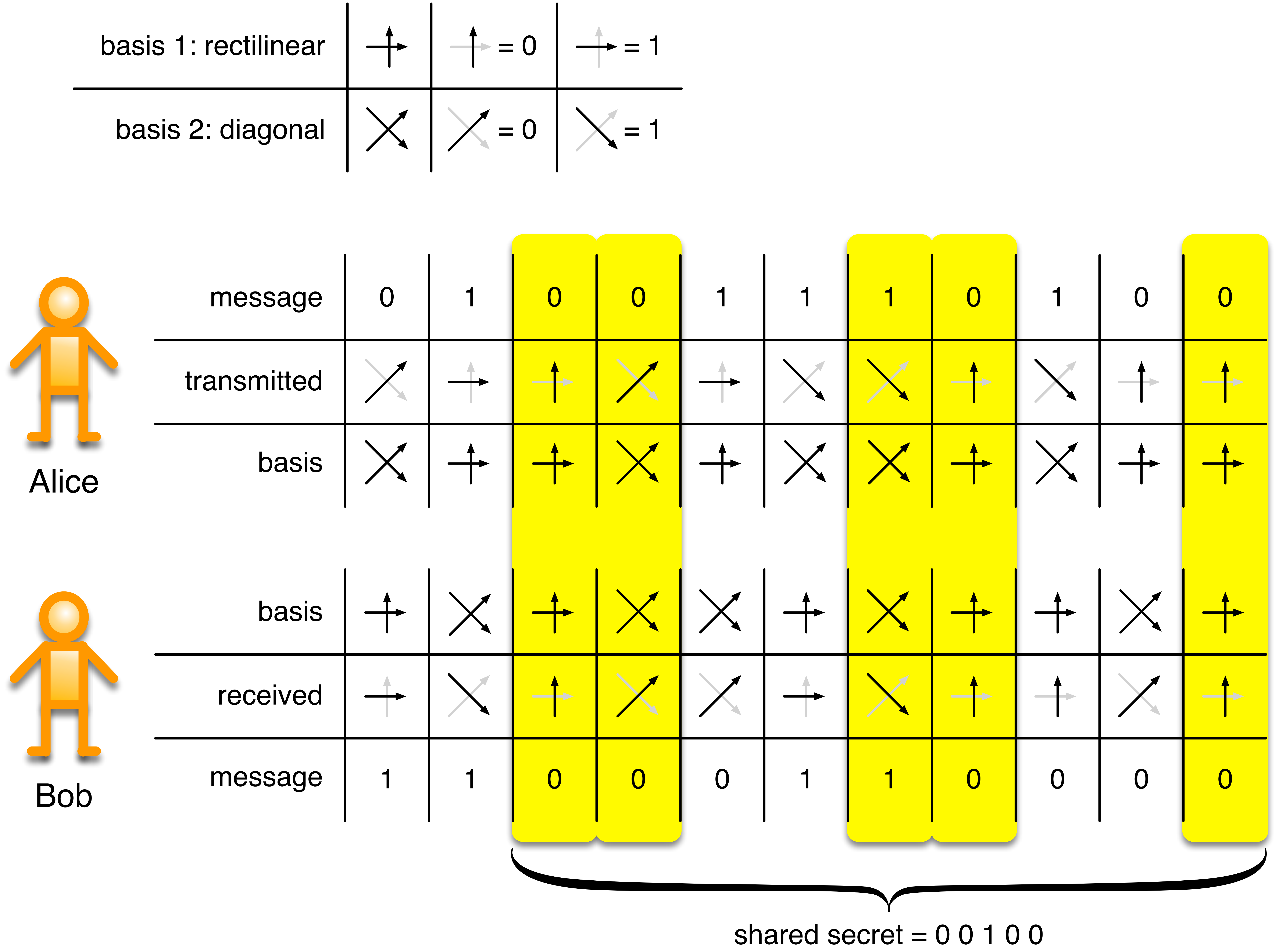
Conceptual QKD in two slides



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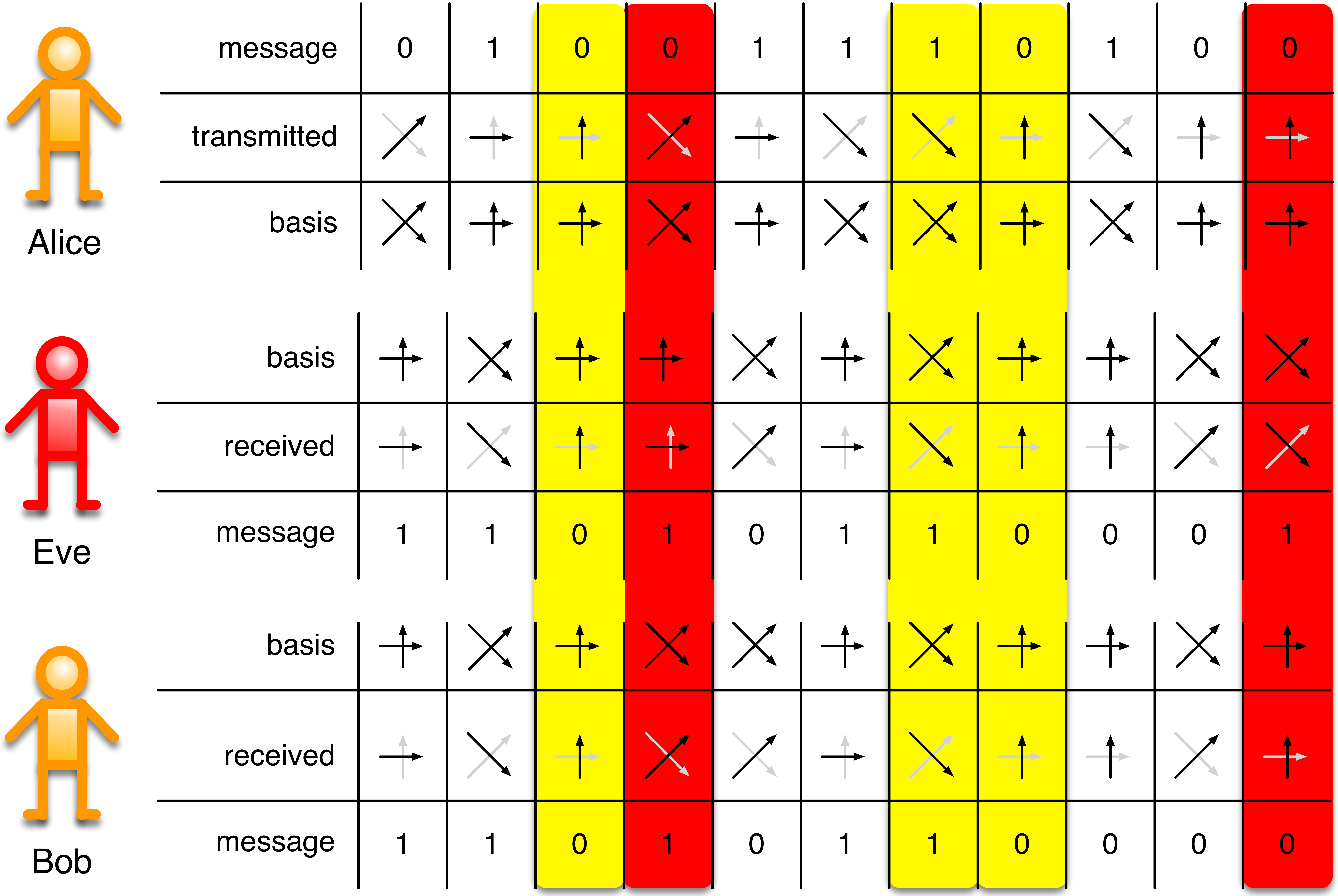
Conceptual QKD in two slides



Issues with QKD

- It **requires "classic" cryptography** to authenticate the communicating parties (am I really sending something to Bob?)

- More importantly, though, **it is vulnerable to attacks**

  - **Photon-splitting attack** (*doesn't that sound awesome?!*)
    QKD relies on single photon emission, but that is actually impossible

  - **Trojan attack**
    Shining a very bright light at the message source, attack can infer chosen polarisation from reflection with 90% accuracy [7]

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Do we really need QKD?

- It is expensive
  - order of €25K/device, you need two!
  - oh, and you need dark fibre
- It is inefficient (bit rate in the order of 1Mbit/s over 50km)
- And there are known attacks, how many are still to come?
- Never underestimate the bandwidth of a truck full of one-time pads 🤪

Photo by VanveenJF on Unsplash

Wrapping up

- There is a lot of hype and hyperbole about quantum computing
- Just as there is about blockchain (hence the title of this talk)
- So we have two takeaways for you:

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Takeaway #1

DON'T PANIC

picture source: Wikimedia Commons

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Takeaway #2

- **Pay attention to Post Quantum Cryptography**
- ...and **give people like Andreas more €€€ for** their **research!**

Photo by Марьян Блан | @marjanblan on Unsplash

So what is the QBC?

Well that, as they say, is simple:

It's a **computer system in someone else's data centre** that **you don't find out actually exists** until you **make a transaction that needs to be persisted on a ledger** after which it **sets fire to said data centre, belching out more pollutants than a brown coal fired power plant in Germany**

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Thank you! Questions?

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