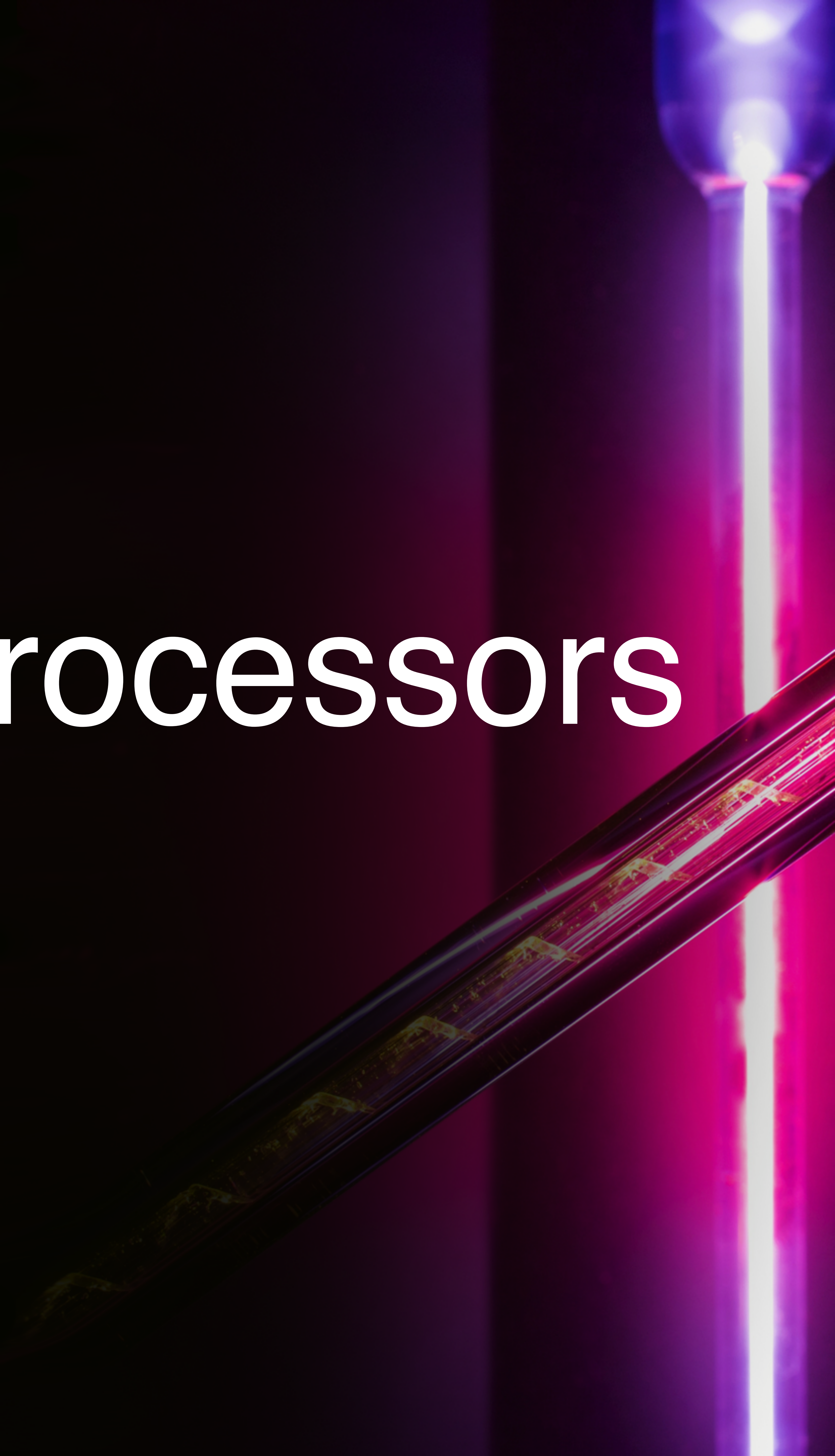
ORCA Computing

Photonic quantum processors

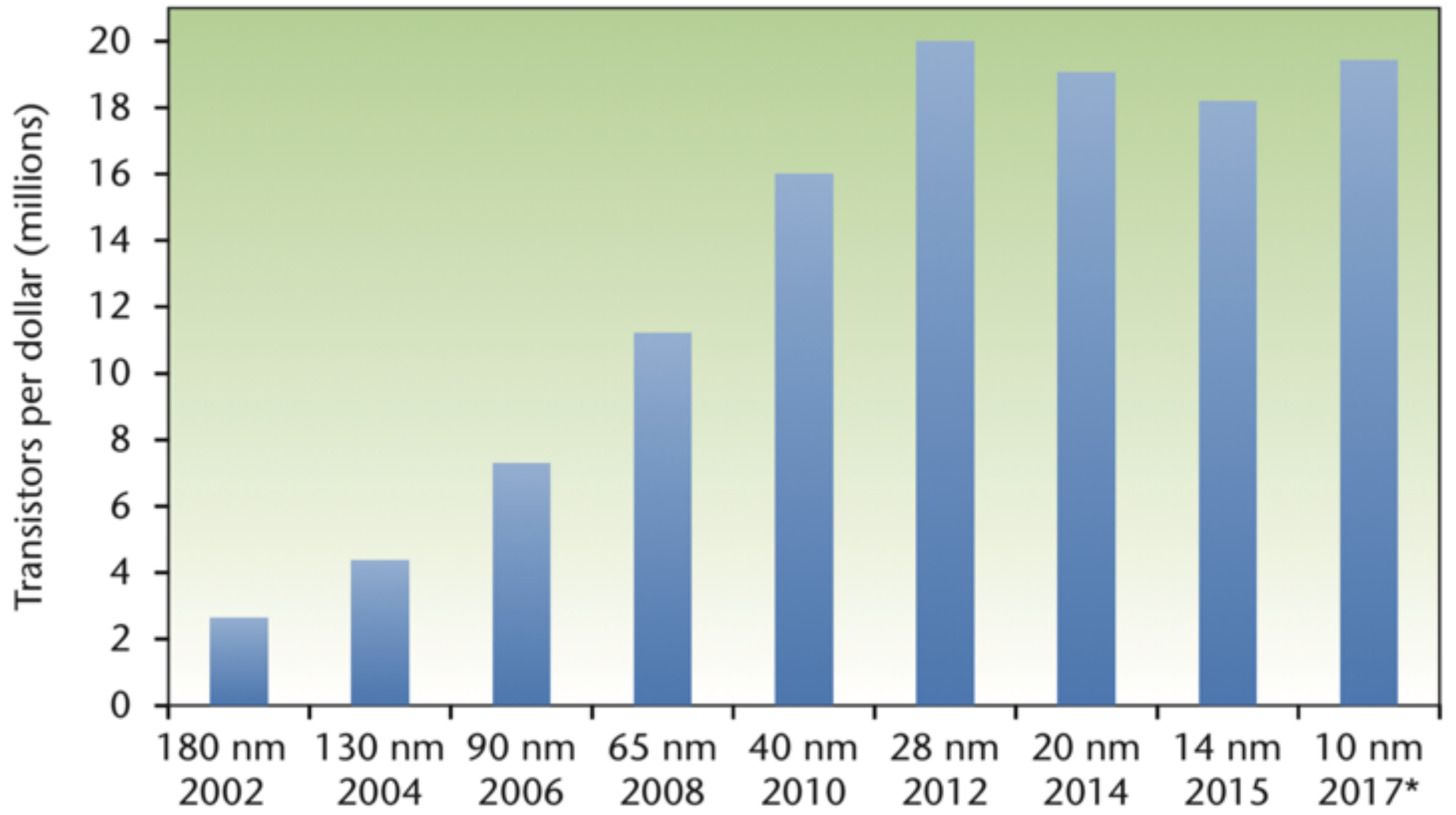


2ND APRIL 2020

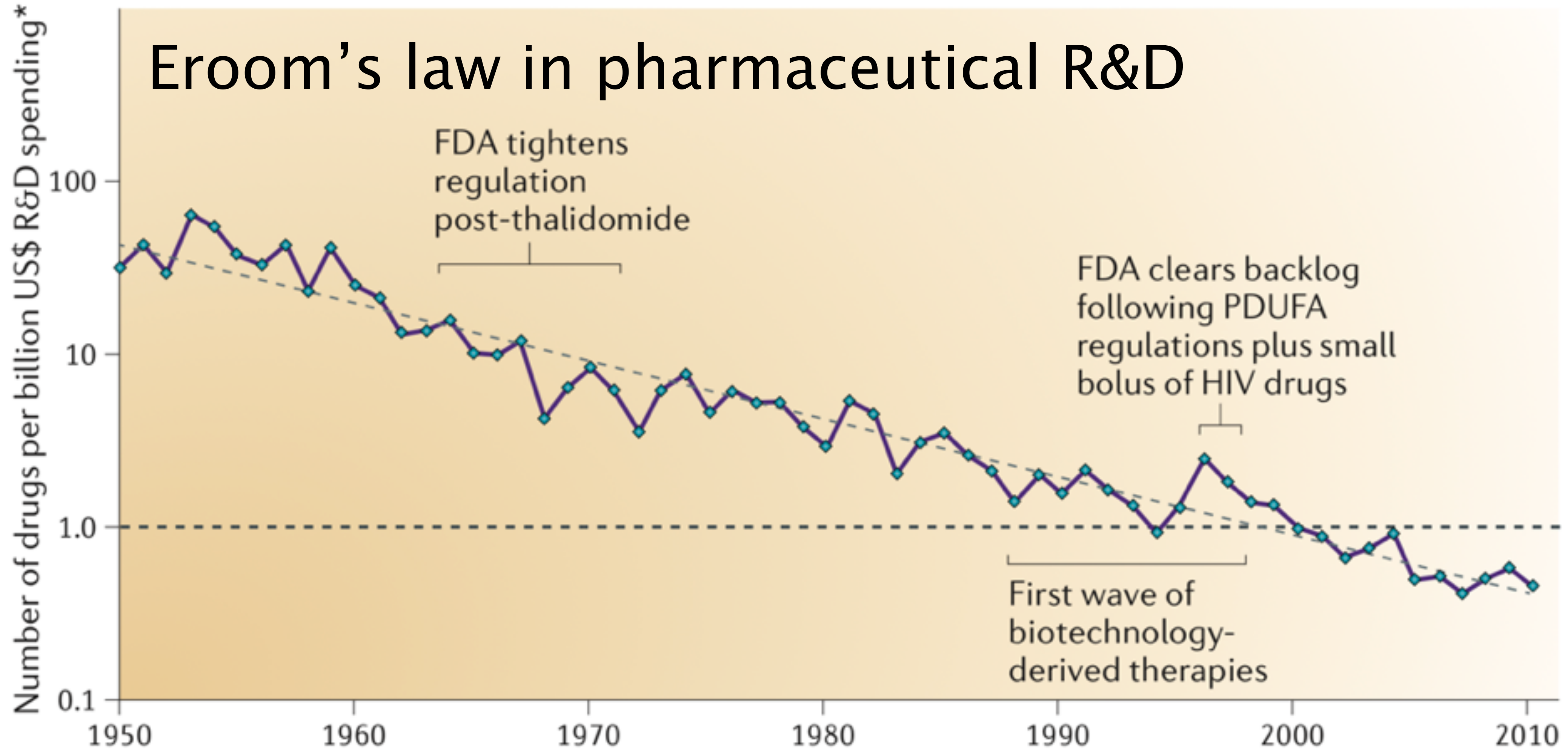
WHY **QUANTUM** COMPUTING

- **Moore's law for conventional computing is over**

[Kwabena Boahen, Stanford, writing in special issue , Comp. Sci. Eng. "The End of Moore's law"]



- **"Natively quantum" problems**

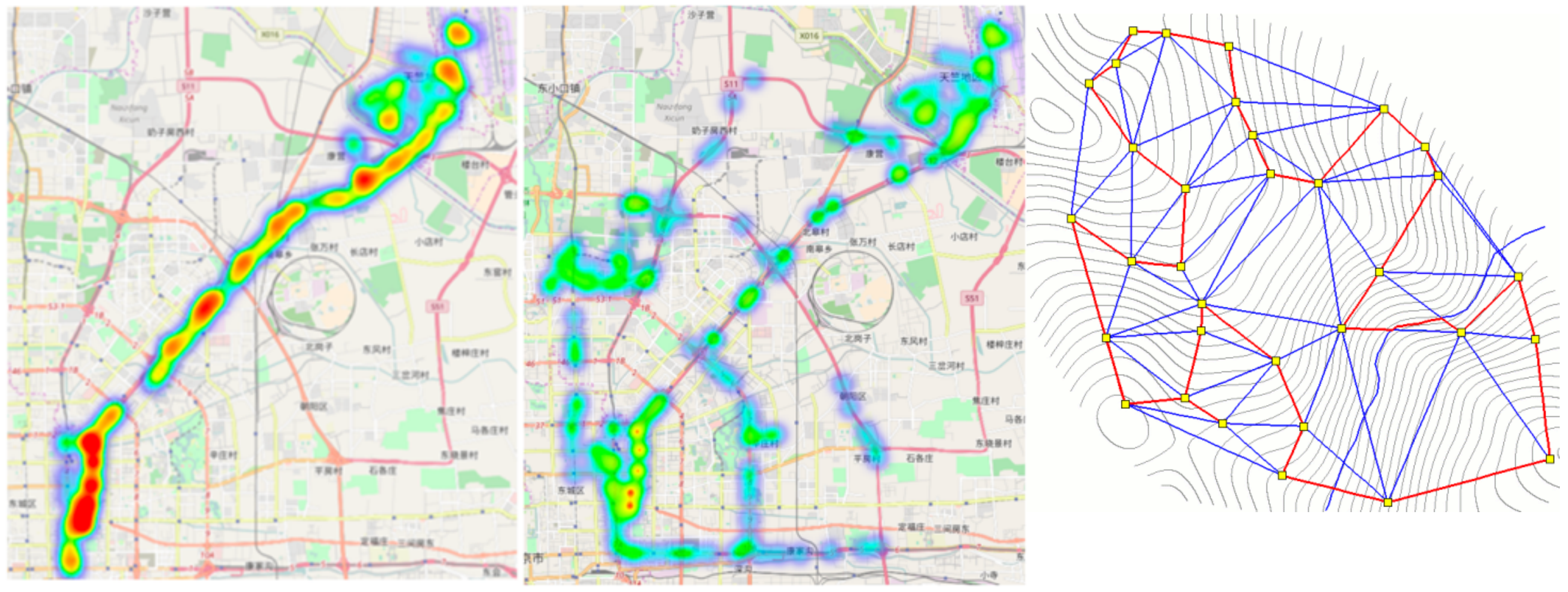


[J. Scannell *et al.* Nat. Rev. Drug Disc. **11** 192 (2012)]

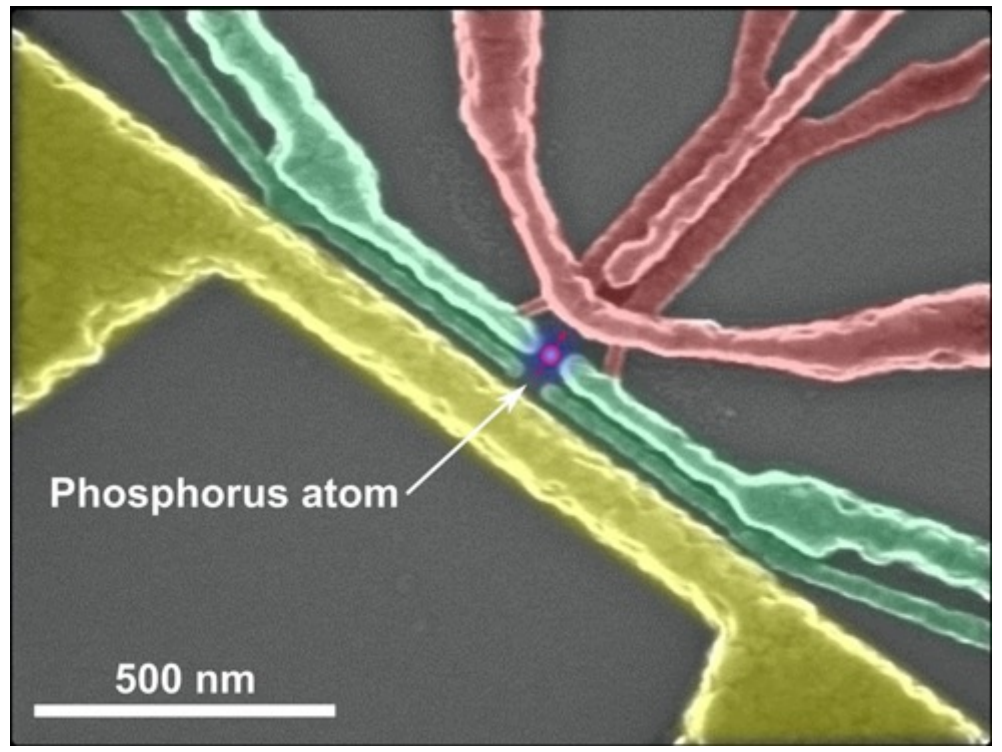
- **optimisations**

[QCAPS final report 2018]

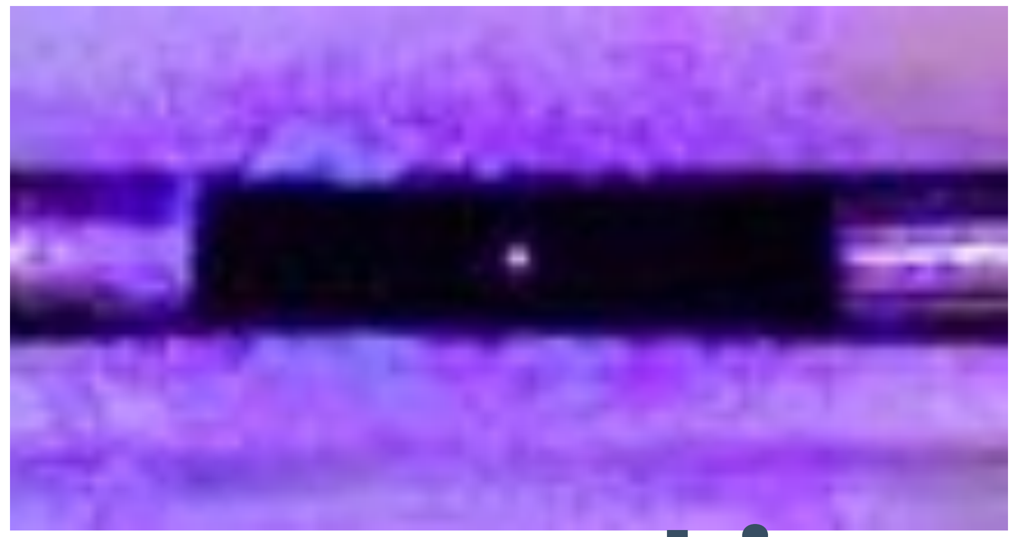
Global market for hybrid solutions	Size (Date)	Size (Date)
Telecoms network optimisation	$1.6Bn (2023)	$6.9Bn (2028)
Distribution logistics	$0.97Bn (2021)	$4.9Bn (2026)
Traffic-flow optimisation (land/air/rail/sea)	$1.4Bn (2022)	$12.7Bn (2027)



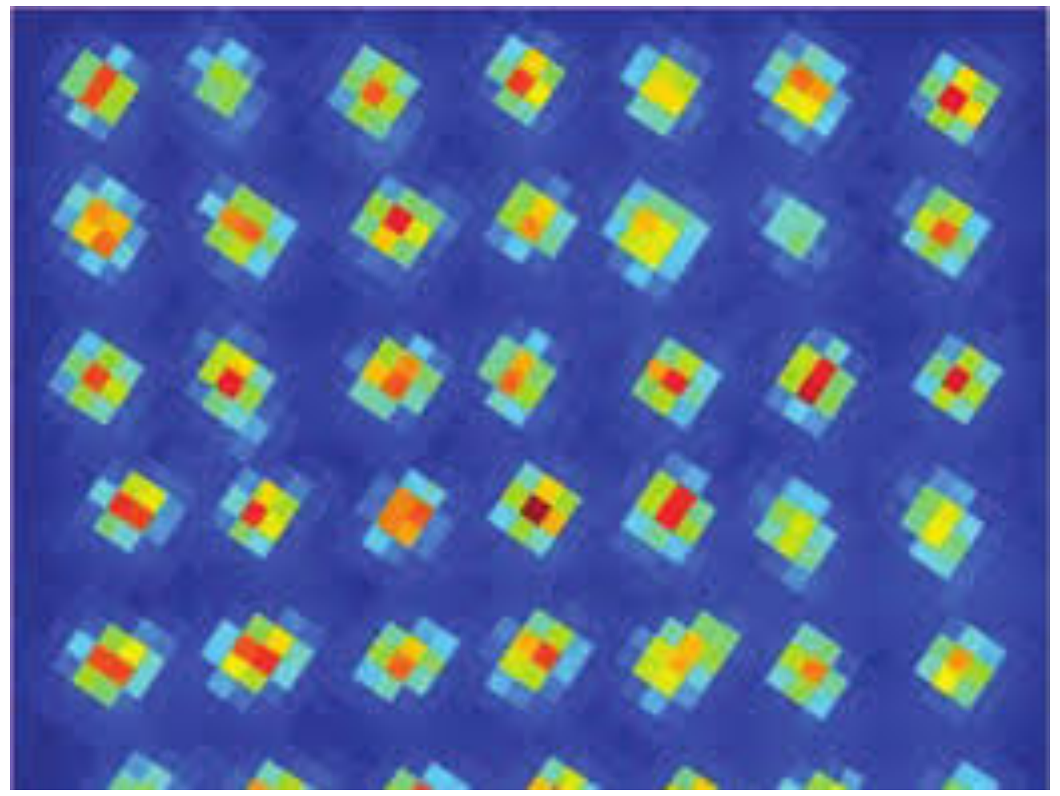
MANY PLATFORMS



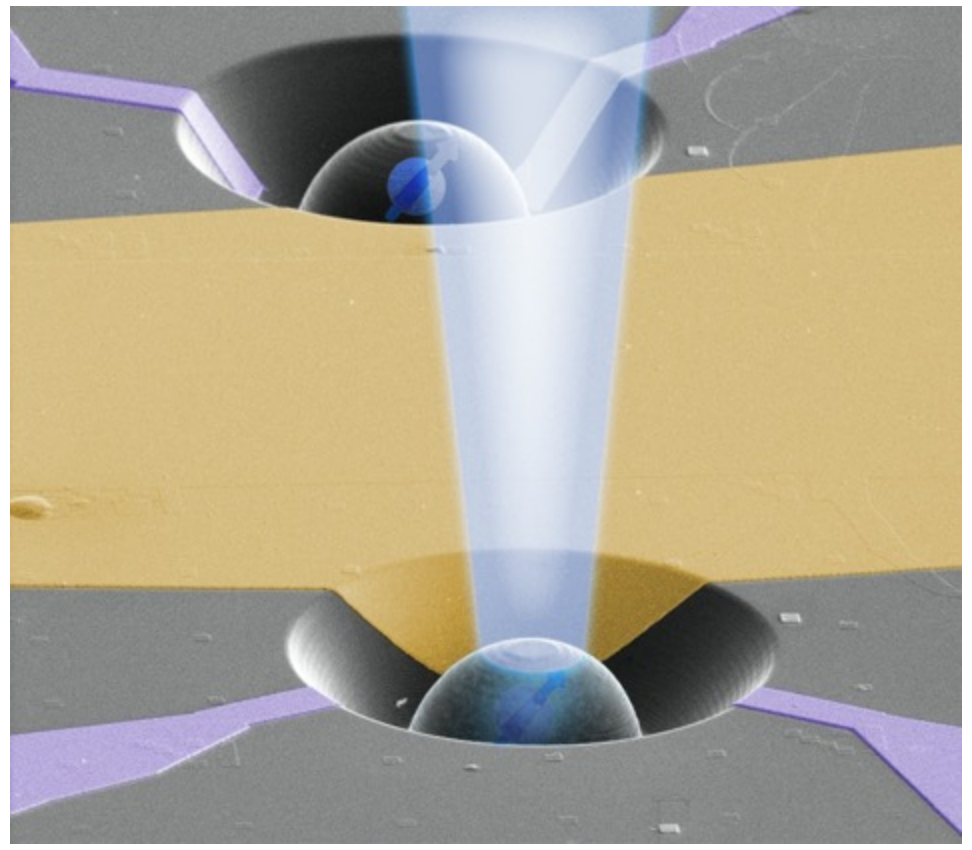
K donors in Si



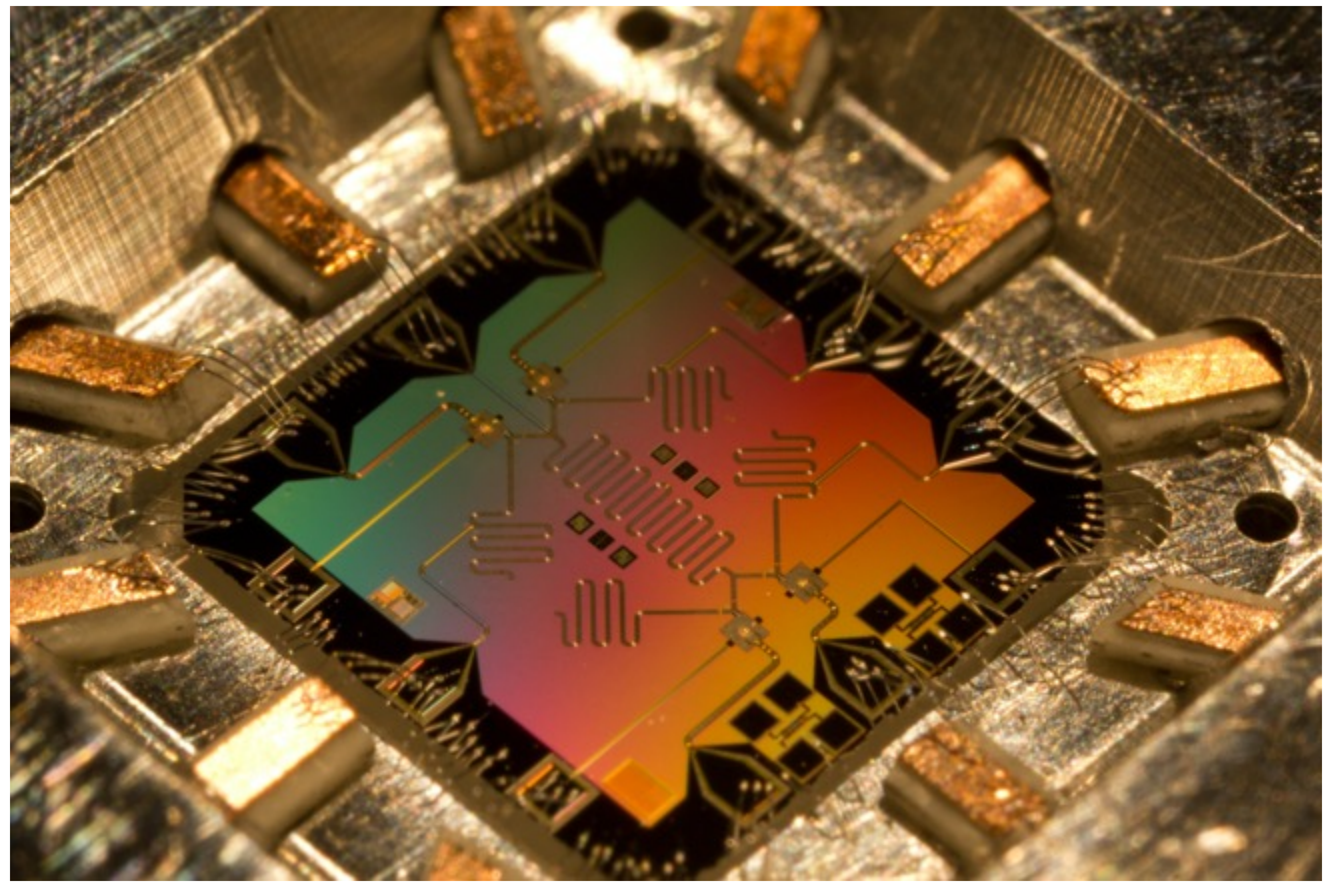
trapped ions



neutral atoms

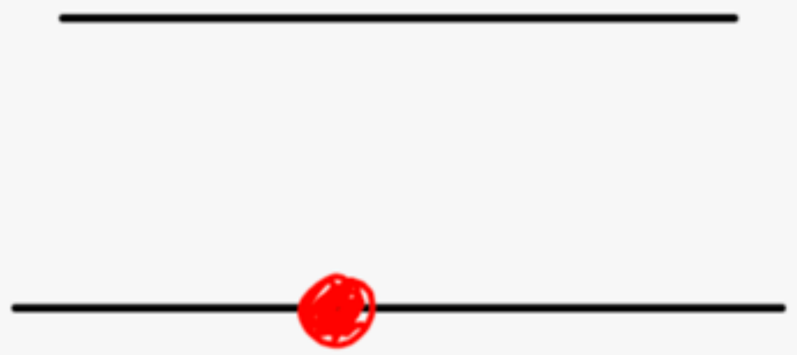


colour centres in diamond

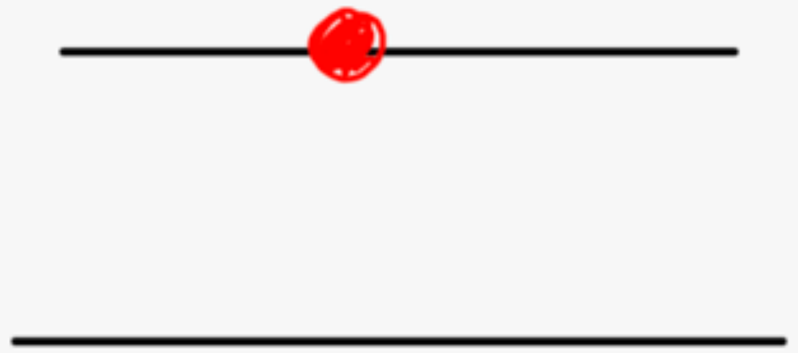


superconducti
ng circuits

PHOTONICS

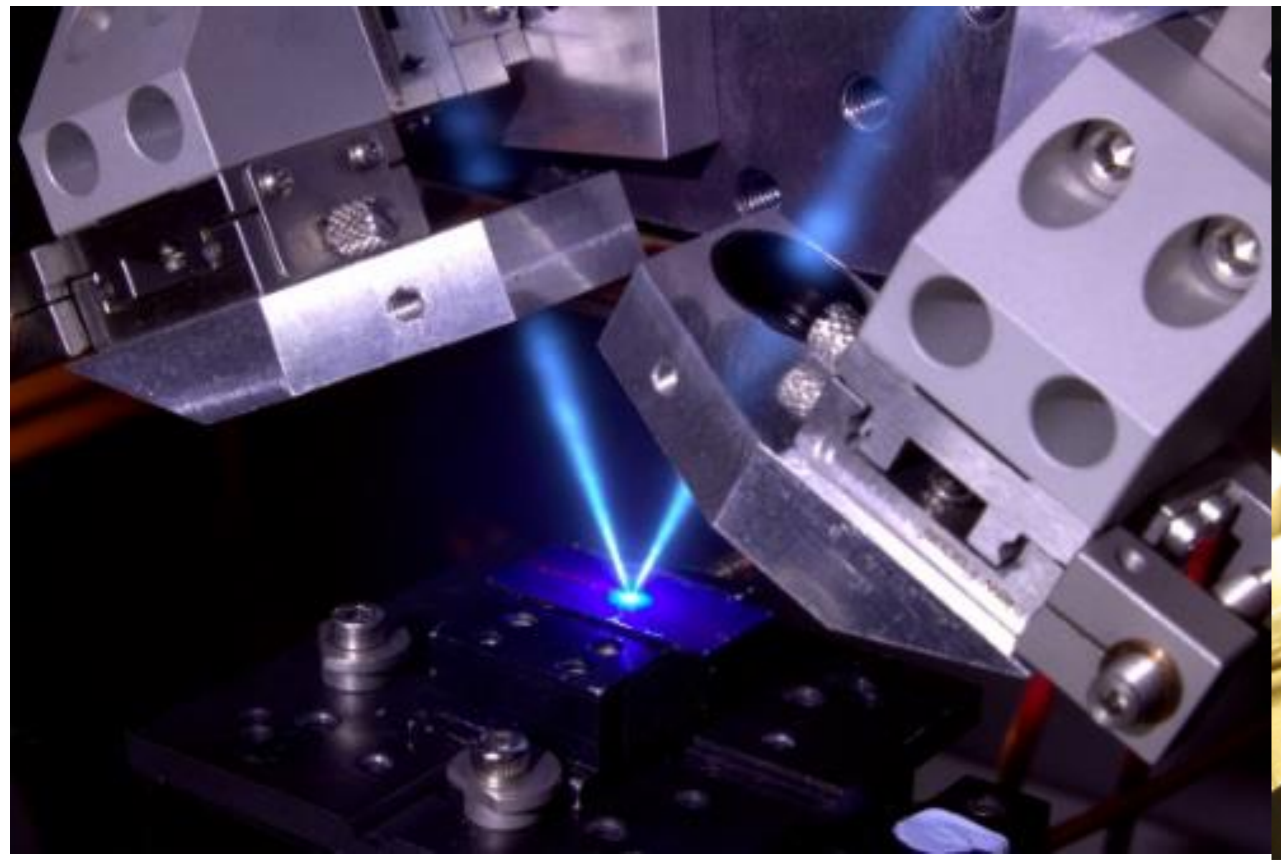


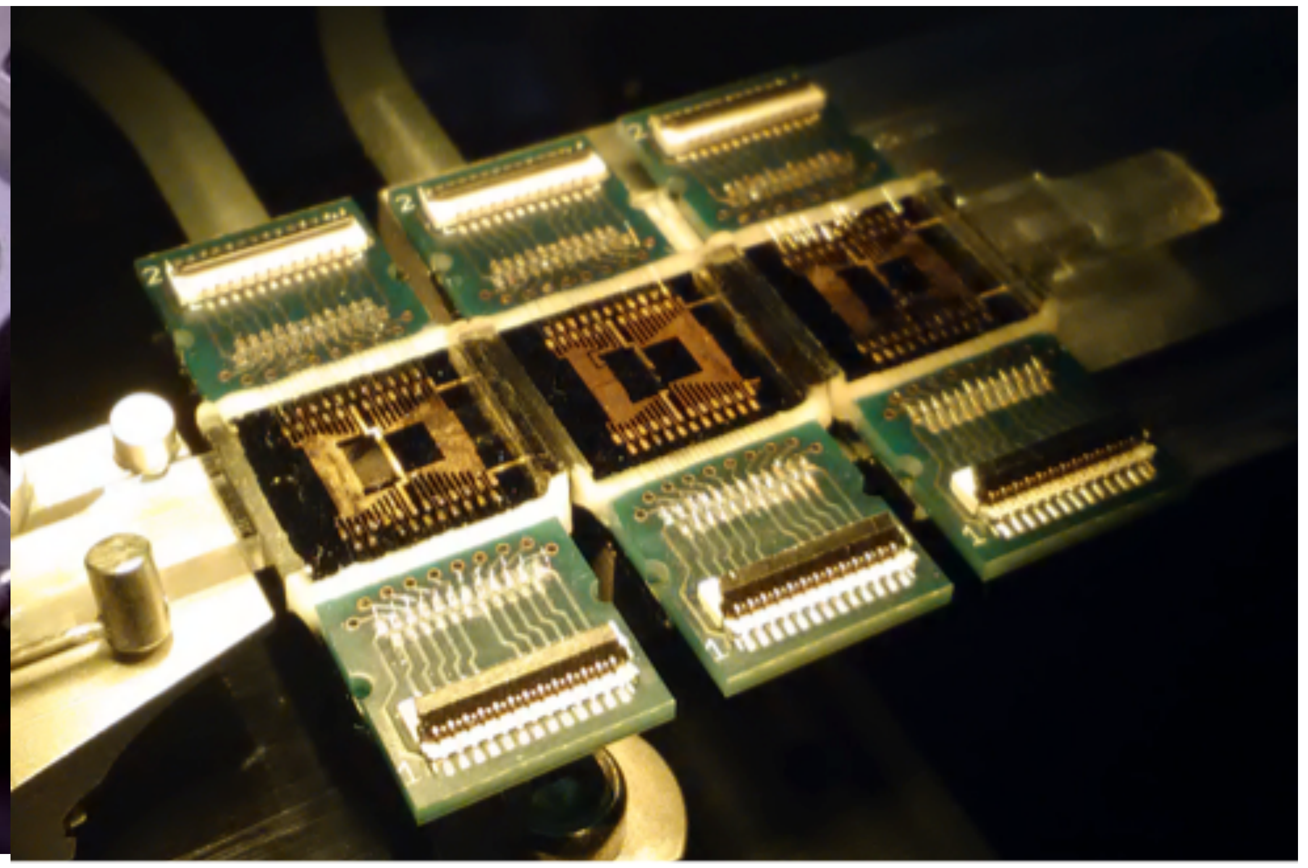
$$= |0,1\rangle = |\downarrow\rangle$$

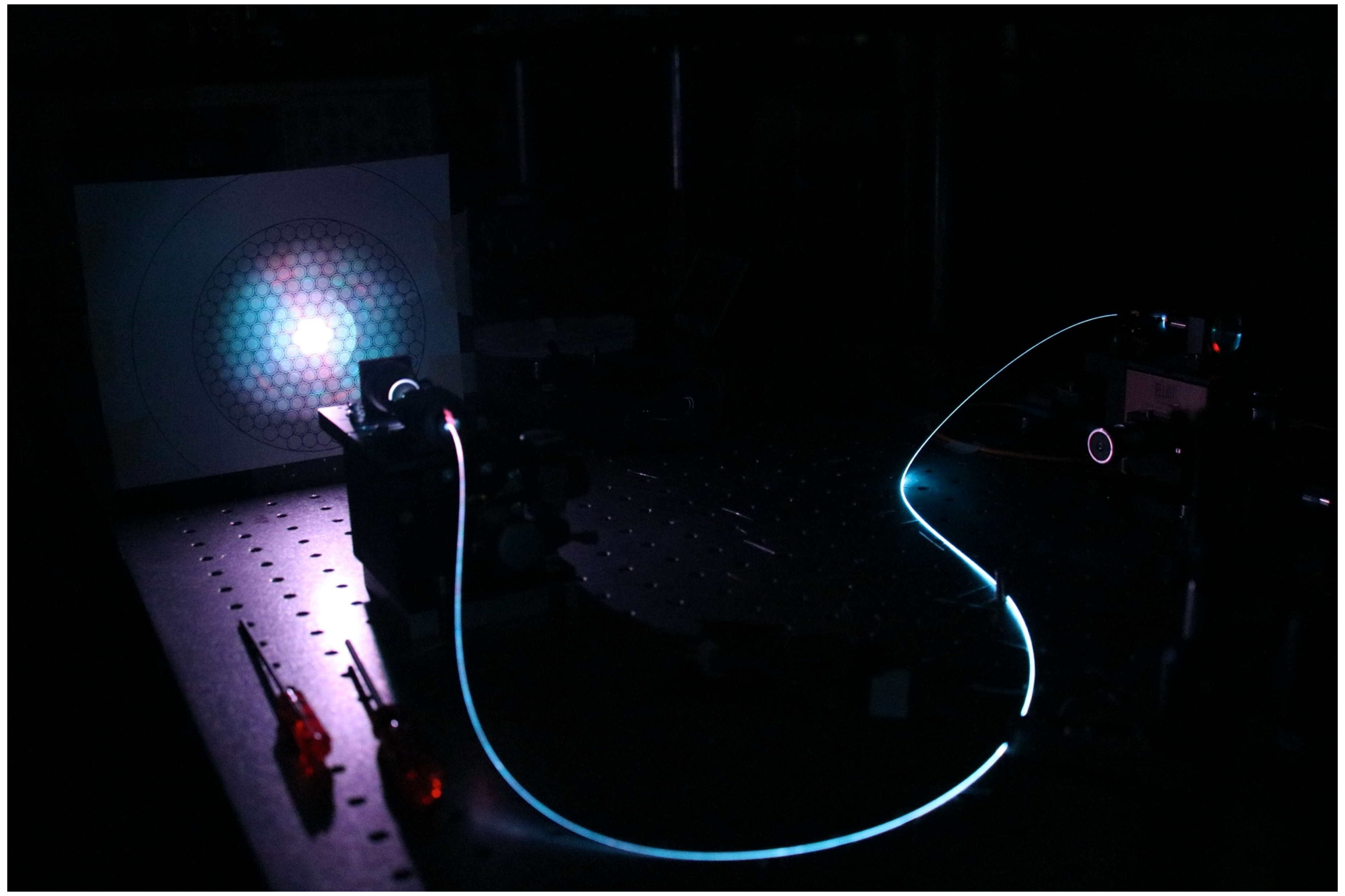


$$= |1,0\rangle = |\uparrow\rangle$$

Photonic qubit

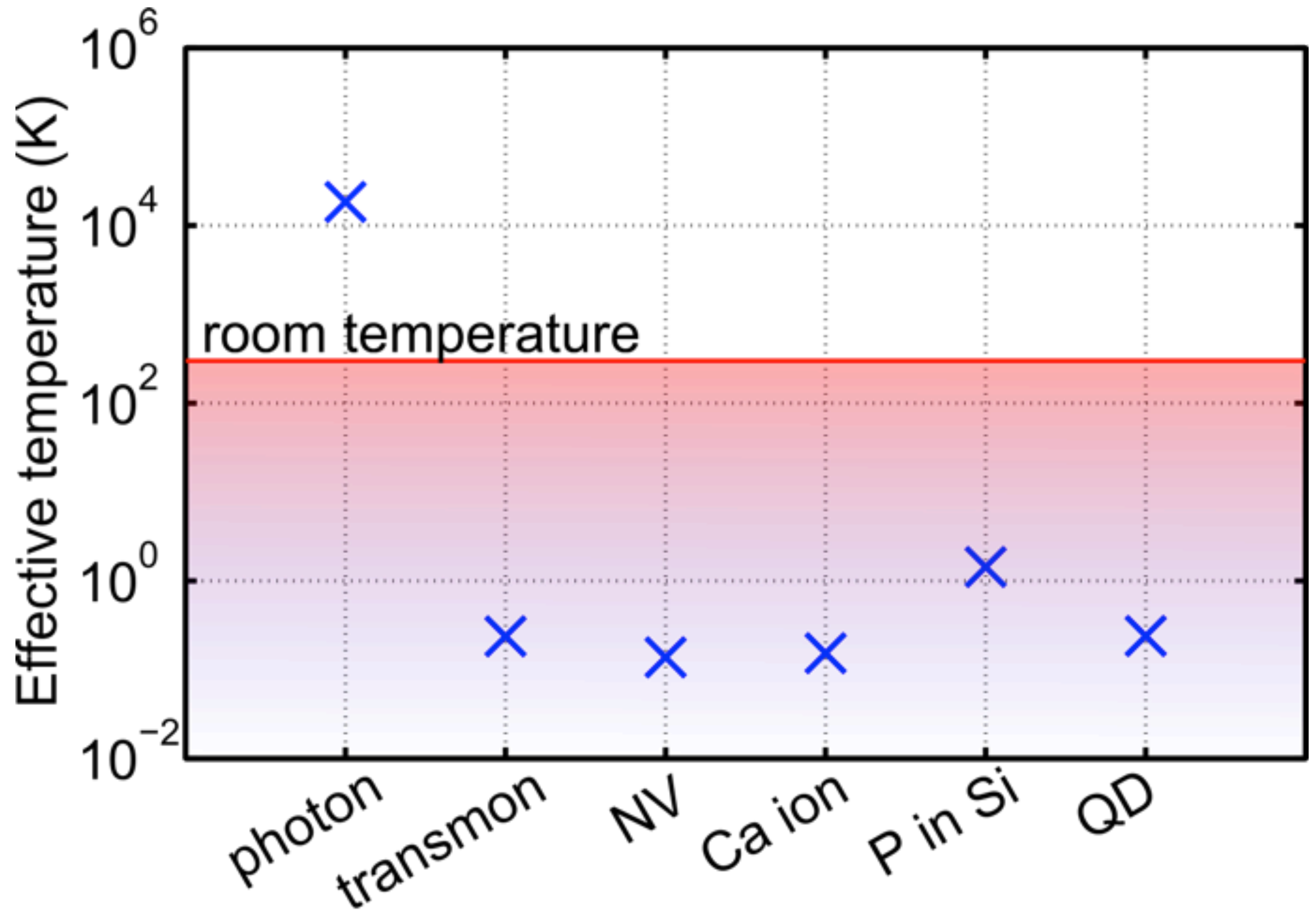






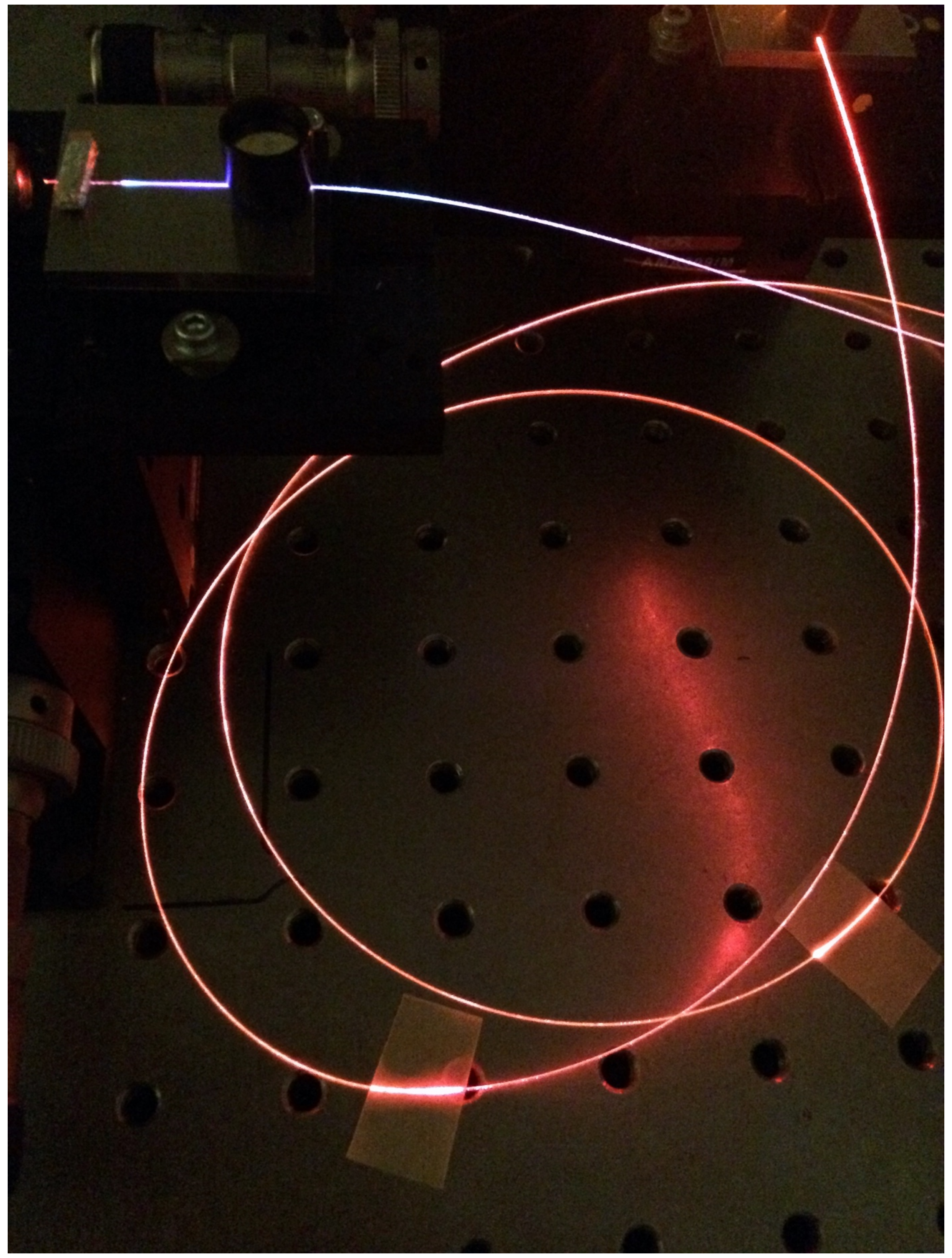
WHY PHOTONICS?

Optical carrier frequency ~100 THz means



- **No cryogenics or vacuum systems needed**
- **System can support highest possible clock-rates (~100 GHz)**

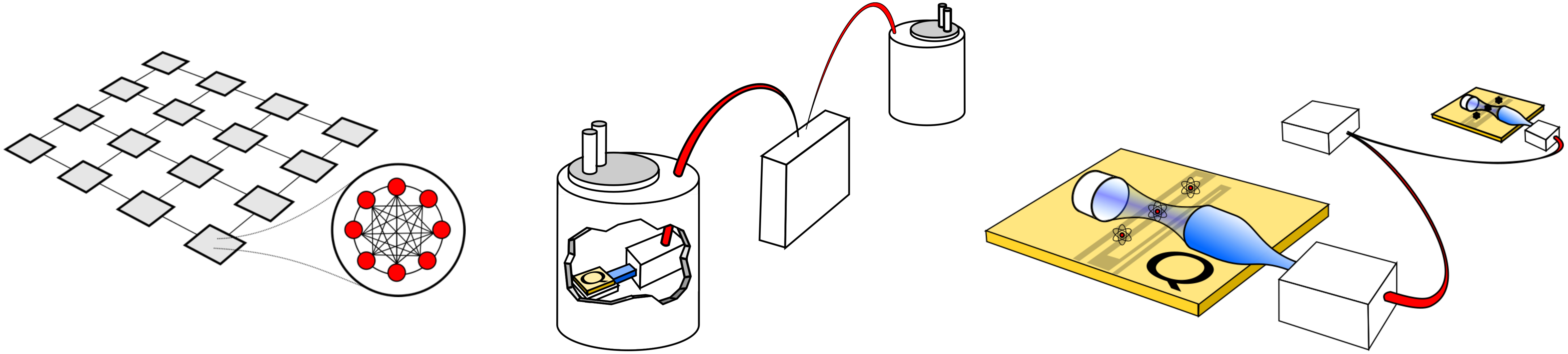
WHY PHOTONICS?



Optical fibre = quantum wiring

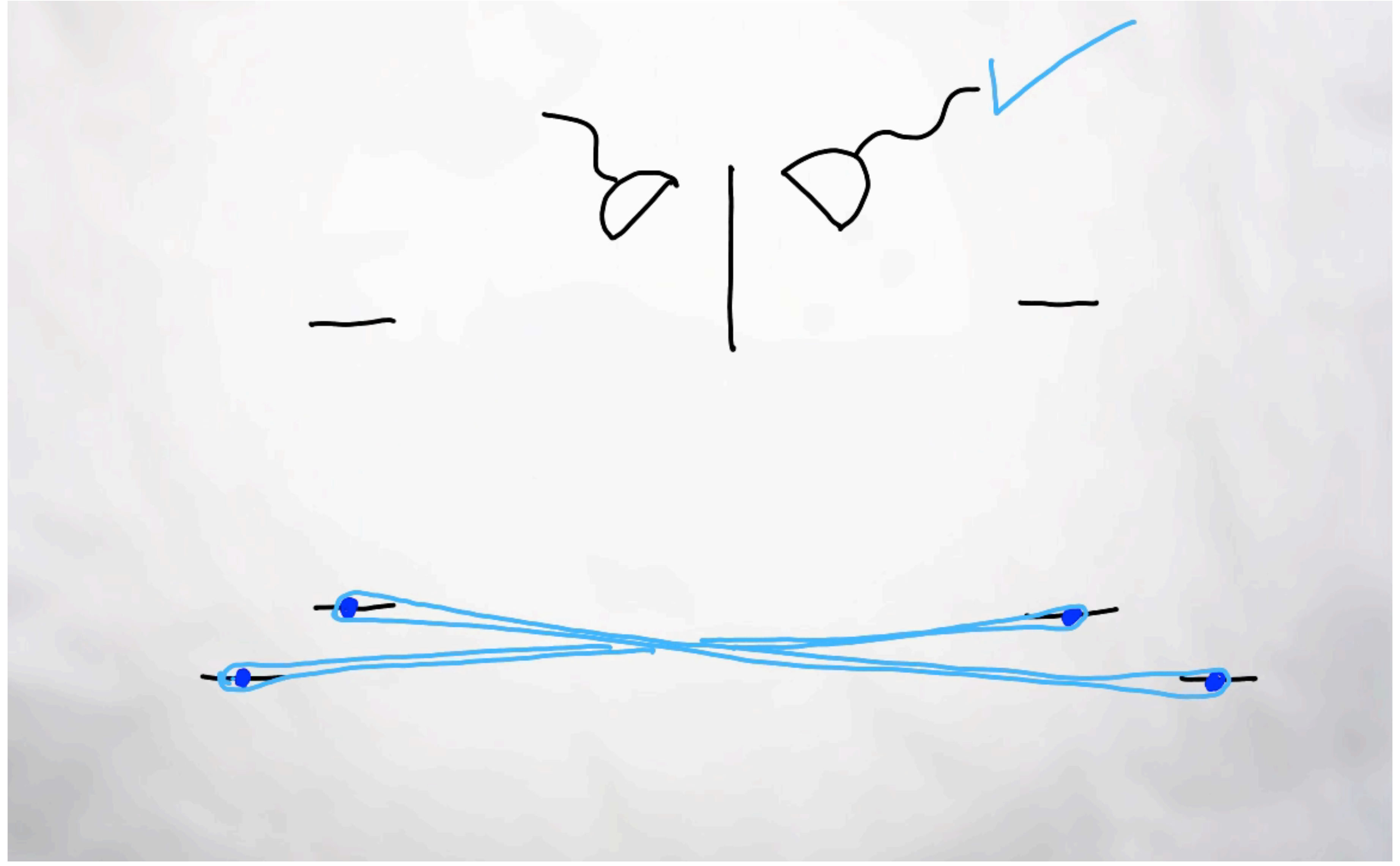
- **Allows arbitrary connectivity**

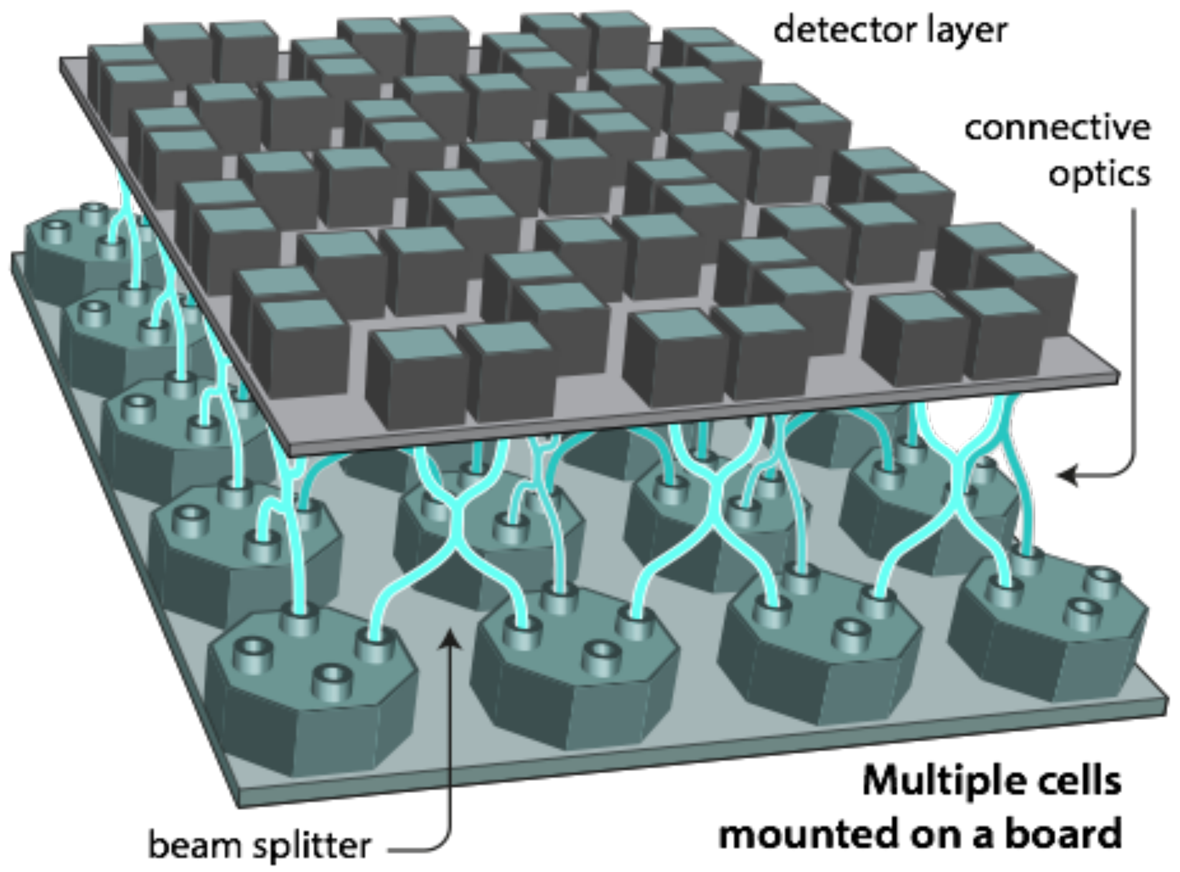
NETWORKED Q. COMPUTING



- **Photonics needed for modularity and extensibility**

NETWORKED Q. COMPUTING



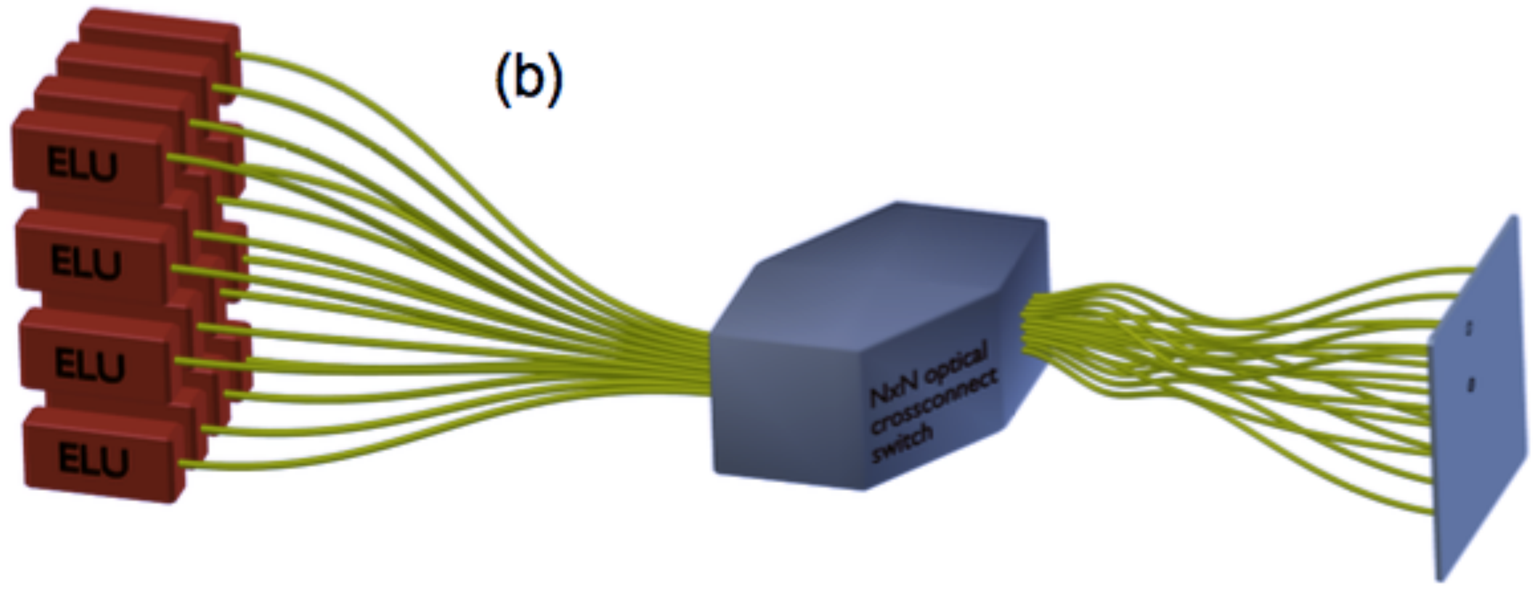


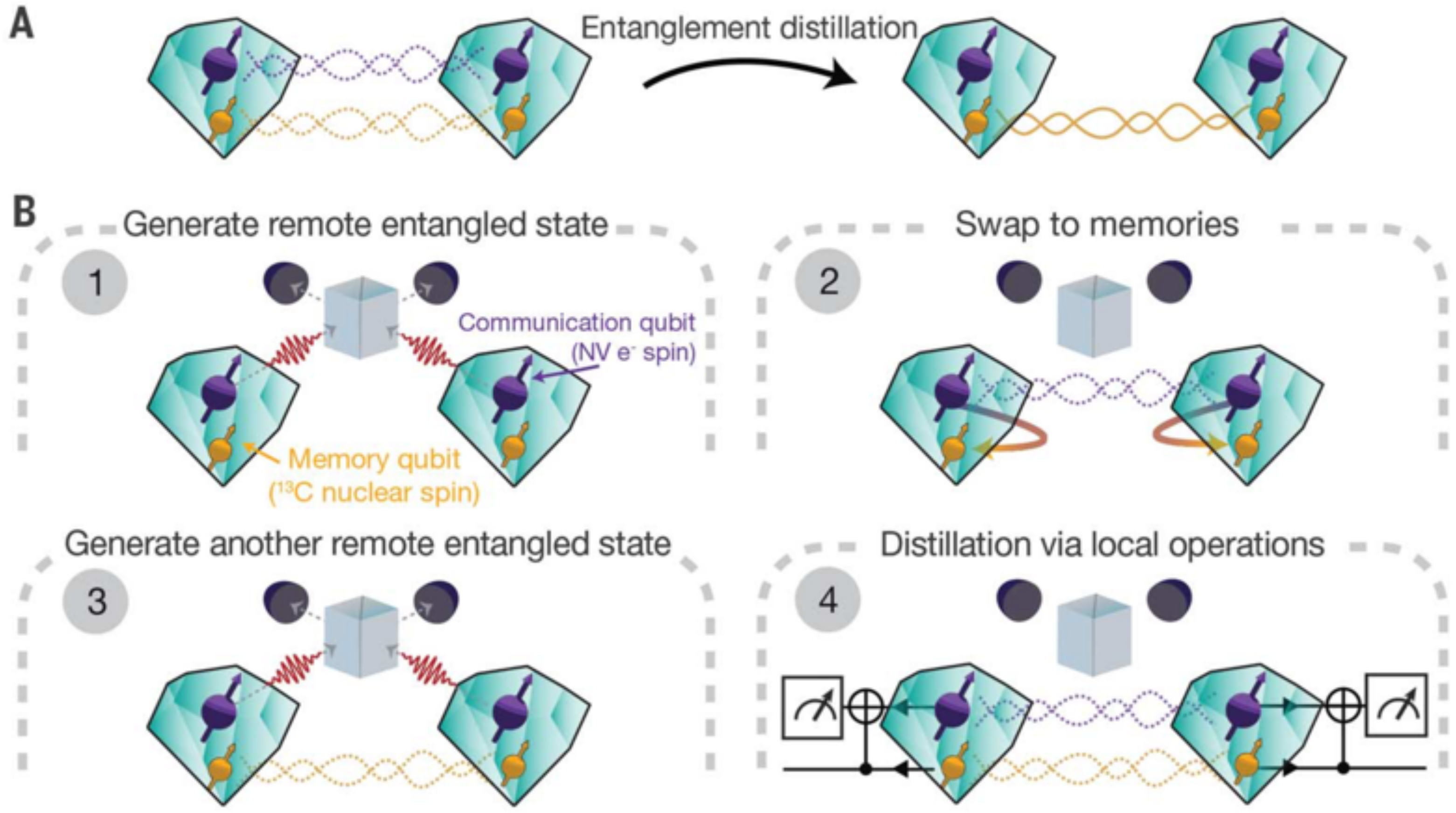
NQIT

PHYSICAL REVIEW A **89**, 022317 (2014)

Large-scale modular quantum-computer architecture with atomic memory and photonic interconnects

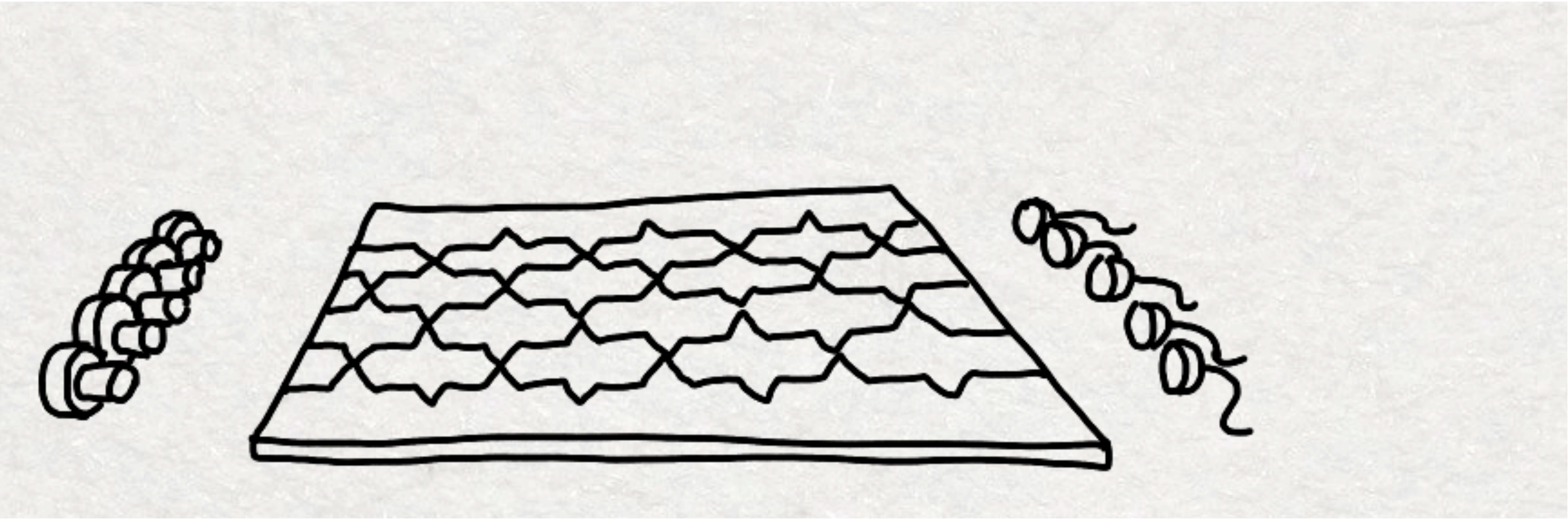
C. Monroe,[1] R. Raussendorf,[2] A. Ruthven,[2] K. R. Brown,[3] P. Maunz,[4,*] L.-M. Duan,[5] and J. Kim[4]





QUTech

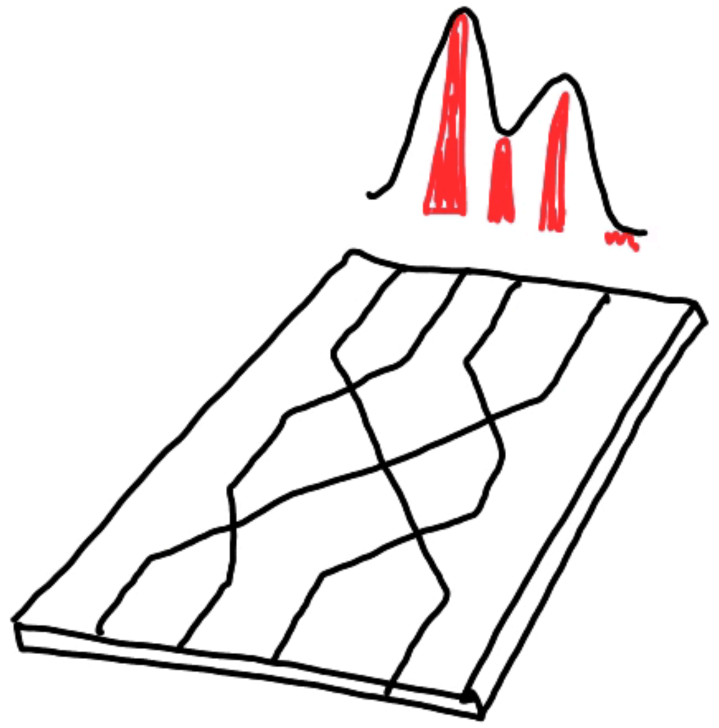
NISQ PHOTONICS



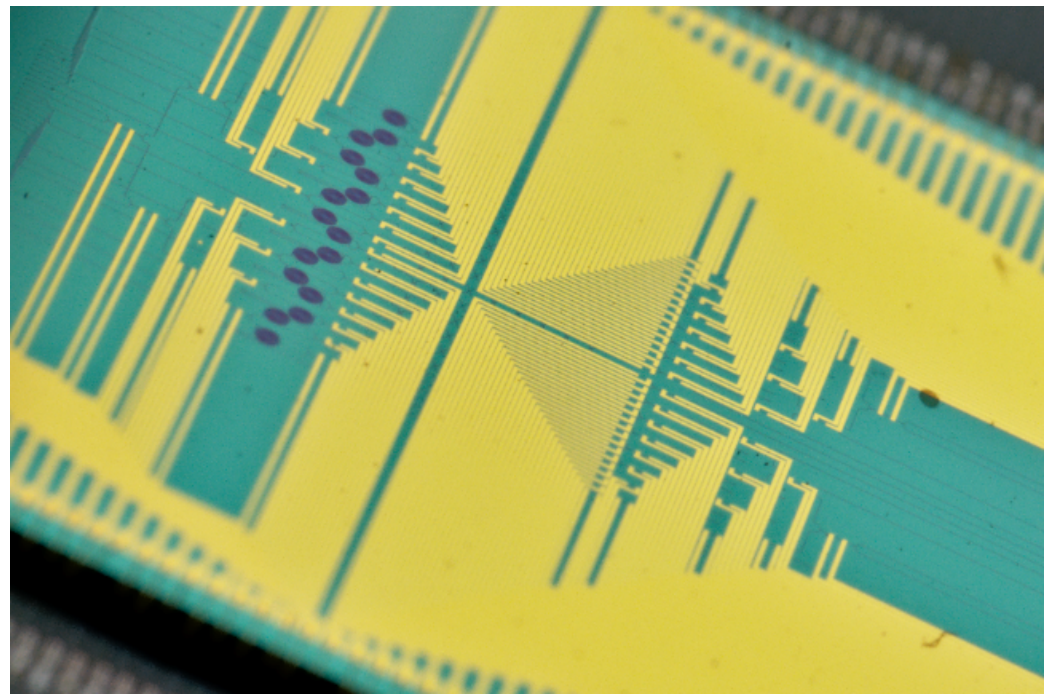
- **Boson sampling: photons statistics computationally hard to predict**

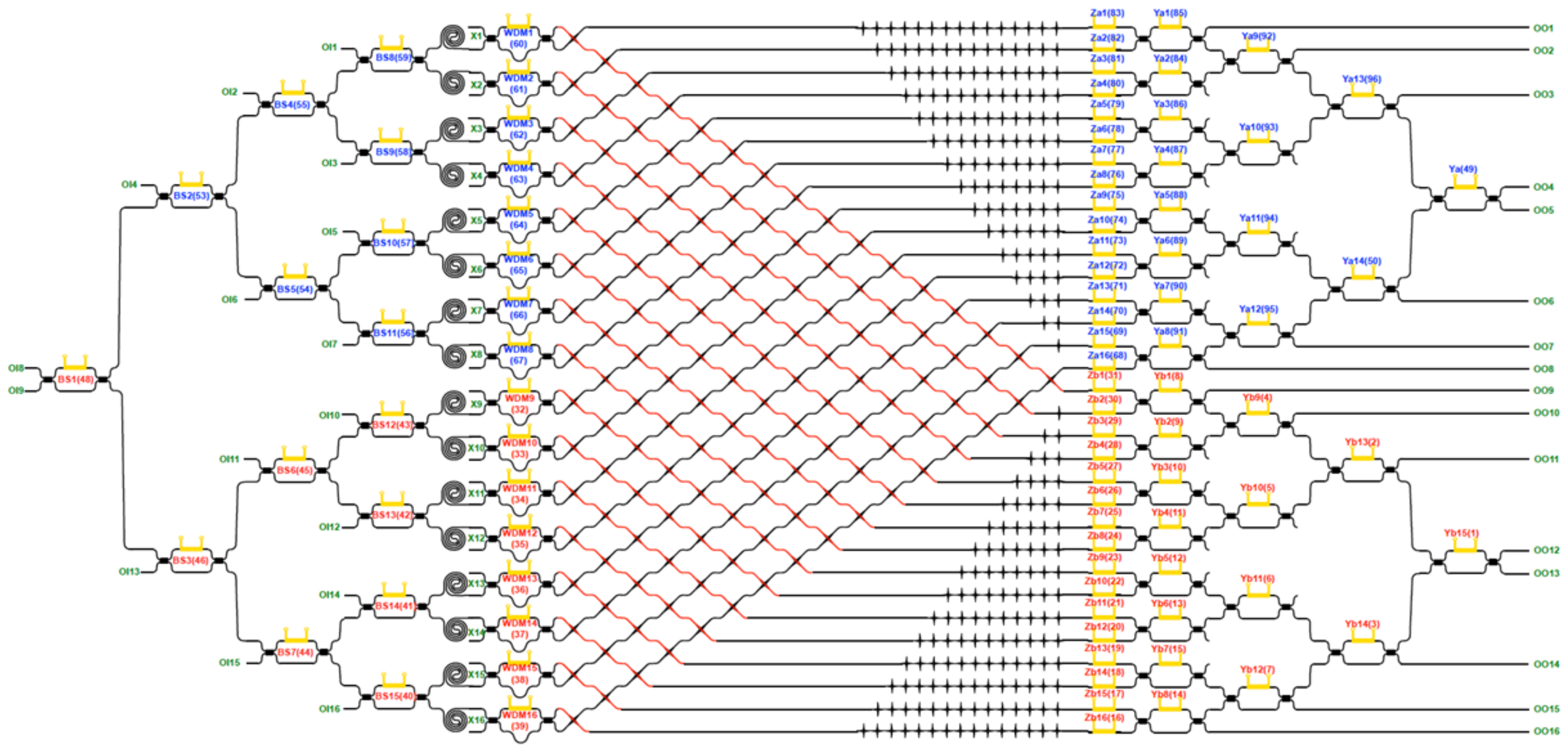
Uses?

➡ **Analog quantum simulators**



NISQ PHOTONICS





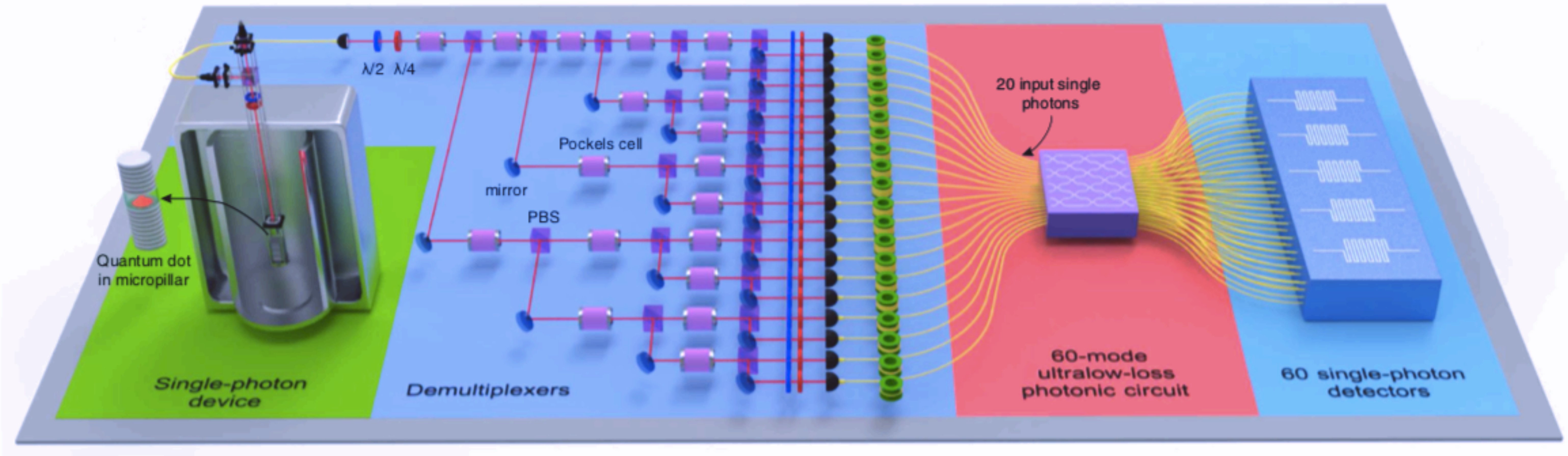
DUALITY QUANTUM PHOTONICS

Multidimensional quantum entanglement with large-scale integrated optics

Jianwei Wang,[1,2*†] Stefano Paesani,[1*] Yunhong Ding,[3,4*†] Raffaele Santagati,[1] Paul Skrzypczyk,[5] Alexia Salavrakos,[6] Jordi Tura,[7] Remigiusz Augusiak,[8] Laura Mančinska,[9] Davide Bacco,[3,4] Damien Bonneau,[1] Joshua W. Silverstone,[1] Qihuang Gong,[2] Antonio Acín,[6,10] Karsten Rottwitt,[3,4] Leif K. Oxenløwe,[3,4] Jeremy L. O'Brien,[1] Anthony Laing,[1†] Mark G. Thompson[1†]

Boson Sampling with 20 Input Photons and a 60-Mode Interferometer in a 10^{14}-Dimensional Hilbert Space

Hui Wang,[1,2] Jian Qin,[1,2] Xing Ding,[1,2] Ming-Cheng Chen,[1,2] Si Chen,[1,2] Xiang You,[1,2] Yu-Ming He,[1,2] Xiao Jiang,[1,2] L. You,[3] Z. Wang,[3] C. Schneider,[4] Jelmer J. Renema,[5] Sven Höfling,[4,6,1]



QUANDELA

CONTINUOUS VARIABLES

$$E = E_0 \cos(\omega t + \phi)$$
$$= X \cos(\omega t) + P \sin(\omega t)$$

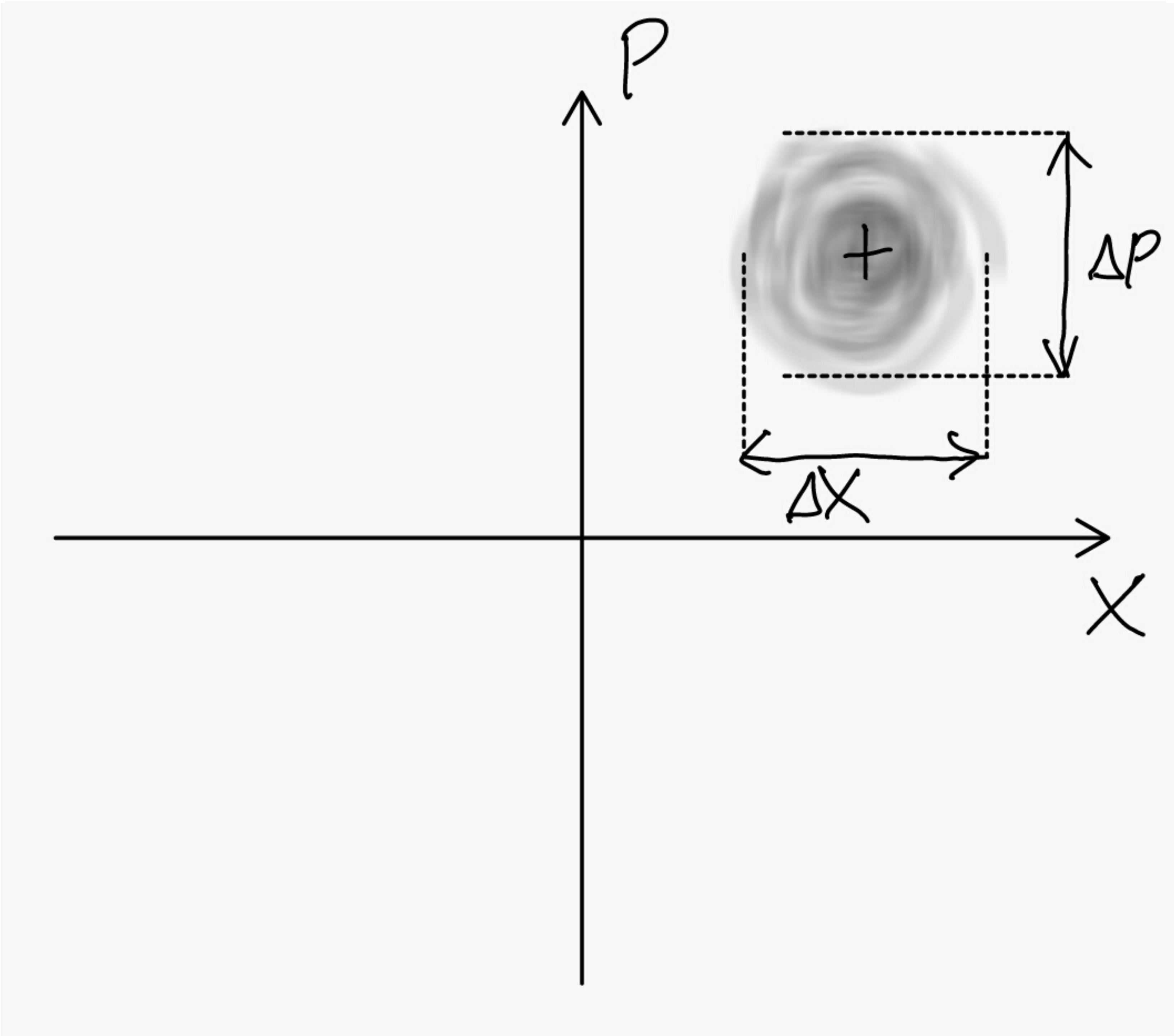
c.f. harmonic oscillator:

$$x = x_0 \cos(\omega t) + \frac{p_0}{m\omega} \sin(\omega t)$$

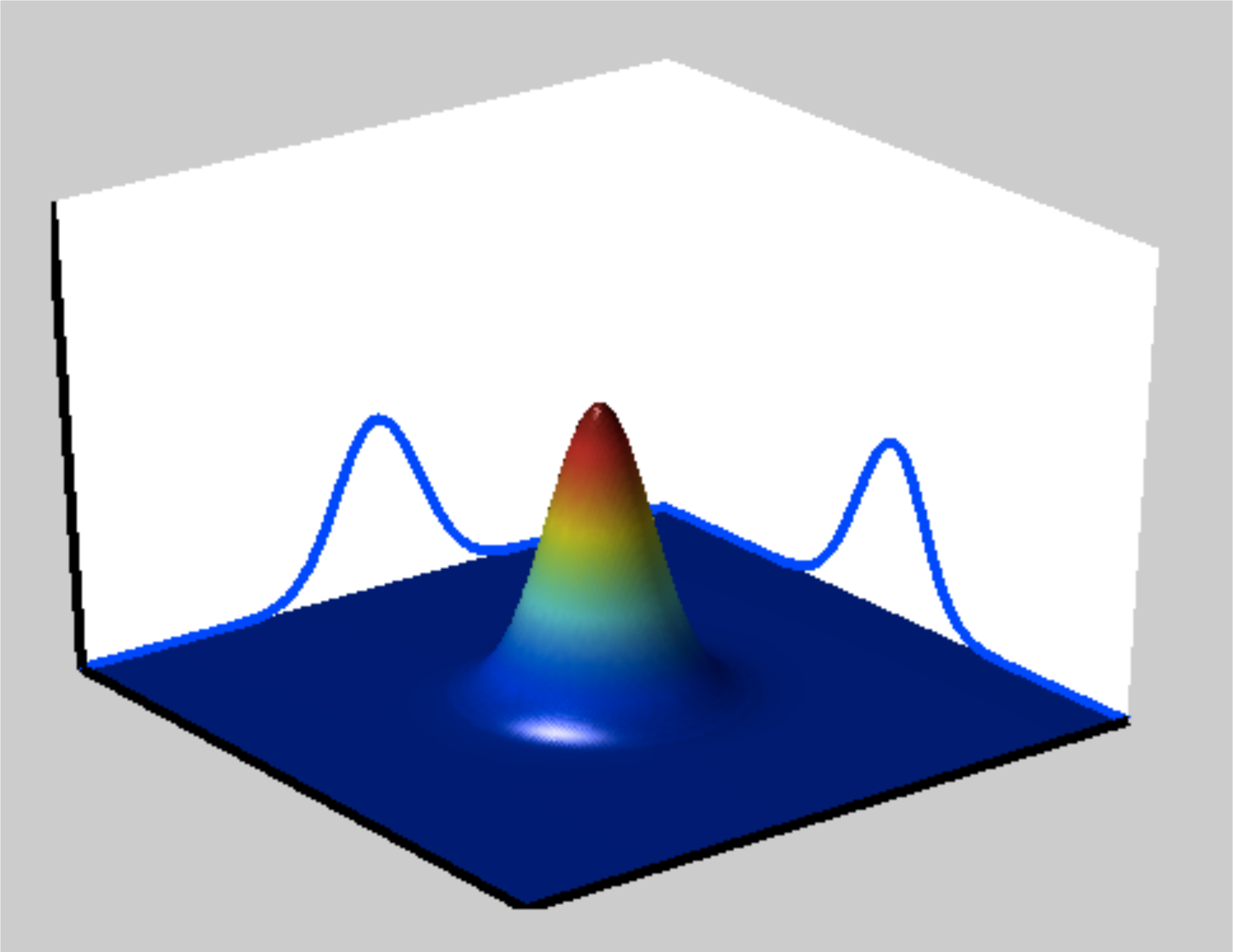
Quantum mechanics: $[x_0, p_0] = i$

Quantum optics: $[X, P] = i$ (ignoring constants like $m, \omega, \hbar$)

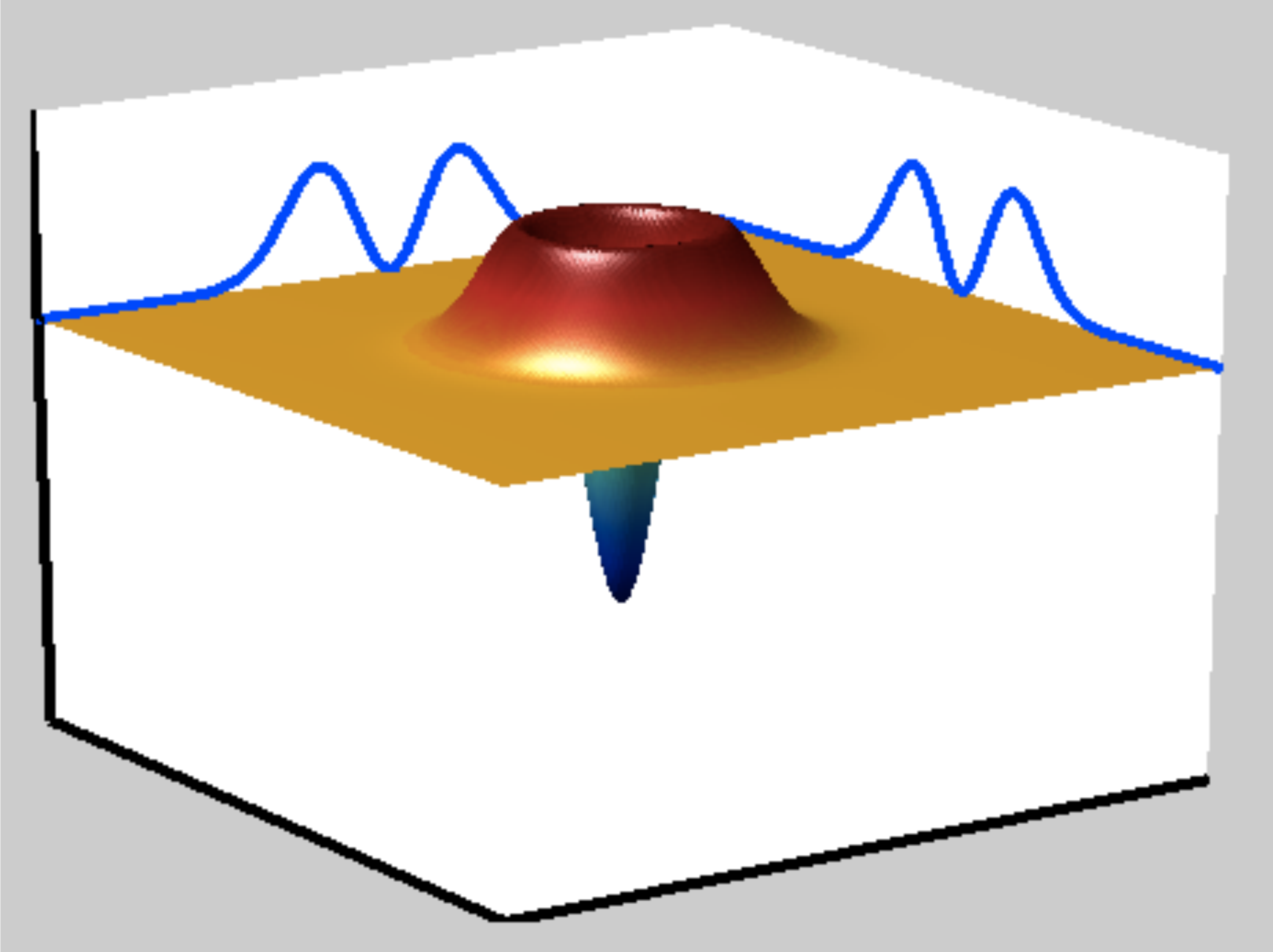
CONTINUOUS VARIABLES



- Uncertainty principle



- Gaussian (quite easy!)



- Non-Gaussian (hard)

Gaussian Boson Sampling

Craig S. Hamilton,[1,*] Regina Kruse,[2] Linda Sansoni,[2] Sonja Barkhofen,[2] Christine Silberhorn,[2] and Igor Jex[1]

Boson Sampling from a Gaussian State

A. P. Lund,[1] A. Laing,[2] S. Rahimi-Keshari,[1] T. Rudolph,[3] J. L. O'Brien,[2] and T. C. Ralph[1]

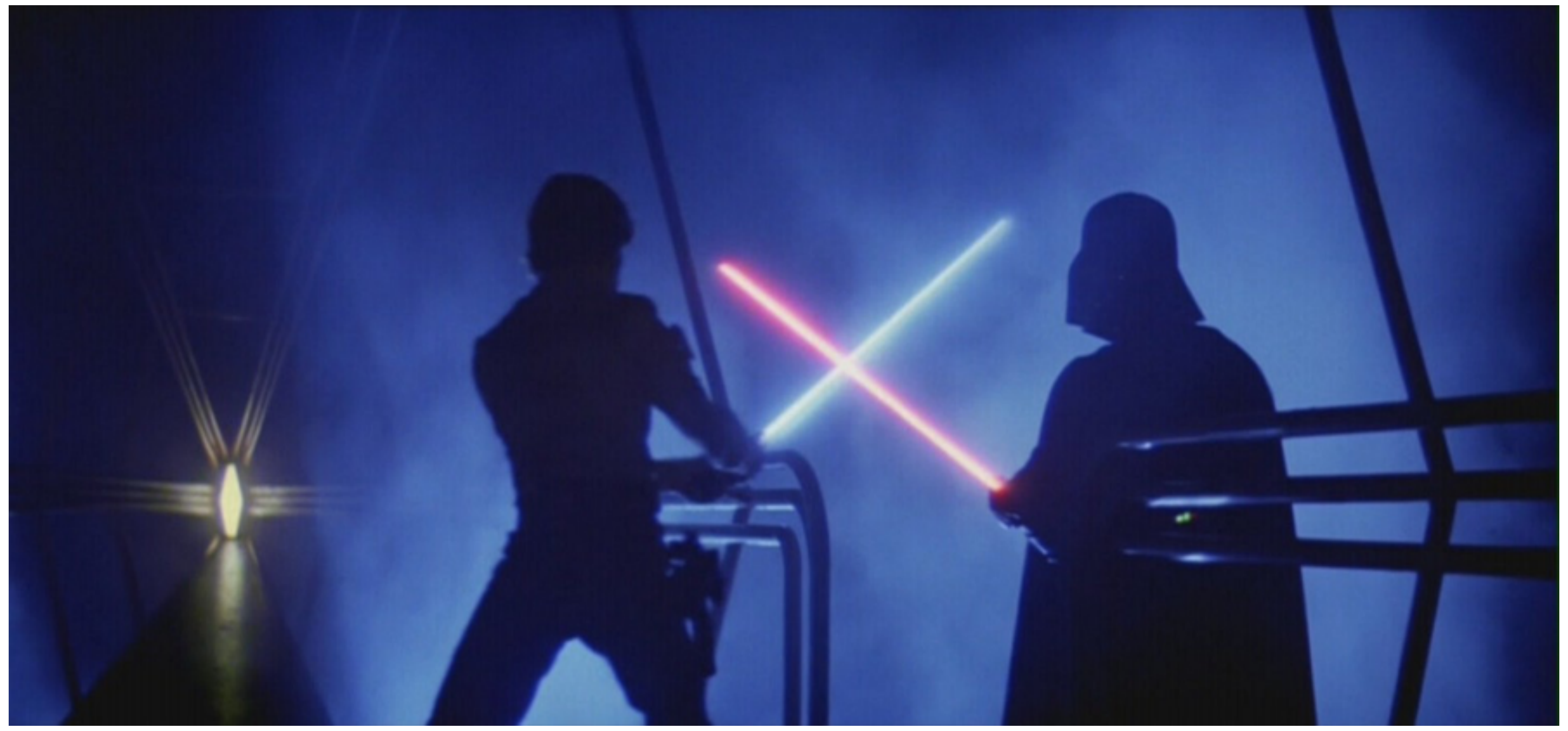
Using Gaussian Boson Sampling to Find Dense Subgraphs

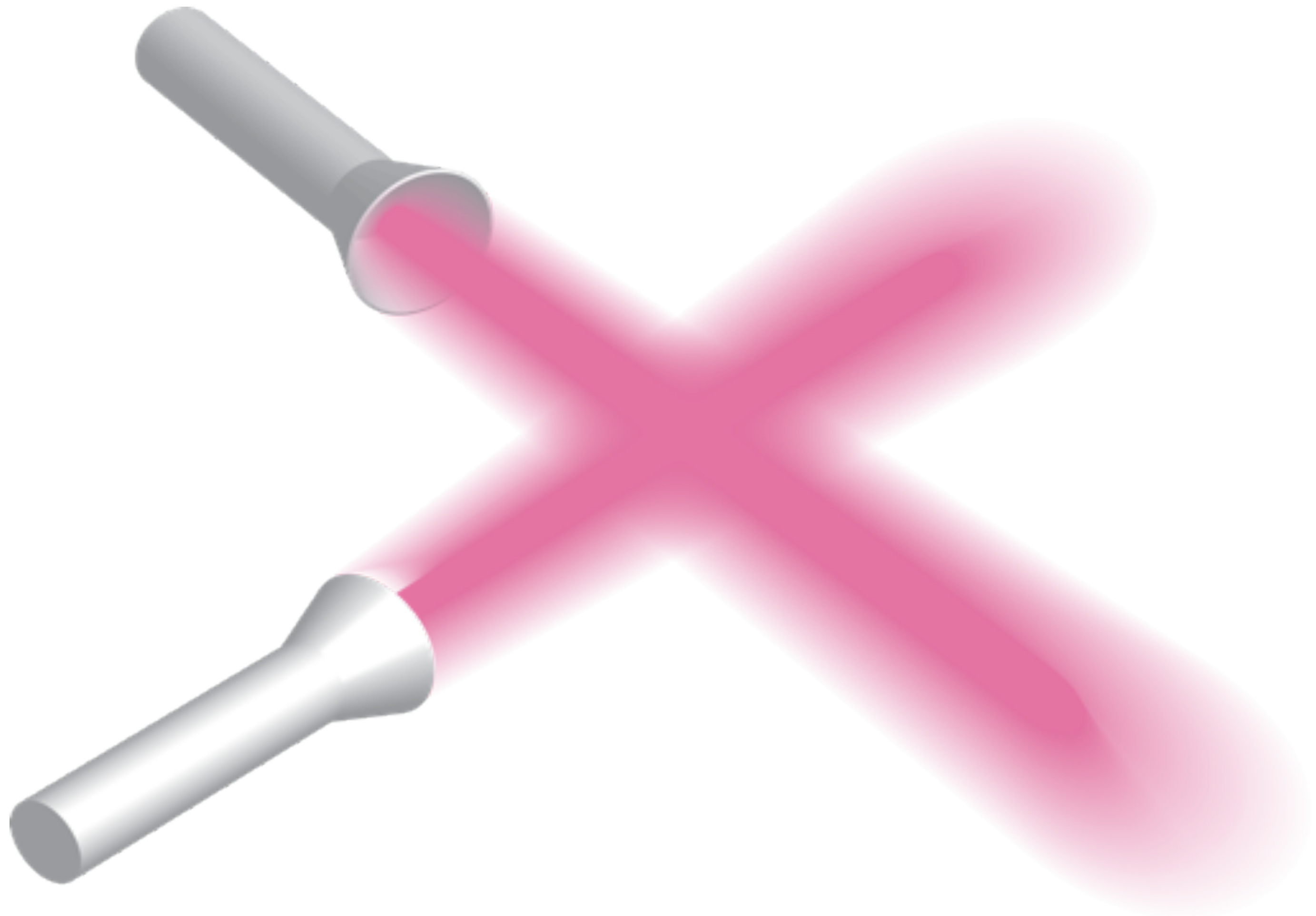
Juan Miguel Arrazola[*] and Thomas R. Bromley[†]
Xanadu, 372 Richmond Street W, Toronto, Ontario M5V 1X6, Canada

The Challenge

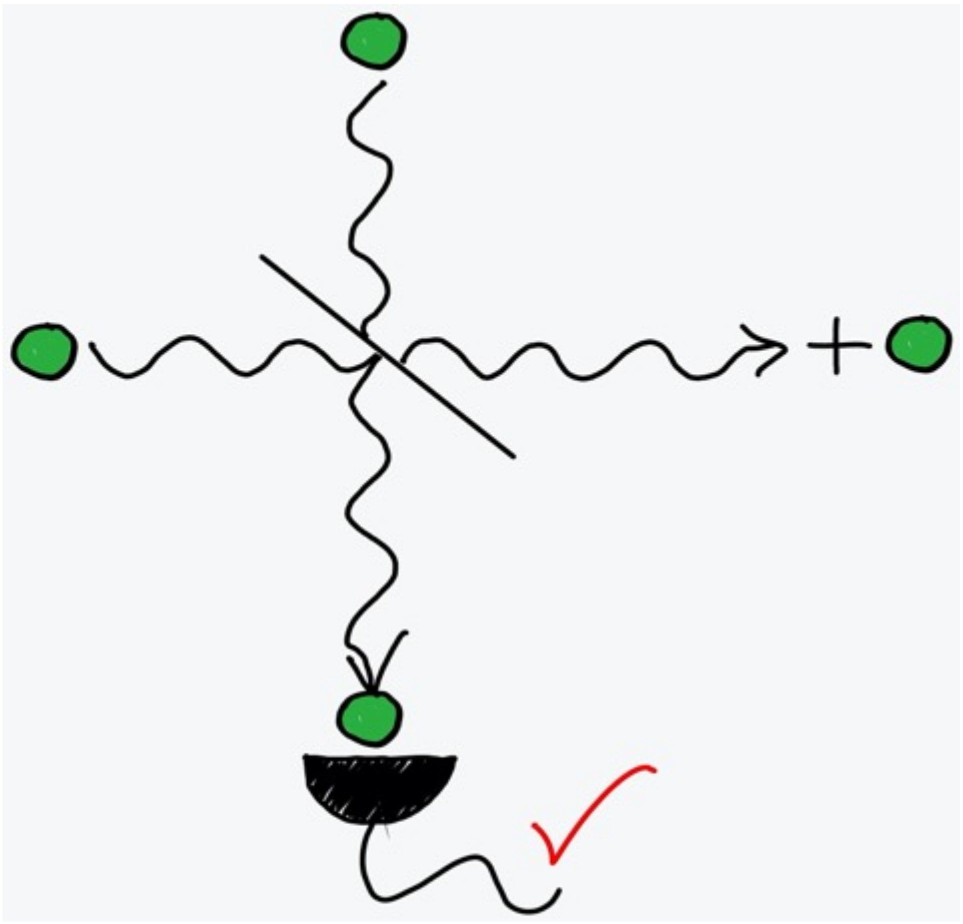
LOGIC GATES?

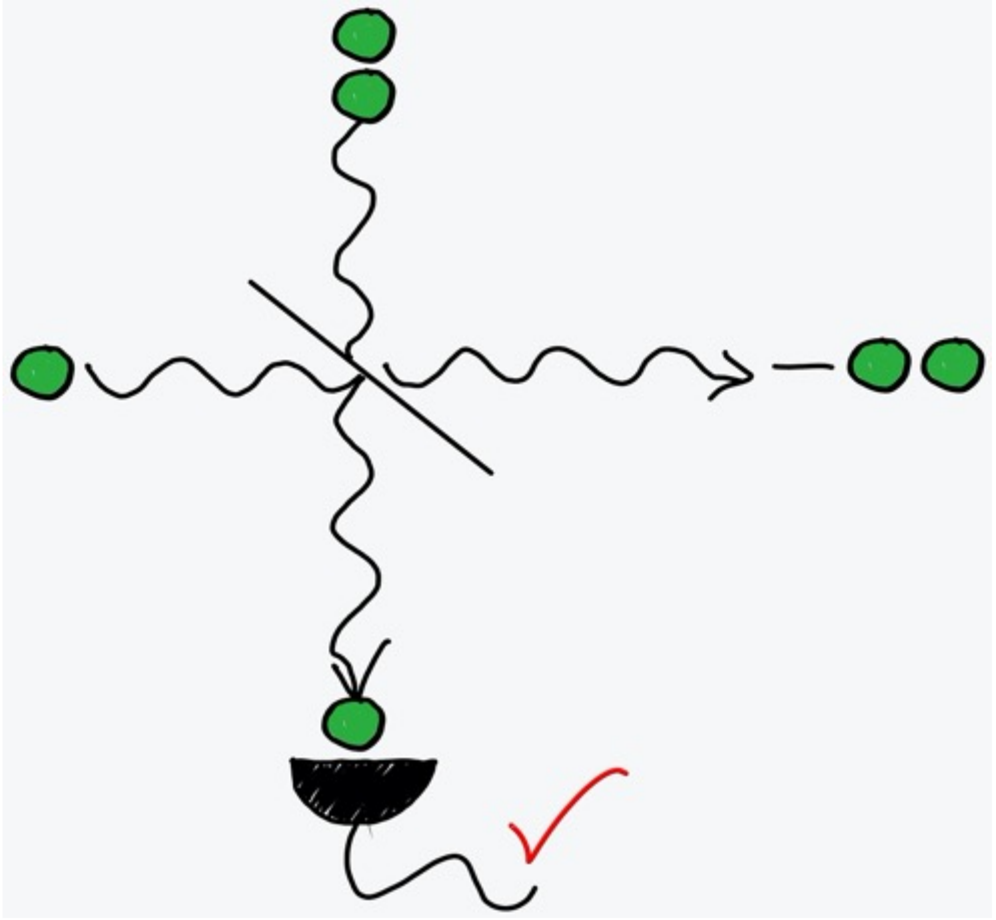
Photons don’t interact with eachother!





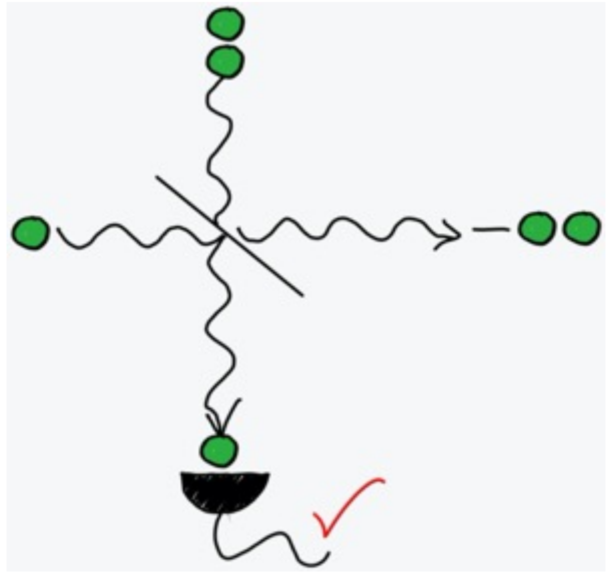
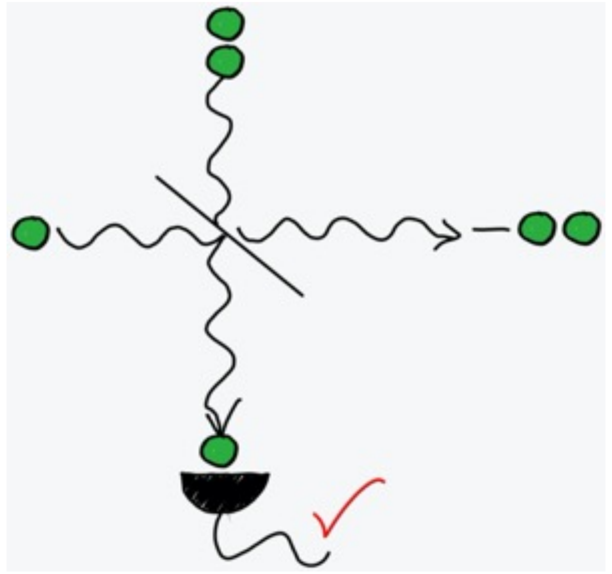
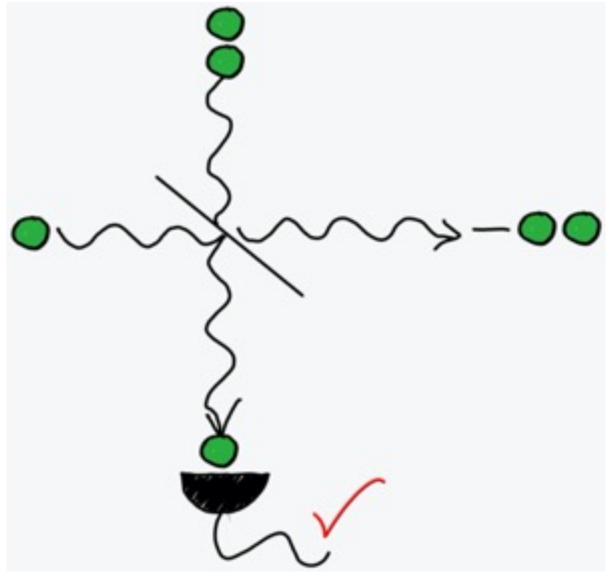
Logic via interference & measurement





LOGIC GATES?

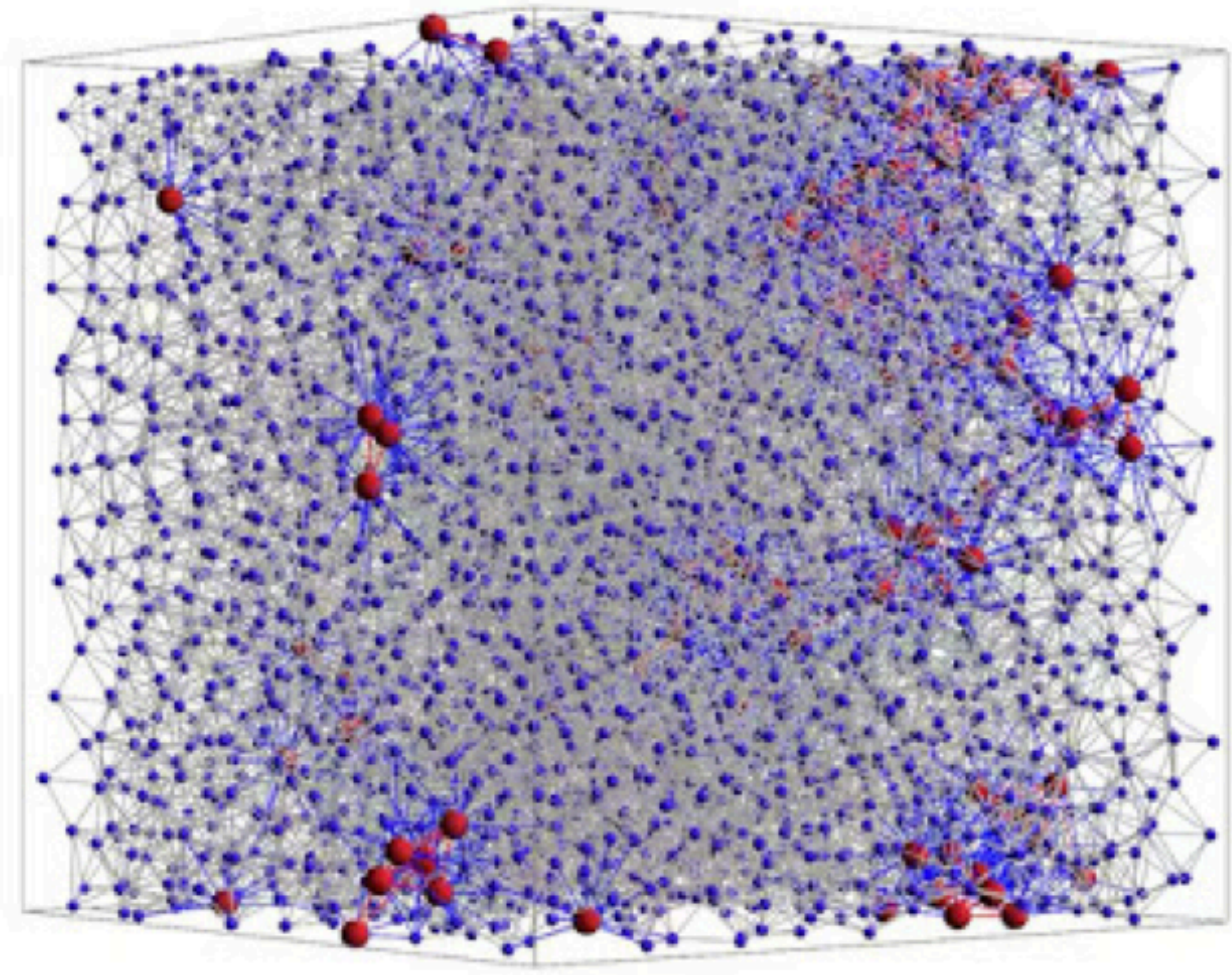
- **Why can't I buy an optical quantum computer yet?**
- **Probabilistic measurements = scaling catastrophe!**

1 in 1000…

MEASUREMENT-BASED Q. COMPUTING

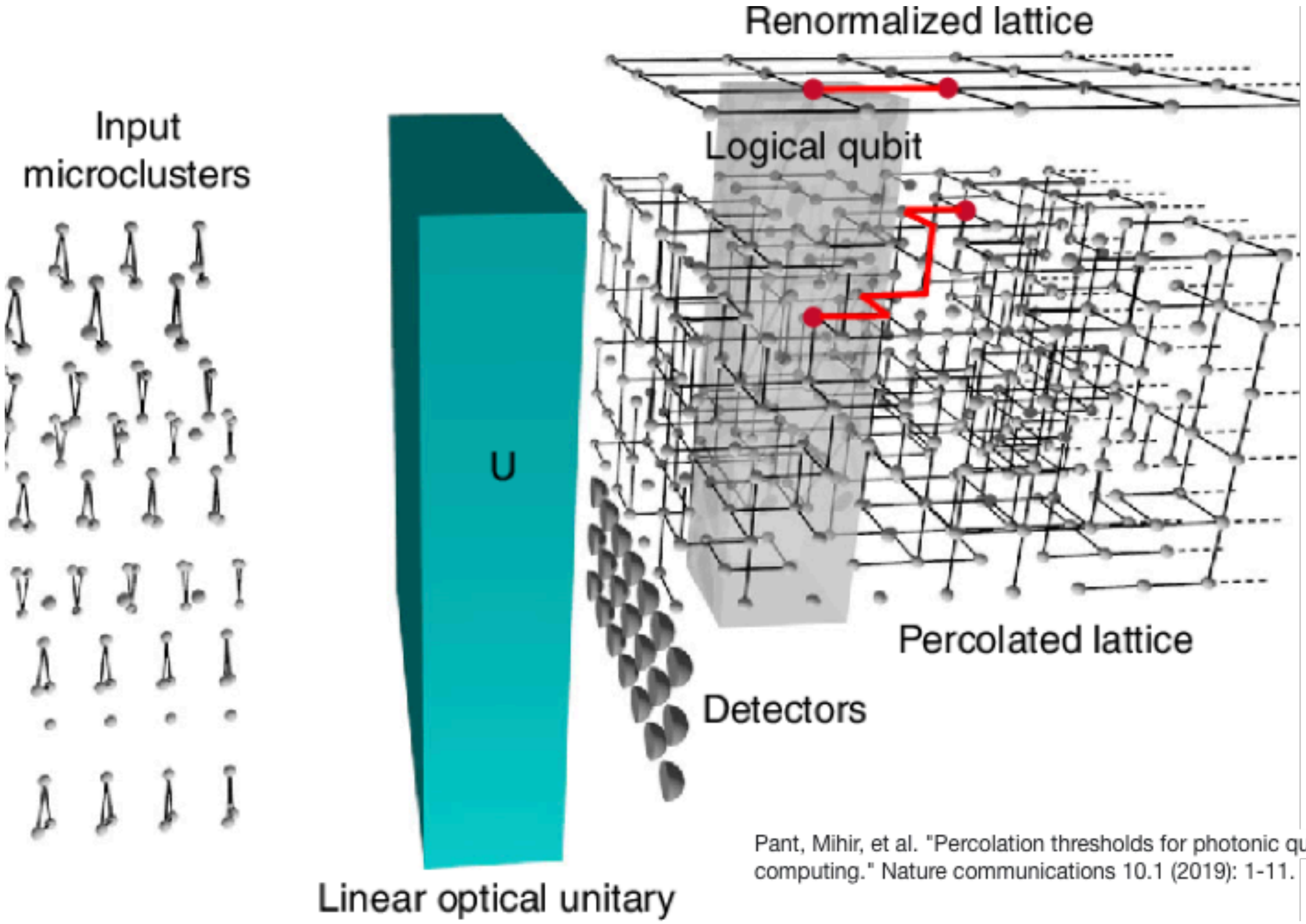
- **Other names: "one-way" or "cluster-state" QC**
- **Build large entangled state first**
- **Gates are performed by making measurements**



[Briegel *et al. Nat Phys.* 5.1 19 (2009)]

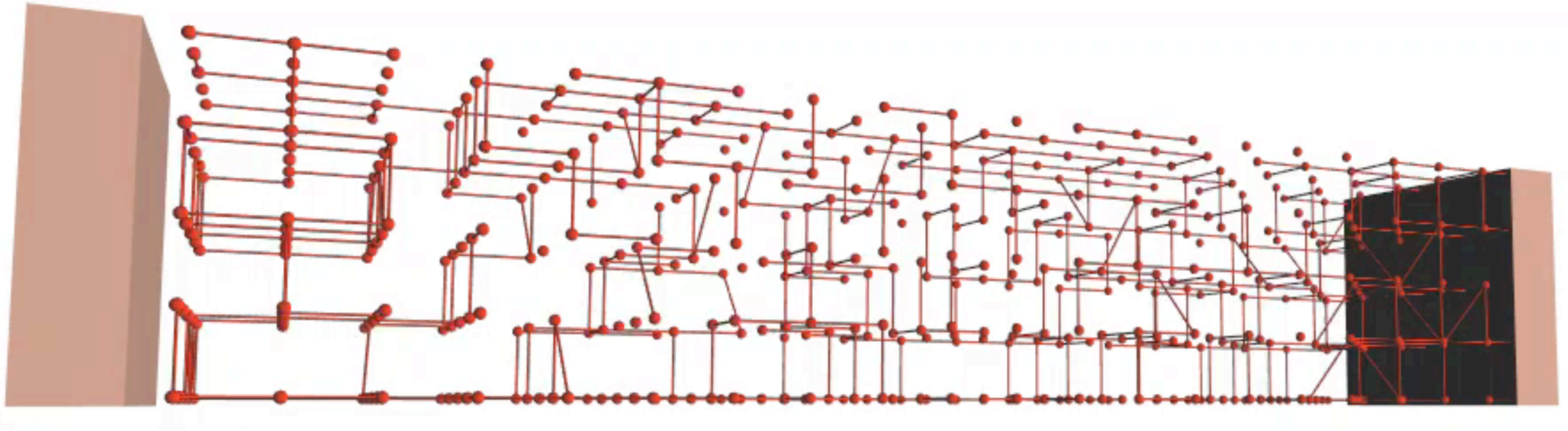
BALLISTIC Q. COMPUTING

- **Problem shifts to preparing entangled microclusters (called GHZ states)**



Pant, Mihir, et al. "Percolation thresholds for photonic quantum computing." Nature communications 10.1 (2019): 1-11.

BALLISTIC Q. COMPUTING



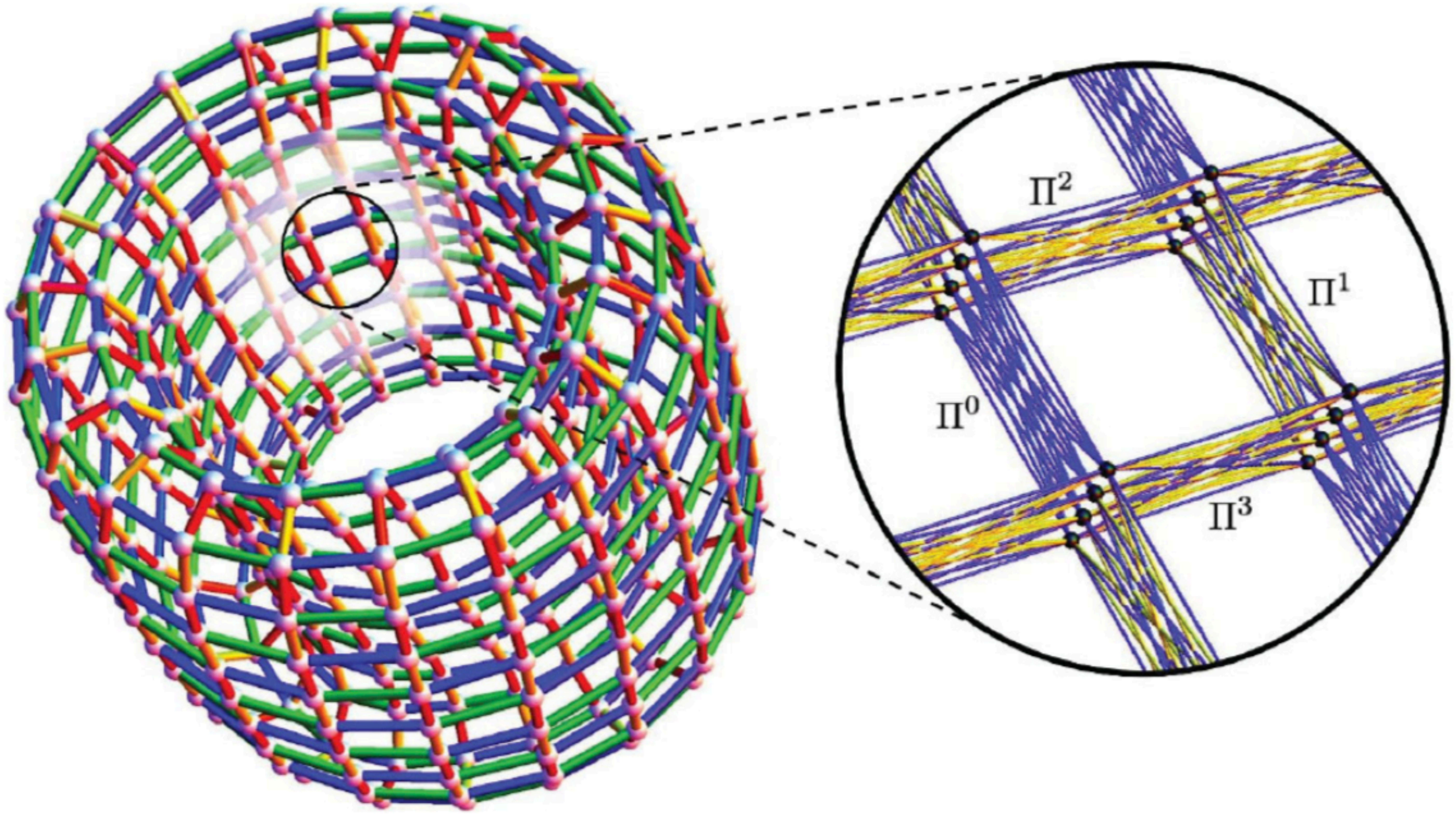
Thanks to Anthony Laing

PsiQ

CONTINUOUS VARIABLE VERSION

One-Way Quantum Computing in the Optical Frequency Comb

Nicolas C. Menicucci,[1,2] Steven T. Flammia,[3] and Olivier Pfister[4]

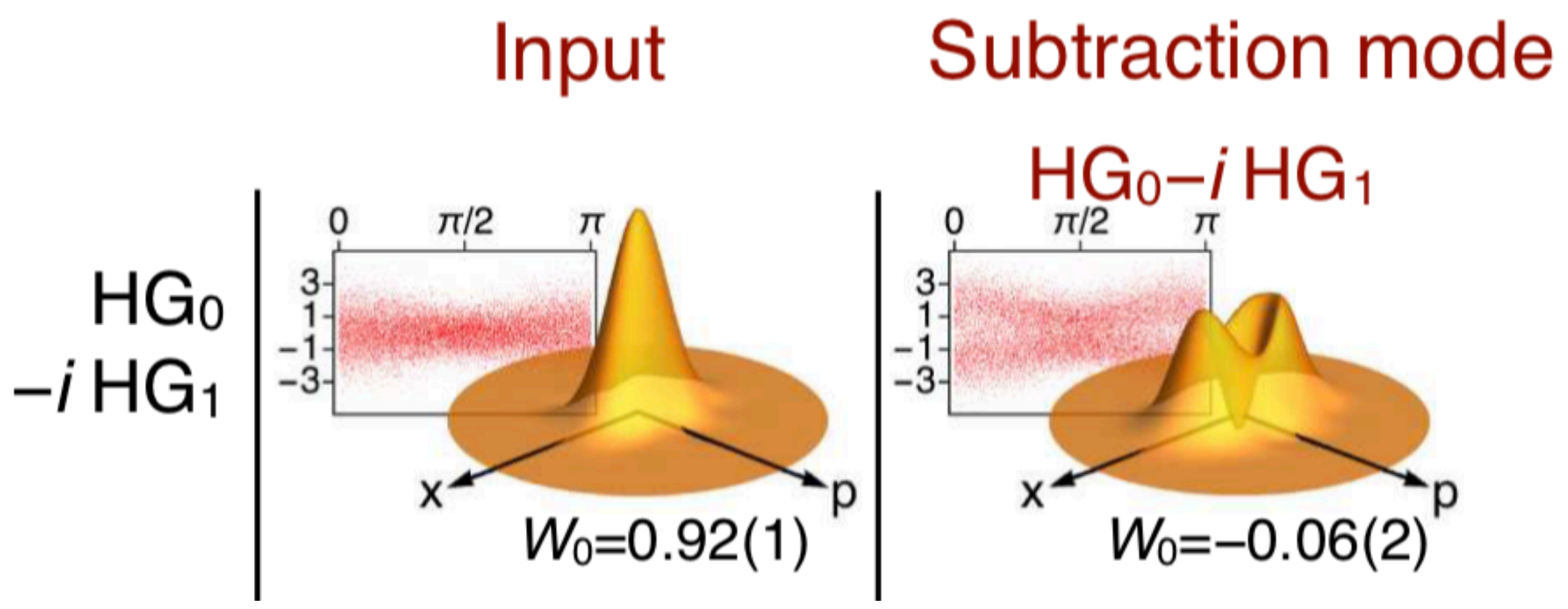


CONTINUOUS VARIABLE VERSION

Non-Gaussian quantum states of a multimode light field

Young-Sik Ra,[1,2,*] Adrien Dufour,[1] Mattia Walschaers,[1]
Clément Jacquard,[1] Thibault Michel,[1,3] Claude Fabre,[1] and Nicolas Treps[1]

- **Problem shifts to preparing non-Gaussian states**

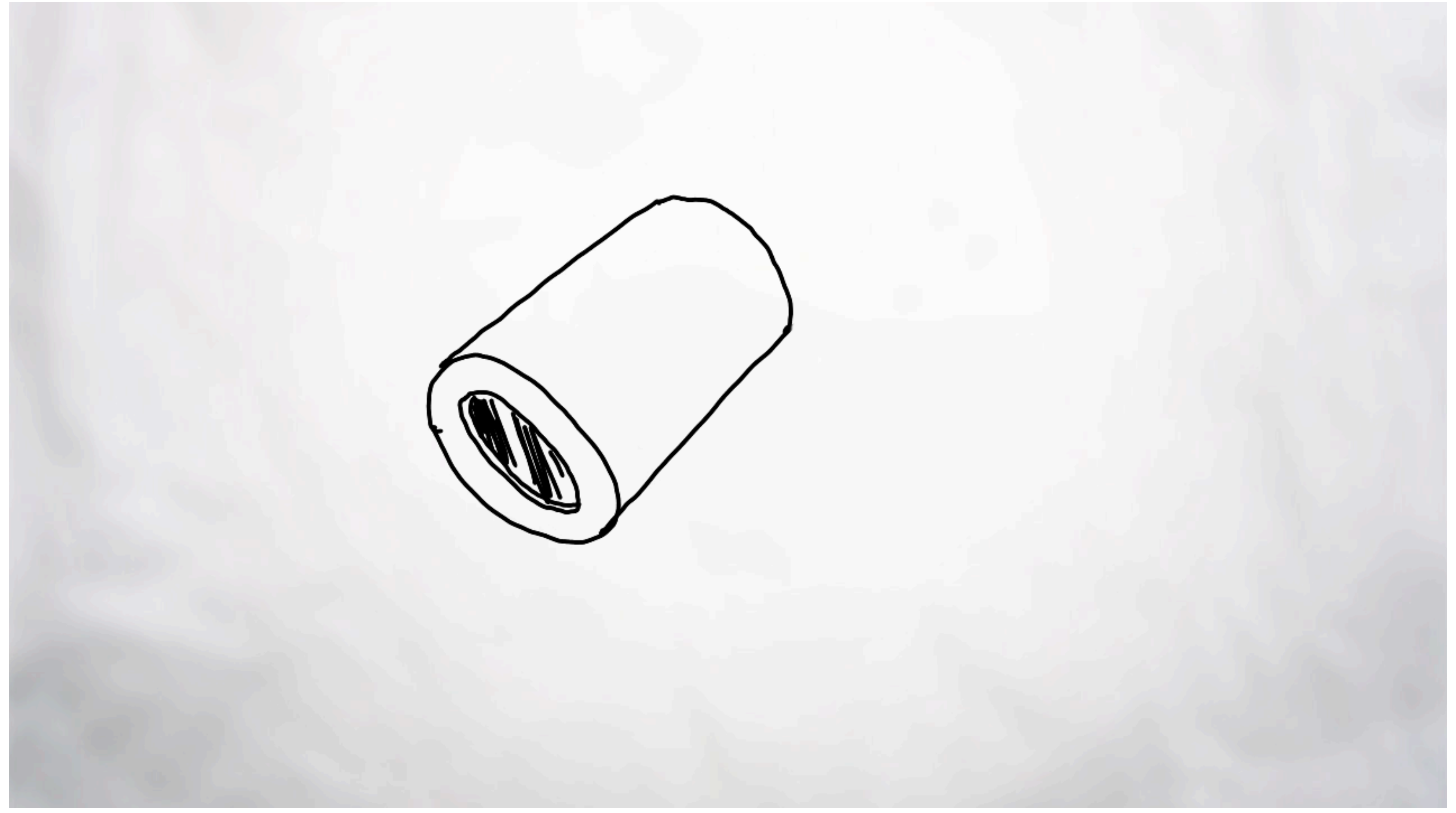


Paris ☺

MULTIPLEXING
NEEDED

- **Why can't I buy an optical quantum computer yet?**

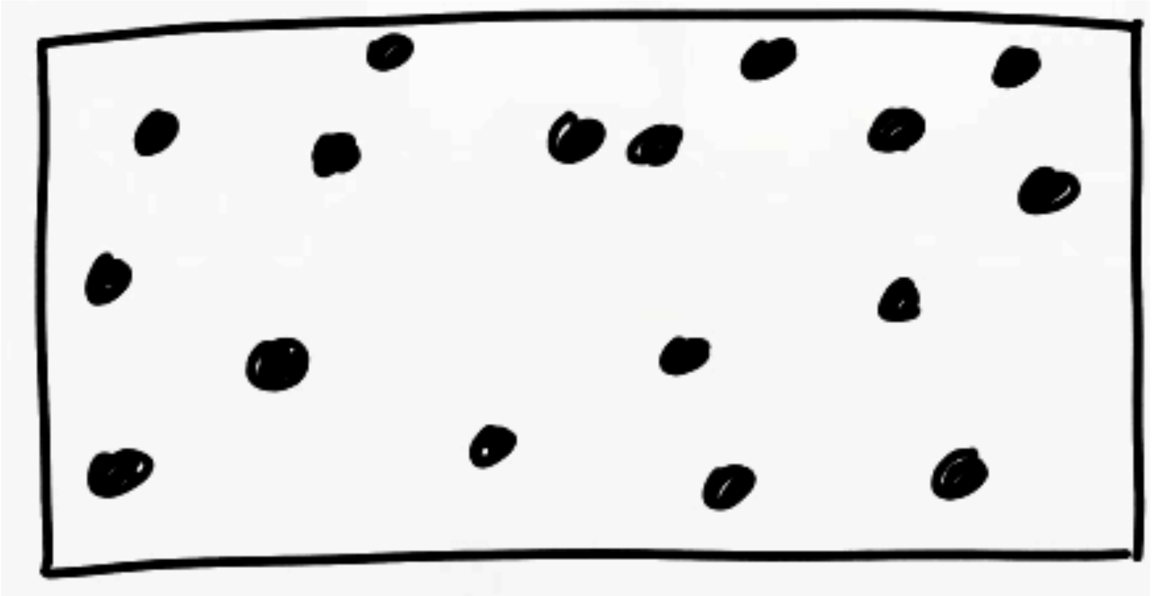
- **Probabilistic measurements = scaling catastrophe!**

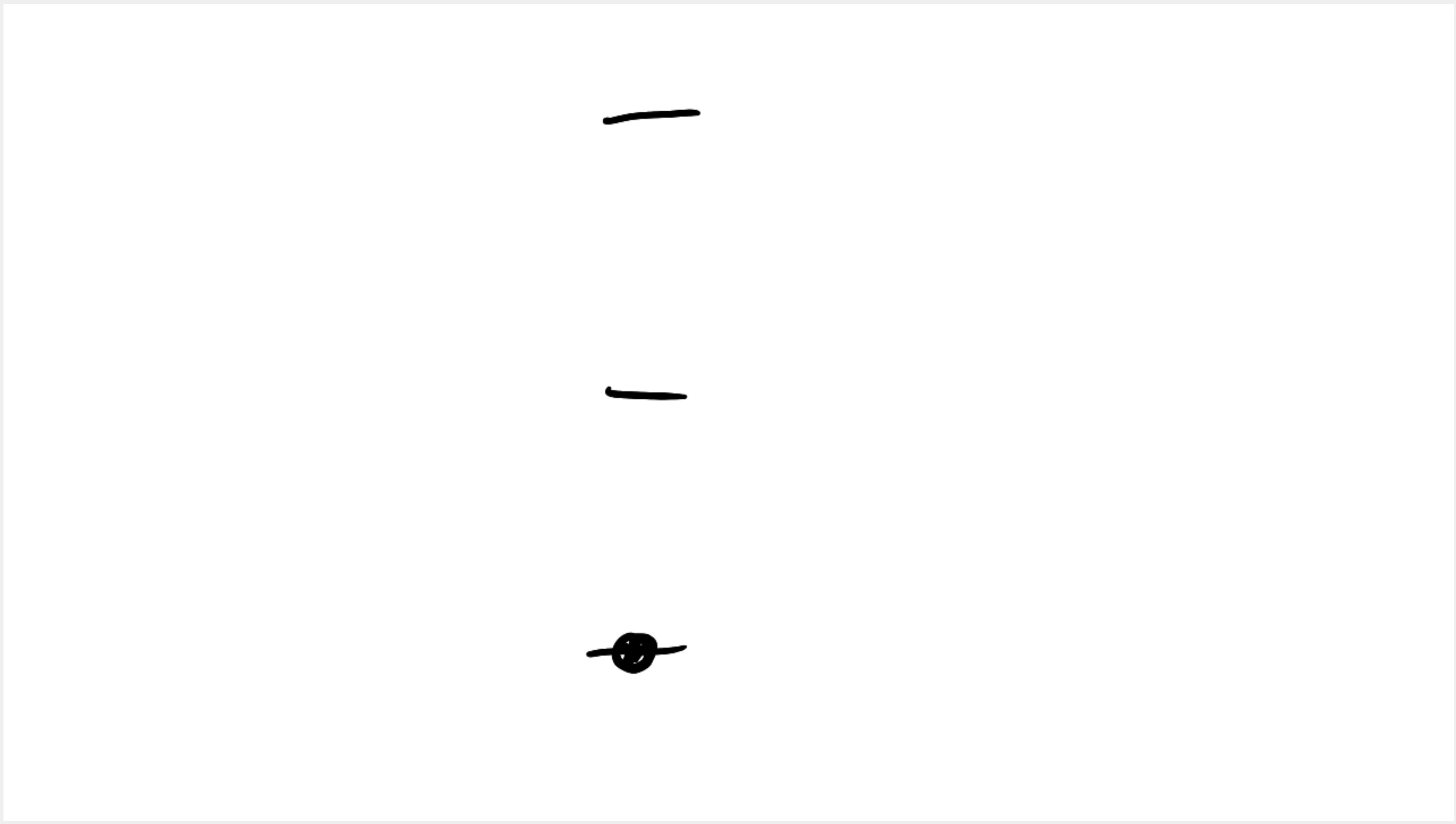


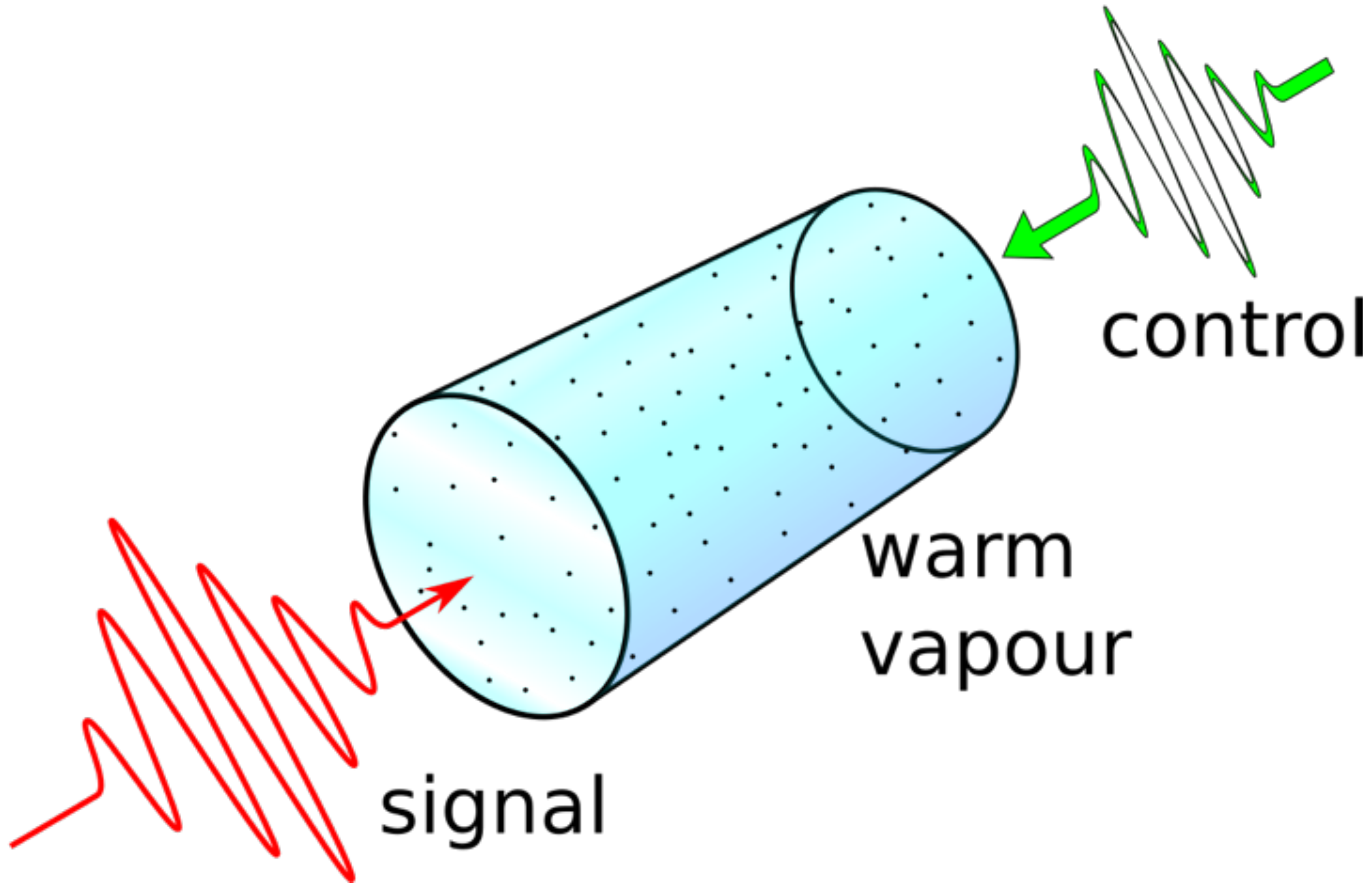
Our solution: quantum memories

- **Repeat-until-success, then storage**

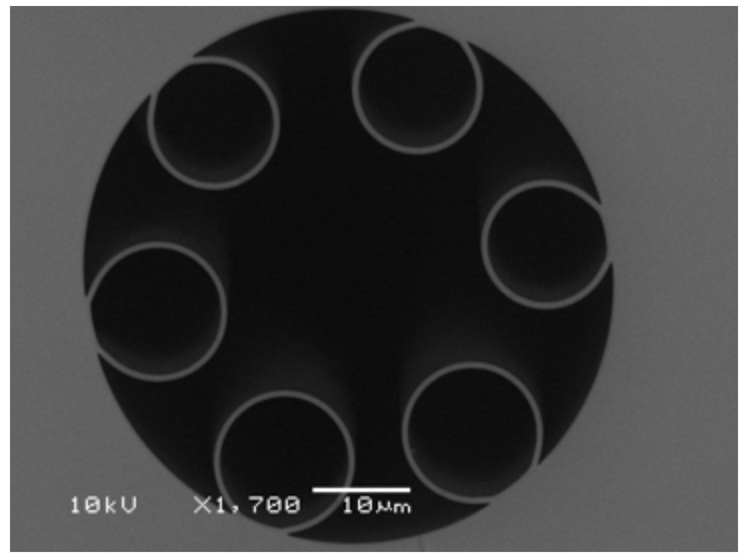
OFF-RESONANT CASCADED ABSORPTION (ORCA)







- **Room-temperature**
- **Broadband**
- **Technically simple**
- **Can be fibre-integrated**
- **Efficient**
- **Noise-free**



ORCA Computing

Team

BUSINESS

CEO

Richard Murray

PRESIDENT & COO

Cristina Escoda

CHAIRMAN

Ian Walmsley

CTO

Josh Nunn

SCIENTIFIC

PRODUCT LEAD

Jamie Francis-Jones

PRODUCT LEAD

Kris Kaczmarek

Progress to date.

$1.6M raised in Venture Capital

$1.1M in non-dilutive grants

2 engineers hired

3 patents granted

ORCA Computing

A new approach towards **photonic quantum computing**

Using proprietary **ORCA memory technology**

Leveraging plug and play **telecoms component**

With a **world class team**

And a **capital efficient** business model