Quantum technologies: from solving complex problems to unhackable communications

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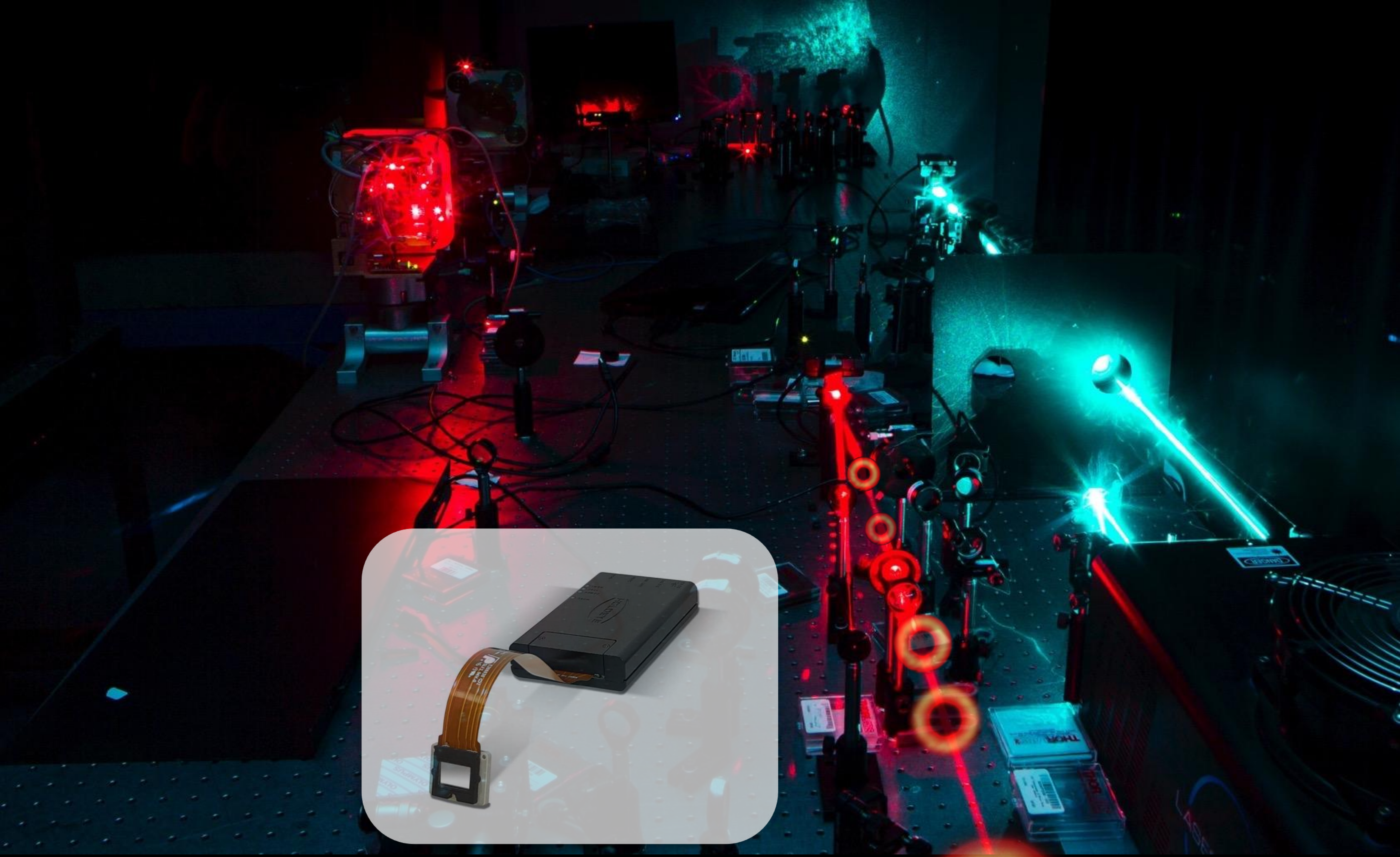
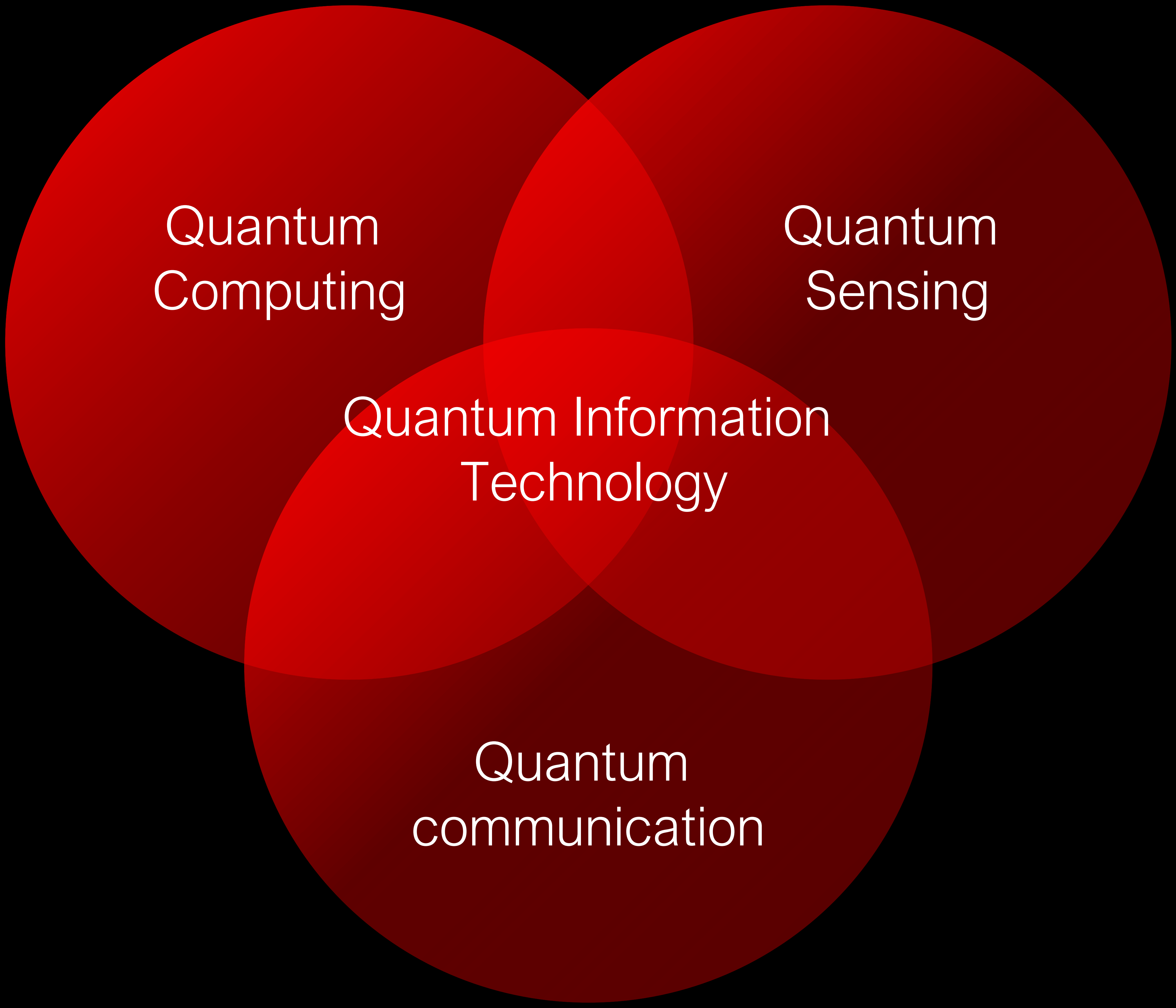


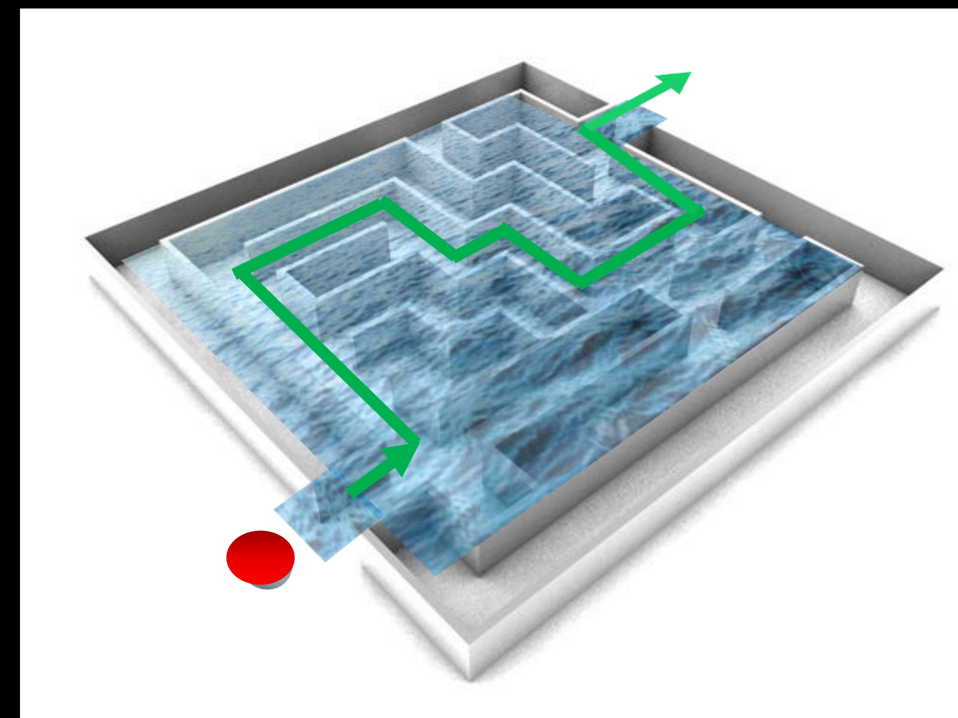
Structured Light Laboratory

A new era of technologies: Second quantum revolution



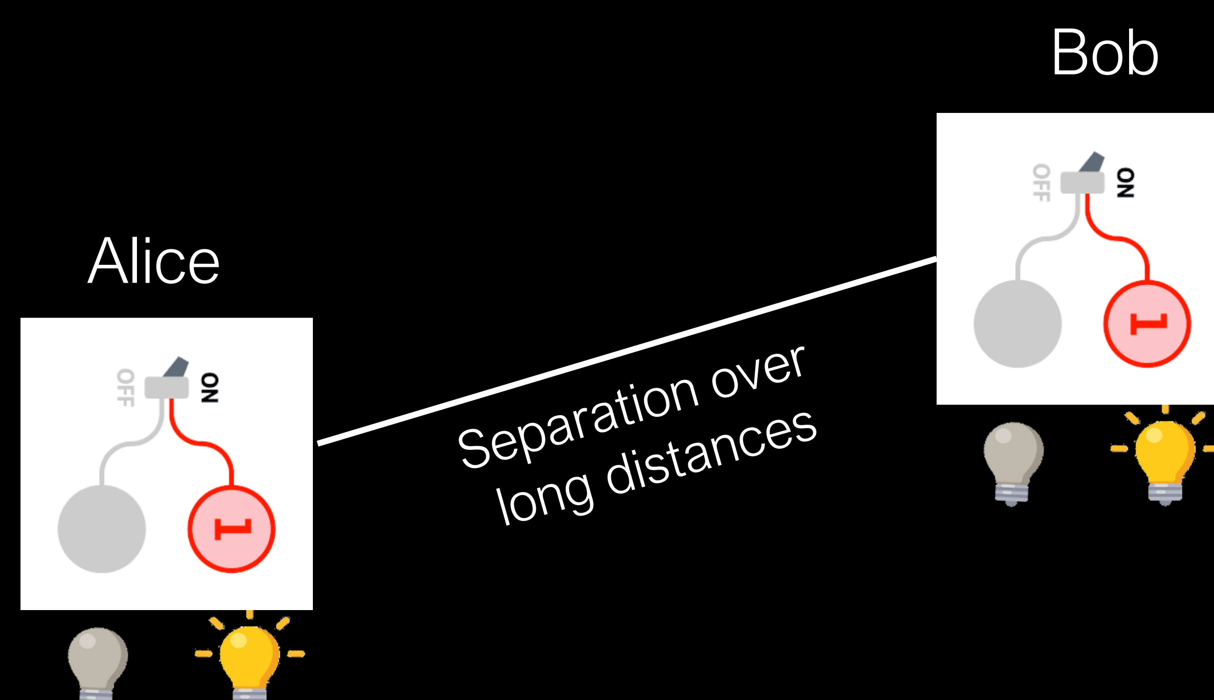
Harnessing features from the quantum world

Quantum superposition
(many possibilities at once)



Seeing all paths
at once

Quantum entanglement
“Spooky action at a distance”



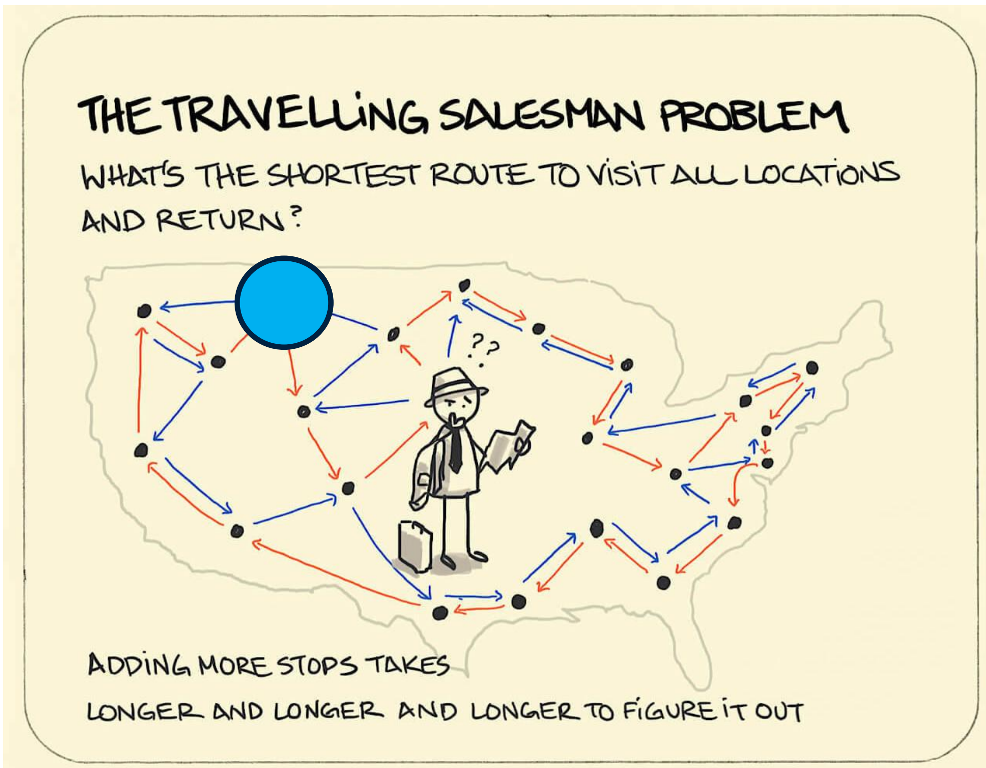
What Alice does to her system affects what Bob observes

Unlocking new quantum sensing modalities: stealth detection with quantum radar

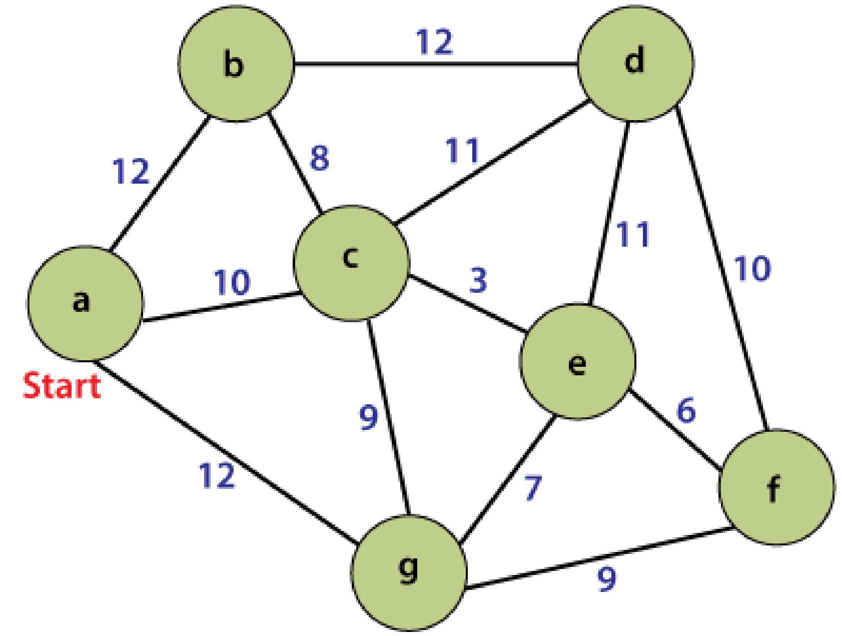
Chinese Report Stealth-Detecting Quantum Radar Enters Mass Production

National, Research   Matt Swayne • October 20, 2025

Solving complex problems using quantum algorithms



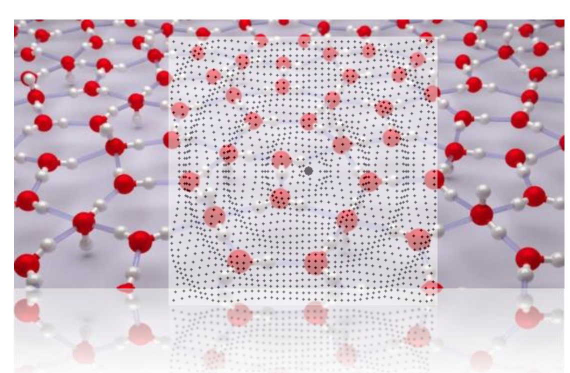
Mapping to a graph

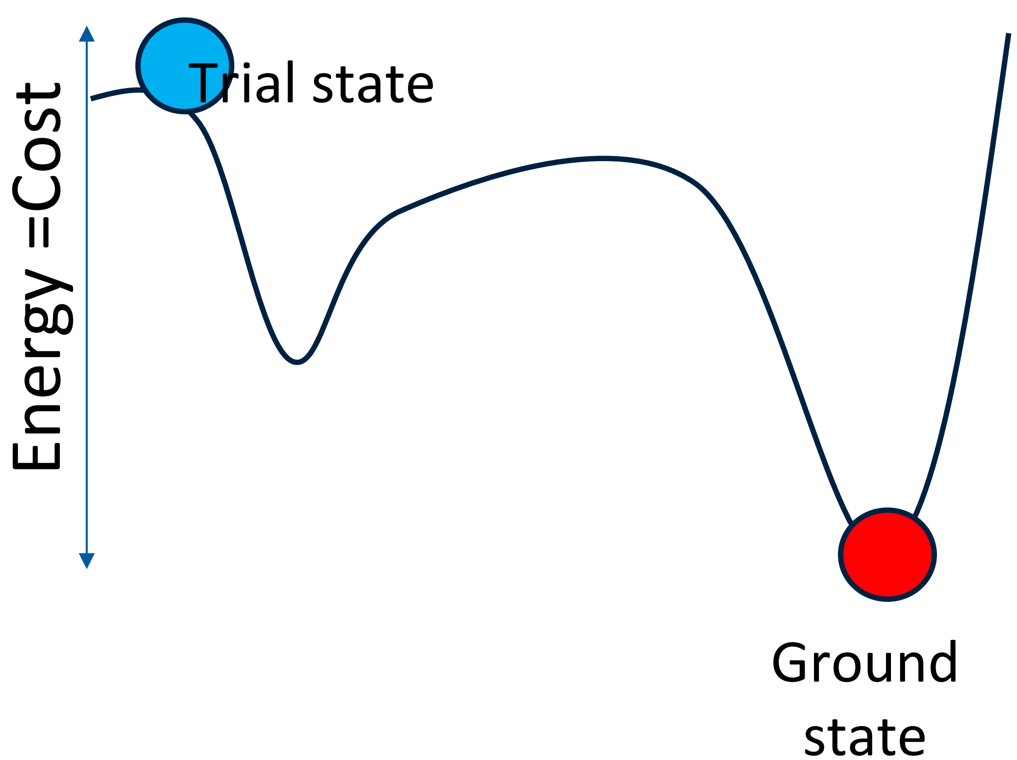


Mapping to Hamiltonian

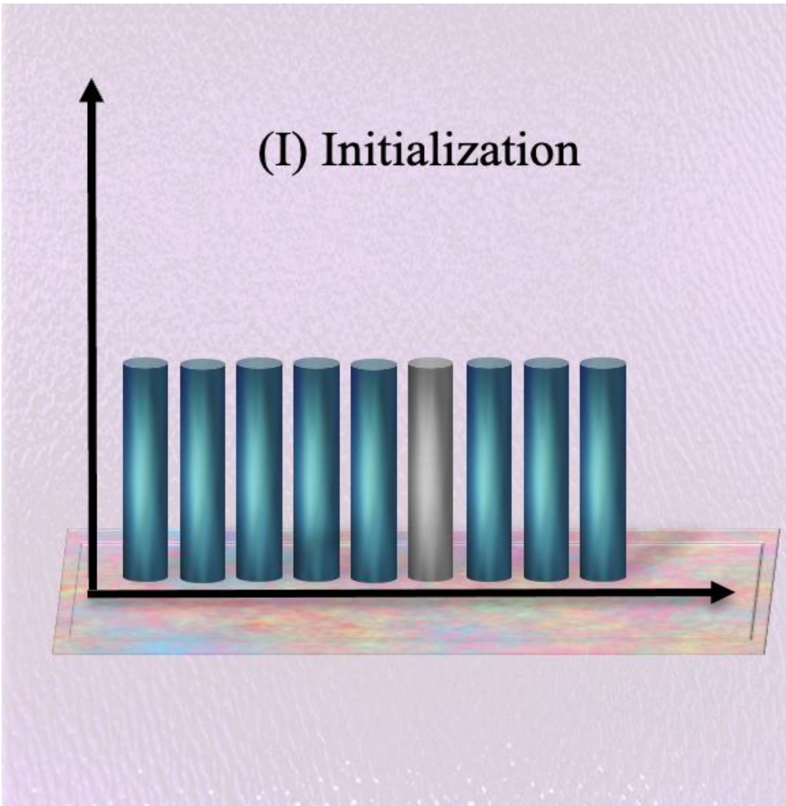
$$
W_0 = \begin{array}{c} \\ X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \end{array}
\begin{array}{c} \begin{array}{ccccc} X_1 & X_2 & X_3 & X_4 & X_5 \end{array} \\
\begin{bmatrix} 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix} \end{array}
$$

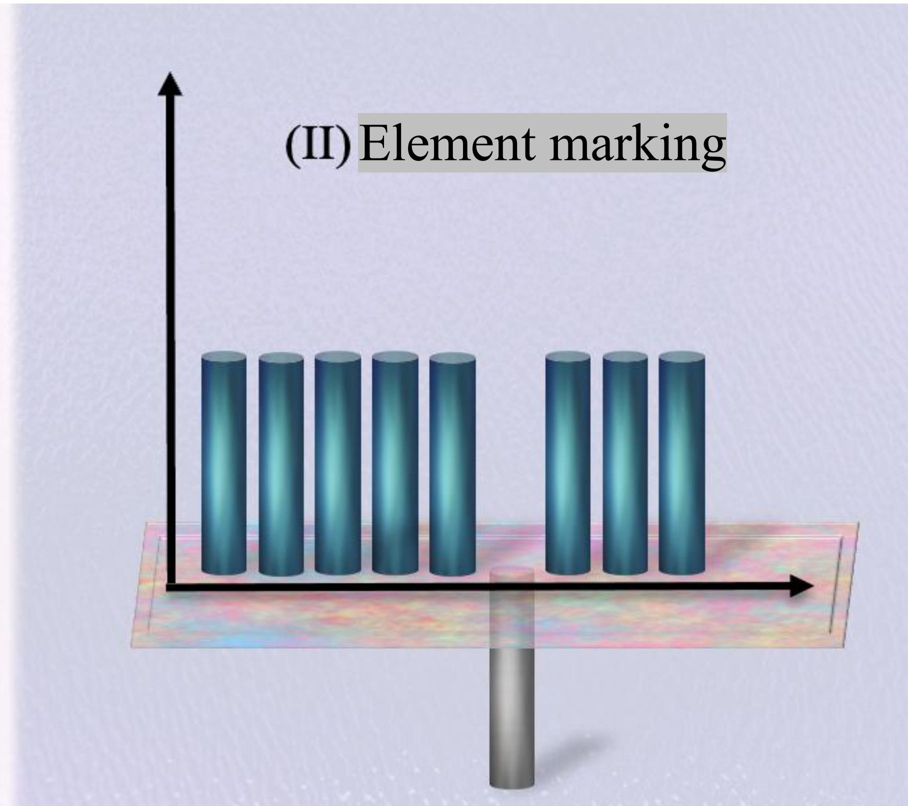
Reformulate as an energy minimization problem in quantum mechanics

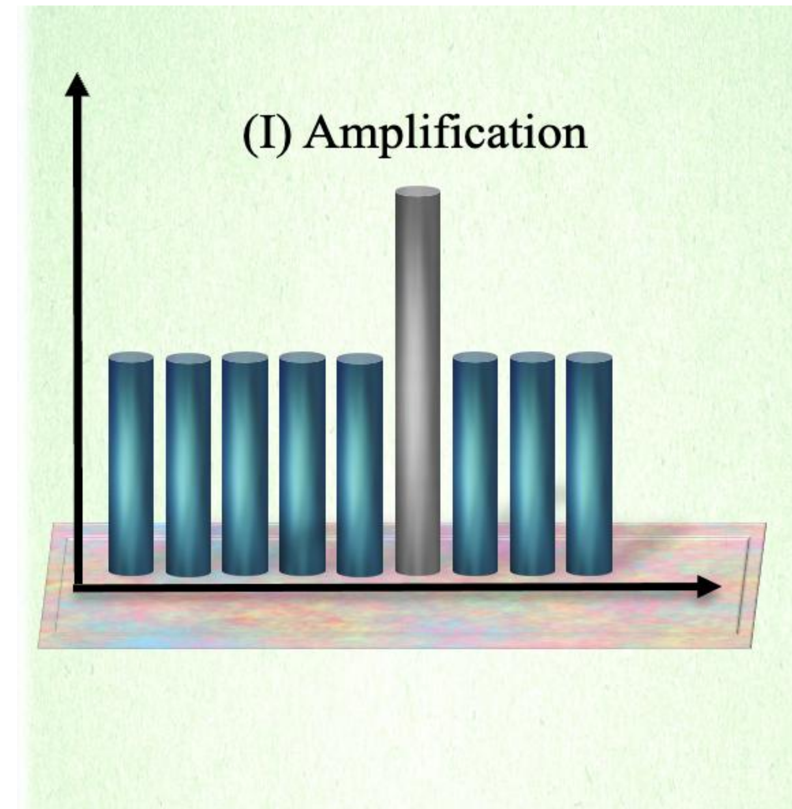


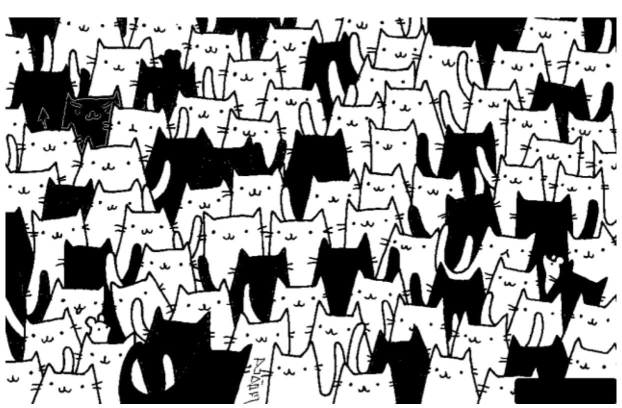


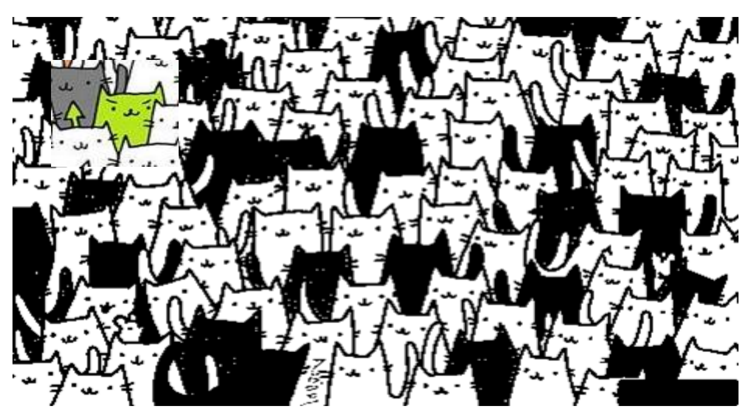
Searching through databases: Grover's search algorithm

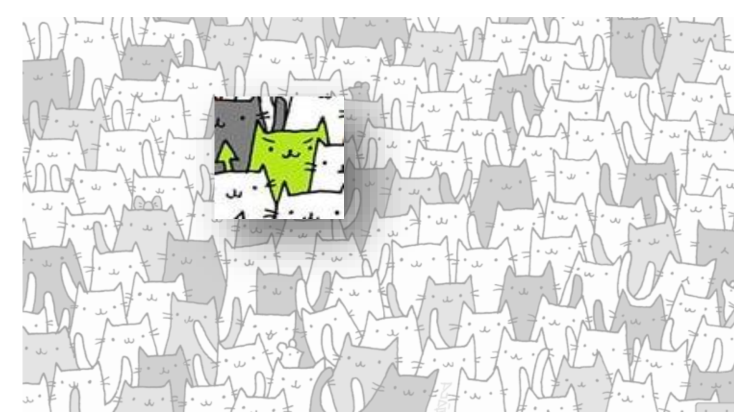






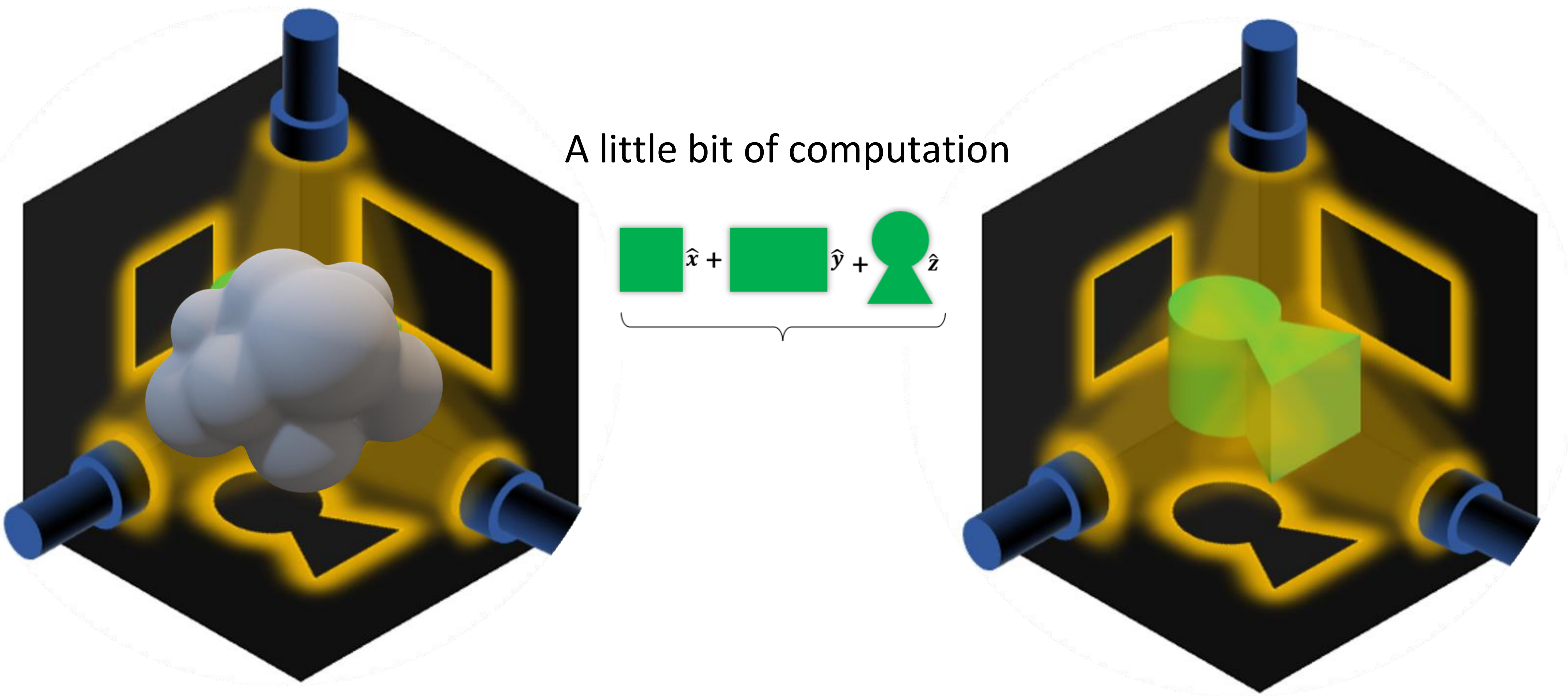






Finding the shape of an object by probing it with structured photons

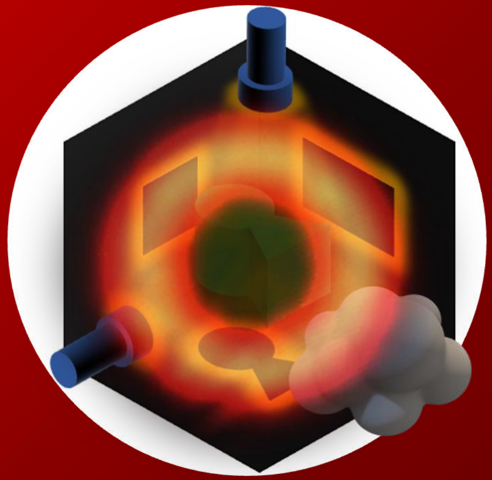
A little bit of computation



Reconstructing objects from projections: a beautiful analogy

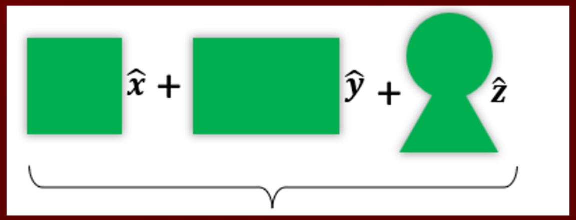
Merging two quantum technologies to solve this

Quantum sensing



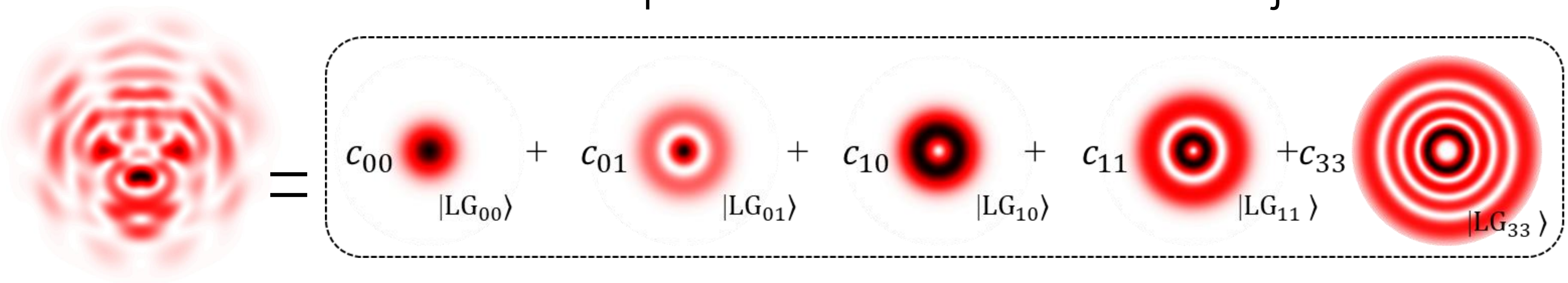
Quantum computing

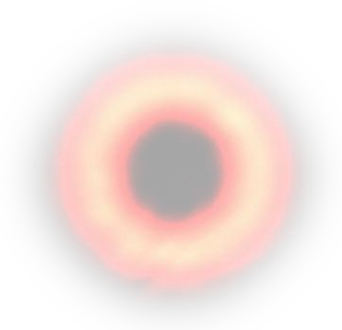
A little bit of computation



We want to extract the information using structured patterns of light

d>2 patterns to construct the object

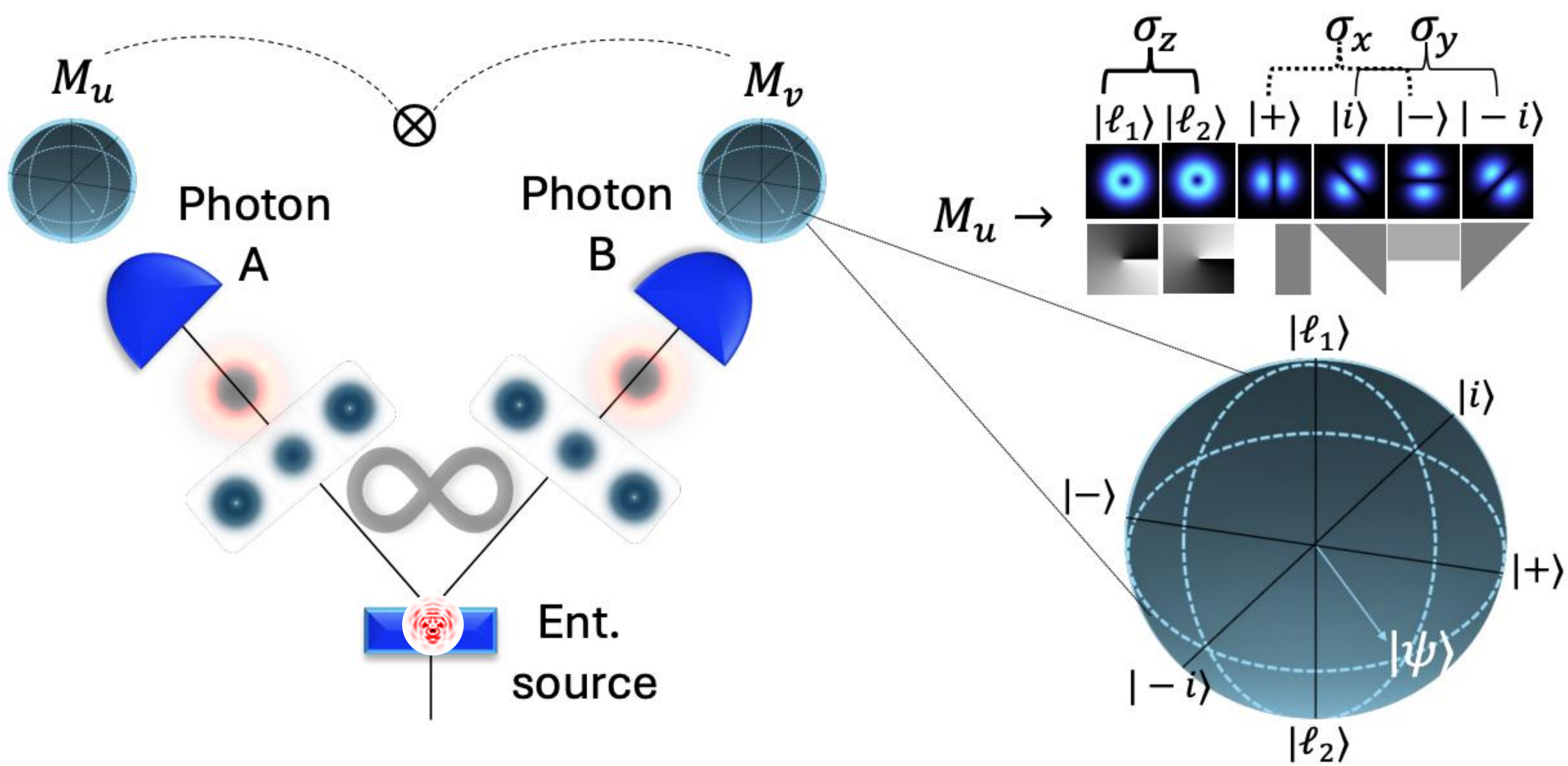




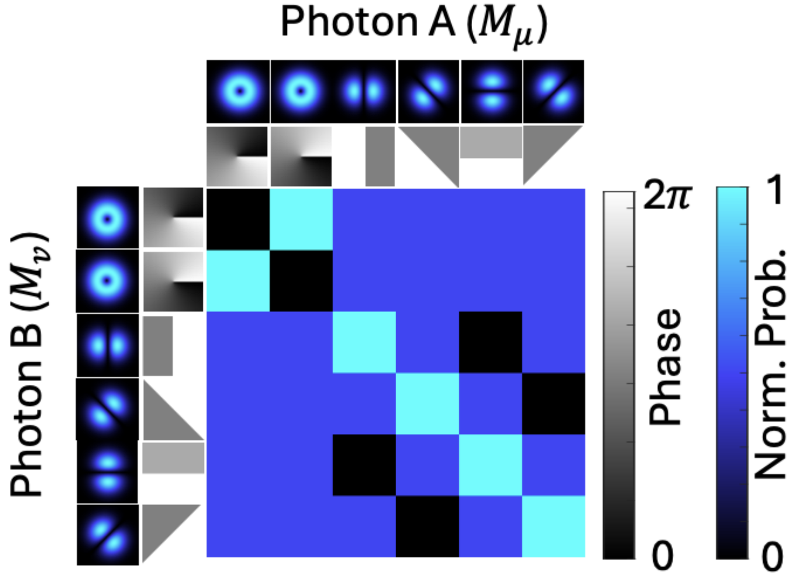
There are many patterns to probe the object with!

$\sim d^n$ measurements and parameters to solve for

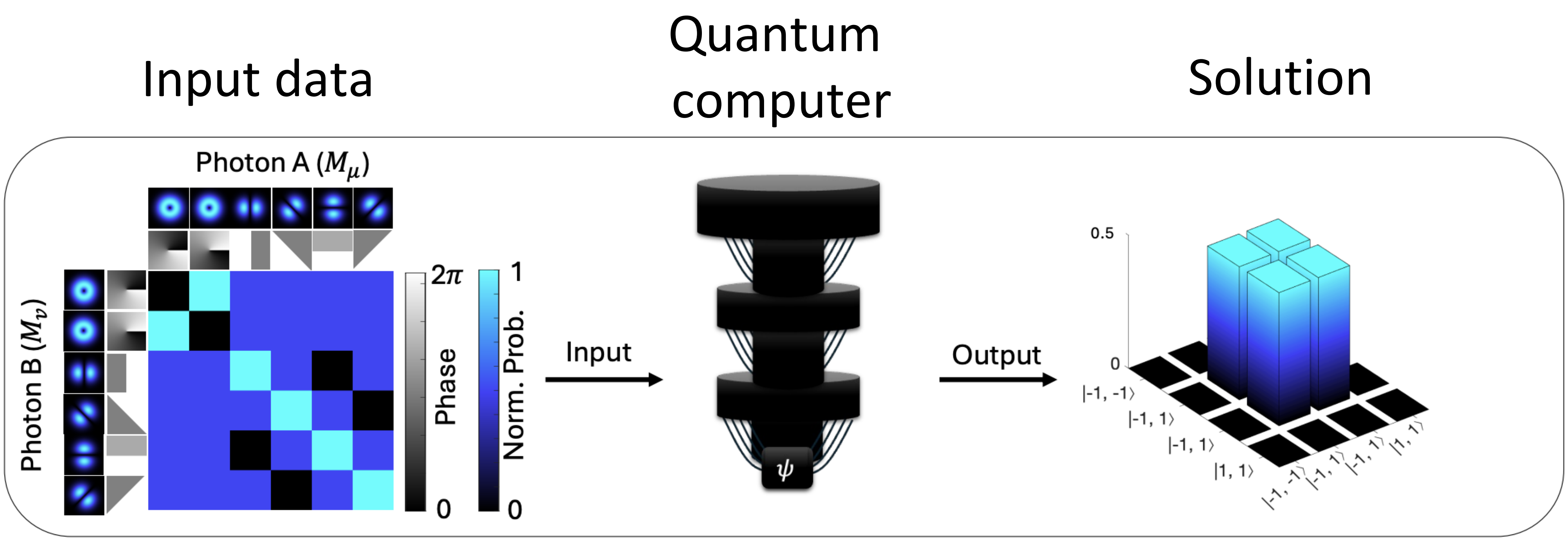
Example: probing an entangled system (d=2, n=2)

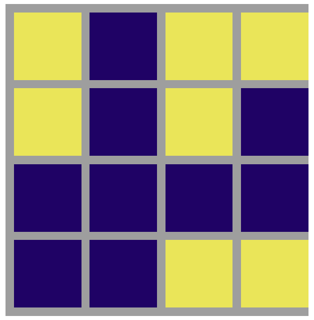


36 measurements



Instead, we want to run an optimization procedure on a QC!



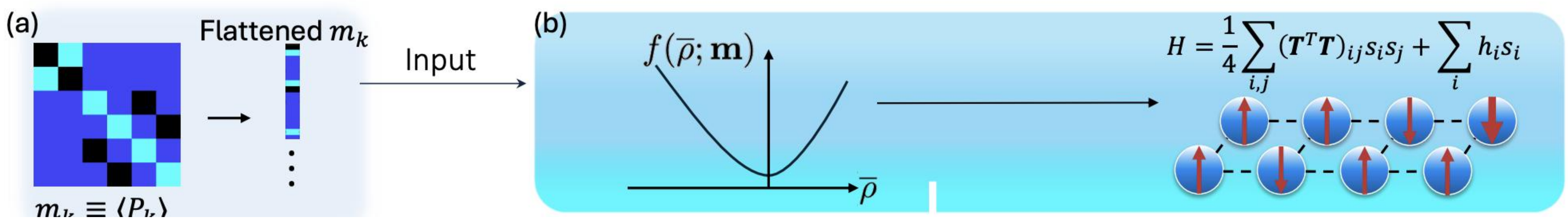


We establish a cost function and minimize it using the quantum computer

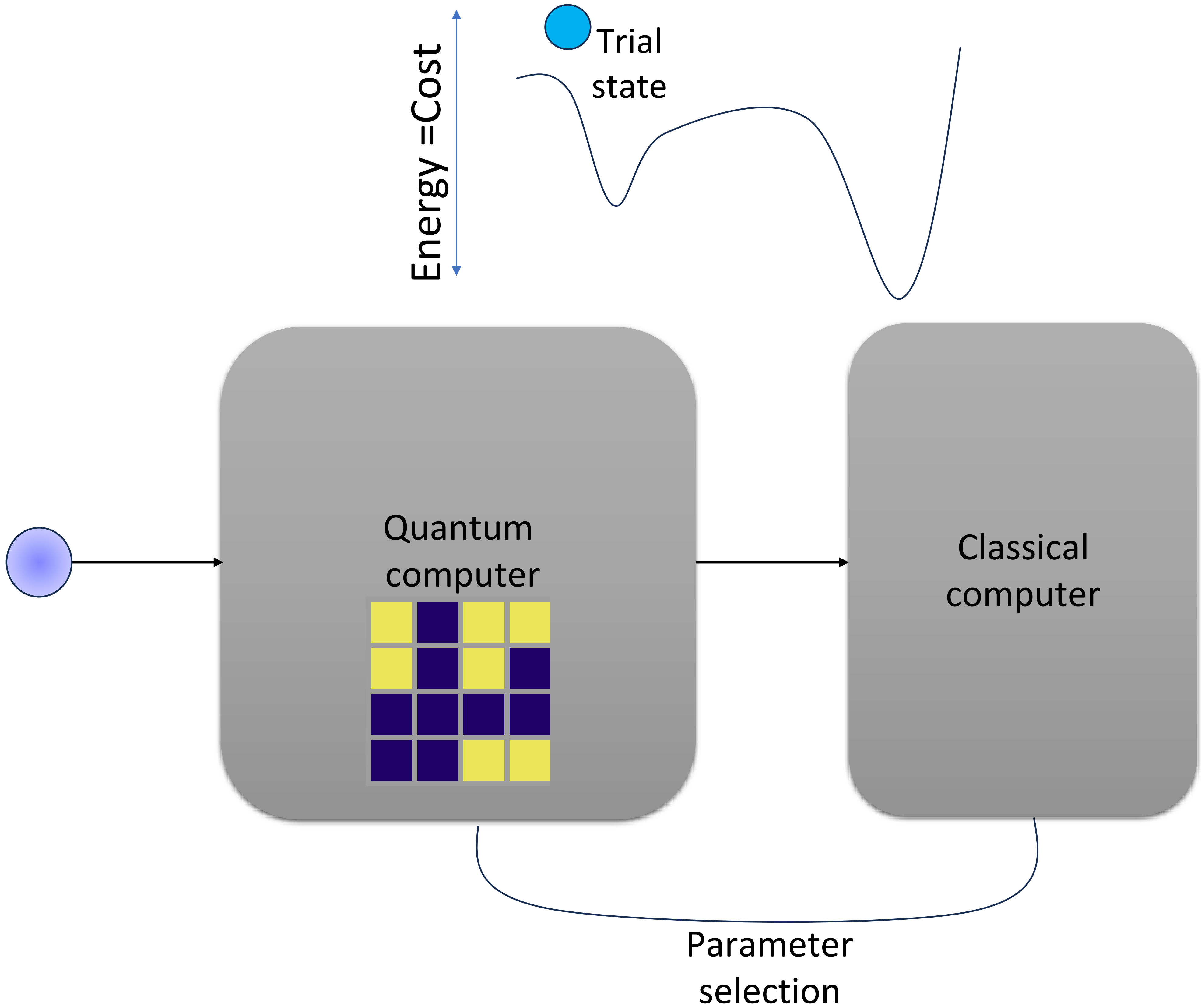
Input data

Cost function

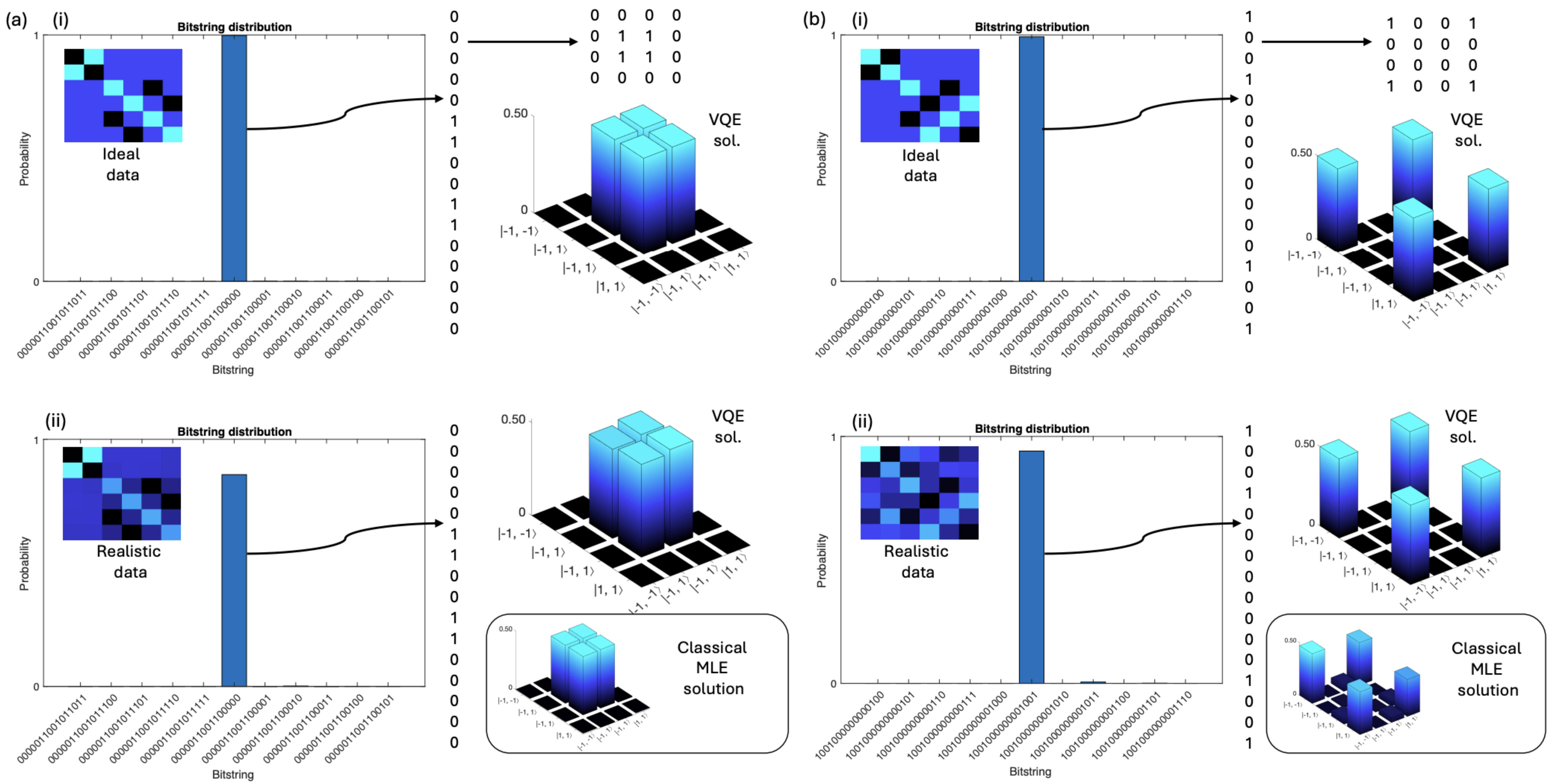
Energy function of a physical system



We use a hybrid loop to do this



We can reliably do this using IBMs quantum computers



arXiv > quant-ph > arXiv:2509.21804

Quantum Physics

[Submitted on 26 Sep 2025]

Towards reconstructing quantum structured light on a quantum computer

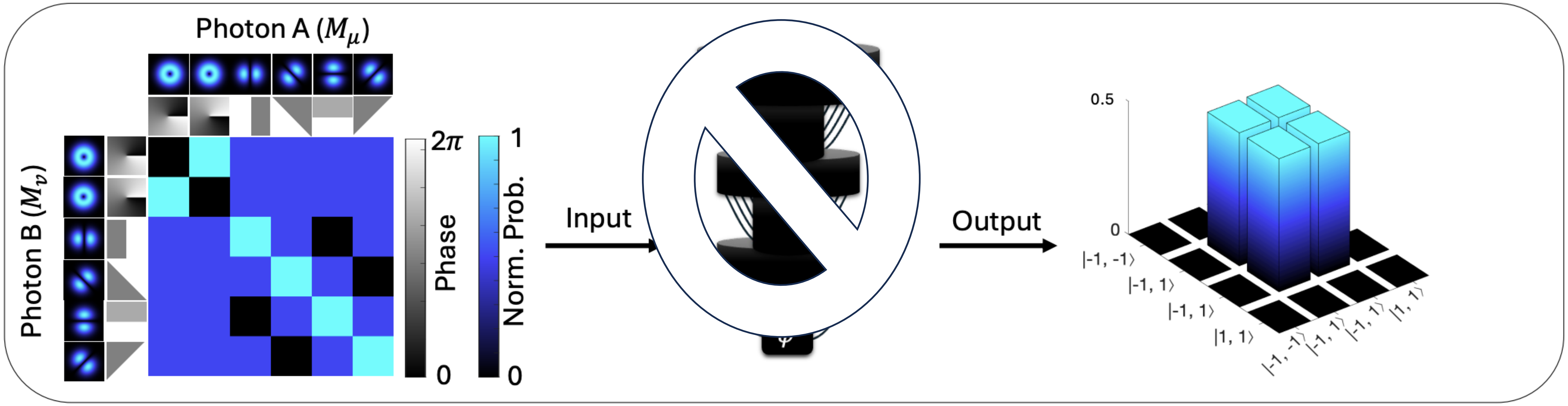
Mwezi Koni, Shawal Kasim, Paola C. Obando, Neelan Gounden, Isaac Nape

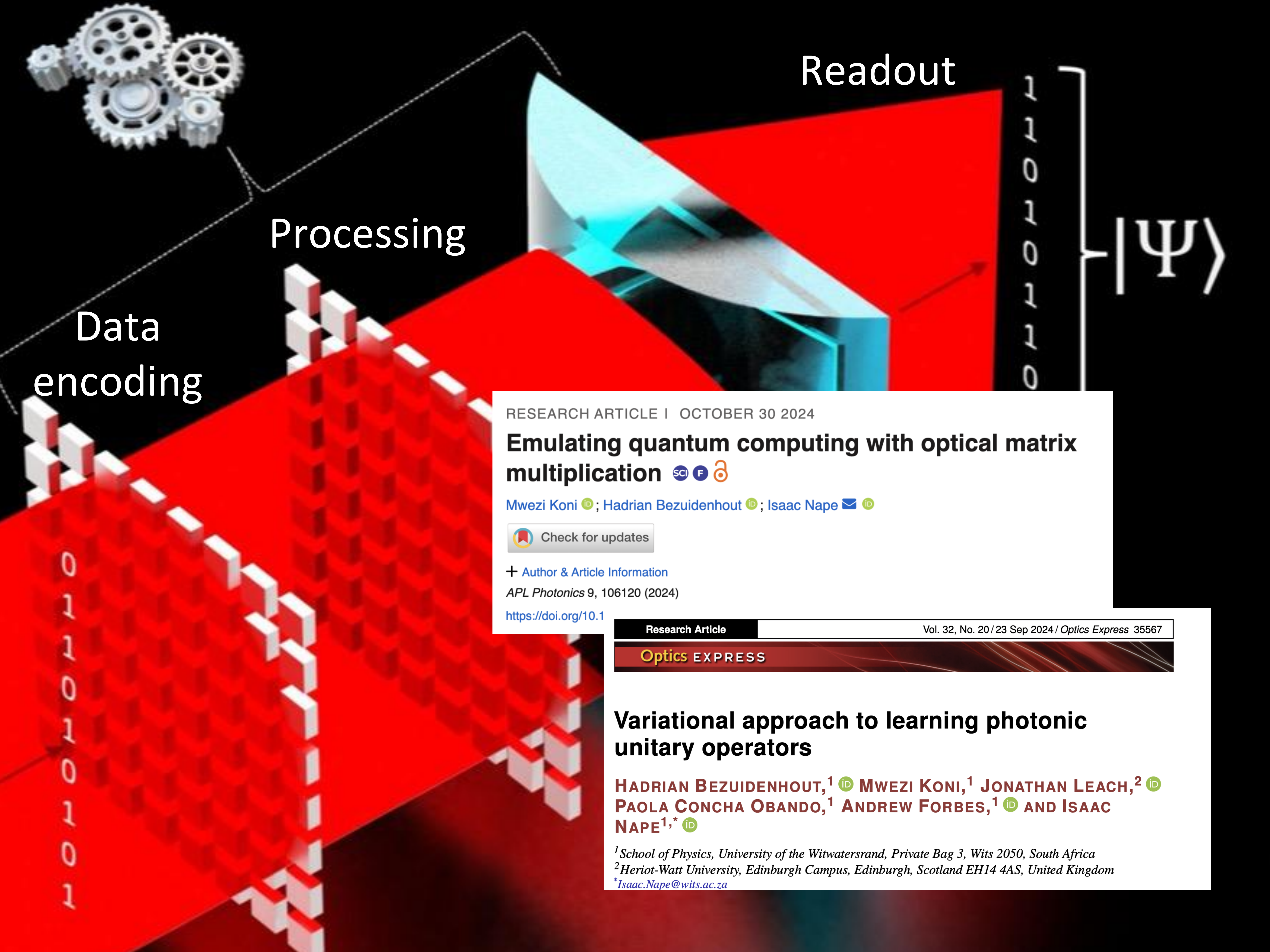
Under review at PRA

Can we instead use quantum optical systems directly

Input data

Solution





RESEARCH ARTICLE | OCTOBER 30 2024

Emulating quantum computing with optical matrix multiplication

Mwezi Koni; Hadrian Bezuidenhout; Isaac Nape

Check for updates

+ Author & Article Information

APL Photonics 9, 106120 (2024)
https://doi.org/10.1

Research Article | Vol. 32, No. 20 / 23 Sep 2024 / *Optics Express* 35567

Optics EXPRESS

Variational approach to learning photonic unitary operators

HADRIAN BEZUIDENHOUT,[1] MWEZI KONI,[1] JONATHAN LEACH,[2] PAOLA CONCHA OBANDO,[1] ANDREW FORBES,[1] AND ISAAC NAPE[1,*]

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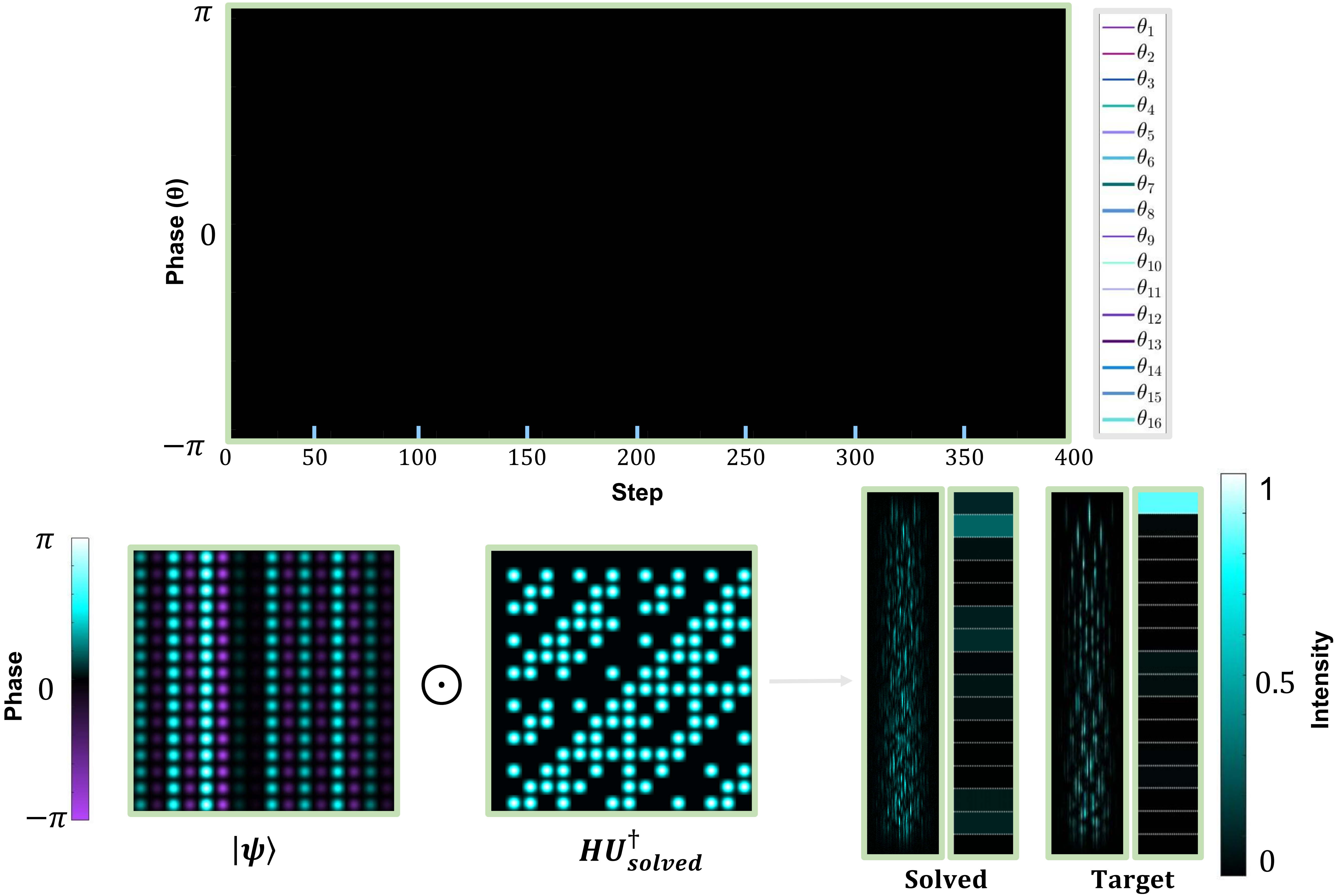
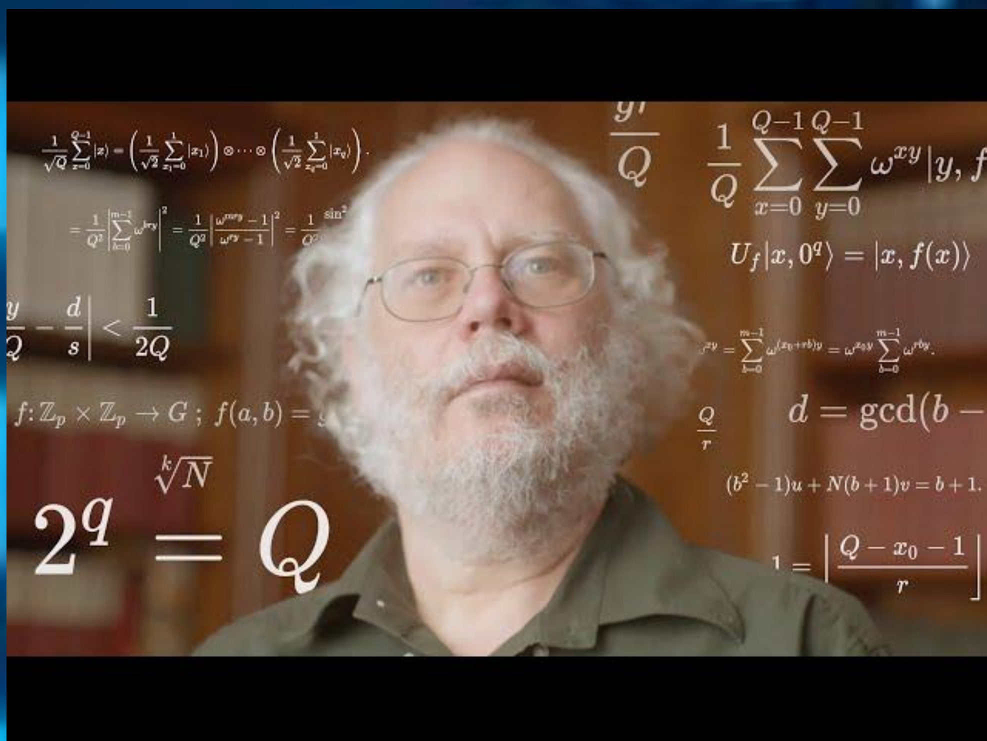
[*]*Isaac.Nape@wits.ac.za*

The optical system is able to learn the unknown parameters using an analogue of the quantum variational algorithm



Soon these algorithms will be able to break our encryption systems



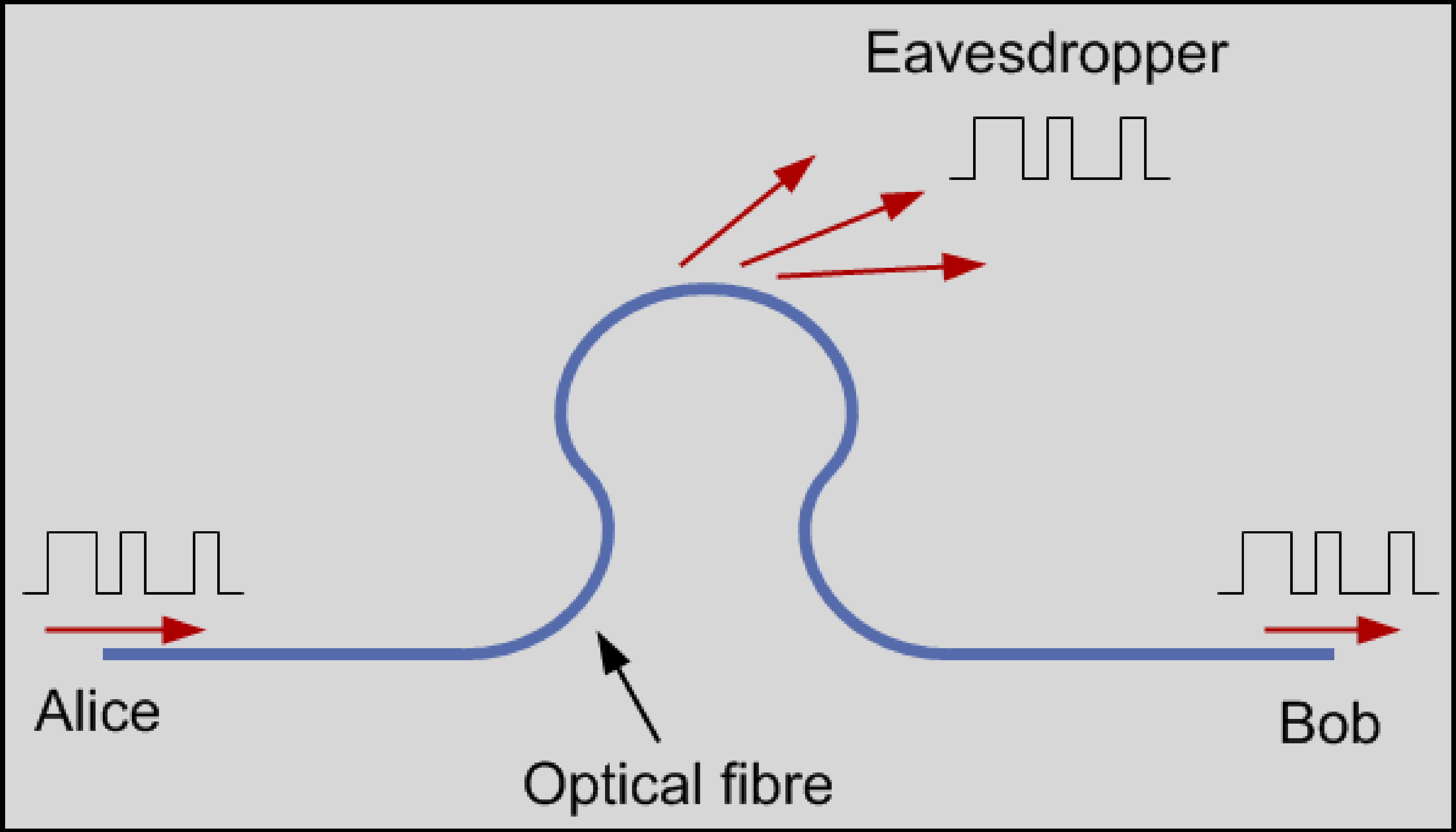
Factoring a 200-digit number

- **Classical:** Days–weeks
- **Quantum (Shor's Algorithm):** Seconds–minutes.

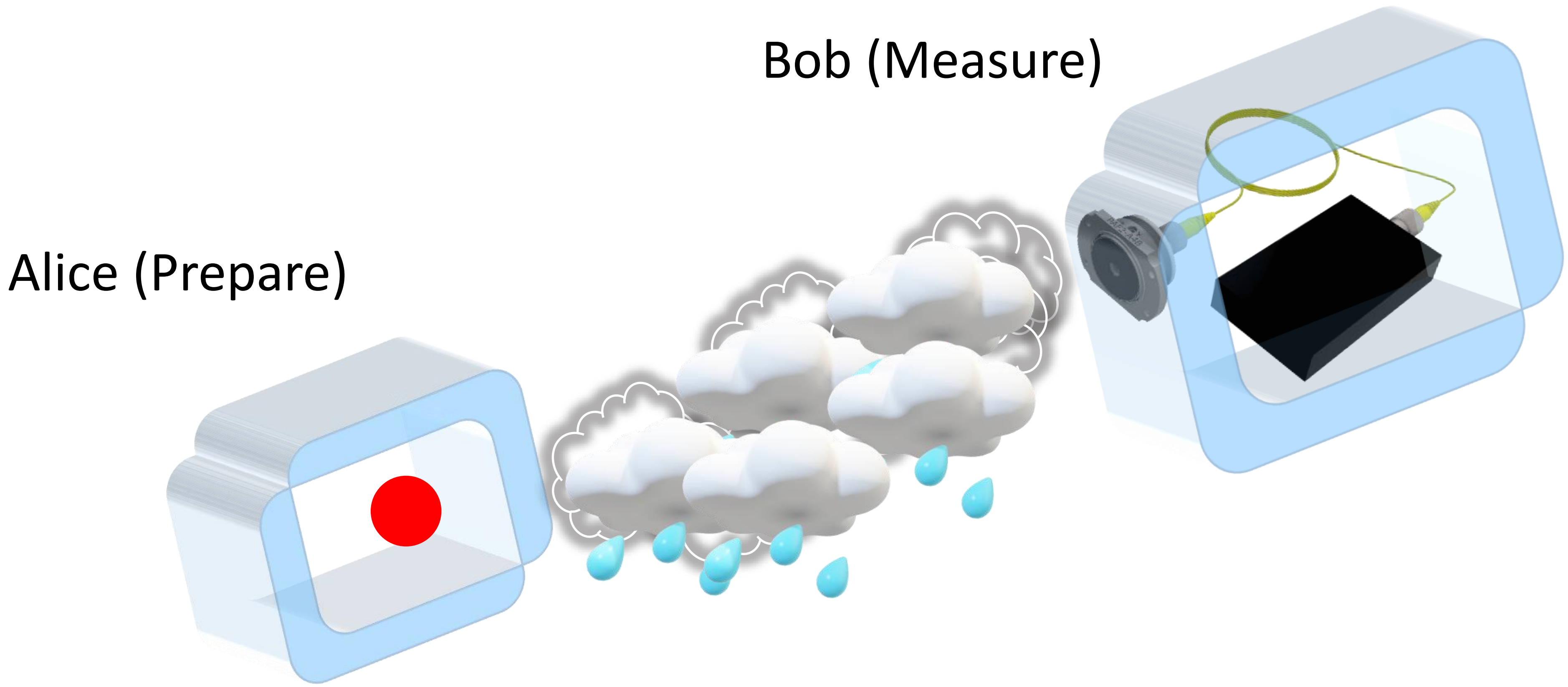
Factoring a 1000-digits number

- **Classical:** Unfeasible (beyond the age of universe)
- **Quantum (Shor's Algorithm):** Hours

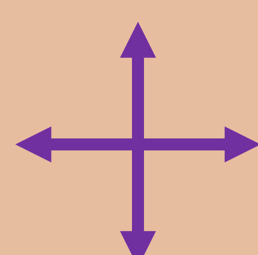
If RSA encryption can be compromised, our communication systems are at risk

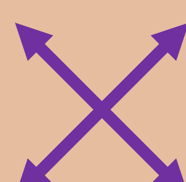


Quantum key distribution is a potential solution



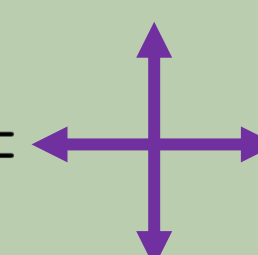
Alice prepares

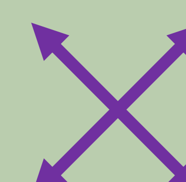
$$\{|\psi\rangle\} =$$ 

$$\{|\phi\rangle\} =$$ 

Alice picks a **state**

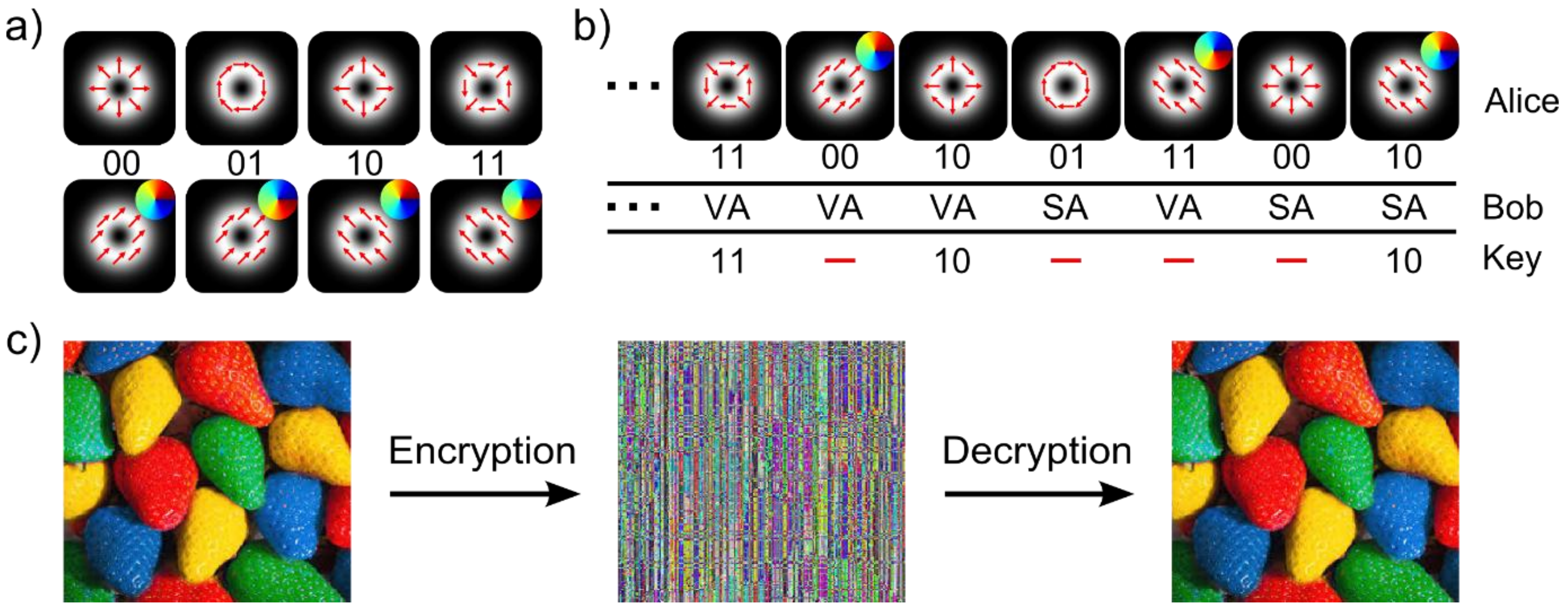
Bob measures

$$\{|\psi\rangle\} =$$ 

$$\{|\phi\rangle\} =$$ 

Bob picks a **basis**

Our work has focused on increasing the encoding capacity (alphabet)



Detecting these modes can be difficult!

I. Nape, et. al. *arXiv preprint arXiv:1612.09261*., 2016.

B. Ndagano**, I. Nape**, et. al - Scientific Reports, 2017.

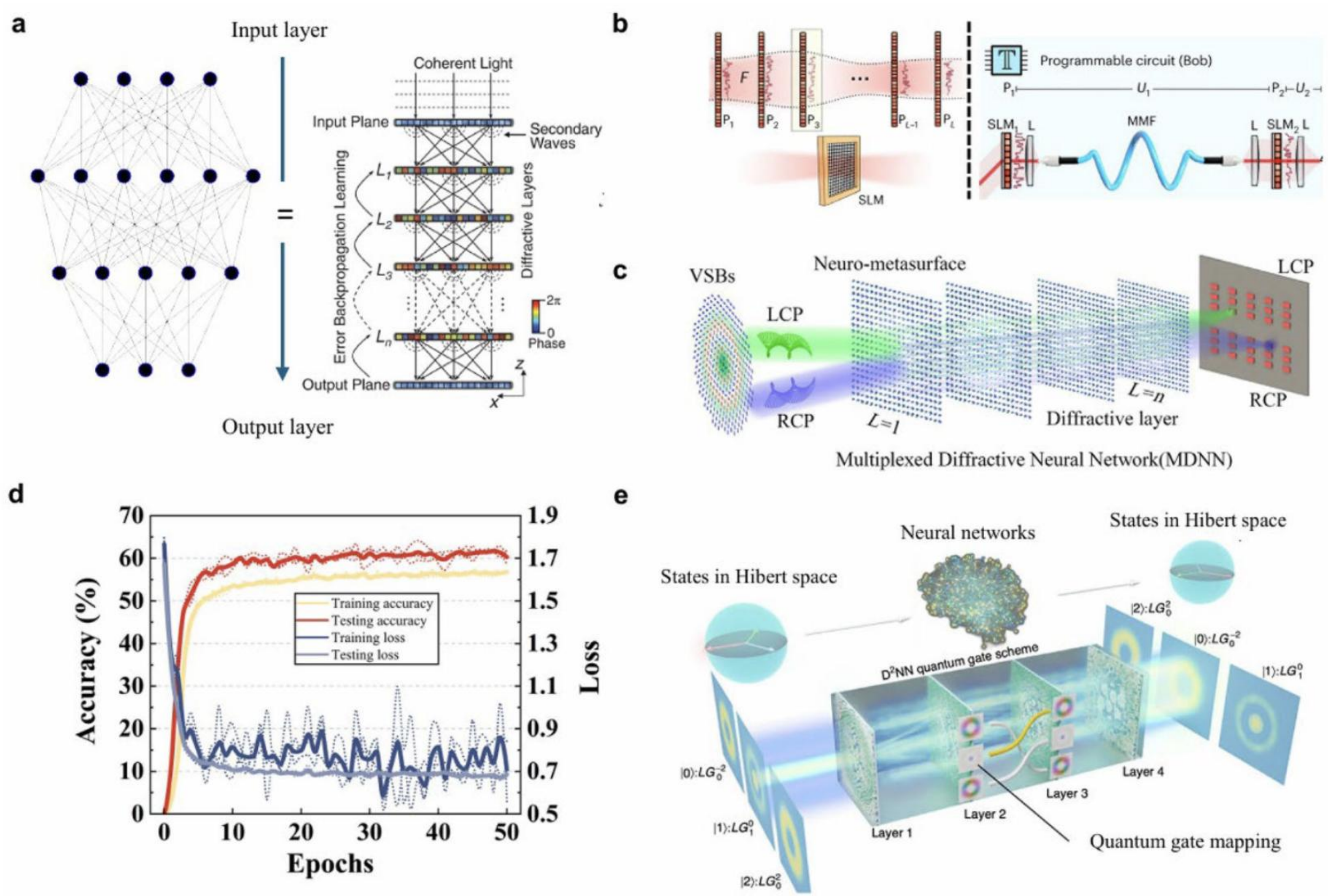
E. Otte, **I. Nape** et. al , *JOSA*, *37*(11), 2020

Zhang *et al. eLight* (2025) 5:26
https://doi.org/10.1186/s43593-025-00102-z elight.springeropen.com

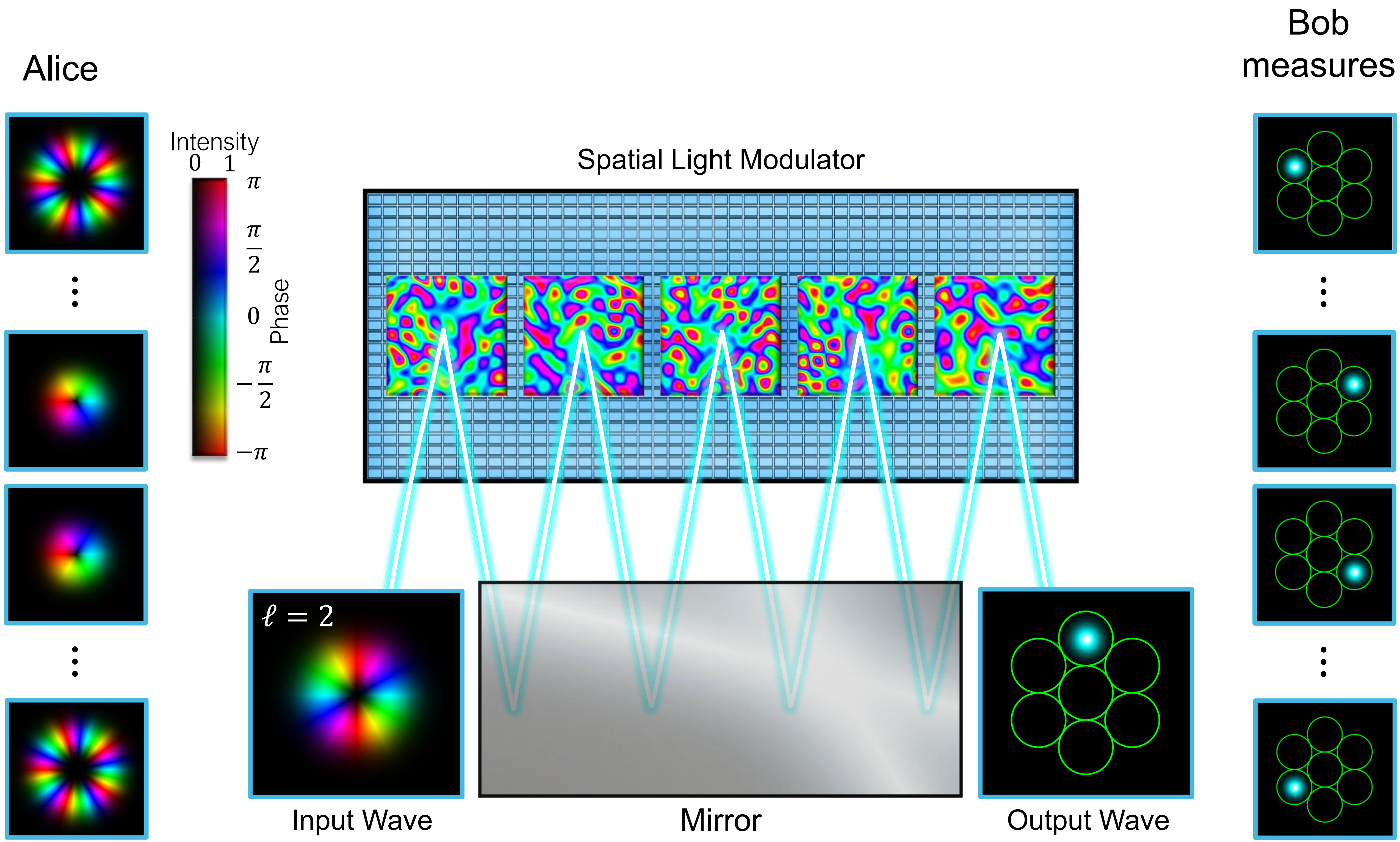
REVIEW **Open Access**

Structured light meets machine intelligence

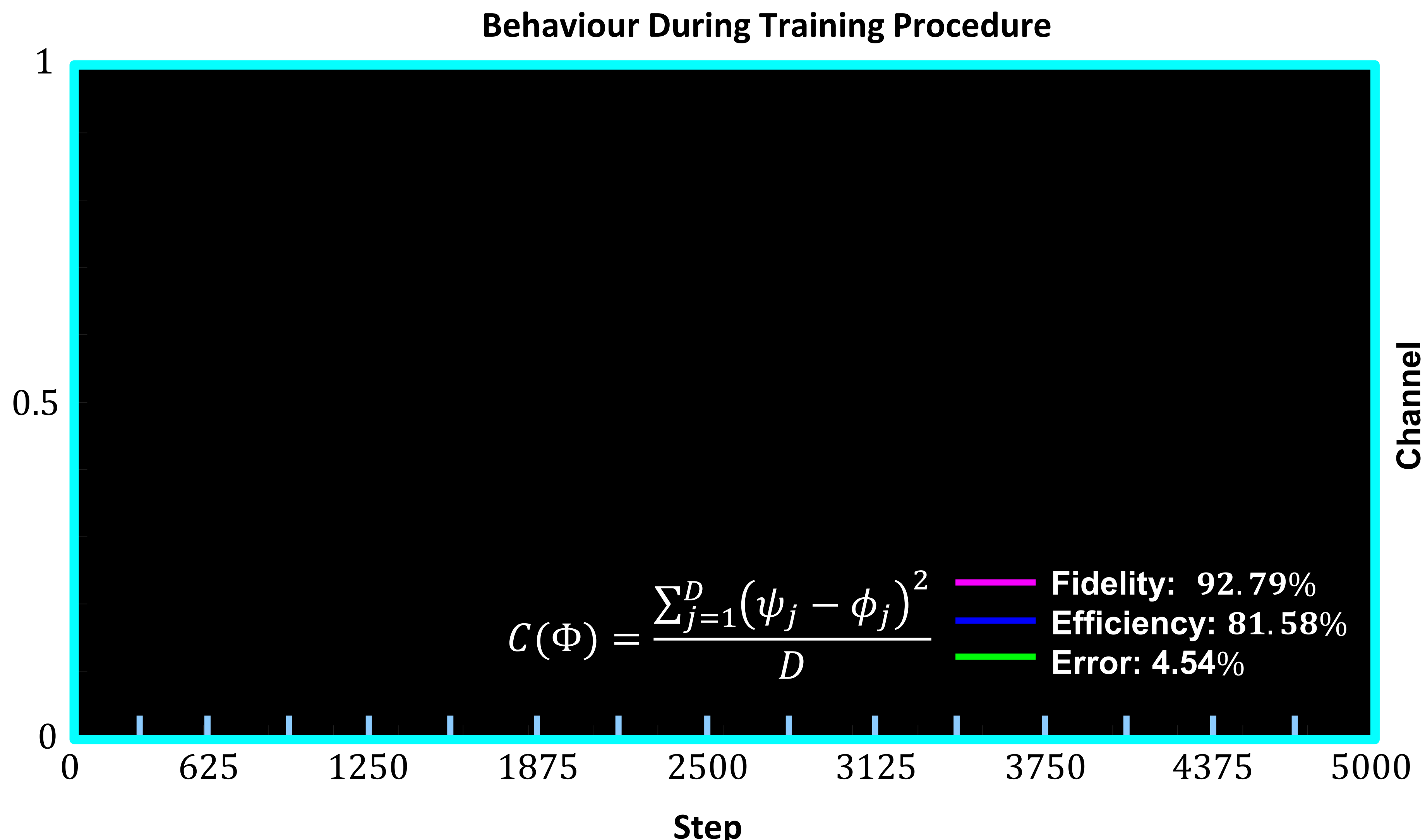
Zilong Zhang[1,2,3*], Lingyu Kong[1,2,3], Lianghaoyue Zhang[1,2,3], Xiangyang Pan[1,2,3], Trishita Das[4], Benquan Wang[4], Baolei Liu[5,6], Fan Wang[5], Isaac Nape[7], Yijie Shen[4,8*] and Andrew Forbes[7*]

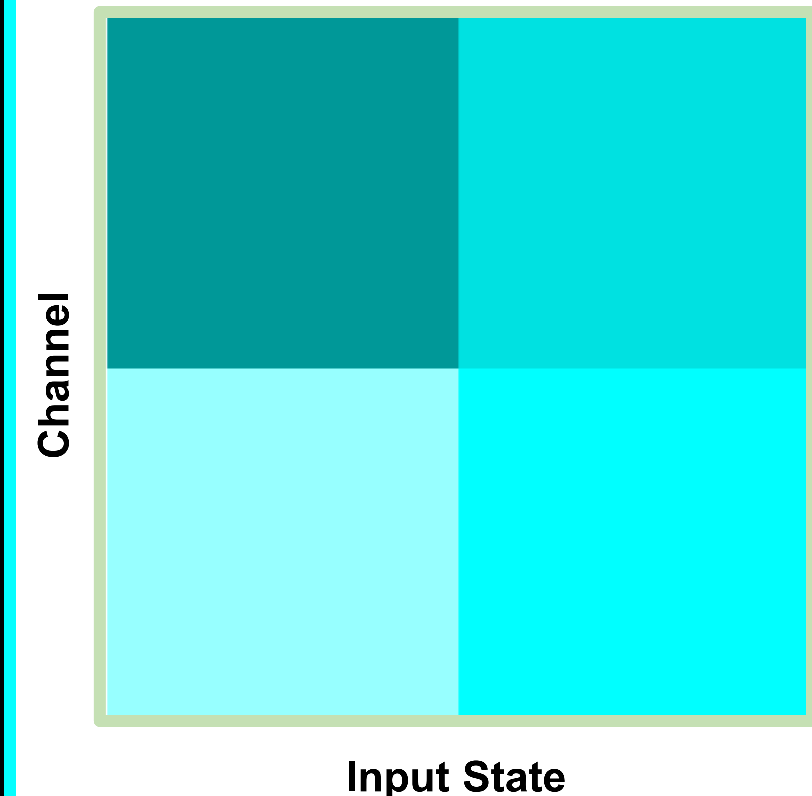


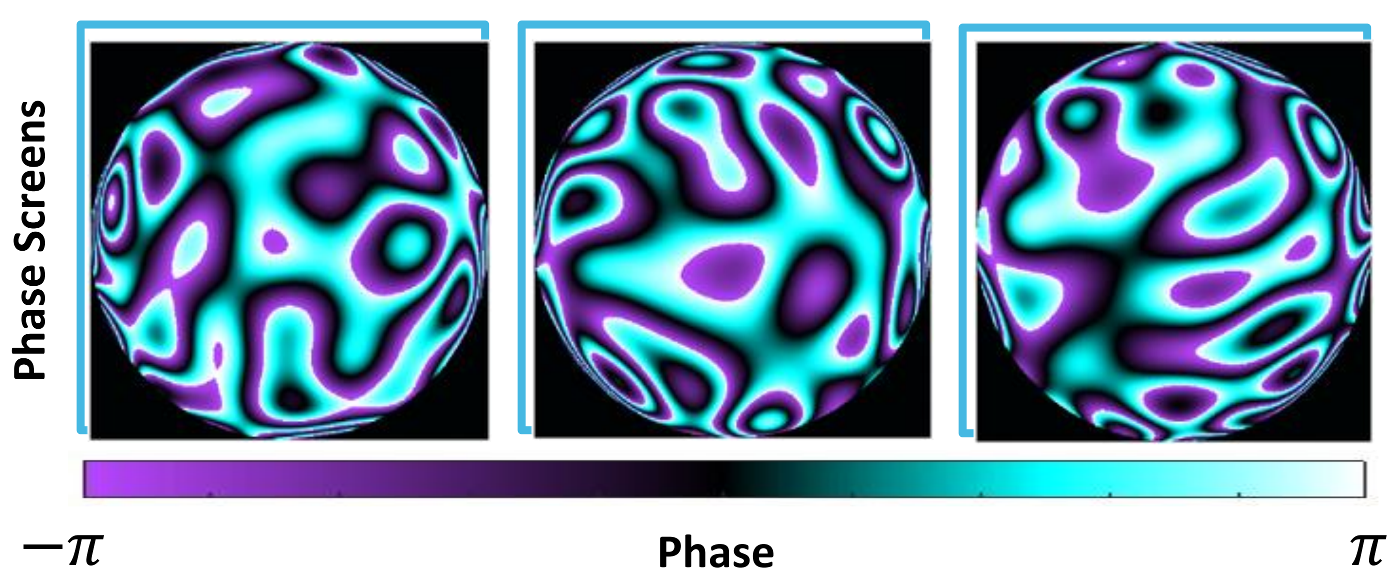
We can solve this problem using diffractive neural networks

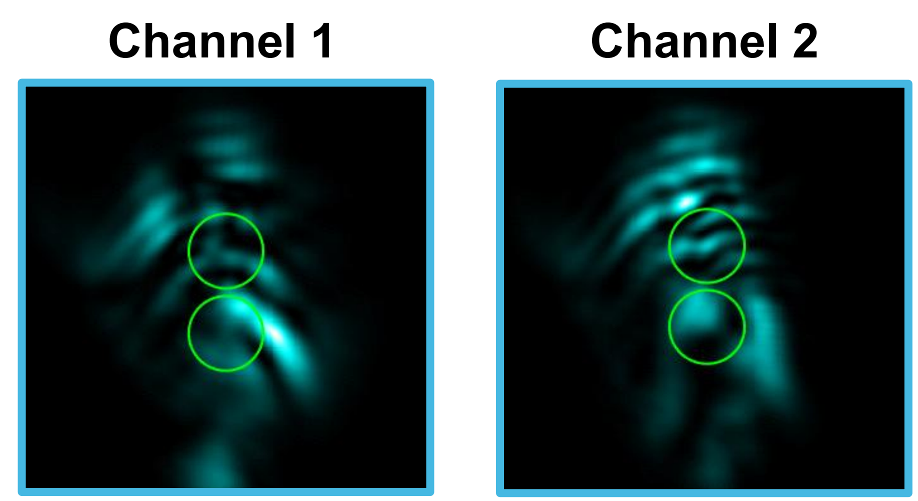


Weightings for the diffractive network are learned using a supervised learning procedure

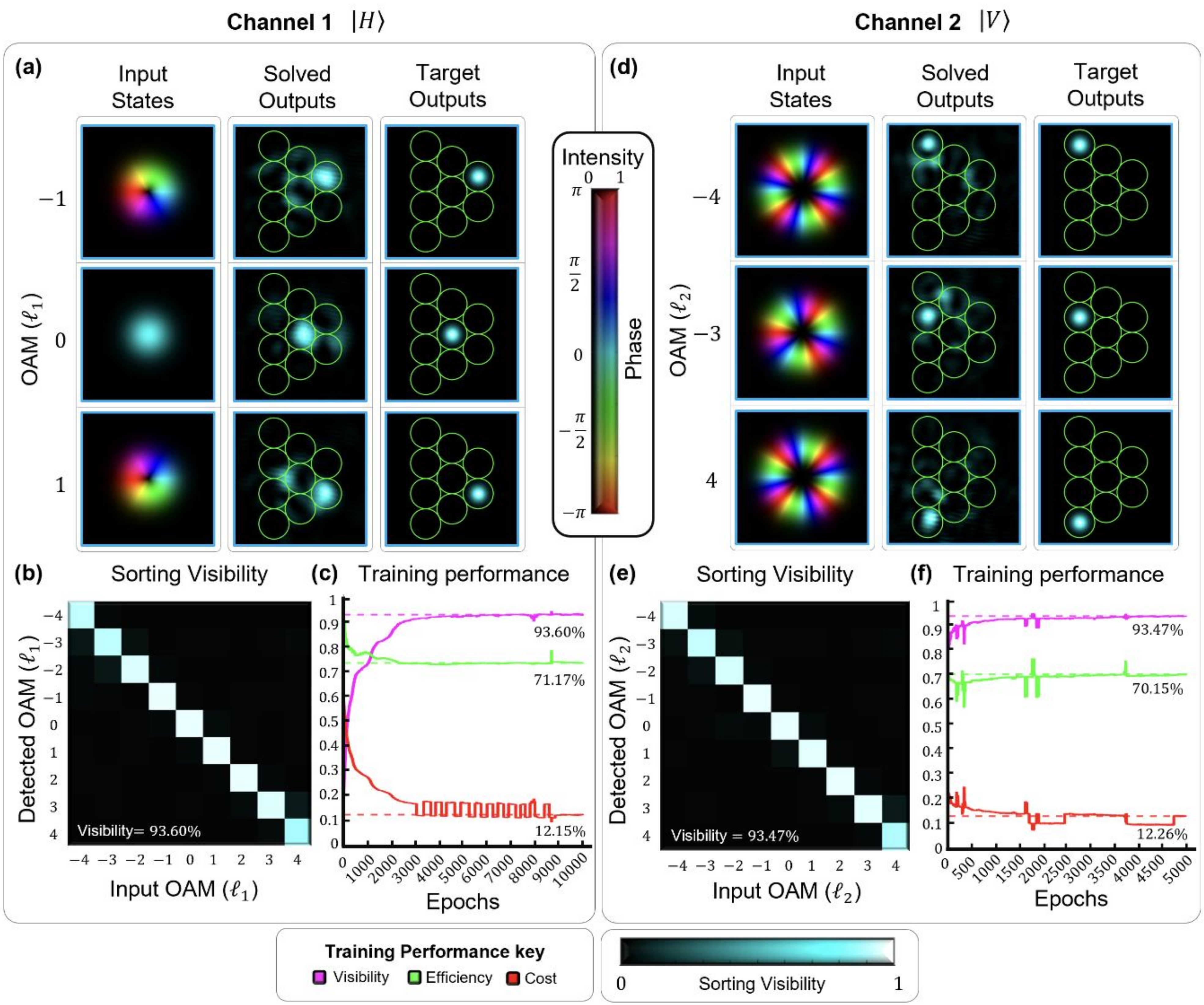




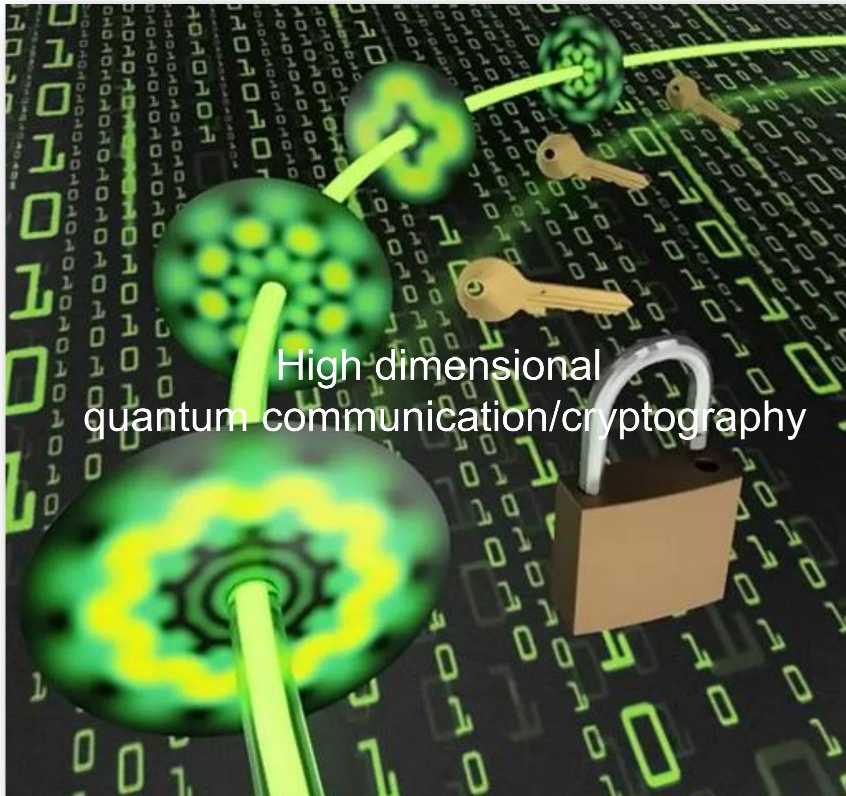


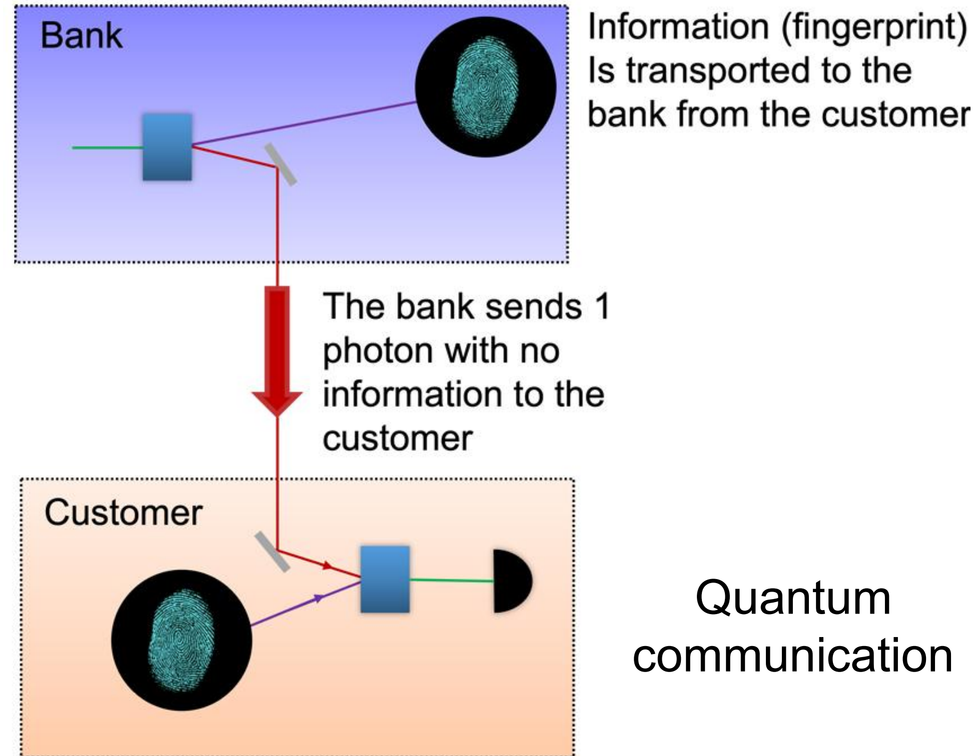


We can successfully detect 9 symbols using our diffractive network

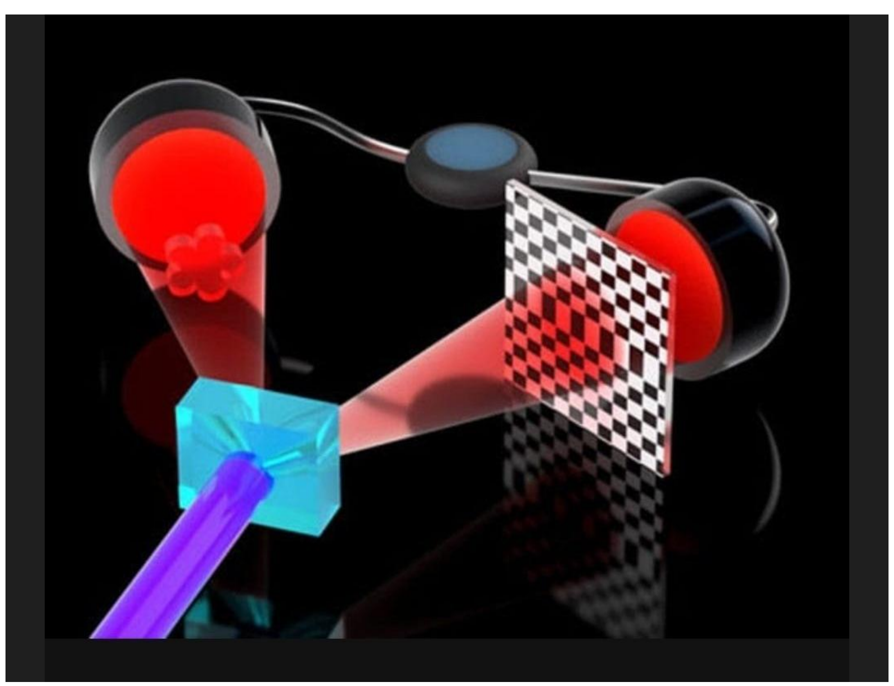


Many more applications to unlocking

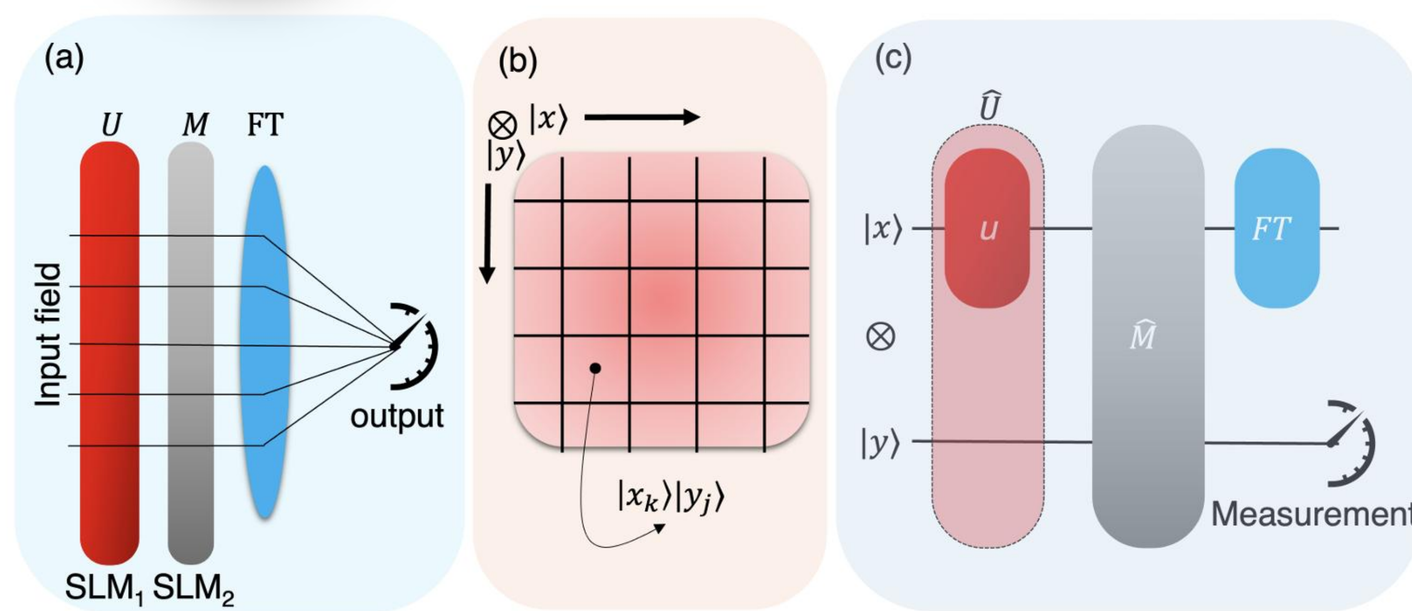




Quantum communication



Quantum sensing



Quantum computing

Structured Light Laboratory

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ASP isotopes

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