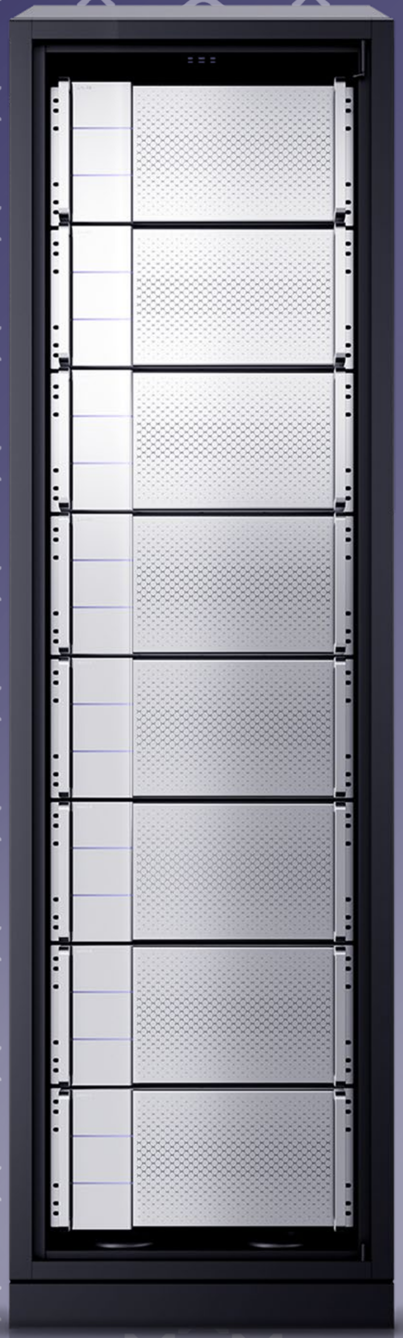
Putting Photons to Work

Yong Meng Sua
CTO
Quantum Computing Inc.

Optica 2024 Quantum Industry Summit



How we got here

CEO
William McGann, PhD

CQO
Prof. Yuping Huang

July 2022

Quantum Computing Inc

QPhoton Inc

Quantum Chemist, Business Leader

30+ years of pioneering innovation, productization, executive excellence

Co-founder Ion Track Instruments, sold the company for $1 billion USD
Co-inventor explosive material detection technique that has been used in every airport around the world the past 20+ years. 26 patents, 70+ publication
CTO Security, Detection & Automation of Leidos Corp, CTO of General Electric Security
VP of engineering for United Technologies Fire and Security,
CEO and board member of Implant Sciences Corp,
CTO at L3Harris Technologies, Security & Detection Systems Division

Quantum Physicist

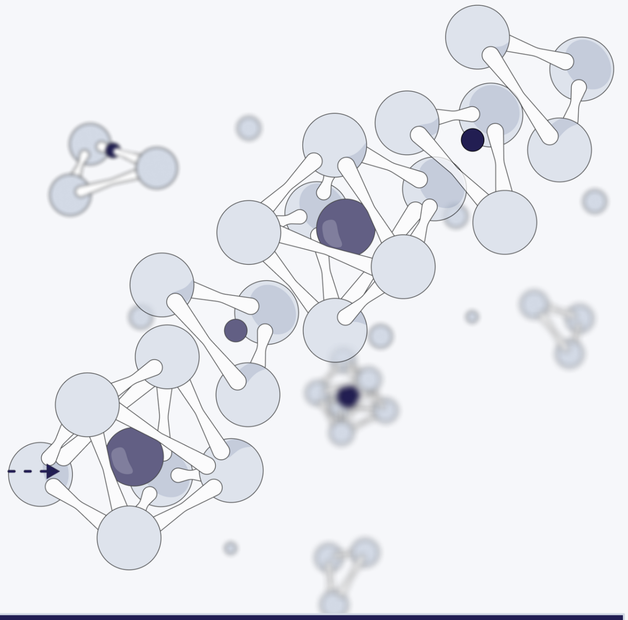
Proven track record of 20+ years leading research quantum technologies

CEO, Founder of QPhoton Inc
Gallaher Professor of Physics, Director of the CQSE, SIT
Edison Patent Award winner, NJ INNOVATE100 Leaders
Secured >$70 million USD funding from U.S Army & NSF
200+ publications, 10+ patents in quantum optics, information processing, nanophotonics, majority of works are core technology of QCi
Editorial Board of Scientific Report – Photonic, SPIE organizing & committee member, CLEO committee, National Science Foundation reviewer & panelist

QCi

Quantum machines for a brighter future

We leverage **light** and its **quantum mechanical properties** as a versatile tool that, when manipulated correctly, can be used as a component for many different applications.



At **Quantum Computing Inc.** (QCi), we are pioneering the production of photonic hardware solutions using non-linear quantum optics, enabling innovative solutions in the fields of quantum computing, machine learning, cybersecurity, and much more.

Quantum optics & Nanophotonics

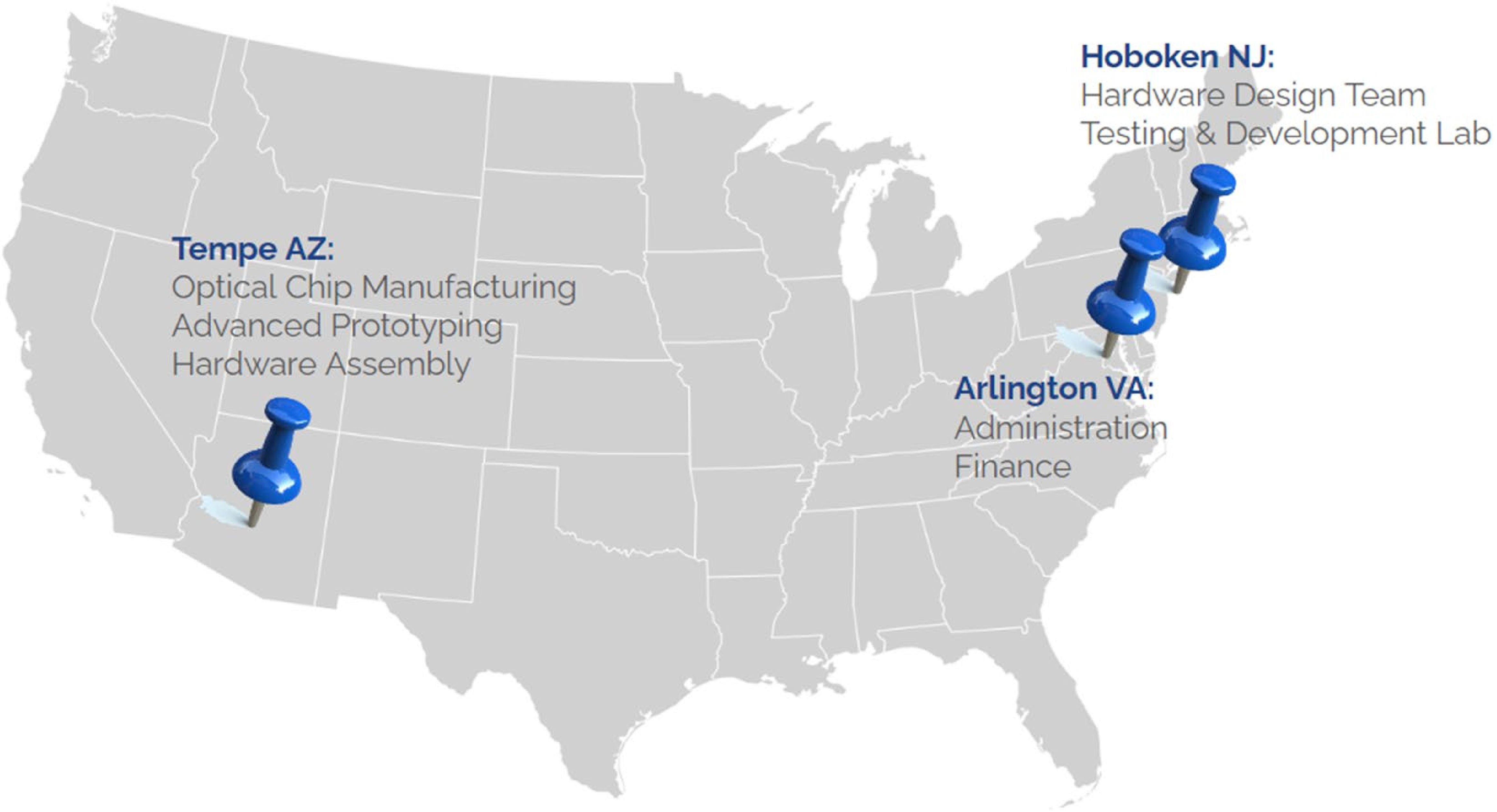
In four key application areas

1. **High Performance Computing**
2. **TFLN Integrated Photonics**
3. Cybersecurity and Communications
4. Imaging and Sensing

In house expertise

We have in suite expertise for all aspects of our technical stack, including:

1. Quantum physics
2. Optics
3. Hardware / Electrical Engineering
4. Nanofabrication
5. FPGA / Embedded Design
6. Mechanical Engineering / Product Design
7. Quantum Algorithm Development
8. Firmware and Software development


Hoboken NJ:
Hardware Design Team
Testing & Development Lab
Tempe AZ:
Optical Chip Manufacturing
Advanced Prototyping
Hardware Assembly
Arlington VA:
Administration
Finance

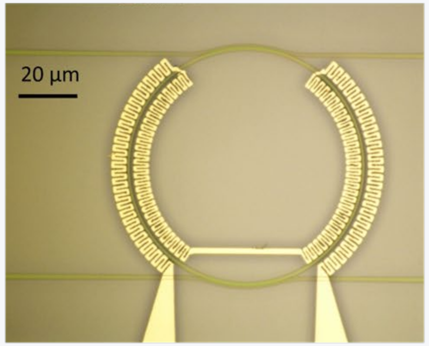
TFLN foundry

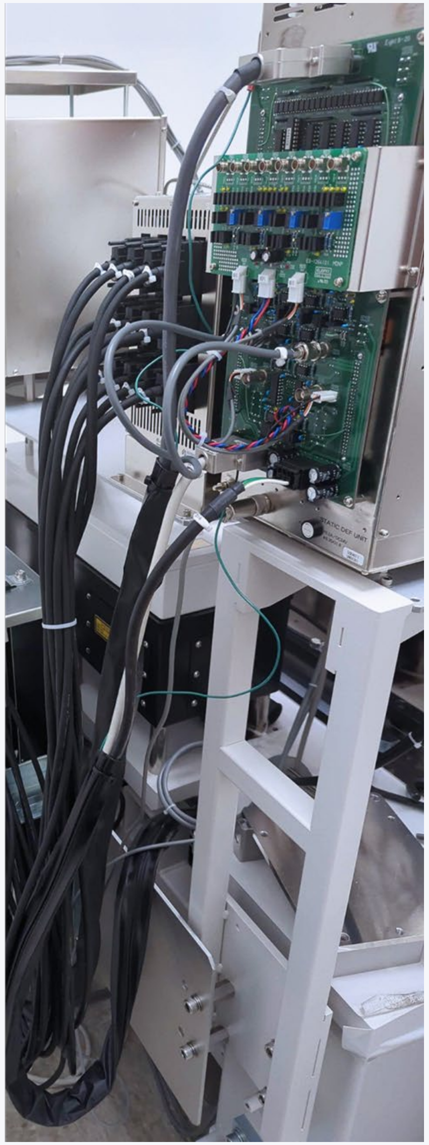
We are building a first of its kind fab devoted to processing thin film lithium niobate (TFLN) fabrication in Tempe, Arizona.

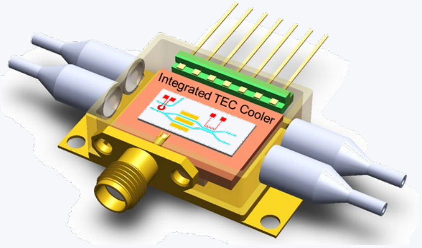
We will be producing:

- → **building block for Quantum Zeno-blockade**
- Electro Optical Modulators
- Periodically Poled waveguides and micro-rings for High Harmonic Generation
- Entangled photon sources, filters and more

Fab-1 Tempe AZ *(under construction, opening Q1 2025)*

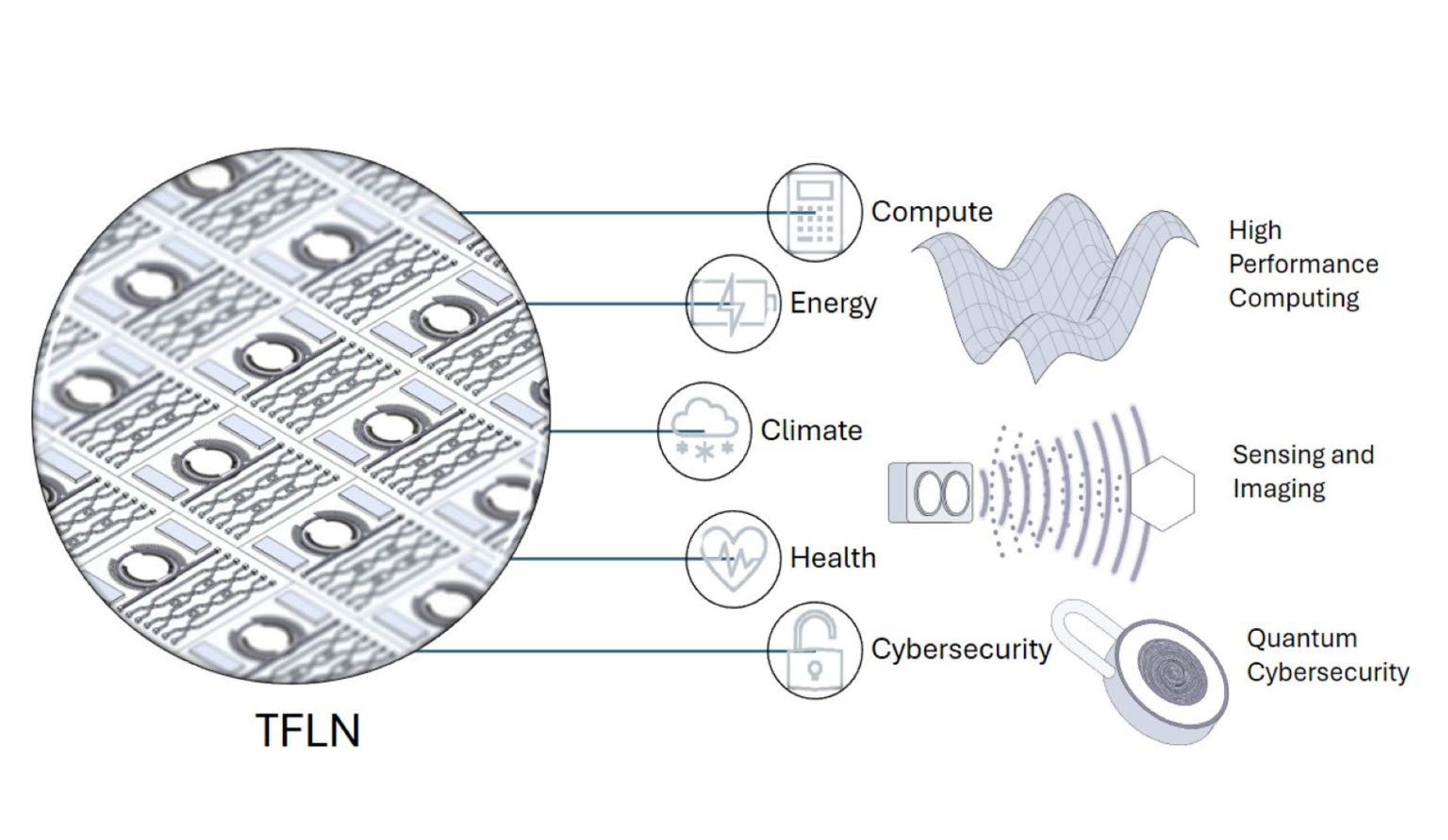






Enables scalable SWaP-C² quantum hardware

Why TFLN : Performance meets scalability

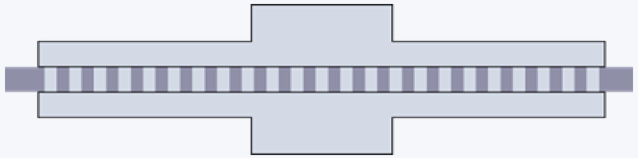


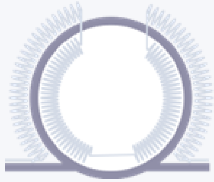
Linear-optics:
- Strong light confinement with low loss
- Capable of Dispersion engineering

Nonlinear-optics:
- Large nonlinear coefficient
- Capable of quasi-phase matching engineering

Electro-optics:
- Large EO coefficient
- 3dB Bandwidth >100GHz @ <1 V

Scalable & integration- complex functionalities
- Diverse photonic components
- Heterogeneous integration (Flip-bond with silicon ASIC)
- CMOS compatible voltage



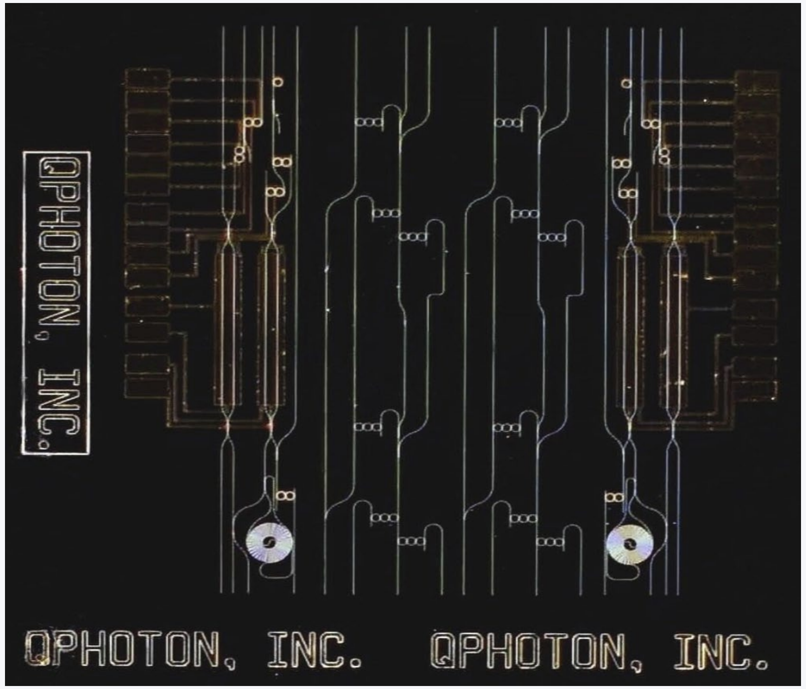


- Establish Quantum advantages for solving critical problems
- Realize Quantum Practicality - enabling technological and cost readiness

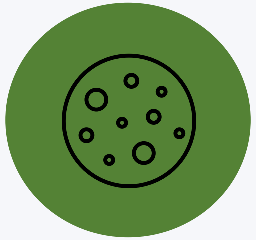
Quantum practicality

With TFLN integrated photonics

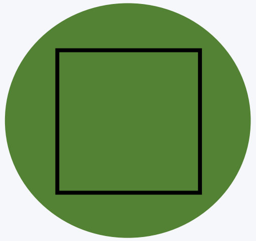
- **Single photon nonlinearity**-enable **deterministic entanglement and cnot gates**, building blocks for quantum computation and quantum communication
- **Scalable & integration**- dense and complex photonics functionalities
- **CMOS compatible**-direct optoelectronic integration of active components



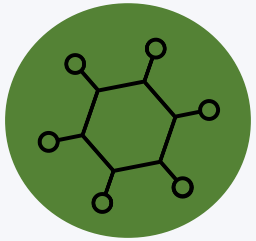
Room temperature



Open quantum system



Decoherence Free Subspace



SWAP-C

High performance computing

Entropy quantum computer

Entropy Quantum Computing

Quantum hardware for non-convex optimization

Dirac-1: Optical Ising Machine
Binary Optimization Solver
11000 quantum modes (qubits)
Uses weak coherent states and time domain encoding for computation

Dirac-2: Optical Potts Machine
Integer Optimization Solver
1000 64-state quantum modes (qudits)

Dirac-3: Optical Potts Machine (forthcoming)
Integer Optimization Solver
10000+ 200-state qudits
Many Body Interactions

Reservoir Computing

Photonic analog computer for directed AI

Photonic Reservoir Computer
AI / ML hardware with significant energy reduction
Uses feed forward algorithms
Designed for Time Series Problems
Excels at classification tasks

FPGA-Based Emulator of the Photonic Reservoir
Low-Cost emulator of the optical machine
Capable of Edge Computing
Ideal for rapid prototyping and algorithm development

Cybersecurity

Learn more on our website [here](#)
or the QR code below

Quantum Authentication

QAP-0 is a quantum cryptographic protocol for verifying information without revealing the secret information itself.

The protocol works by distributing two photons that are produced at specific wavelengths. When they are measured they will both collapse into specific measurement bases either in time or frequency domain. Measurements will occur in one of several bases repeatedly until the approver is either able to verify the secret information or rejects that the secret is correct.

Quantum Random Number Generation

We generate genuine random numbers by measuring the arrival time of single photons. Single photons derived from a coherent source are in superposition over all possible temporal modes, which collapses into a single time bin when measured using a single photon detector. We exploit this innate phenomenon of quantum mechanics to generate uniformly distributed random numbers.

Remote Sensing & Single Photon Imaging

Vibrometer

Single and few photon remote sensing:

Key Innovation: the ability to project spatial quantum states of single photons onto coherent modes

Ideal for: Vibrometry, detecting changes in position, measuring surface topology and mechanical structure (demonstrated 100nm vibrational amplitude resolution)

High Speed (up to 20 MHz single photon count rates)

Long Range (tested up to 10m)

Capable of penetrating 70+ cm into soil

Single photon imaging system:

Capable of Deep Tissue Imaging

Uses eye-safe IR light

Chemical (Raman) specificity for molecular identification

QCi approach to quantum computing hardware

Summary

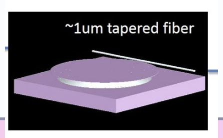
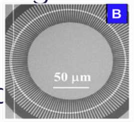
Entropy computing approach - open quantum systems for both

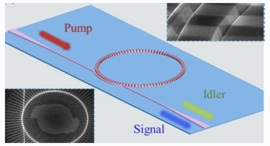
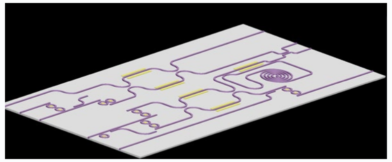
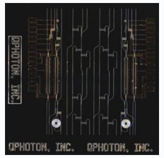
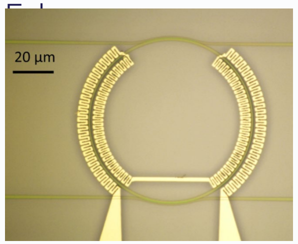
Gate-based quantum computers **(in progress)**

Analog-based quantum optimization machine - Dirac 3 **(available today)**

Proven track record: block by block to large-scale integrated nonlinear photonic quantum computing

Gate-based: single photon nonlinearity

2008	2010	2011	2013	2017	2019
Theory of quantum Zeno gates	Theory of all-optical switching via quantum Zeno effect	Theory of quantum optical Fredkin gates in χ^2 microdisk	Experiment realization all optical switching via quantum Zeno effect and quantum optical Fredkin gates	Observation of Quantum Zeno Blockade on Chip 	Ultra-efficient frequency conversion in quasi-phase-matched lithium niobate microrings   High extinction ratio electro-optic mod on lithium niobate thin film
Theory development using open quantum system approach to create decoherence free subspace			Building block realized on optical table	Building block realized on chip	Achieved **23X state-of-the-art on-chip** nonlinearity

2020	2021-2022	2023-2024
Ultra-bright Quantum Photon Sources on Chip  Achieved **orders of magnitude improvement on photon pairs generation rate**	  Patent granted, small scale integrated chip	Dedicated TFLN 

QCi patent, Devices and methods for giant single-photon nonlinearities, https://patents.google.com/patent/US11754908B2/en
Z Li, et al, Invertible all-optical logic gate on chip, Optics Letters 49 (12), (2024)
Z Li, et al, Parametric all-optical modulation on a chip, Physical Review Applied 21 (6), (2024)
Huang, Yu-Ping, et al. "Interaction-and measurement-free quantum Zeno gates for universal computation with single-atom and single-photon qubits." Physical Review A (2008)
Huang, Yu-Ping, et al. "Interaction-free all-optical switching via the quantum Zeno effect." Physical Review A 82, no. 6 (2010)
Huang, Yu-Ping, et al. "Interaction-Free Quantum Optical Fredkin Gates in "χ^2 Microdisks." IEEE Journal of Selected Topics in Quantum Electronics 18, no. 2 (2011)
McCusker, Kevin et al . "Experimental demonstration of interaction-free all-optical switching via the quantum Zeno effect." Physical review letters 110, no. 24 (2013)
Sun, Yu-Zhu et al, "Photonic nonlinearities via quantum zeno blockade." Physical review letters 110, no. 22 (2013)
Chen, Jia-Yang, et al. "Observation of quantum zeno blockade on chip." Scientific reports 7, no. 1 (2017)
Jin, Mingwei, et al. "High-extinction electro-optic modulation on lithium niobate thin film." Optics letters 44, no. 5 (2019)
Chen, Jia-Yang, et al. "Efficient quasi-phase-matched frequency conversion in a lithium niobate racetrack micro-resonator." Coherence and Quantum Optics, Optica Publishing Group, (2019)

Entropy Quantum Optimization Machine

Advantages
a. Data security and privacy
b. Eliminate latency from upload/download
c. Not more maintenance than regular server
d. Free firmware upgrades
e. Free on-prem installation and training

On prem starting $300,000 USD/unit

(Leasing/Buying dedicated unit on QCi server options available)

Dirac-3

Hybrid Quantum Optimization Machine

Qudit – Integer and Continuous Variables Optimization

954 number of variables maximum (customized more if needed)

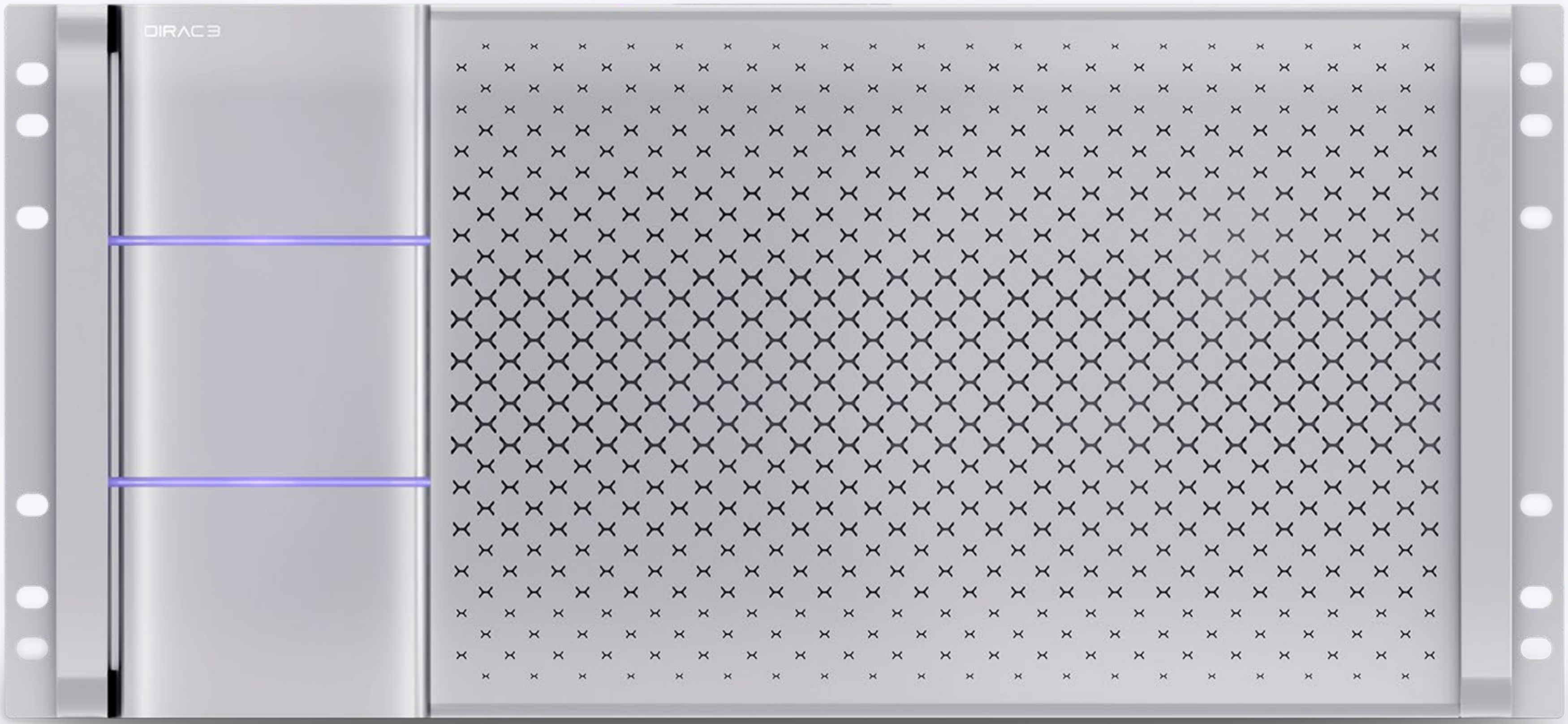
All-to-all connectivity

Any types of second-order up to fifth order of correlations

Less than 100 W power consumption

25 ˚C / 77 ˚F operating temperature

5U rack-mountable unit
Connect via Ethernet gRPC



Thank you

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