IOTWeek

Dublin —— June 20-23, 2022

Quantum Technologies: trends & impact

Laure Le Bars
SAP - Research project Director
QuIC - President
DAIRO – Vice-President

GLOBAL VISION:
IoT TODAY AND BEYOND

IOTForum

Quantum technologies: trends & impact

IOTWeek Dublin —— June 20-23, 2022

- Quantum Technologies: what & why — Deirdre Kilbane
- Research to innovation
  - Quantum photonics & Quantum sensors — Ortwin Hess
  - Integrated photonics for QT — Peter O’Brien
  - Quantum Communication — Deirdre Kilbane
- Ecosystem
  - Equal1 — Jason Lynch
- Roadmap, trends, challenges

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Quantum Technologies: what & why

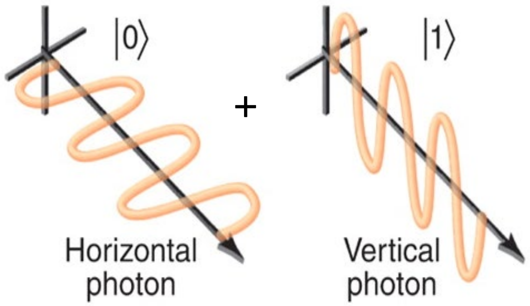
Dr. Deirdre Kilbane
Director of Research
Walton Institute
South East Technological University, Ireland

Quantum Technologies: What?

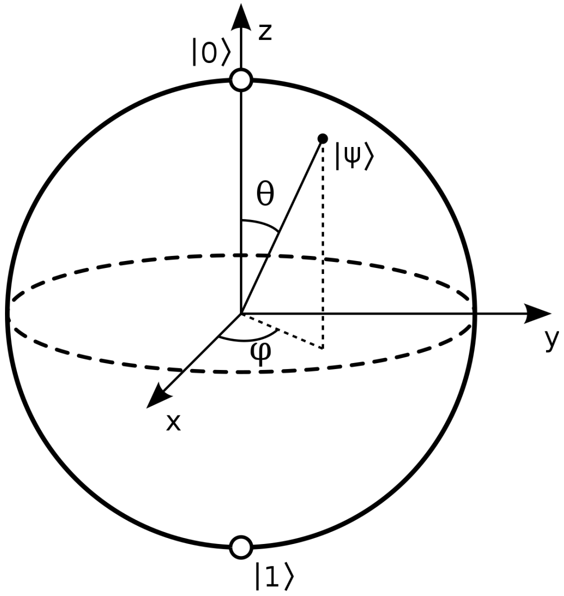
Quantum Mechanics

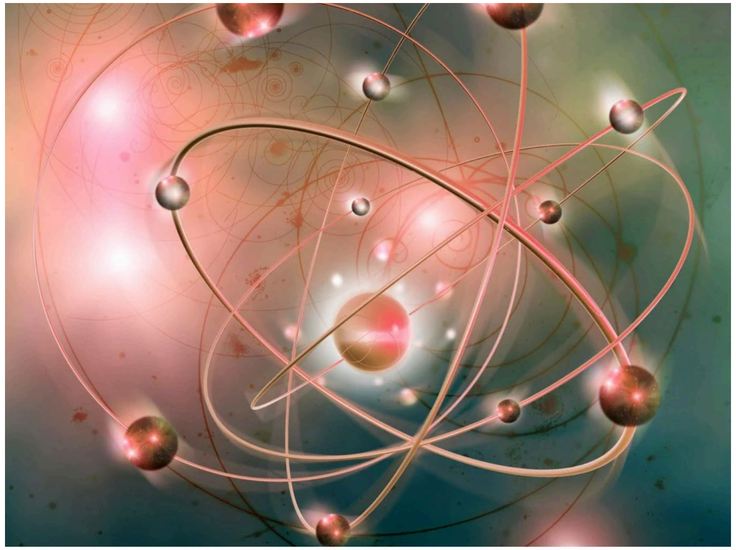
Qubit is a quantum two-state system e.g. photon polarization

Superposition objects exist in many states at the same time



$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle, \quad |\alpha|^2 + |\beta|^2 = 1$$

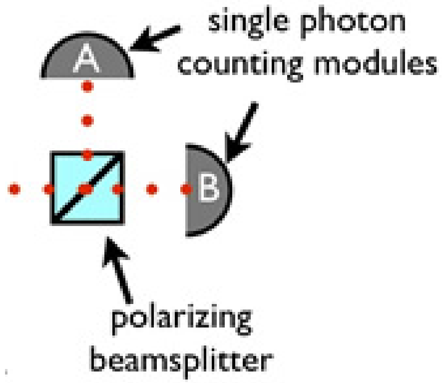


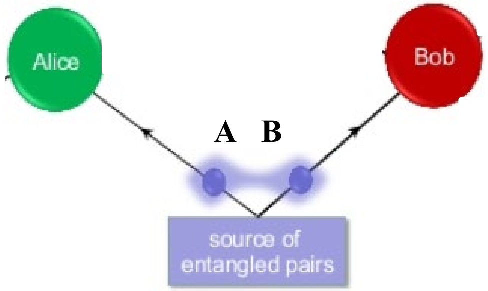


Quantum Technologies: What?

Measurement if you observe a qubit, it collapses into one of the two states $|0\rangle$ or $|1\rangle$ with the outcome a 0 or 1 classical bit

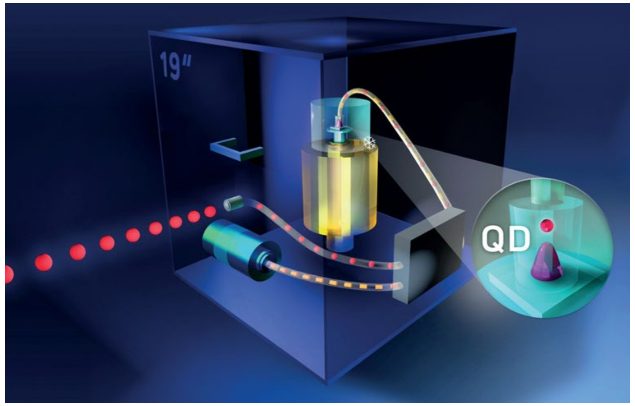
Entanglement measuring the state of one qubit influences the state of the other qubit



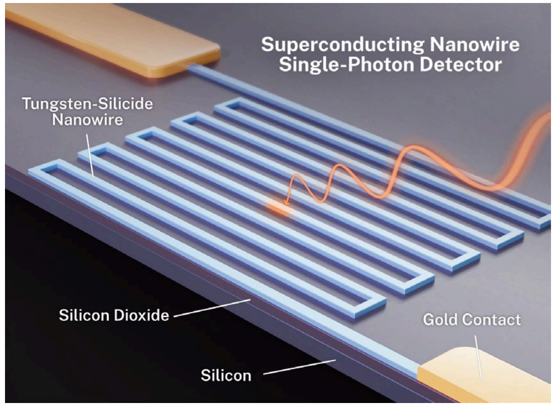


Quantum Devices

Single photon sources
Entangled photon pair sources
Single photon detectors



Musiał Adv. Quantum Technol. 3 2000018 (2020)



Kelley NIST(2021)

Quantum Technologies: Why?

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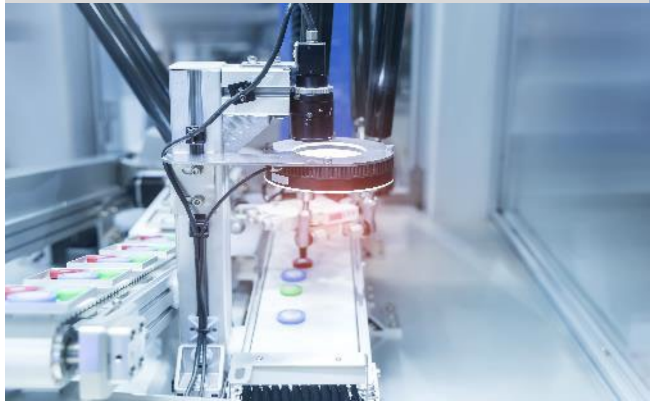
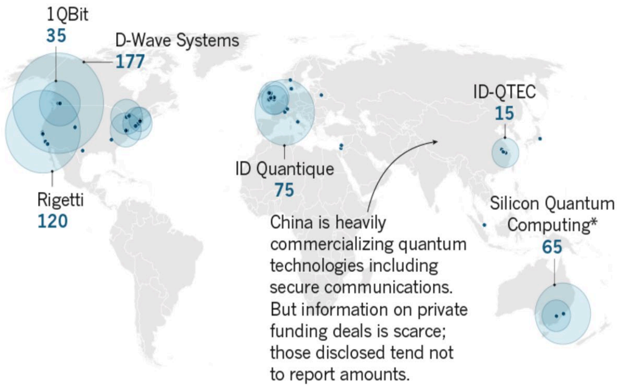
Quantum Computing	Quantum Communications	Quantum Sensing & Metrology
		

Investment

- Global effort $24.4 Bn
- China $10 Bn
- US $1.2 Bn
- Germany $3.1 Bn
- France $2.2 Bn
- EU Quantum Flagship $1.1 Bn

QUERCA Ltd. (2021)

LOCATION OF INVESTMENTS 2012–18
(US$, millions)



Gibney Nature 574 22 (2019)

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QuIC:
European Quantum Industry Consortium

Europe: a fertile quantum ecosystem

Long and decorated history in quantum research.

Wide network of world-leading universities & research organisations.

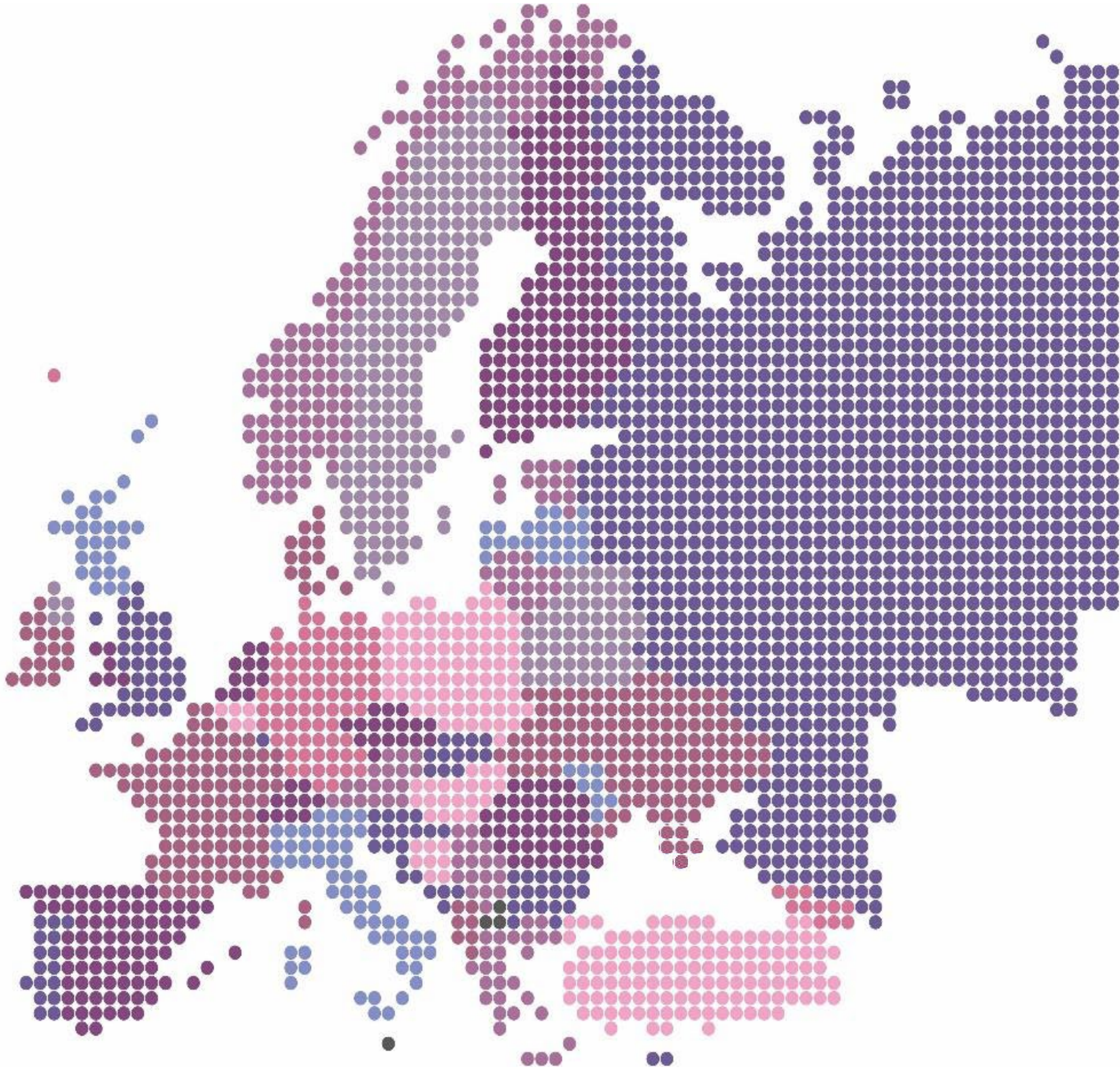
Skills, know-how: a diverse & qualified workforce.

Broad & reliable industrial base of enabling tech.

Strong and committed government support for the European quantum industry.

Leading standardisation organisations and a demonstrated committed to quality technology.

QuIC: the integration of these key ingredients to achieve the maximum commercial success of the pan-European quantum Industry



QuIC in brief

Non-for-profit **association** established in 2021 by several major business actors – large enterprises, SMEs, startups, investors – from across Europe.

QuIC is the voice of the European Quantum Technology (QT) industry

Our aim is to enhance the **pan-European industry competitiveness** in quantum technologies on the global scale.

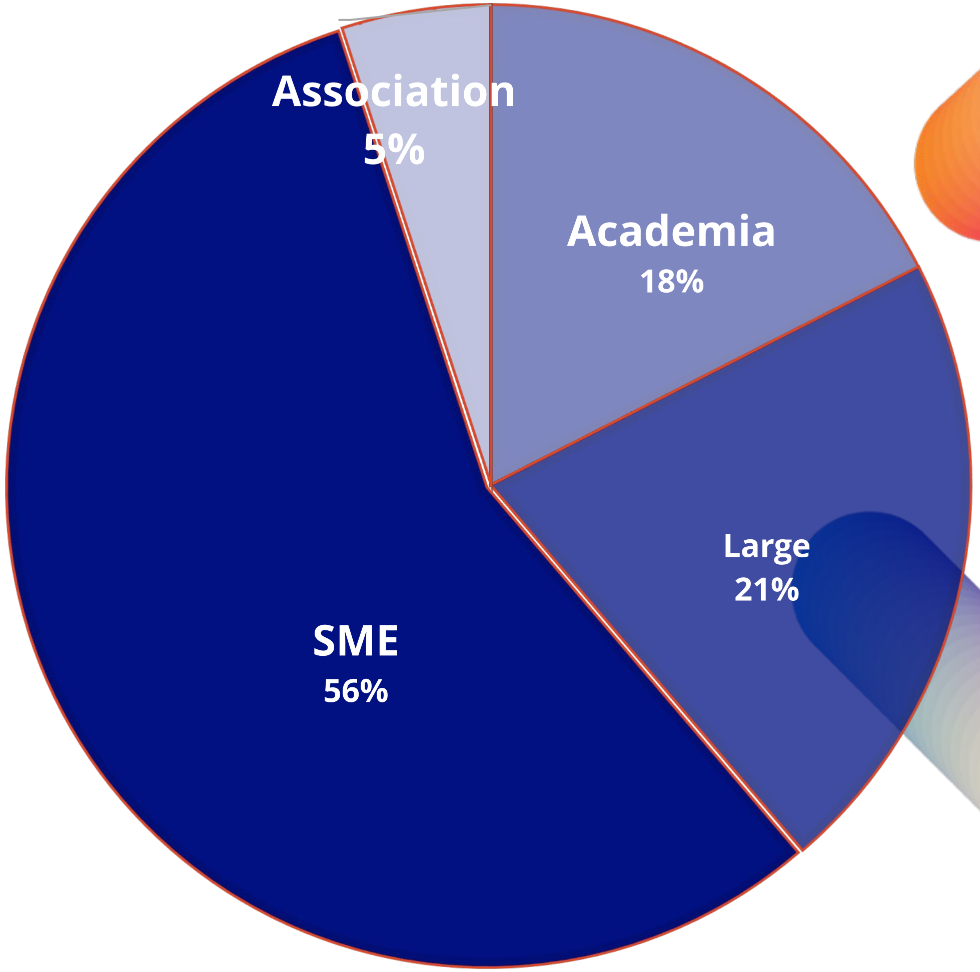
QuIC operates as a **collaborative hub** throughout Europe to build a strong, vibrant ecosystem between SMEs, large corporations, investors, and leading researchers.

QuIC
European Quantum Industry Consortium

QuIC members

Member type	Full	Associate	Total
Large Enterprise	24	10	34
SME	65	25	90
Academic Research, RTO		28	28
Association		8	8
Total	**89**	**71**	**160**

(Members as of 31 May 2022)



QuIC European Quantum Industry Consortium

QuIC Work Groups

WG - MTU: Market Trends & Use Cases

WG - SIR: Strategic Industry Roadmap

WG - MTI: Market & Technology Intelligence

Quantum Computing & Simulation

Quantum Communi-cation

Quantum Sensing & Metrology

Enabling Technologies

WG - IPT: Intellectual Property & Trade

WG - ST: Standards

WG - EDU: Education

WG - ECO: QT Ecosystem

WG - SF: SME & Funding

WG - NC: National Chapters

QuIC - benefits for members

Part of the largest and most influential industry voice on quantum technologies in Europe

Influencing the Strategic Industry Roadmap on quantum technologies

Informing policies and strategic orientations of European countries in the area of quantum technologies

Networking and partnering with industrial and research partners in the pan-European QT Value Chain

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Quantum Technologies

Research & innovation

Quantum Research:
Nanoplasmonics as Enabler of Quantum Photonics and Quantum Sensing at Room Temperature

Ortwin Hess

School of Physics and CRANN Institute
Trinity College Dublin
Dublin 2, Ireland

Science Foundation Ireland sfi For what's next

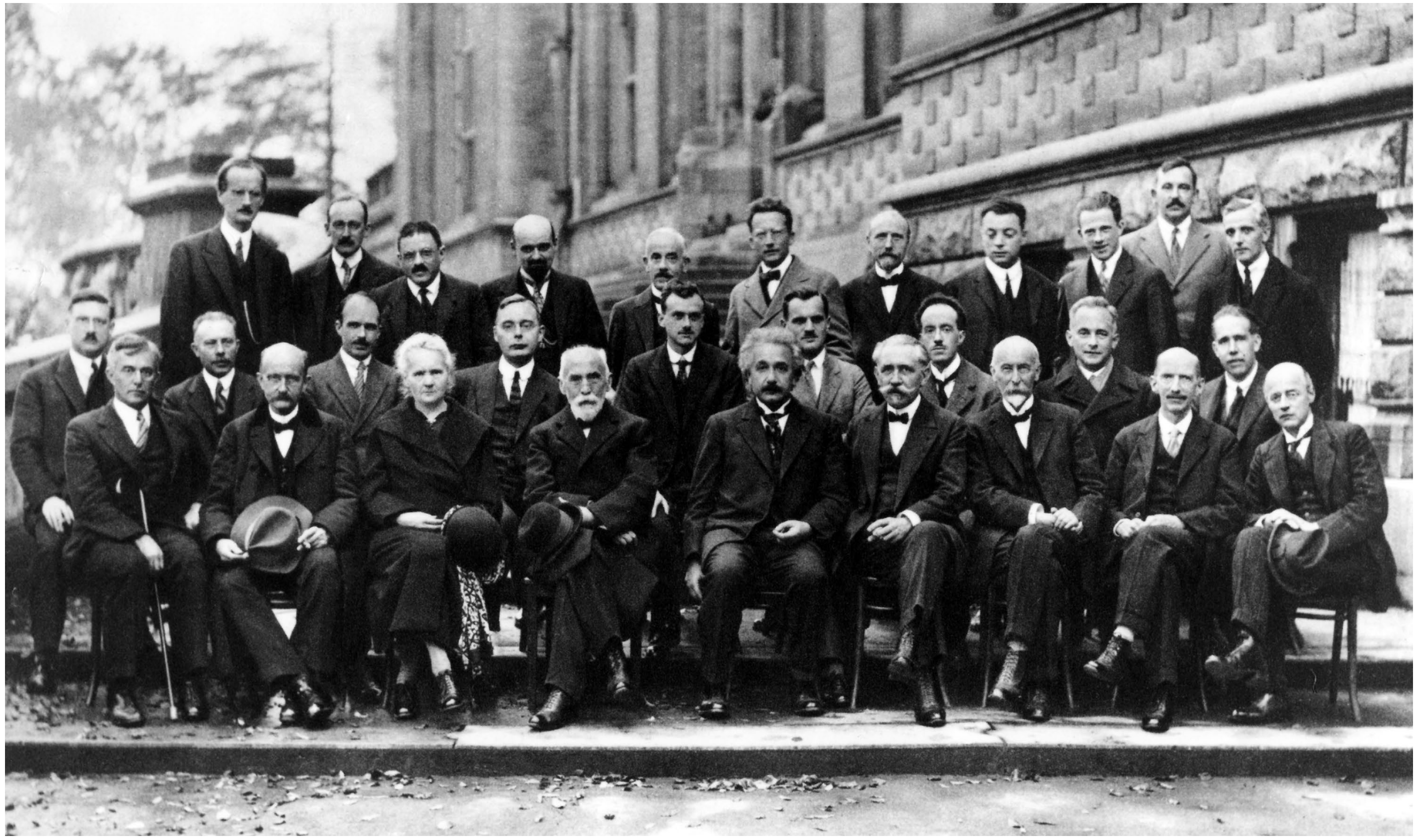
The Blackett Laboratory
Imperial College London
London, UK

EPSRC Pioneering research and skills

https://www.tcd.ie/Physics/research/groups/quantum-nanophotonics/

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

Quantum Physics
Solvey Conference on Electrons and Photons (1927)



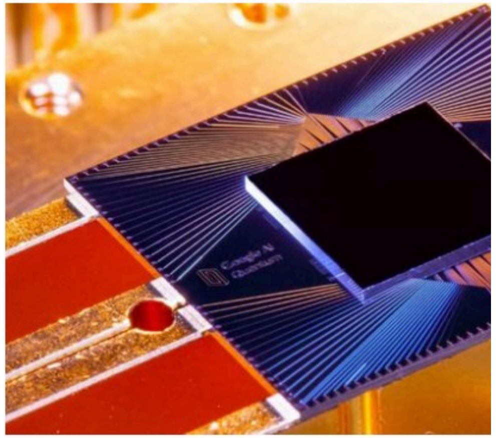
[Wikipedia]

Quantum Technologies
Quantum Computing

Google claims 'quantum su computer

By Paul Rincon
Science editor, BBC News website

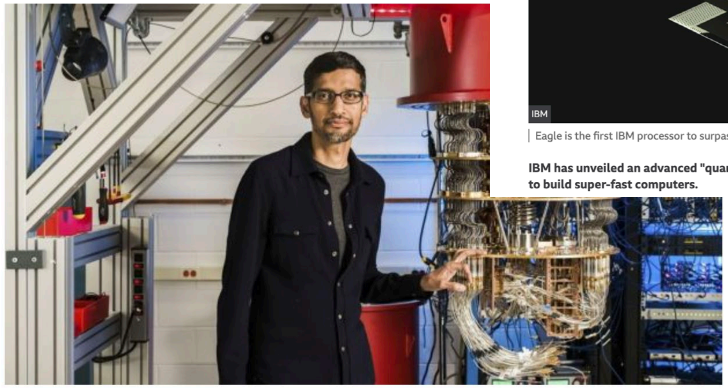
23 October 2019



Google unveils computer wit supremacy', rivals say wait a

Tech giant flags advancements in AI, chemistry

Wed, Oct 23, 2019, 20:49

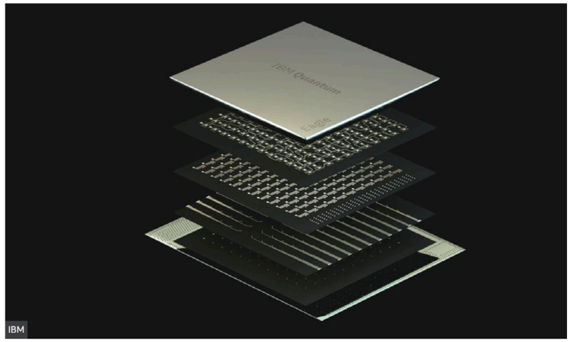


Google chief executive Sundar Pichai with one of the company's quantum computers. Photograph: AFP (from Google handout)

IBM claims advance in quantum computing

By Paul Rincon
Science editor, BBC News website

17 November



Eagle is the first IBM processor to surpass 100 qubits

IBM has unveiled an advanced "quantum" processor that is part of an effort to build super-fast computers.

Physical Realizations of Qubits

Quantum system	**Physical property**	**|0>**	**|1>**
Nucleus	Spin	Up	Down
Electron	Spin	Up	Down
Two-level system	Excitation state	Ground state	Excited state
Photon	Linear polarization	Horizontal	Vertical
Photon	Circular polarization	Left	Right
Josephson junction	**Electric charge ('transmon')**	**N Cooper pairs**	**N+1 Cooper pairs**
Superconducting loop	Magnetic flux	Up	Down

Physical Realizations of Qubits

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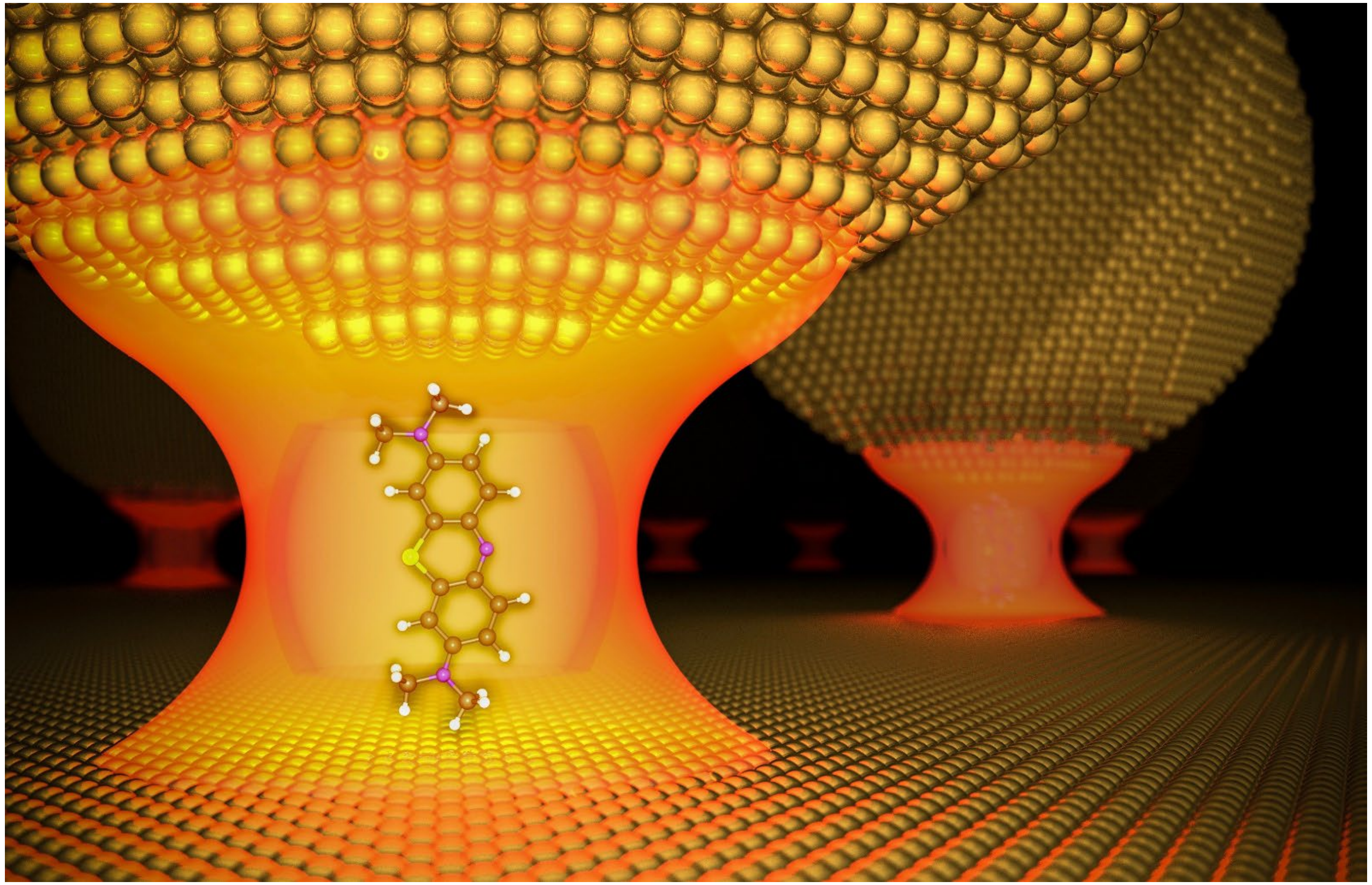
Quantum Nanophotonics

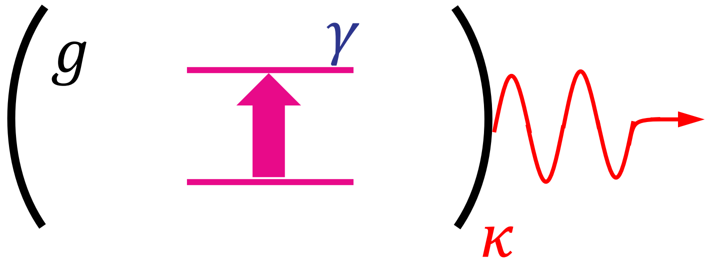
Single-Molecule Strong Coupling at Room-Temperature



R Chikkaraddi, … O Hess, JJ Baumberg, *Nature* **535**, 127 (2016)

Strong Coupling
Cavities

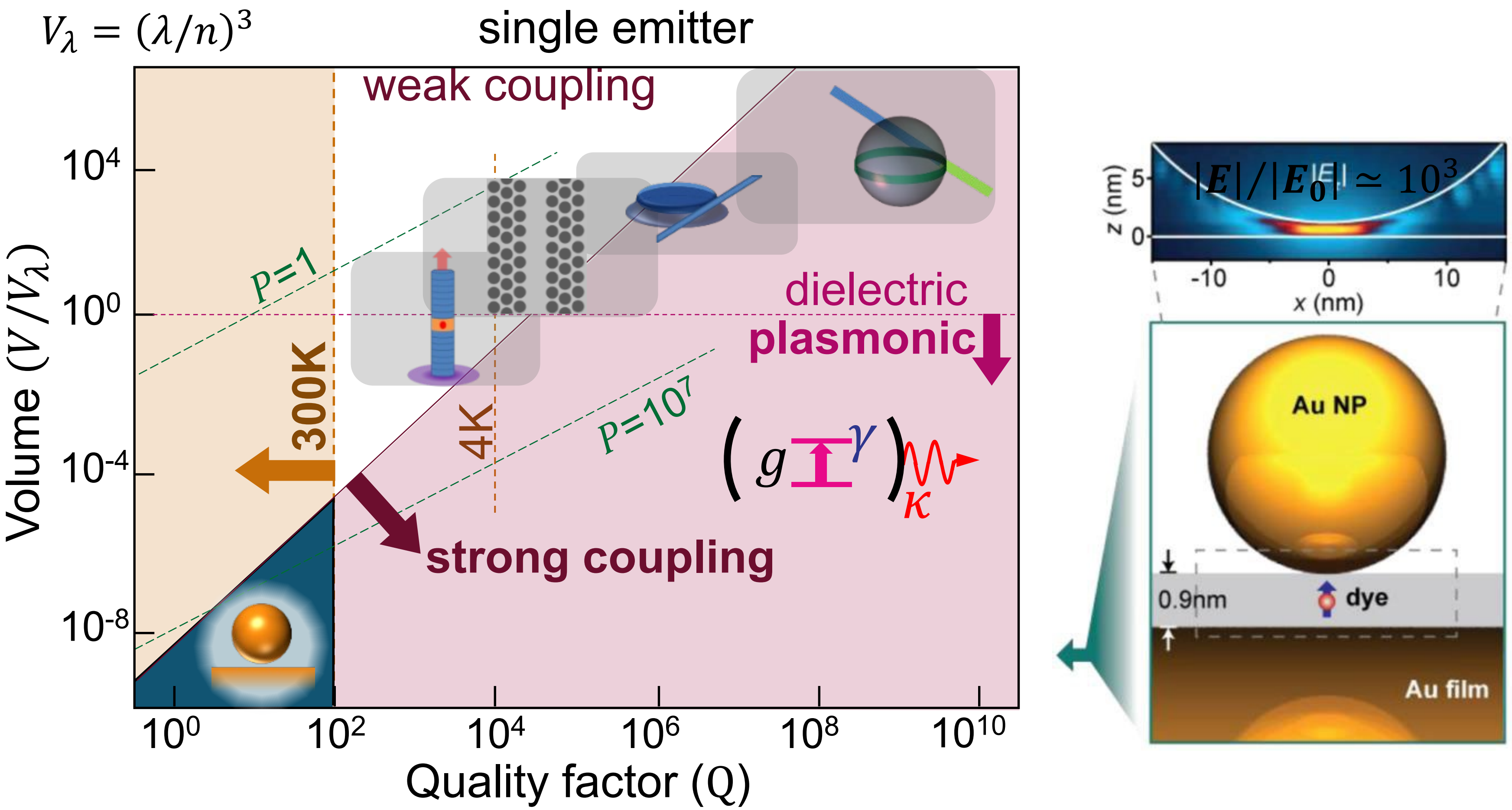
$$g > \gamma, \kappa$$



$$\kappa \propto 1/Q$$

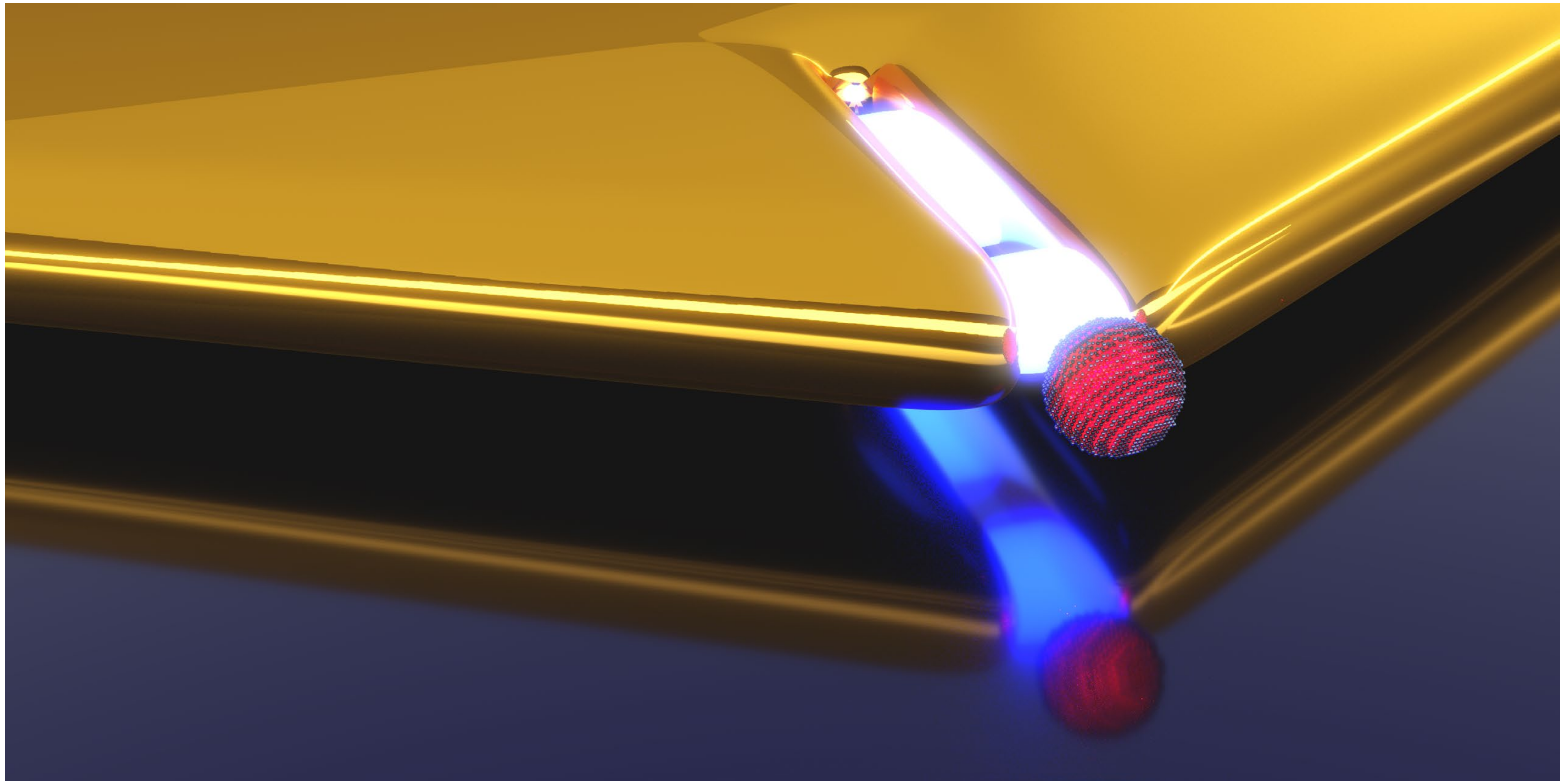
$$g \propto 1/\sqrt{V}$$

Strong Coupling
Cavities



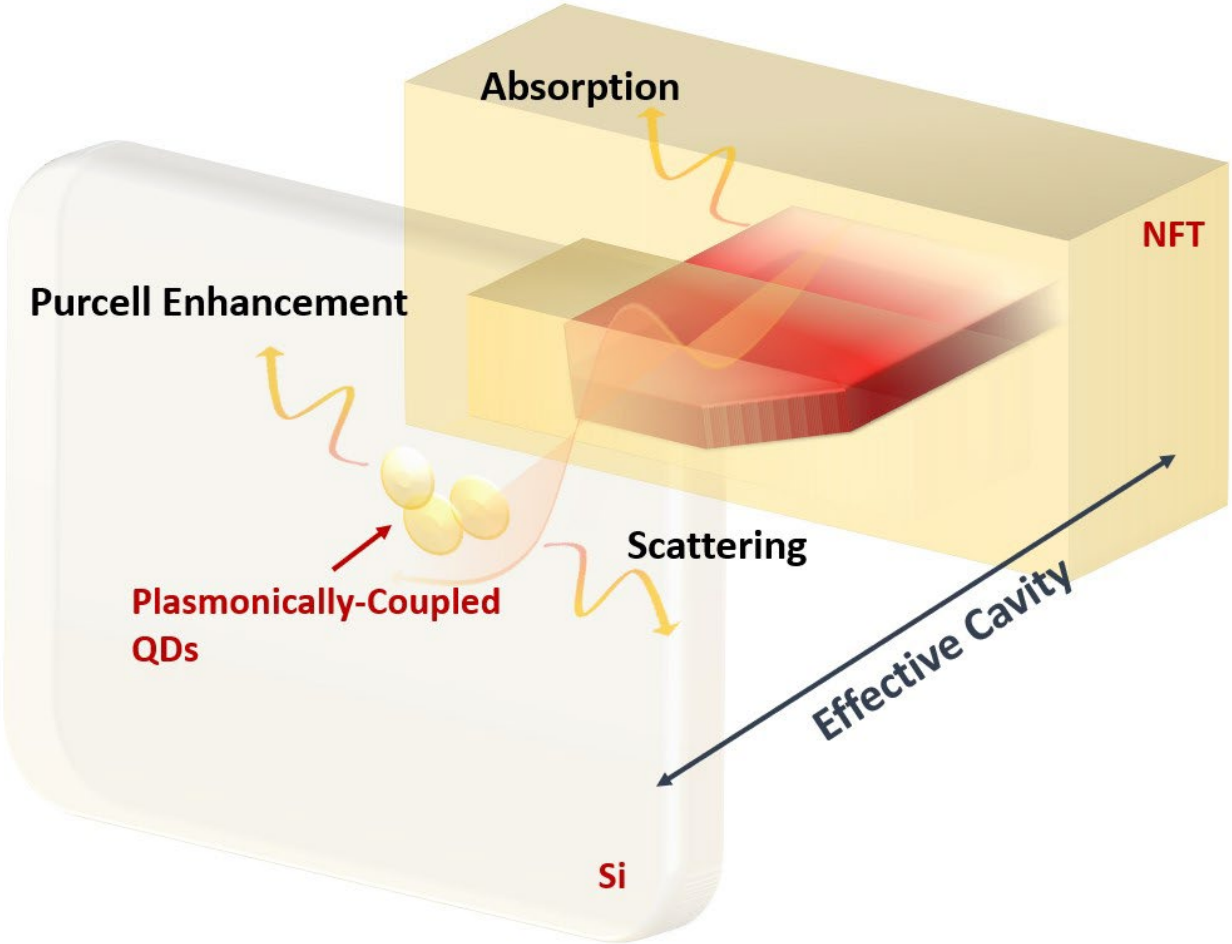
Near-Field Strong Coupling
Quantum Dot Emitters

Prof Ortwin Hess (ortwin.hess@tcd.ie)



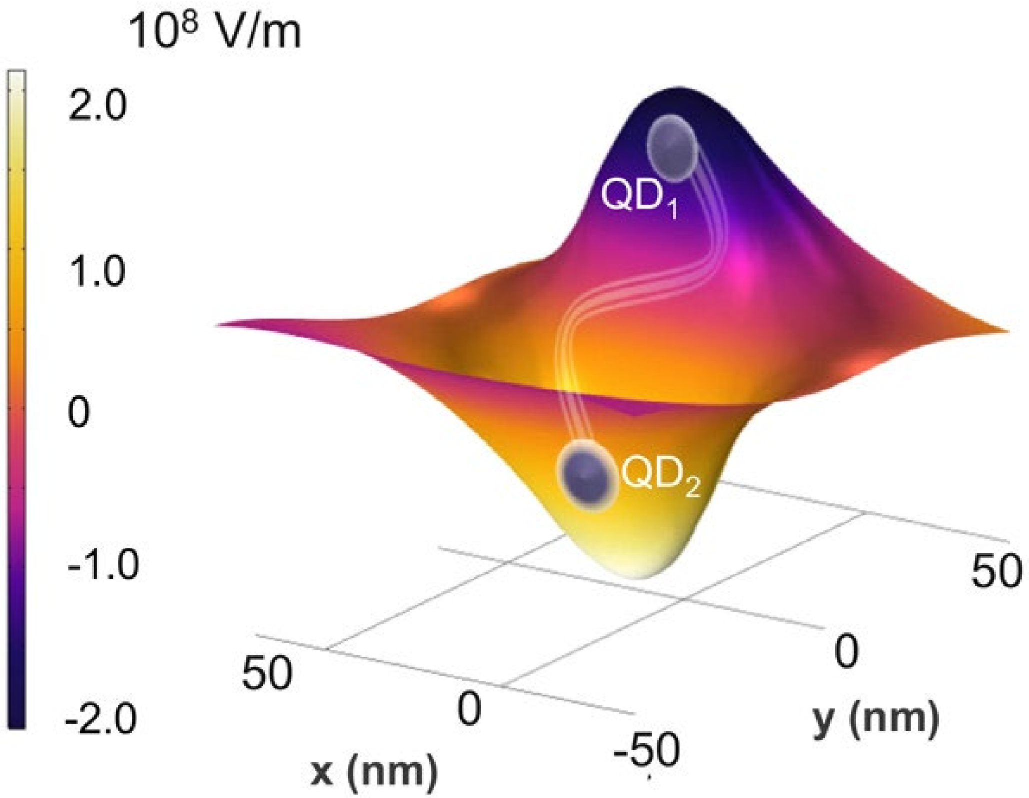
H Groß, JM Hamm, T Tuffarelli, O Hess and B Hecht, *Science Adv.* 2018;4:eaar4906 (2018)

Nanoplasmonic Quantum Networks
Ultrafast Multipartite Quantum Entanglement



F Bello, N Kongsuwan, and O Hess,
Nano Letters **22**, 2801 (2022)

Near-Field Strong Coupling
Ultrafast Dynamic Bi-Partite Entanglement



F Bello, N Kongsuwan, JF Donegan and O Hess,
Nano Letters **20**, 5830 (2020)

Nanoplasmonic Quantum Networks
Ultrafast Multipartite Quantum Entanglement

Prof Ortwin Hess (ortwin.hess@tcd.ie)

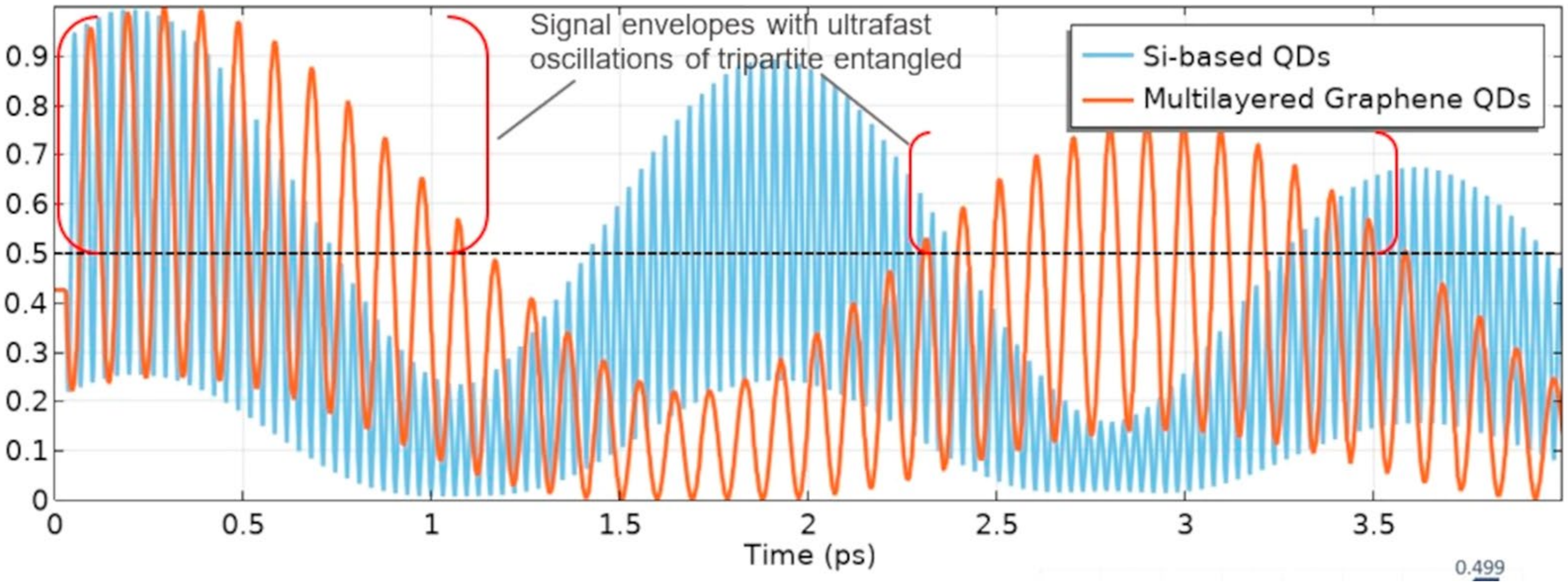
F Bello, N Kongsuwan, and O Hess,
Nano Letters **22**, 2801 (2022)

Ultrafast Multipartite Quantum Entanglement

Fidelity of Greenberger-Horn-Zeilinger (GHZ) State

For three quantum emitters:
Greenberger-Horne-Zeilinger (GHZ_3) state: $(|000\rangle + |111\rangle)/\sqrt{2}$

Fidelity: $\frac{1}{2}(\rho_{11} + \rho_{88} + C)$ with $C = 2|\rho_{18}|$

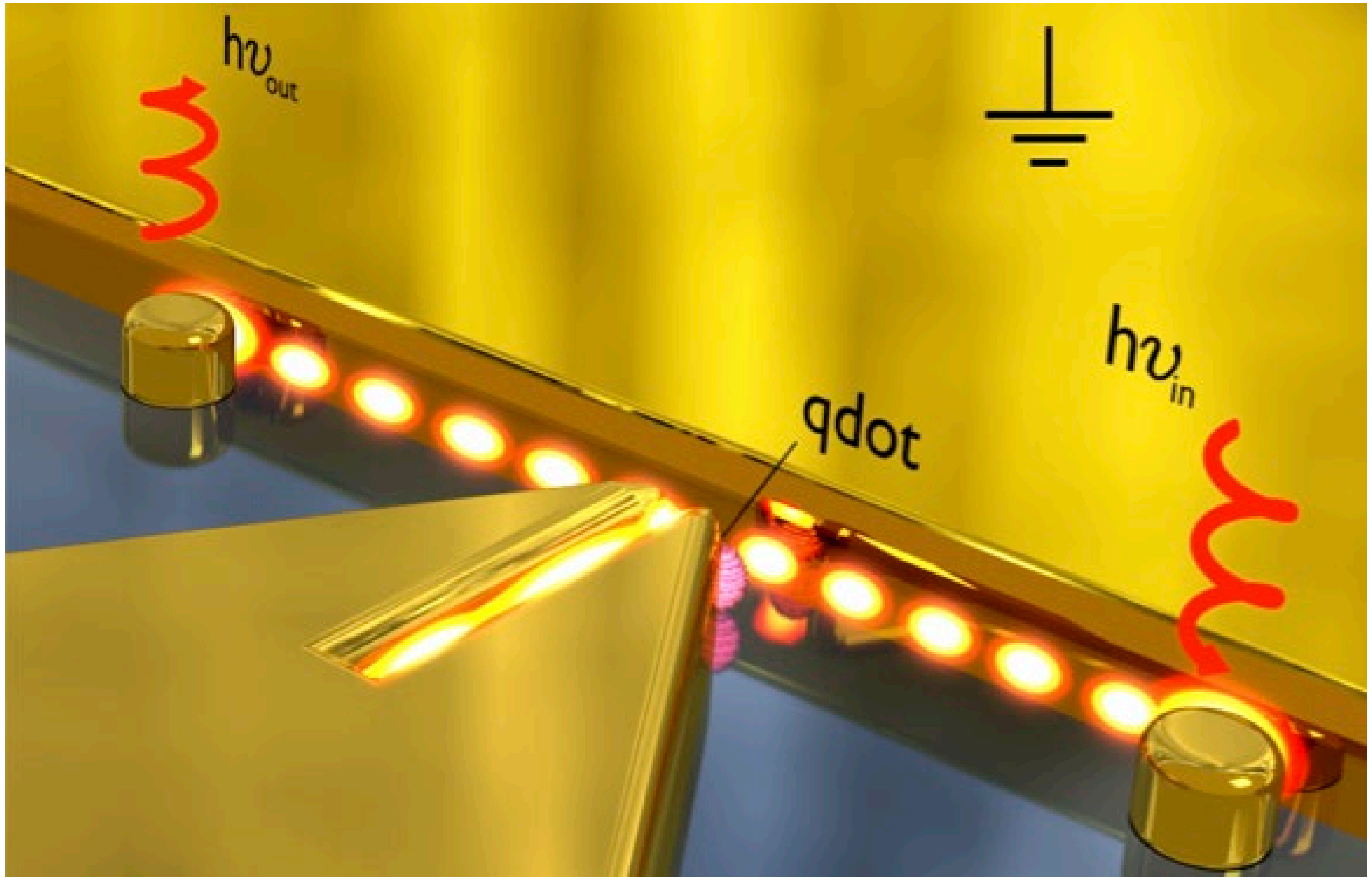


F Bello, N Kongsuwan, and O Hess,
Nano Letters **22**, 2801 (2022)

Quantum Light Single Photon Transistor

Dicke-Enhanced Single-Emitter Strong Coupling at Ambient Conditions as a Quantum Resource

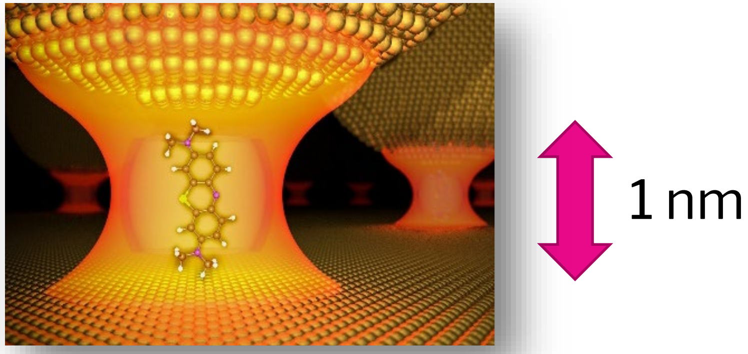
Prof Ortwin Hess (ortwin.hess@tcd.ie)



Quantum Light Single Photon Transistor

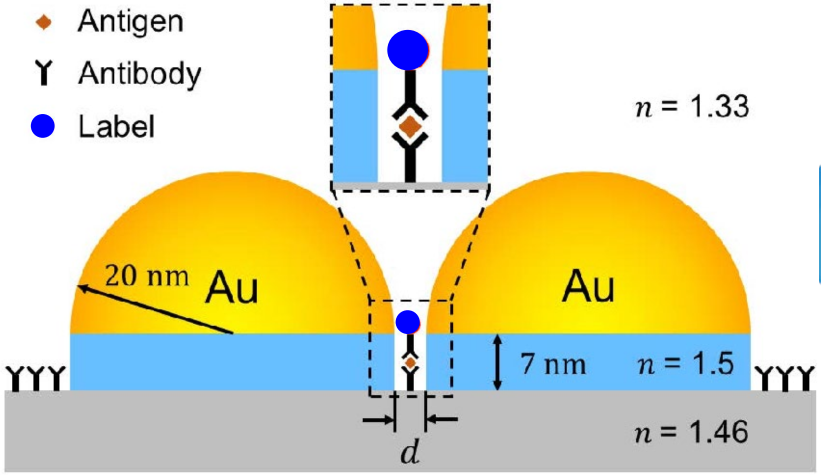
Quantum Plasmonic Immunoassay Sensing
Sensing: Plasmonic Immunoassay

Room-Temperature
Single-Molecule Strong-coupling
in Nanoplasmonic Cavities



Nature **535**, 127 (2016)

Plasmonic Immunoassay



Quantum Plasmonic Immunoassay Sensing

Sensing: Plasmonic Immunoassay

Room-Temperature
Single-Molecule Strong-coupling
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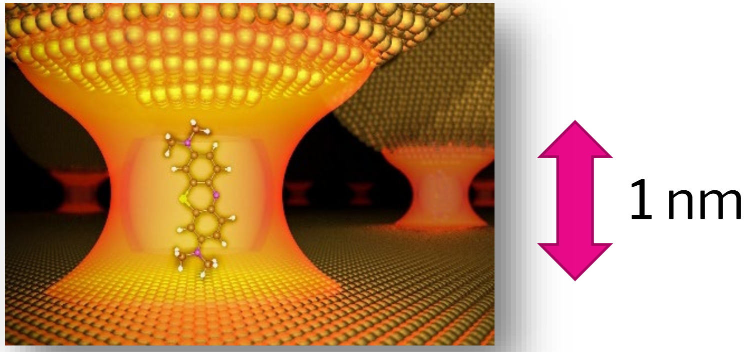
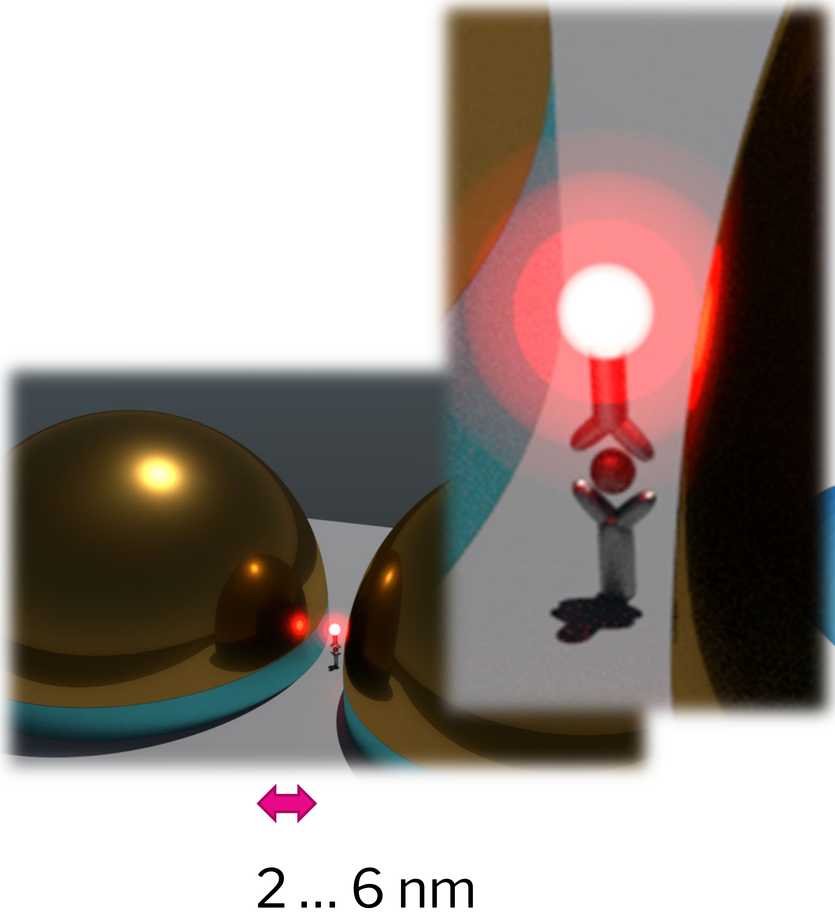


Nature **535**, 127 (2016)



Quantum Plasmonic Immunoassay Sensing

Plasmonic Immunoassay – Strong Coupling

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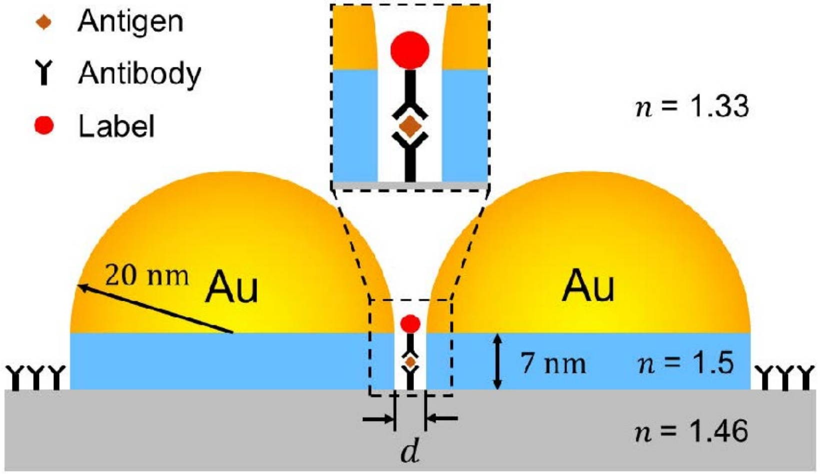
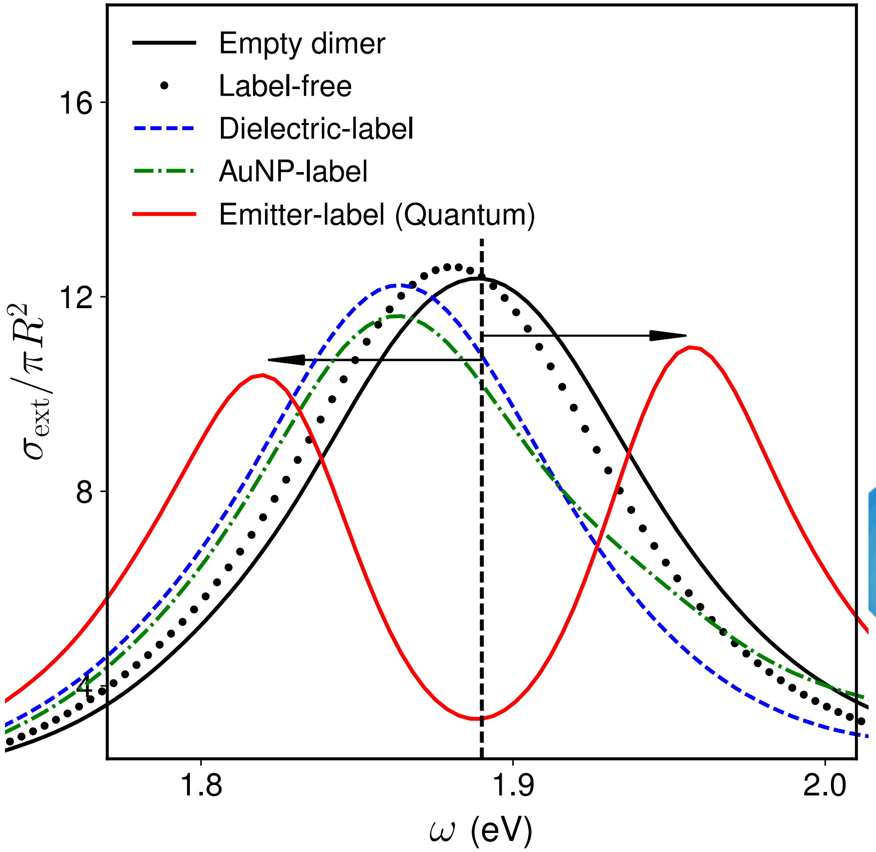
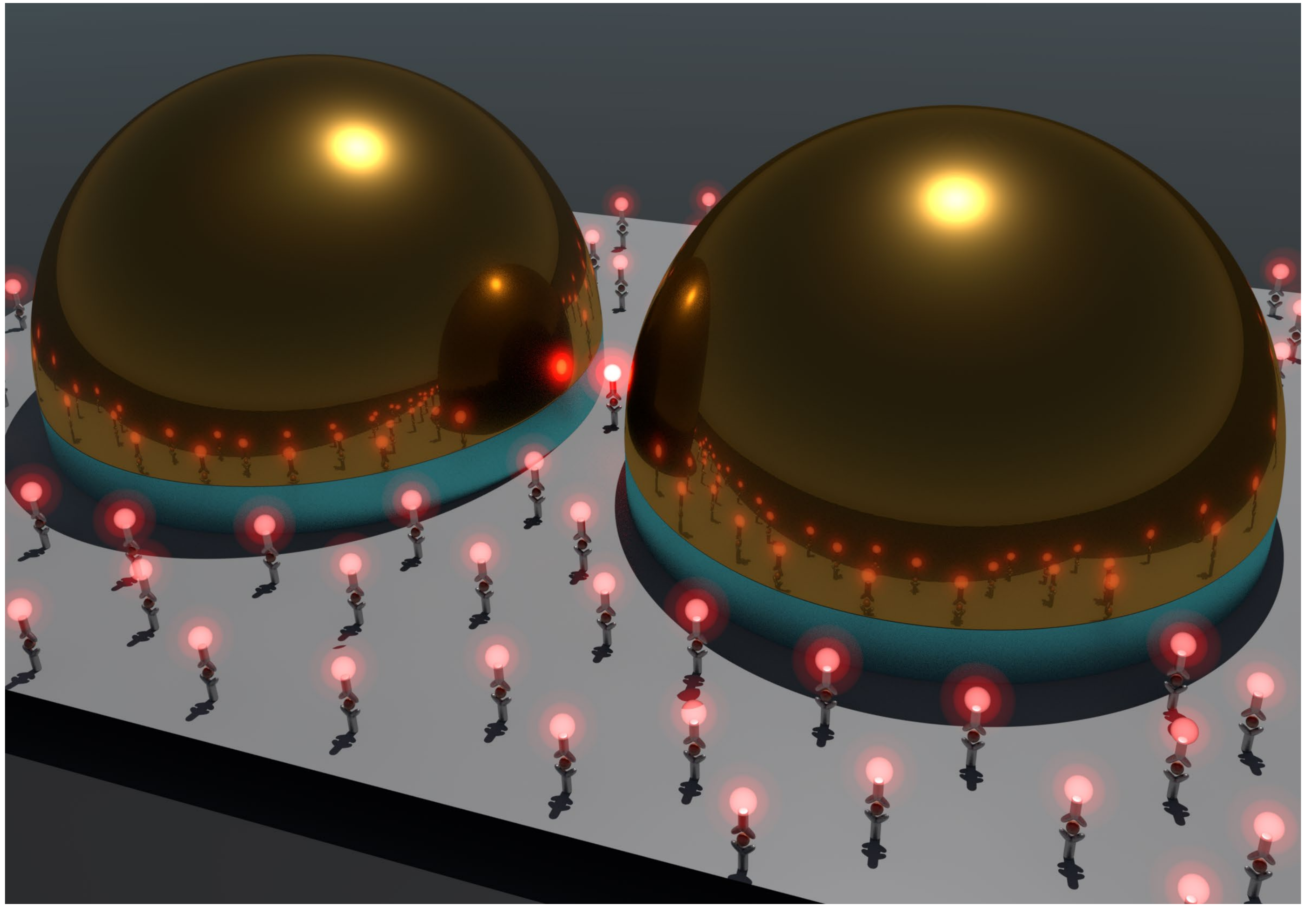




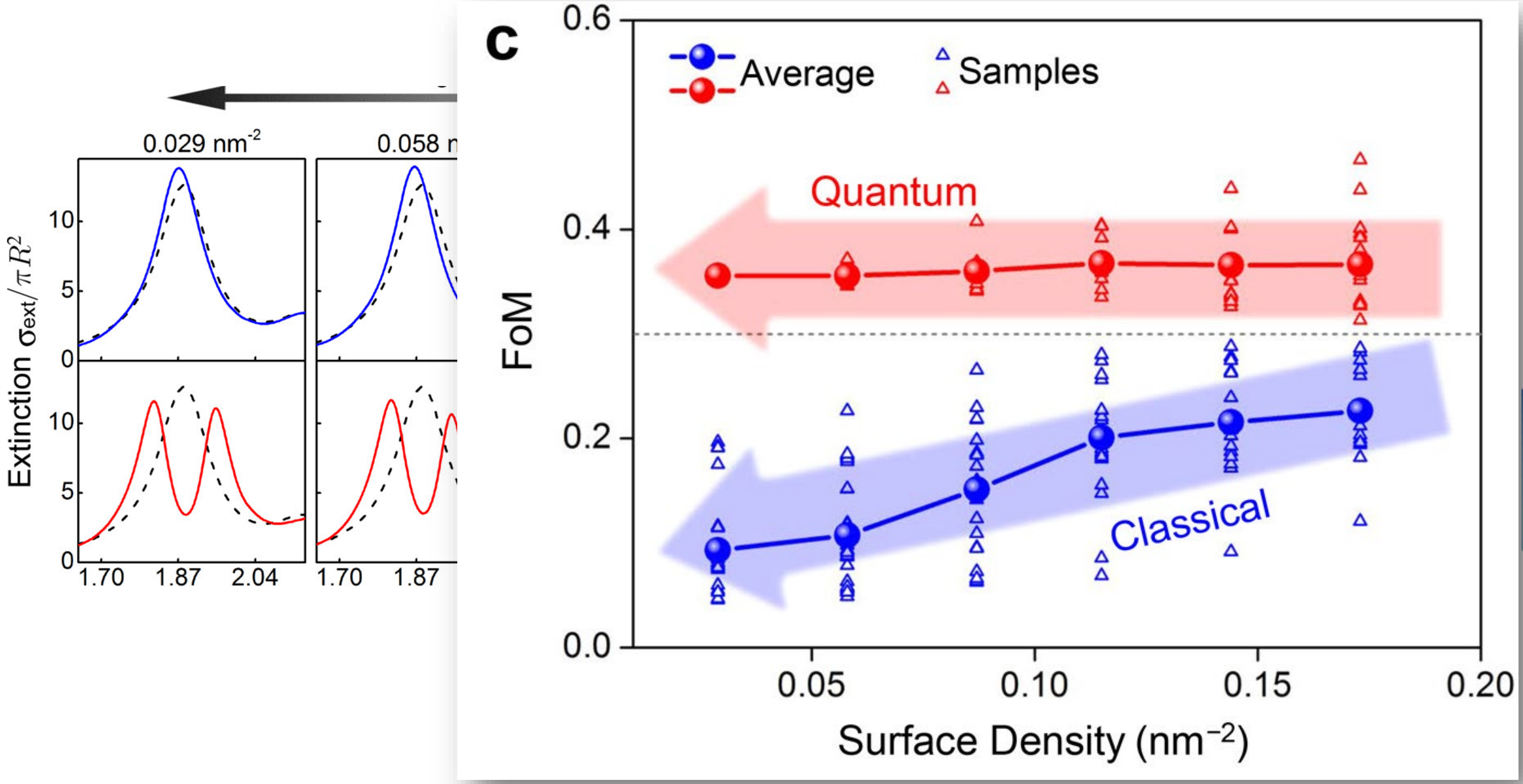
Quantum Plasmonic Immunoassay Sensing

Quantum Emitter Ensembles



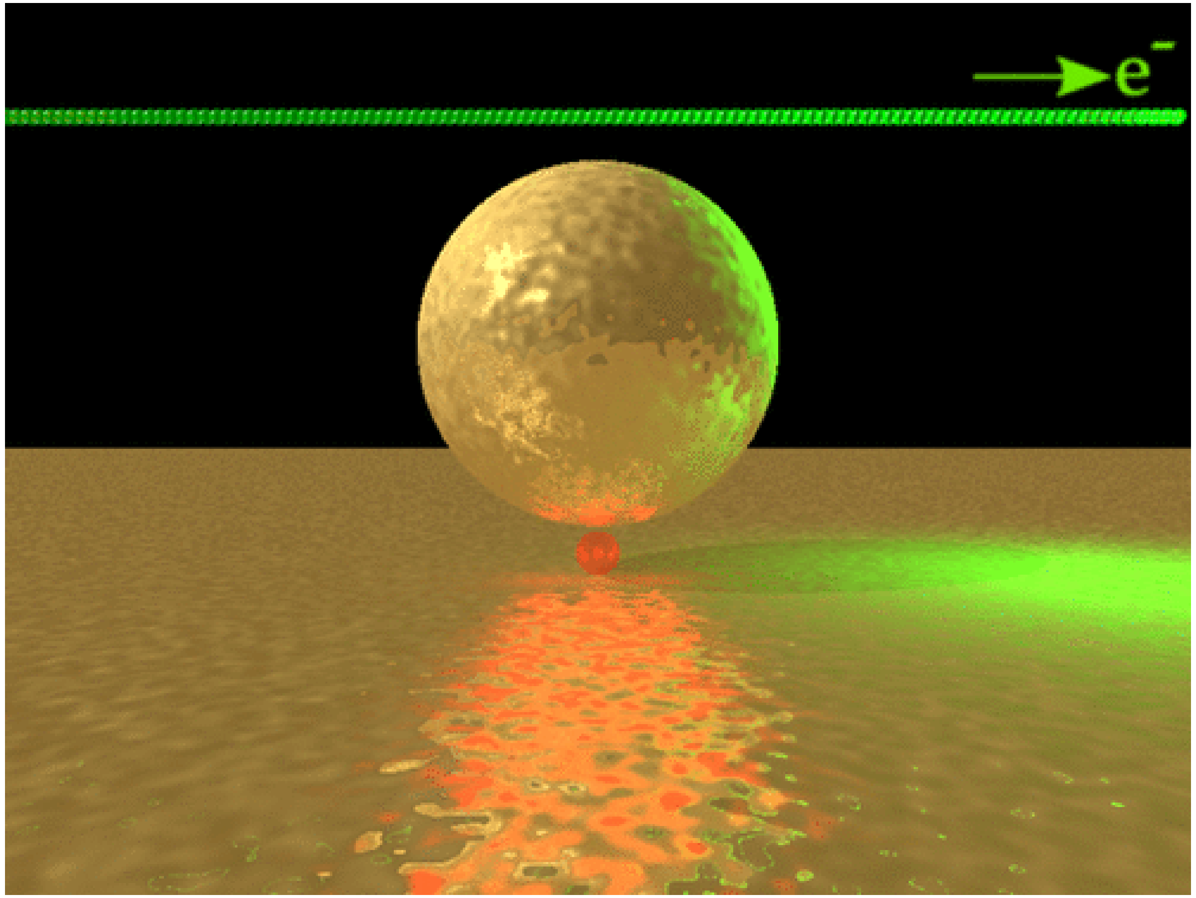
Quantum Plasmonic Immunoassay Sensing

Quantum Emitter Ensembles



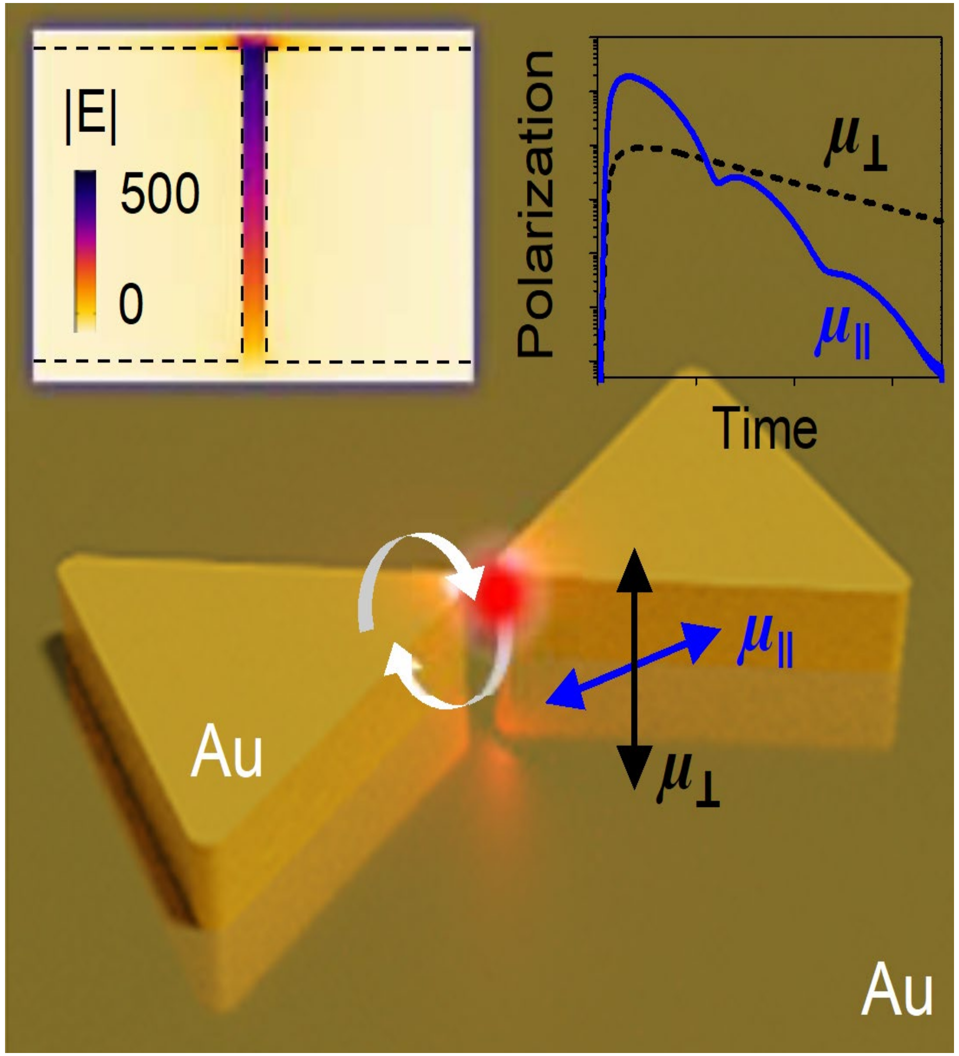
N Konsuwan, X Xiong, P Bai, J-B You, CE Png, L Wu and O Hess, *Nano Lett* **19**, 5853 (2019)

Ultrafast Quantum Sensing
Electron Beam Interrogation and Control



A Crai, A Demetriadou and O Hess,
ACS Photonics **7**, 401 (2020)

Strong Coupling Quantum Sensing
Nanoplasmonic ‘Hot-Spot’ Control

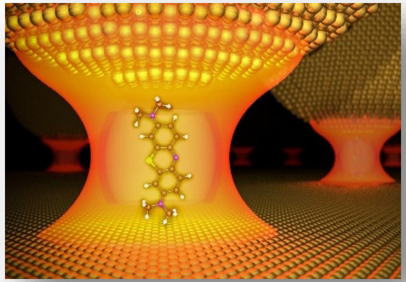


Xiao Xiong, … and Ortwin Hess, *Advanced Optical Materials* (2022)

Room-Temperature Quantum Nanophotonics enabled by Nanoplasmonics

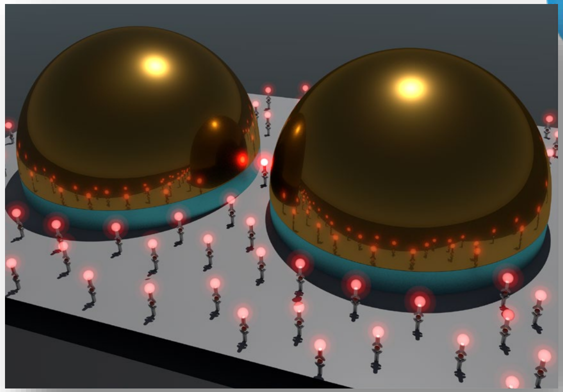
Quantum Nanoplasmonics

- plasmonic nano-confinement
- room-temperature quantum dynamics
- dynamic bipartite quantum entanglement
- ultrafast multipartite quantum entanglement
- quantum light optical trannsistor



Quantum Sensing

- nanoplasmonic structured surface
- room-temperature quantum plasmonic immunoassay



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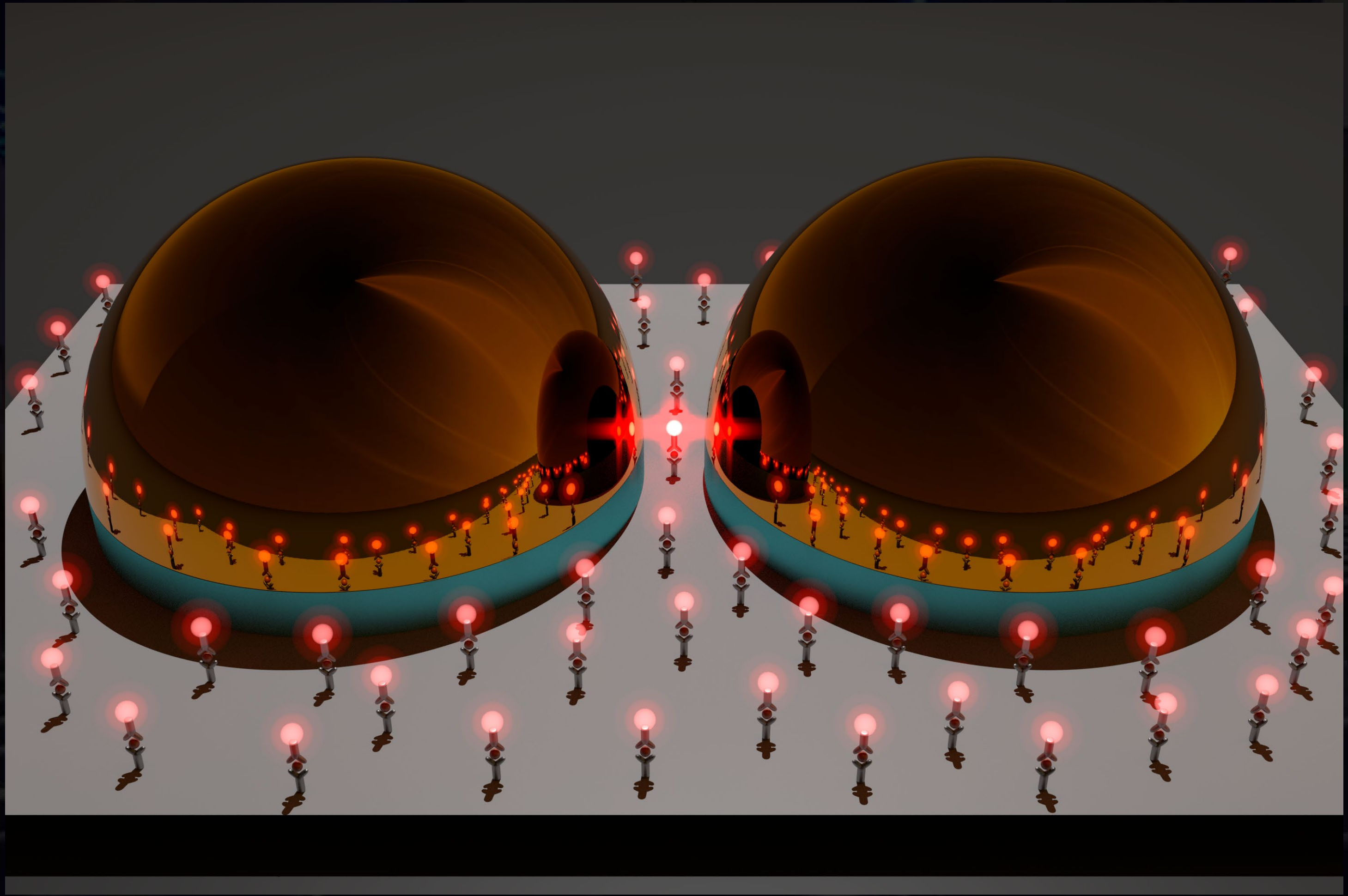
Thank you



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Integrated Photonics for Quantum Technologies

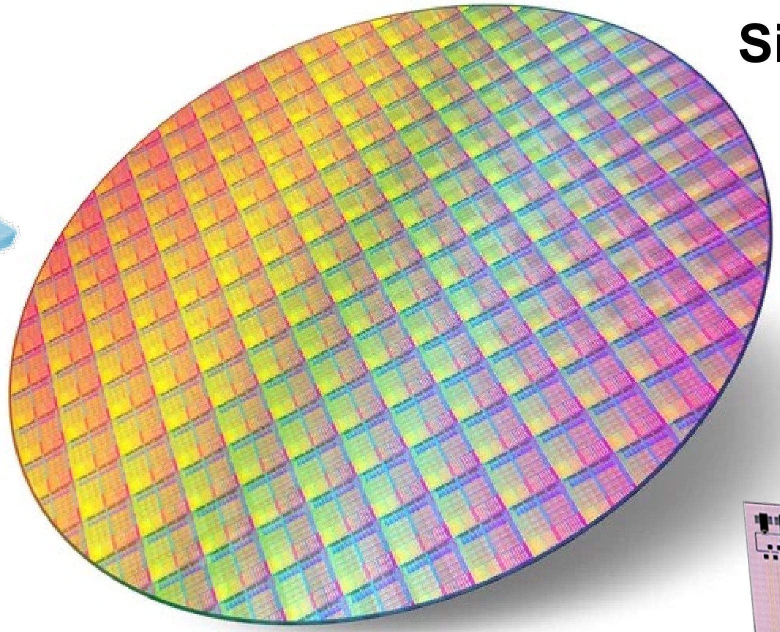
Prof. Peter O'Brien

Head of Group (Photonic Packaging & Systems Integration)

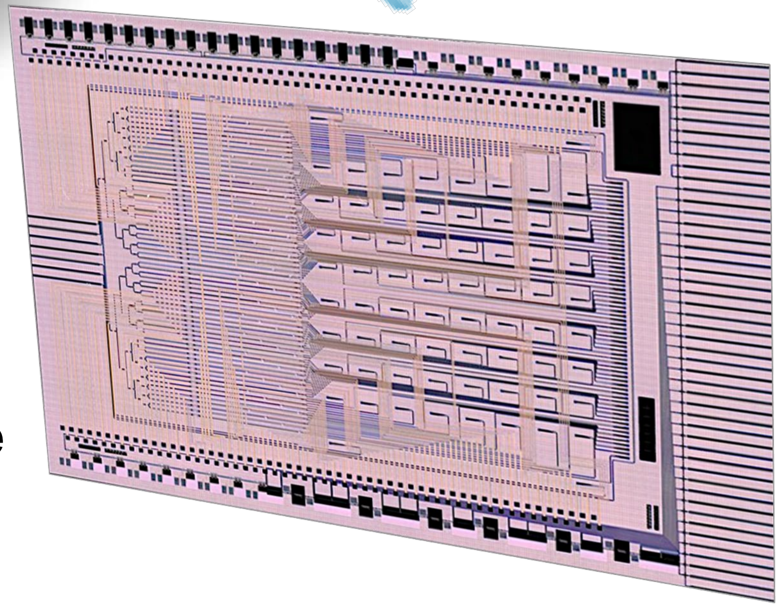
Tyndall Institute,

University College Cork, Ireland.

Integrated Photonics for Quantum Technologies

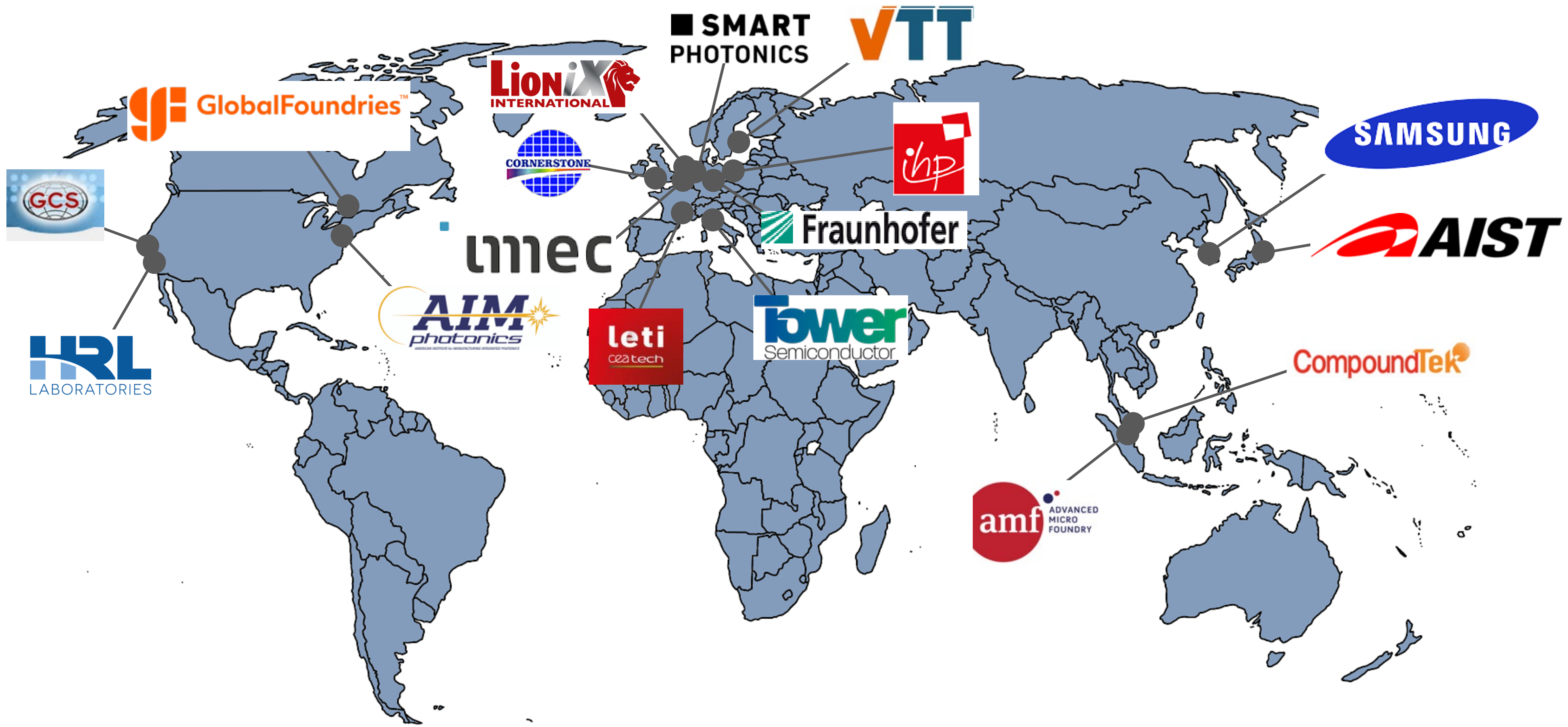


Silicon Photonic Wafer

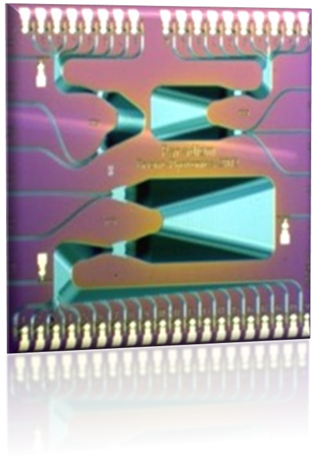


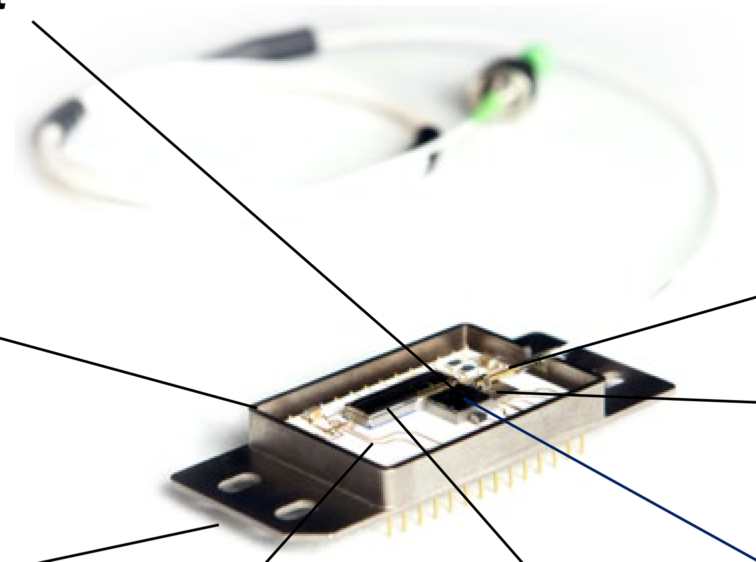
Silicon Photonic Device
(MIT & Tyndall)

Large Investments in Manufacturing



Packaging & Systems Integration Challenges





Packaging & Systems Integration at Tyndall Institute

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fibre pa

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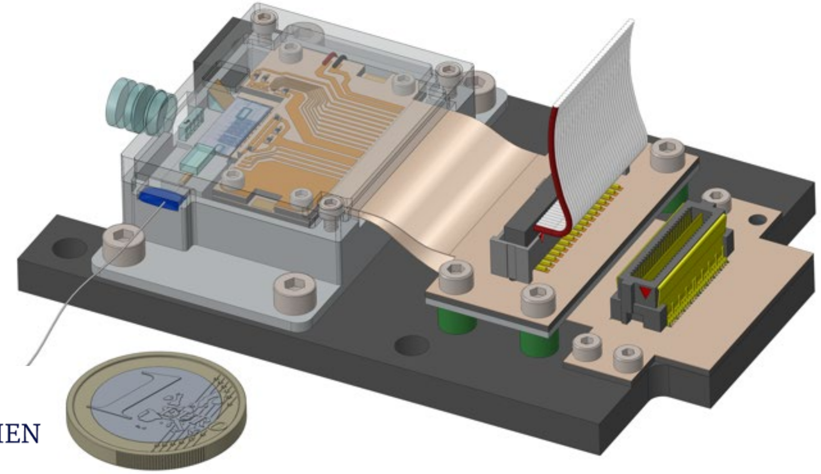
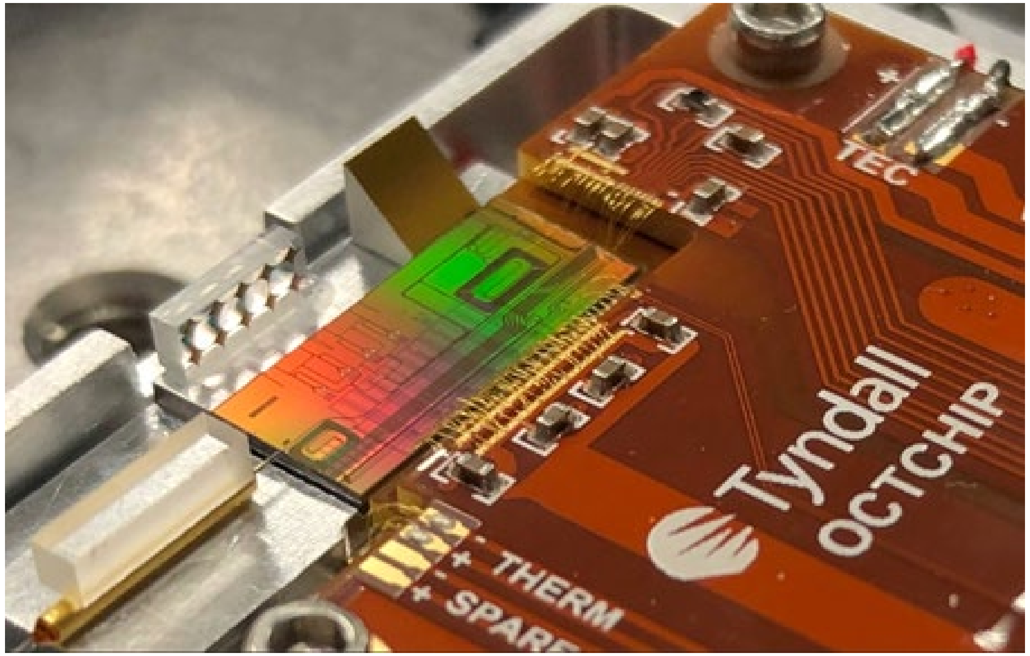
From Design to Integrated Systems

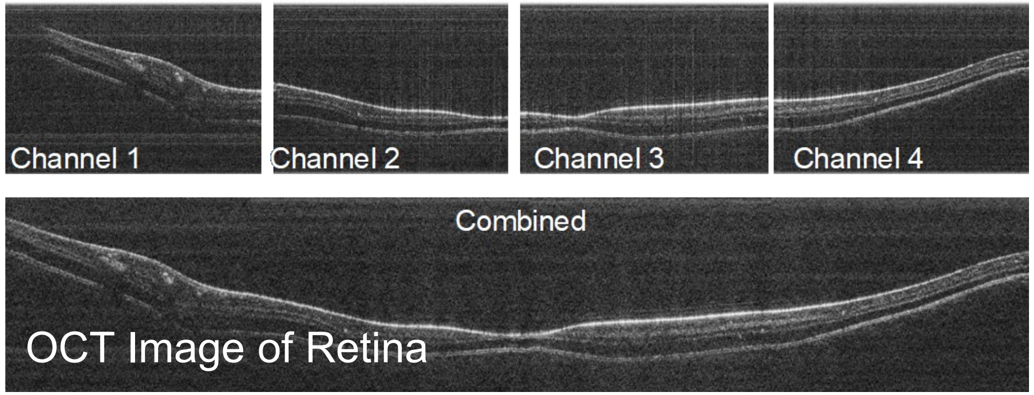
Tyndall National Institute
Institiúid Náisiúnta

ZEISS

MEDIZINISCHE UNIVERSITÄT WIEN







From Advanced Prototypes to Pilot Scale Manufacturing

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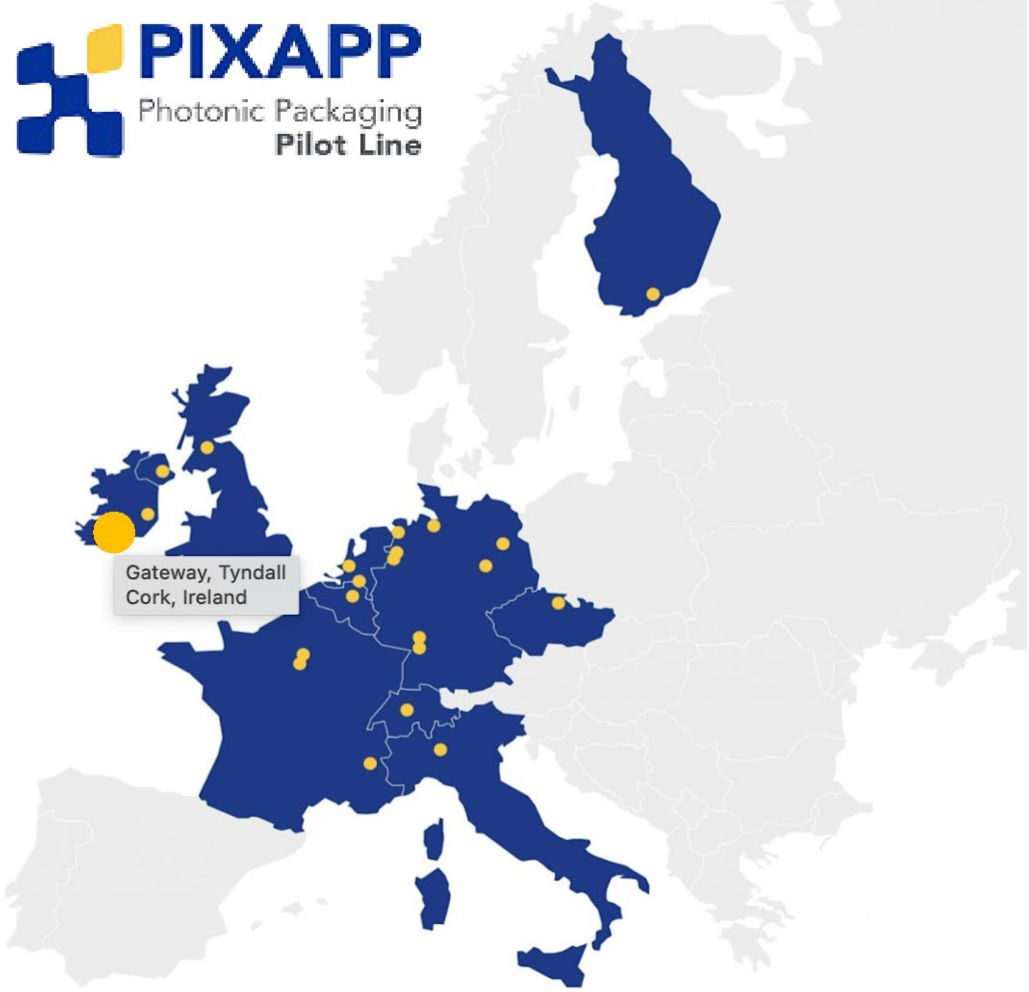

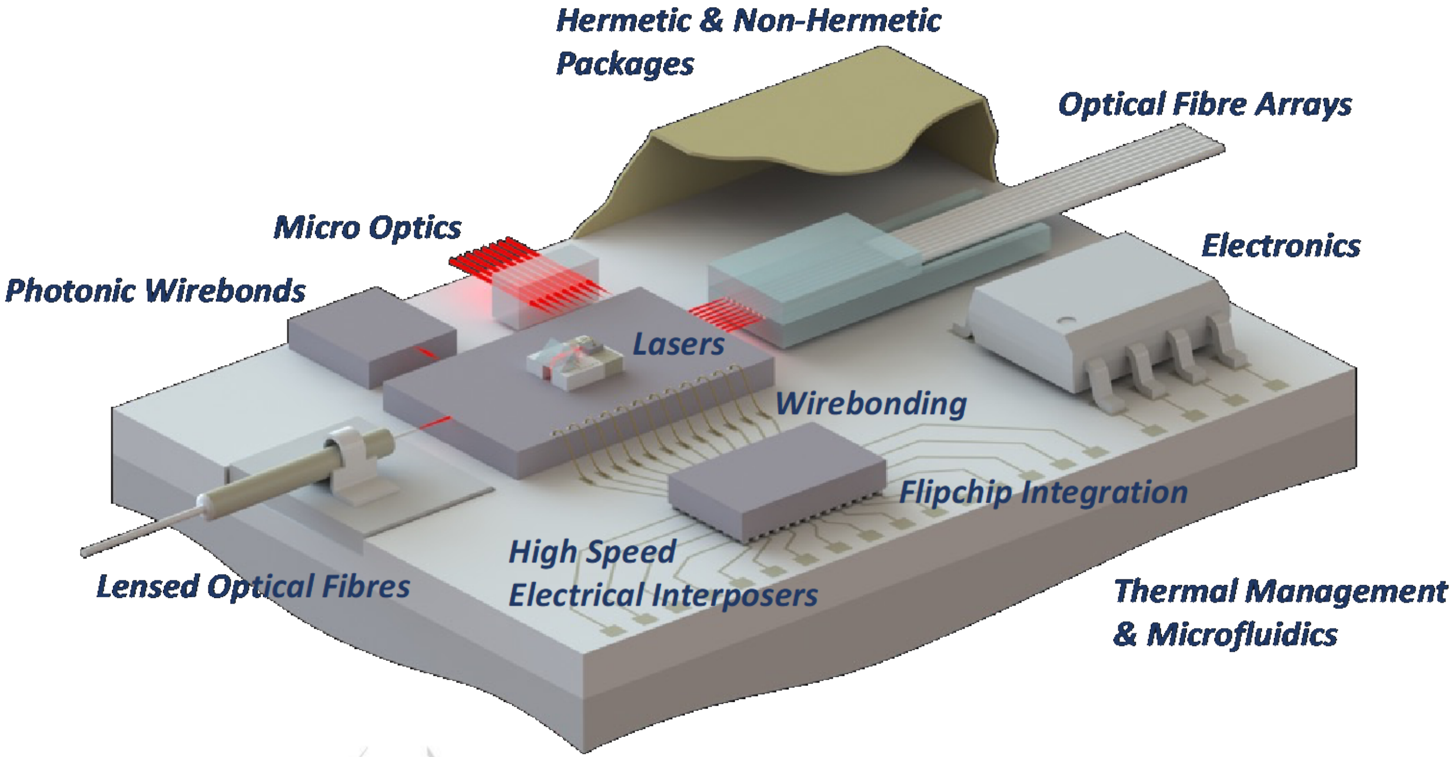

European Commission

Funded by the European Commission

Integrated Photonic Design Standardisation

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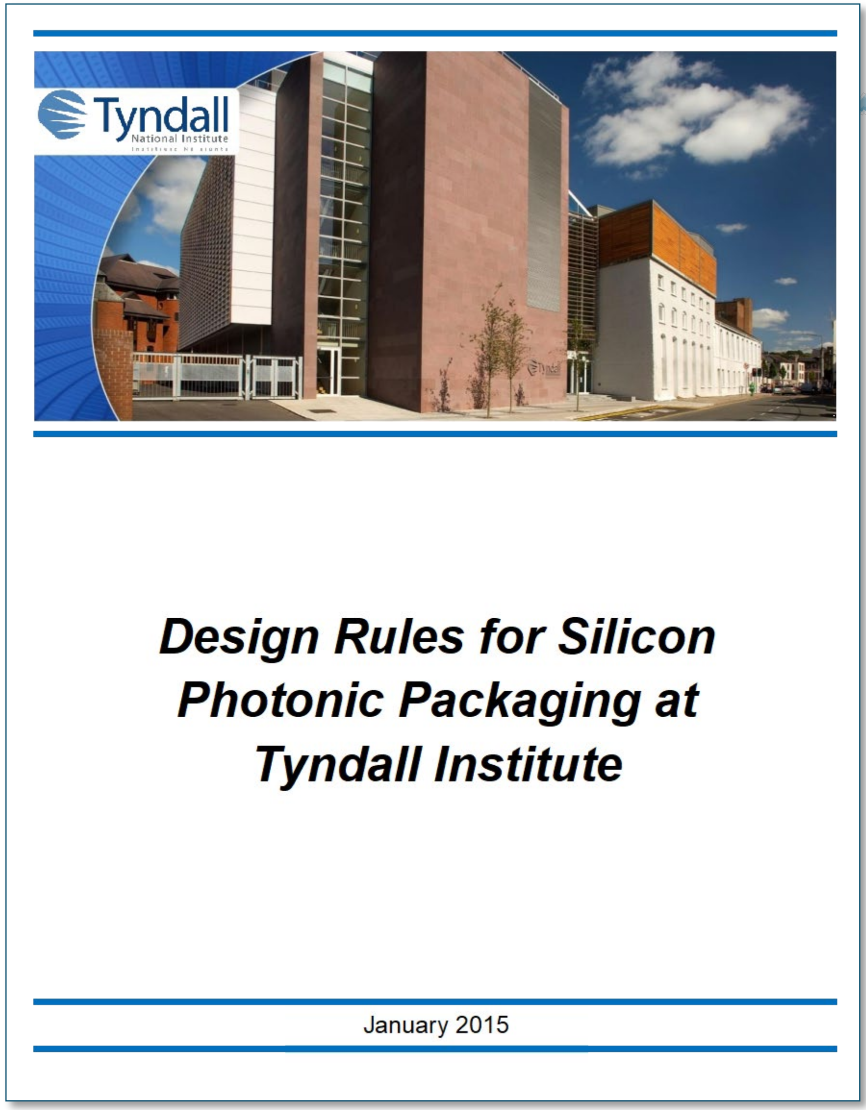
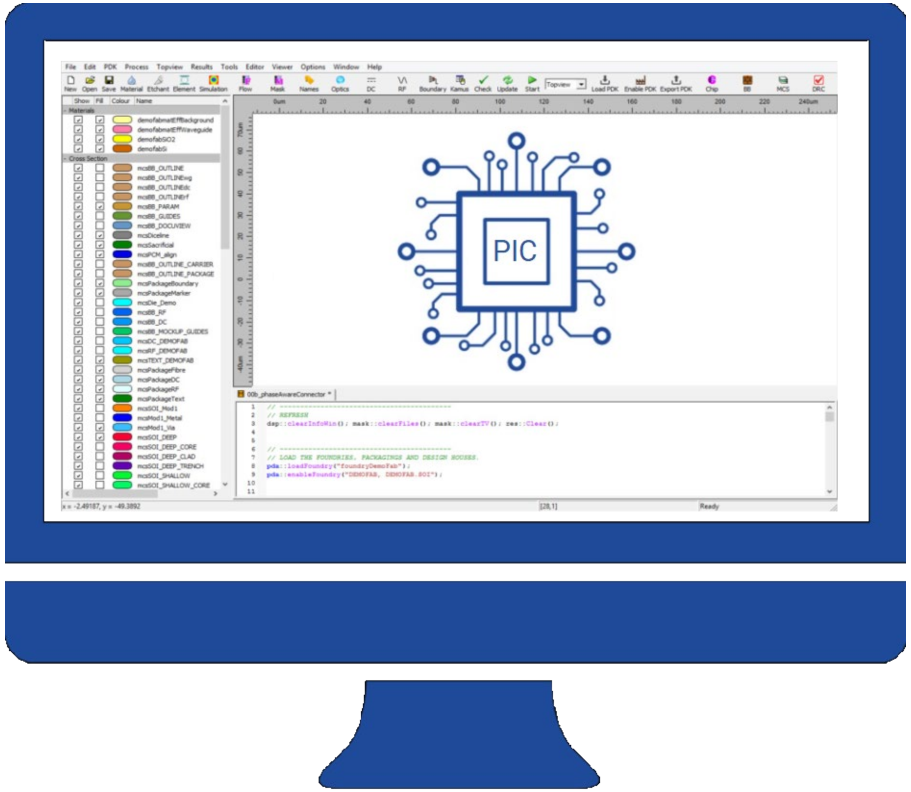


Tyndall National Institute

Design Rules for Silicon Photonic Packaging at Tyndall Institute

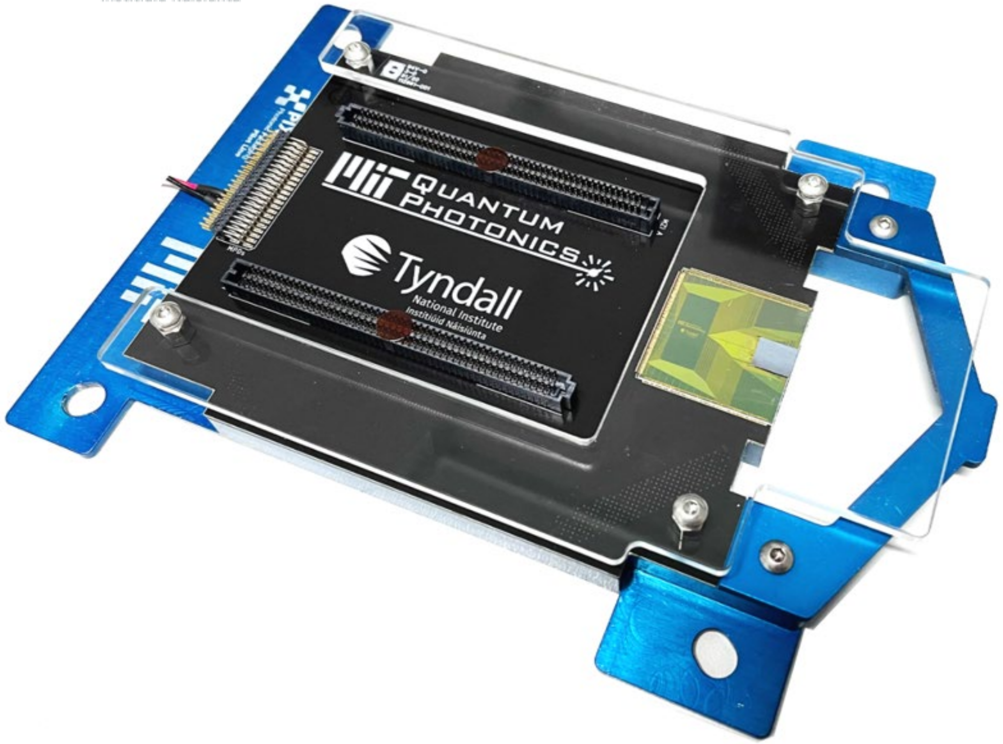
January 2015

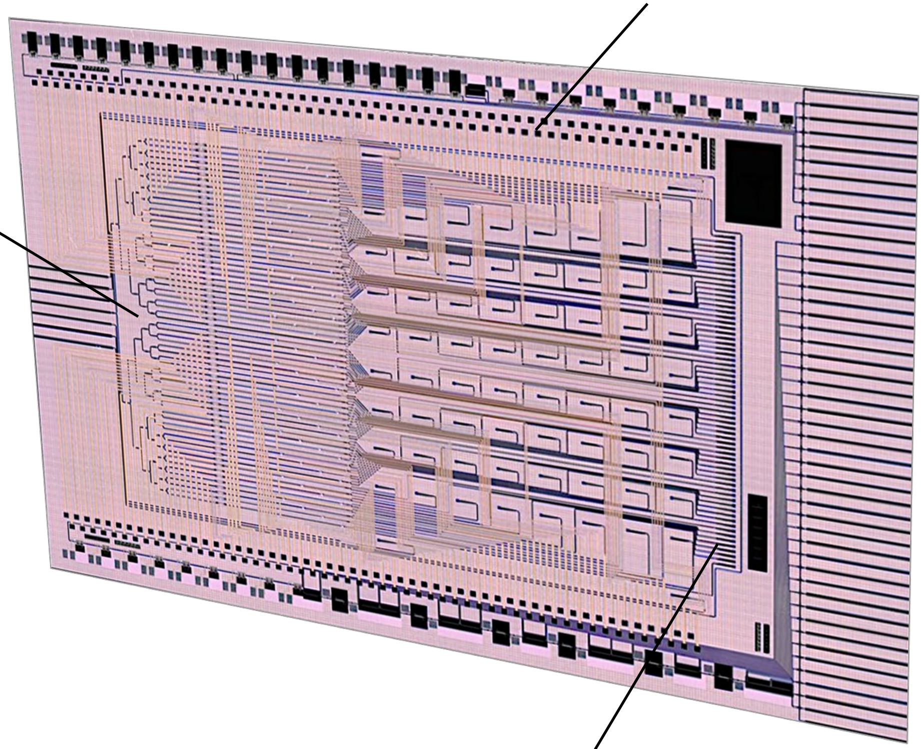


Quantum Photonic Design Standardisation

Massachusetts Institute of Technology

Tyndall National Institute
Institiúid Náisiúnta





Quantum Photonic System Engineering

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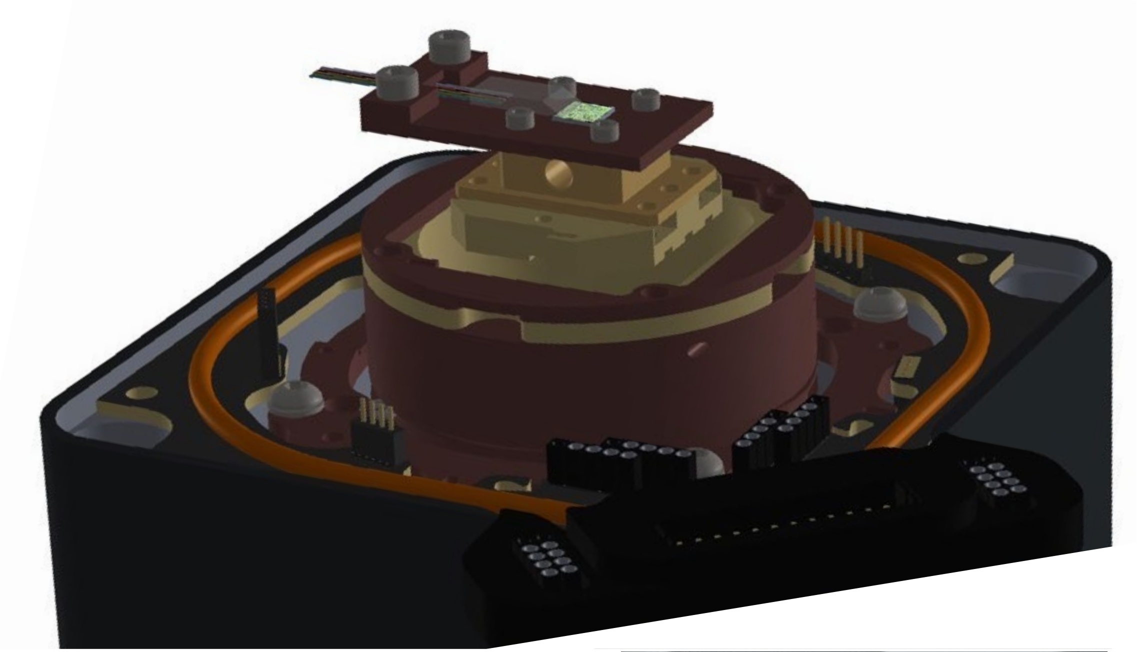
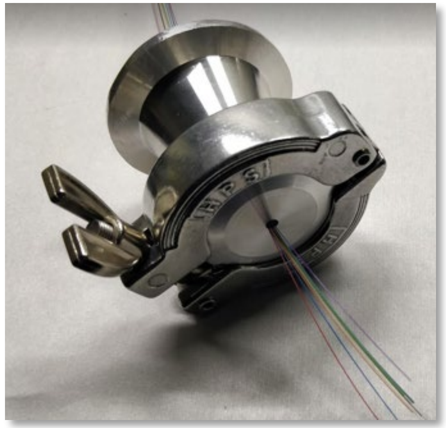
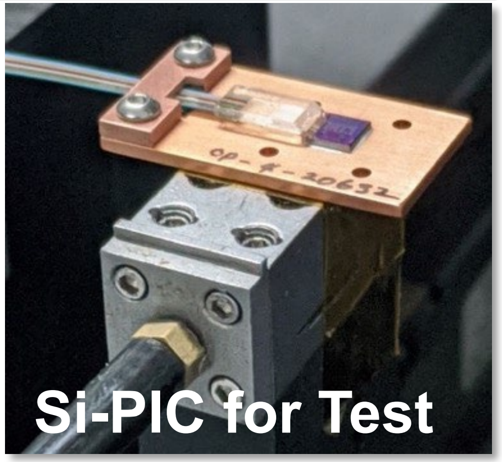
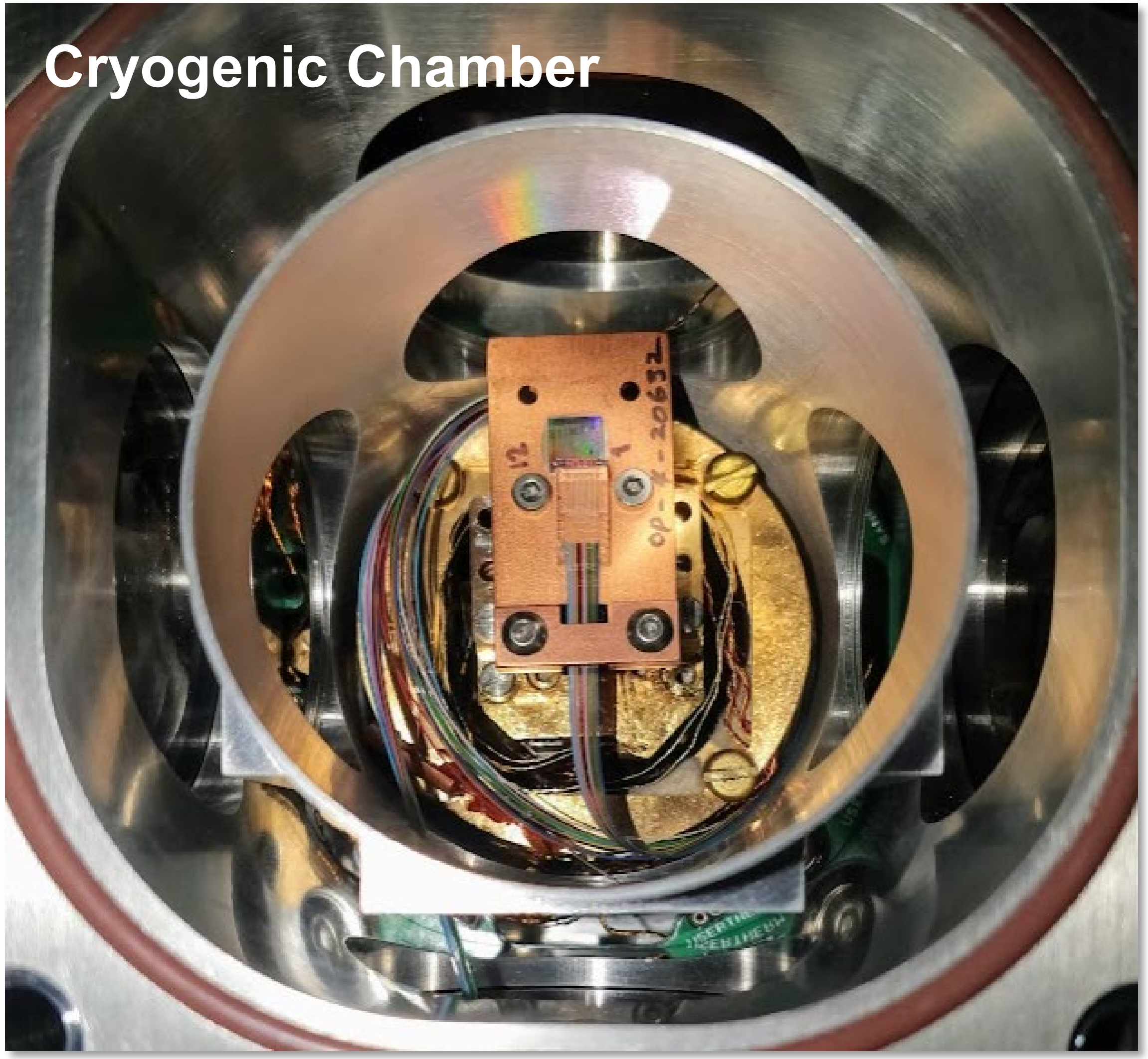
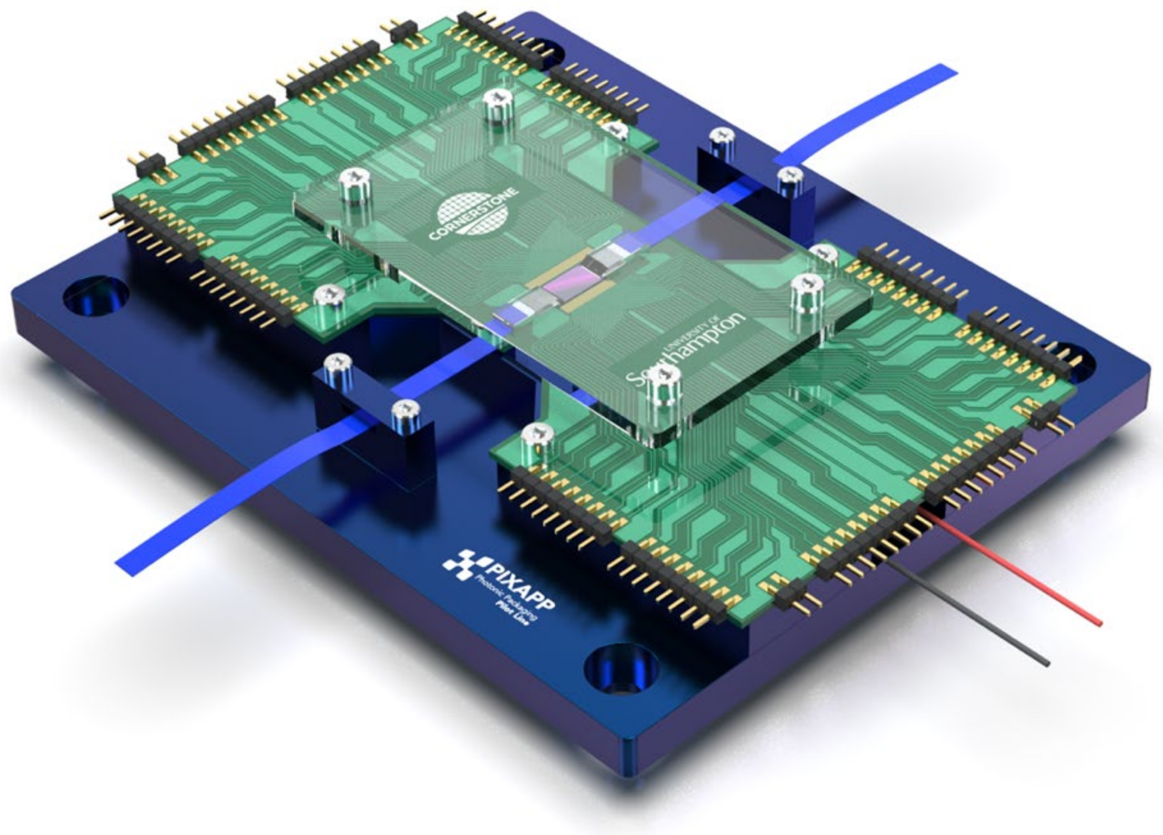




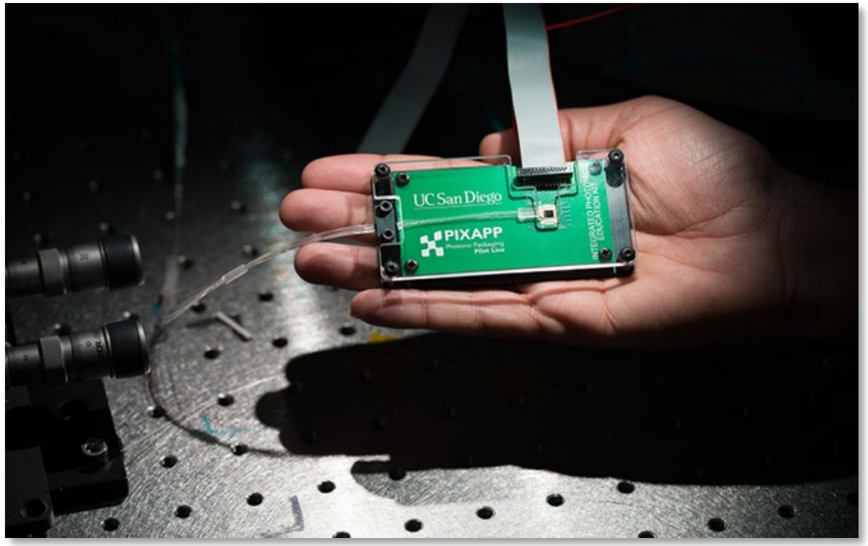




Quantum Photonic Education & Training



Integrated Photonic Education Kits



From Quantum Devices to Quantum Systems (Roadmap)

Quantum System Manufacturing

Quantum System Prototypes

Packaging & Systems Integration

Sources, Detectors, Electronics, Operating Environment

Grand Challenges

Thank you!

Find more:

www.pixapp.eu

peter.obrien@tyndall.ie

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iotweek.org

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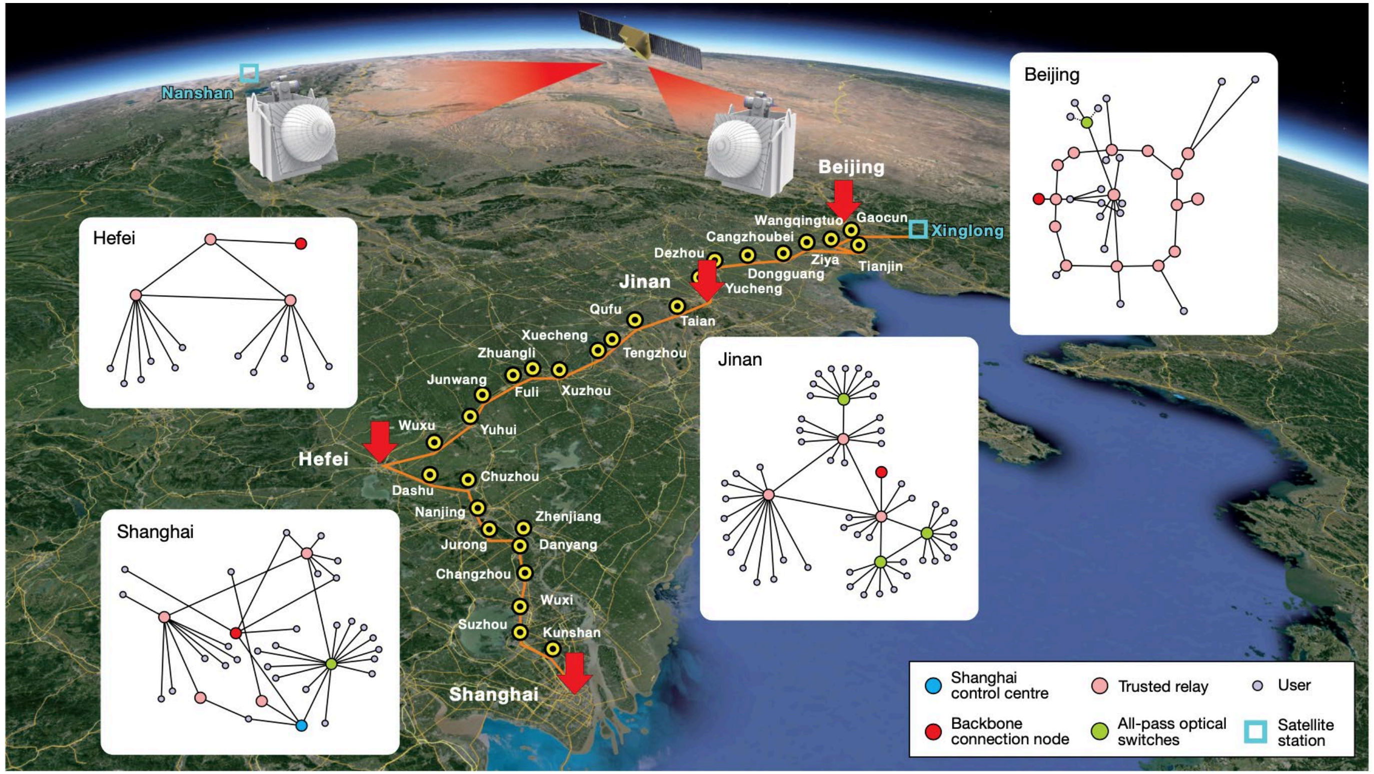
Quantum Communication

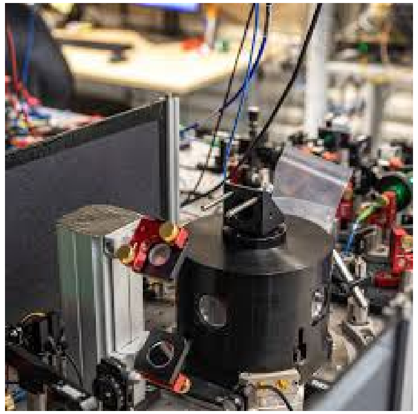
Deirdre Kilbane

Quantum Internet



Chen Nature 589 214 (2021)

Hermans Nature 605 663 (2022)



EuroQCI – EU secure Quantum Communication Infrastructure

Digital Europe Programme €440 M
Connecting Europe Facility €200 M

2020 – 2023 1st Phase (Preparatory and first deployment)
Deploy advanced national quantum systems and networks
Testing quantum communication technologies
Integrating them with existing communication networks
Terrestrial and Space Segments

2024 – 2027 2nd Phase (Operational deployment)
Operational deployment, testing, validation and operationalisation

IrelandQCI: Building a National Quantum Network for Ireland

IOTWeek
Dublin — June 20-23, 2022

Consortium

Dr. Deirdre Kilbane (Walton)
Prof. Dan Kilper (TCD)
Prof. Peter O'Brien (Tyndall)
Mr. Eoin Kenny (HEAnet)
Mr. Jerry Horgan (Walton)
Mr. John Regan (ESB Telecoms)
Dr. Venkatesh Kannan (ICHEC)
Prof. Jiri Vala (NUIM)
Prof. Bogdan Staszewski (UCD)

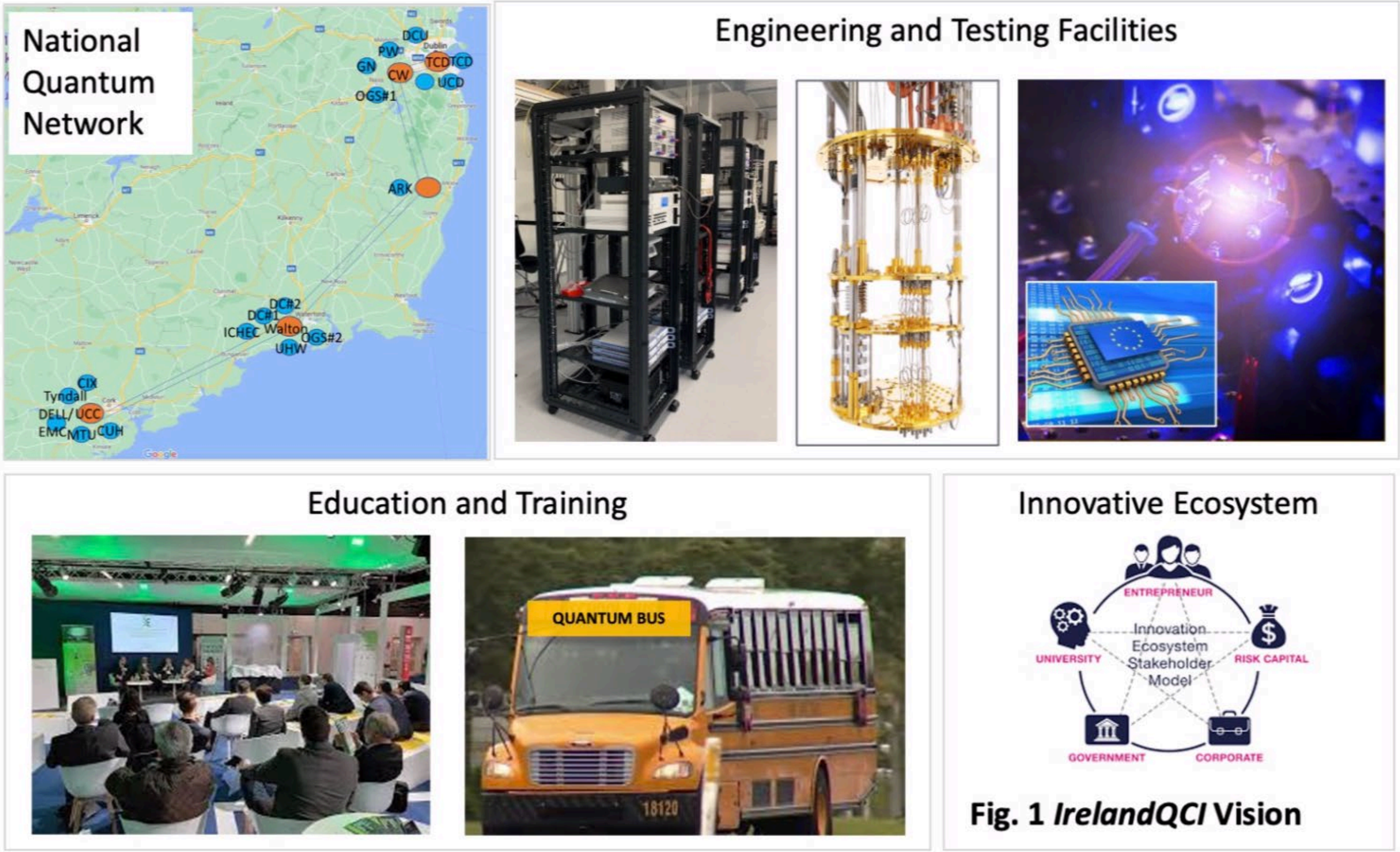


Fig. 1 *IrelandQCI* Vision

WALTON Institute for Information and Communication Systems Science
A World Leading SFI Research Centre
Science Foundation Ireland sfi For what's next
CONNECT SFI Research Centre for Future Networks

Quantum Technology Roadmap

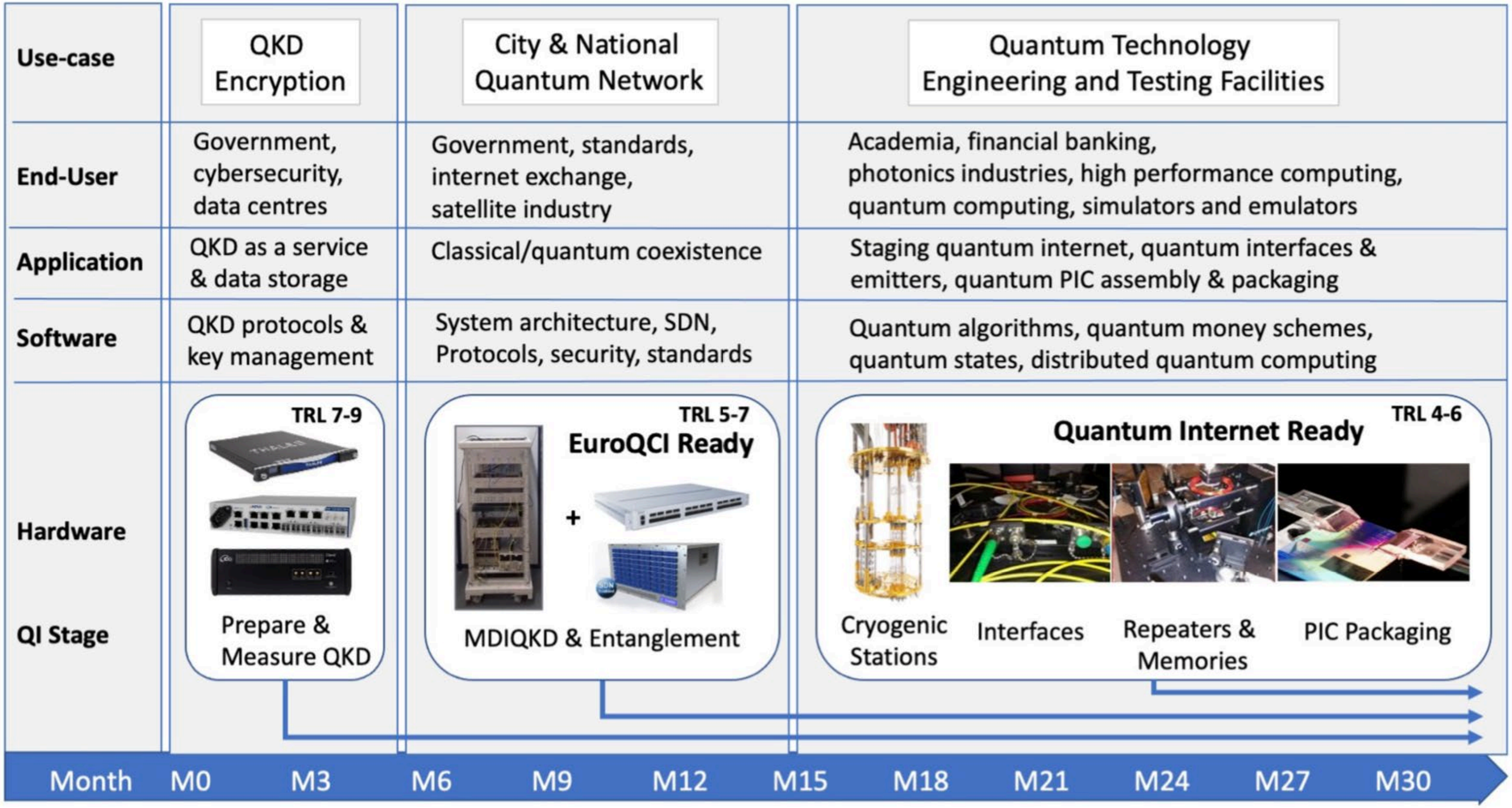


Fig. 2 ***IrelandQCI*** **roadmap towards EuroQCI and the quantum internet**

IOTWeek

Dublin — June 20-23, 2022

Thank you!

Find more:

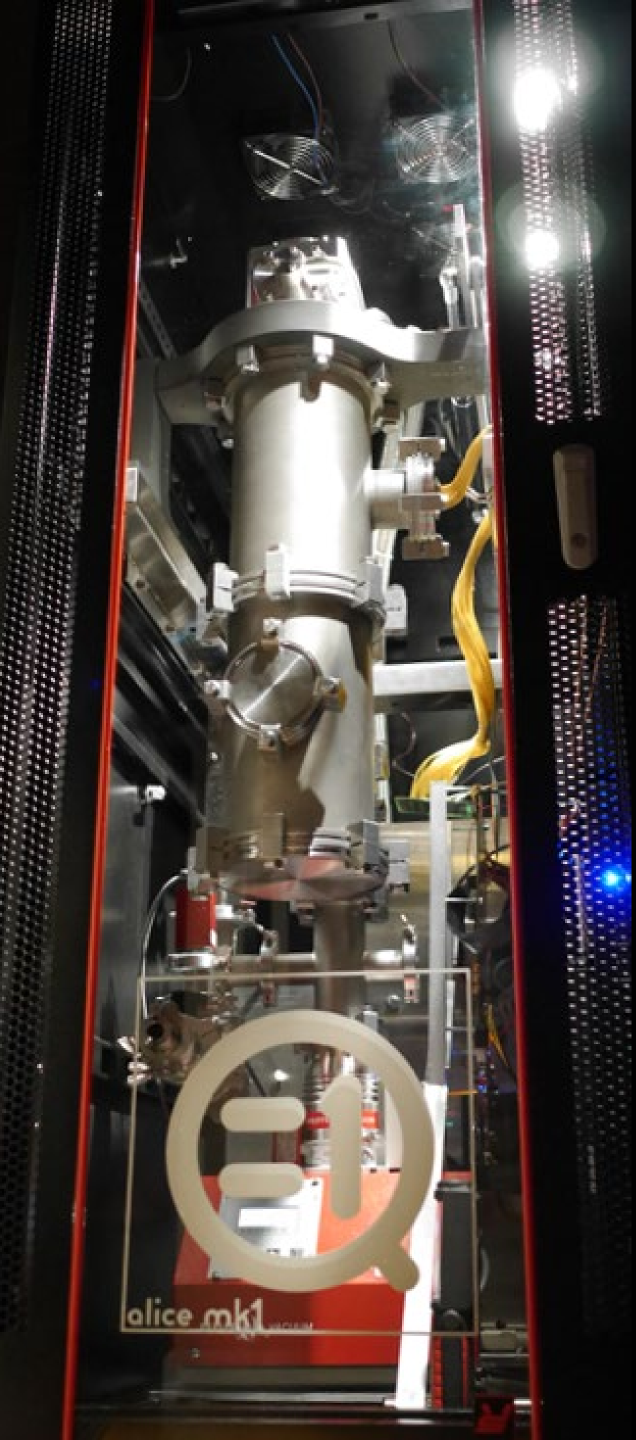
www.waltoninstitute.ie

deirdre.kilbane@waltoninstitute.ie

iotweek.org

Quantum Communication

Jason Lynch
CEO
Equal1



Quantum Technologies: trends and impact

IoT Week

June 20th 2022

The promise of quantum computing

IOTWeek
Dublin — June 20-23, 2022

AIRBUS

"Quantum technologies are expected to create a massive paradigm shift in the way aircraft are built and flown."

Lee-Ann Ramcherita
Flight Physics Innovation
Airbus

MERCK

"The problem is that most quantum chemical problems scale exponentially with system size. And classical computers struggle to cope with this exponential scaling. Realistically, they will never enable quantum chemistry to tackle real-world systems. This intrinsic limitation can only be overcome with a technological paradigm shift, which is why quantum computing is so promising."

Philip Harbach
Head of In Silico Research

Microsoft

"The world is running out of computing capacity. Moore's law is kind of running out of steam. We need quantum computing to create all of these rich experiences we talk about, all of this artificial intelligence."

Satya Nadella
CEO
Microsoft

Pfizer

"The growing application of quantum computing will drive speed in discovery and development that we cannot imagine today."

Lidia Fonseca
EVP
Pfizer

Significant market opportunity

IOTWeek
Dublin — June 20-23, 2022

$170B
Market Size 2030

$850B
Market Size 2040

61

30%
CAGR

Source: Boston Consulting Group

QS and QComms start-ups saw slight investment increases, but QC still has the largest estimated market and number of players.

Number of players[1] | Total raised start-up funding[2] | Estimated market 2040[3]

Quantum computing (QC)

228[1]

$3.0 billion[2]

$9 billion–$93 billion[3]

Quantum computing market estimates still have a high level of uncertainty, caused by:

- Technological challenges in hardware development
- Lack of transparency on business impact due to limited availability of detailed end-to-end quantum solutions

Quantum sensing (QS)

58[1]

$0.4 billion[2]

$1 billion–$7 billion[3]

Quantum communications (QComms)

111[1] | $0.7 billion[2] | $1 billion–$6 billion[3]

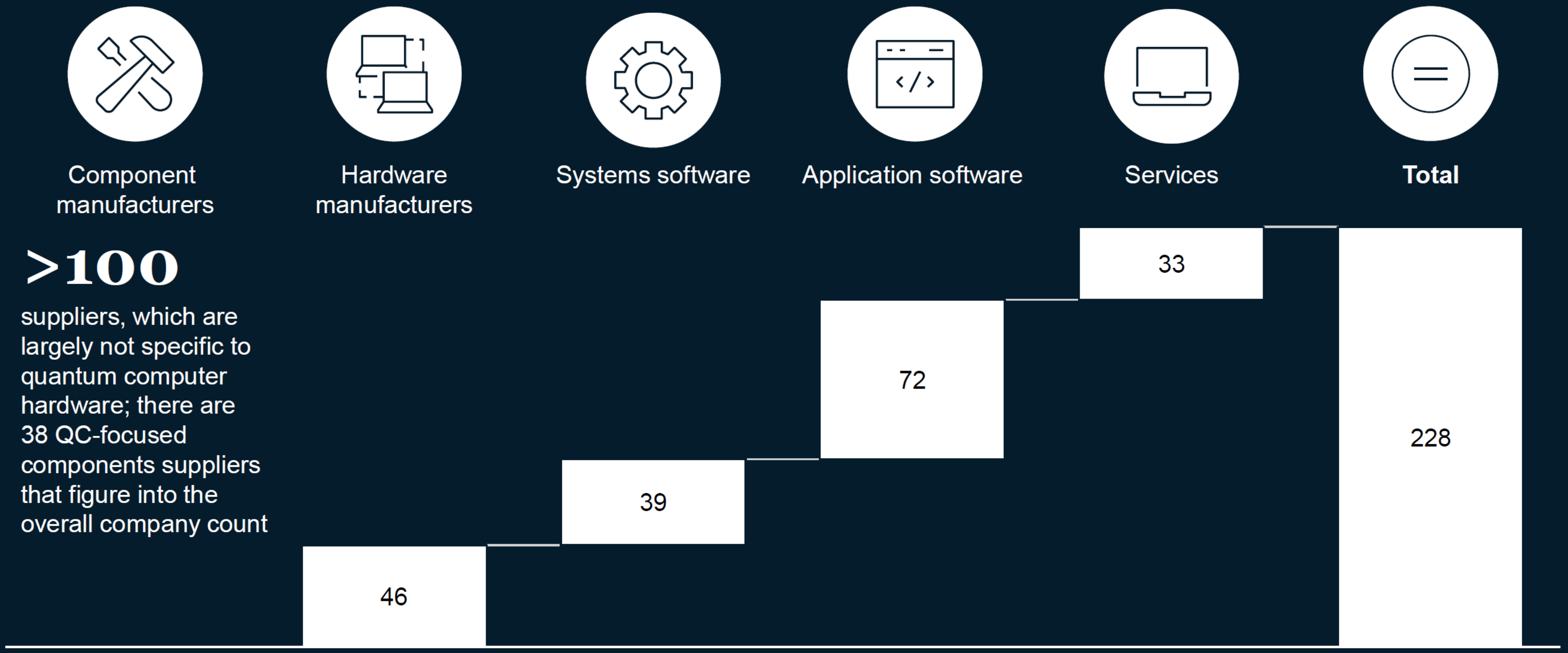
1. Includes start-ups and incumbents that develop or offer QT products; see methodology page for details. Companies that develop products for multiple QTs are included in all relevant categories.
2. Based on public investments in start-ups recorded on Pitchbook and announced deals from 2001 to 2021. Actual investment is likely higher, excludes investments in internal QT departments or projects by incumbents.
3. Exchange rate for market estimates EUR to USD: 1.19.

Source: CapitalIQ; Crunchbase; PitchBook; press search; Quantum Computing Report; expert interviews; McKinsey analysis

Most players are component and application software companies, but hardware start-ups still get the biggest share of funding.

Number of QC players, by value chain segment[1]

Number of players



	Component manufacturers	Hardware manufacturers	Systems software	Application software	Services
Share of start-up funding[1]	4%	73%	14%	7%	2%

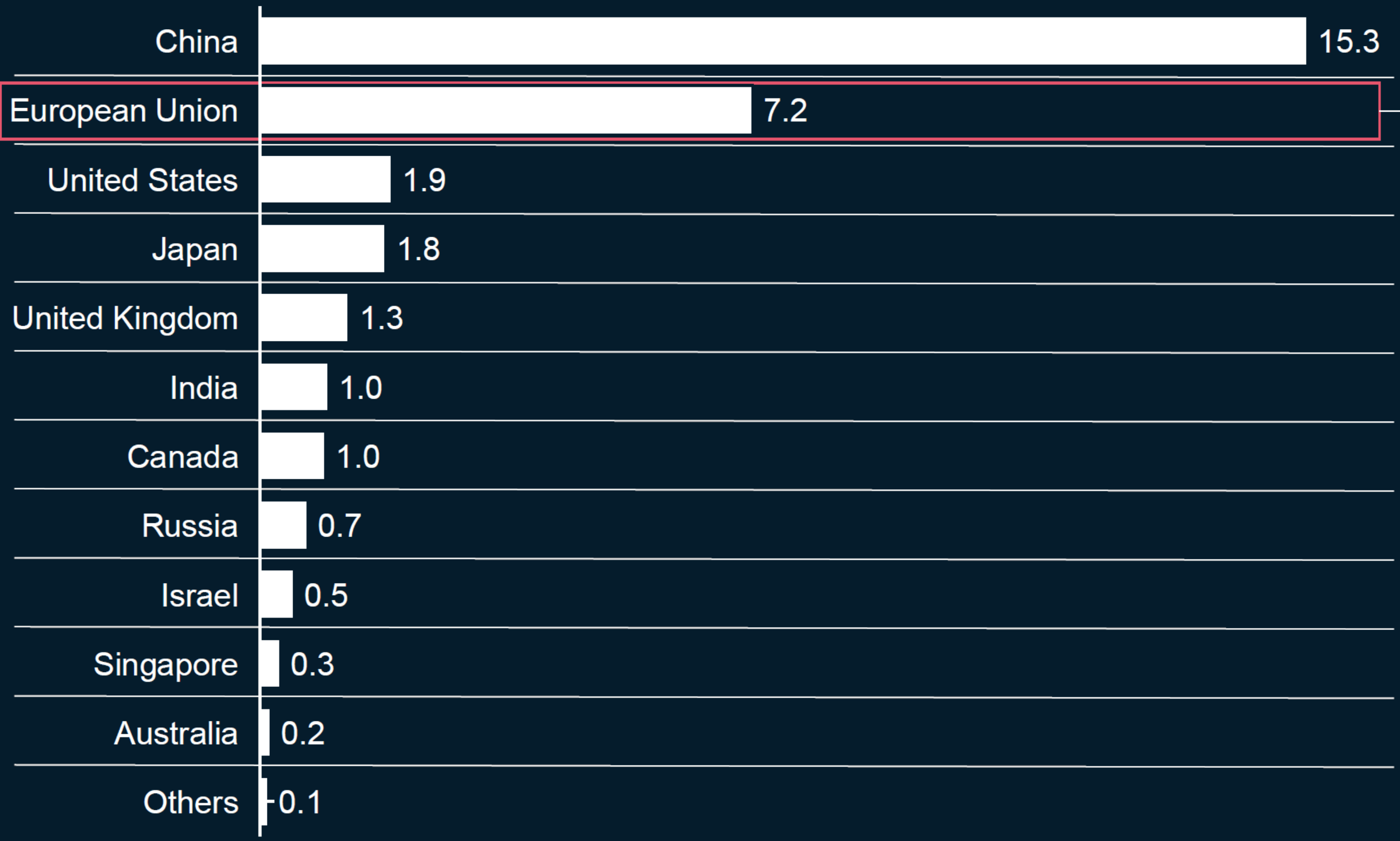
1. Includes start-ups and incumbents that develop or offer QT products; see methodology pages for details.
2. Based on public investments in start-ups recorded on PitchBook and announced in the press; includes announced deals for 2021; excludes investments in internal QT departments or projects by incumbents; actual investment is likely higher.

Source: CapitalIQ; Crunchbase; PitchBook; press search; Quantum Computing Report; expert interviews; McKinsey analysis

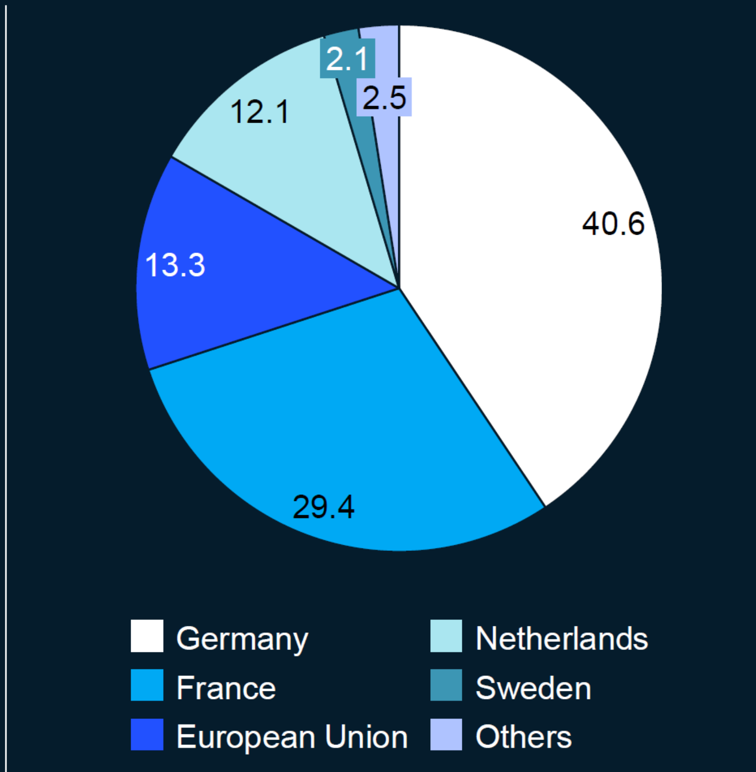
China and the European Union have announced the most public funding planned for QC efforts; Germany has announced most in EU.

Not exhaustive

Announced planned governmental funding[1]
$ billion



EU public funding sources, %



1. Total historic announced funding; timelines for investment of funding vary per country.

Source: Johnny Kung and Muriam Fancy, *A quantum revolution: Report on global policies for quantum technology*, CIFAR, April 2021; press search June 2021

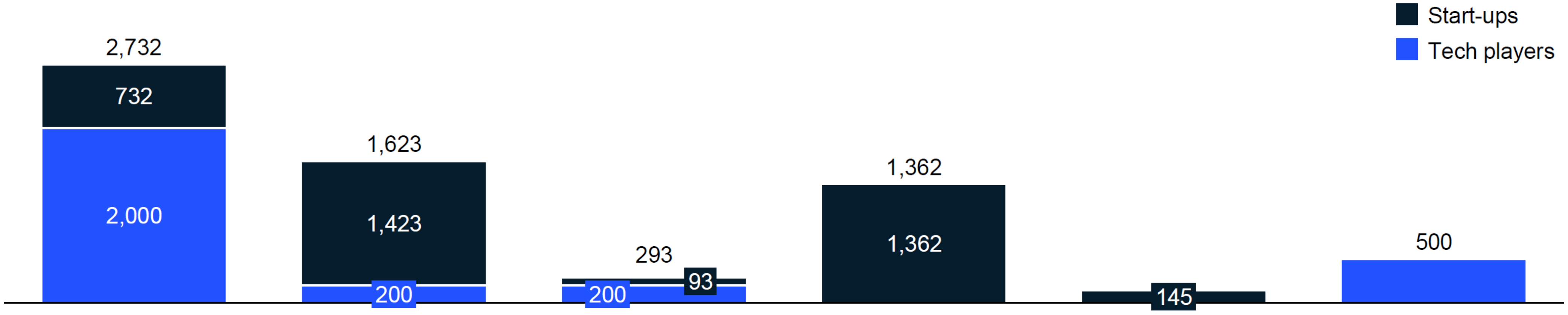
Technology giants dominate in superconducting qubits; start-ups are catching up on trapped ions and photonic networks.

Non-exhaustive

Preliminary

Technology	**Superconducting circuits**	**Trapped ions**	**Spin qubits**	**Photonic networks**	**Neutral atoms**	**Majorana fermions**
Qubit description	Difference in Cooper pairs between two islands of a Josephson tunnel junction	Internal energy levels of ions trapped by electromagnetic fields	Electron spin of one electron localized in a semiconductor quantum dot or insulator defect (eg, NV centers in diamond)	Occupation of a photonic waveguide	Internal energy levels of highly excited atoms trapped by laser fields	Two Majorana modes at superconductor/ semiconductor interfaces
Maturity						

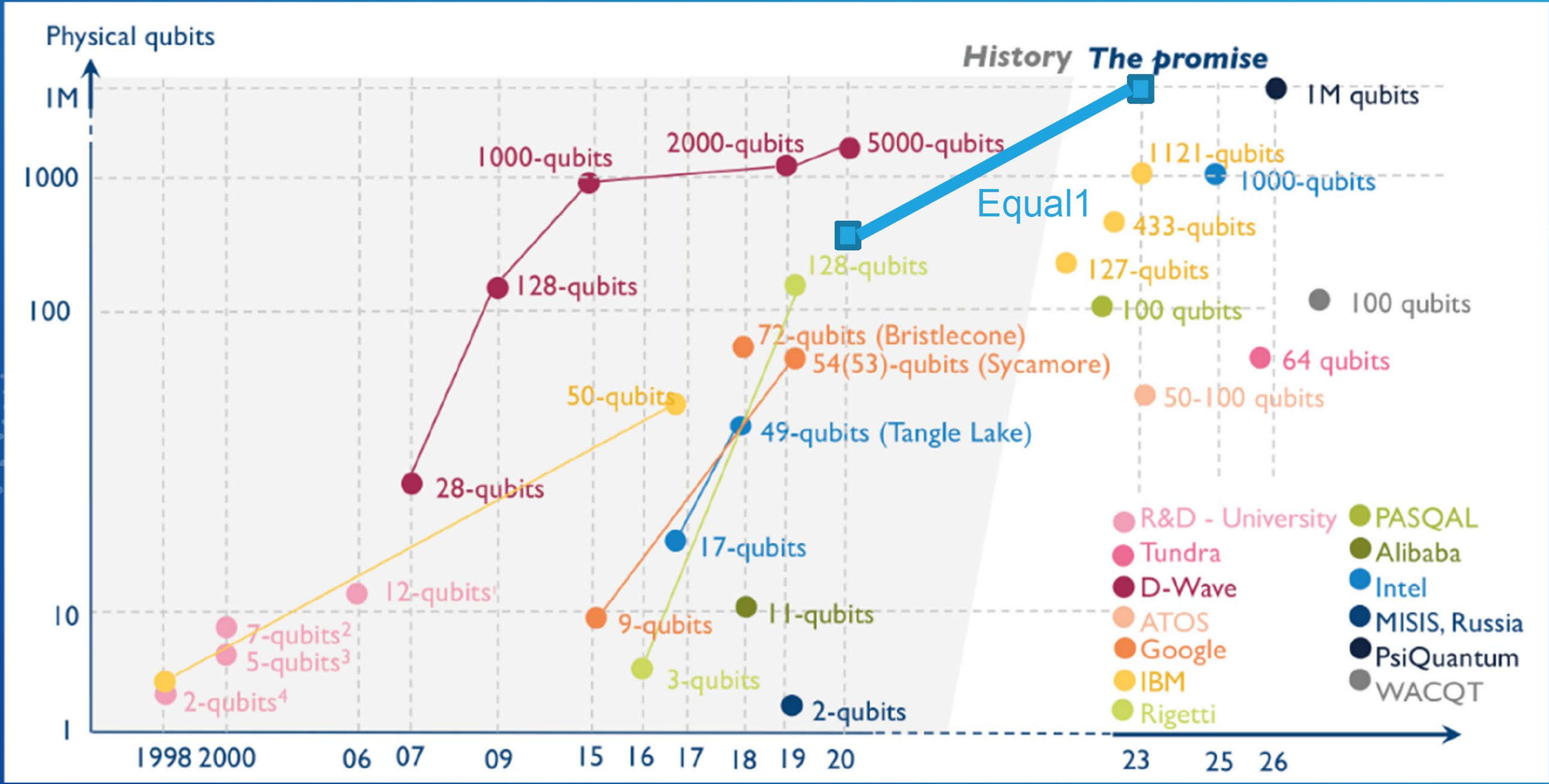
Funding ($m)



1. Assumptions: $500m per strongly invested player (Alibaba, AWS, Google, IBM, Microsoft), $200m per moderately invested player (Honeywell before merger with CQC, Intel).

Source: Crunchbase; Capital IQ; PitchBook; Quantum Computing report; expert interviews; team analysis

Competitive Landscape



Source: Yole [http://www.yole.fr/iso_album/illus_quantum_technologies_1998_2026_physicalqubitroadmap_yole_june2021.jpg}

QCS top-5 use cases

QUIC European Quantum Industry Consortium

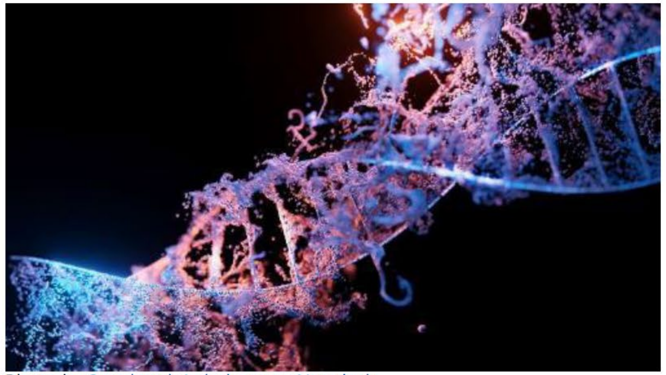


Photo by Sangharsh Lohakare on Unsplash

Quantum Simulation

Drug Discovery

Battery Development

Nitrogen fixation

Fast realistic ranking of design ideas based on binding energy can speed up the discovery of new drug candidates and new battery chemistries however current bottlenecks are limited circuit depth due to noisy qubits and the efficient mapping of electrons to qubits to handle dispersive interactions.

Photo by Arturo Castaneyra on Unsplash

Transportation optimisation

This use case represents all the Knapsack and Routing optimization problems, which also apply to many industries.

Supervised Machine Learning

In our image recognition and fraud detection use cases, classic implementations so far outperform their quantum partners, however, as quantum computers improve the hope is that for certain problems, they will gain an upper hand.

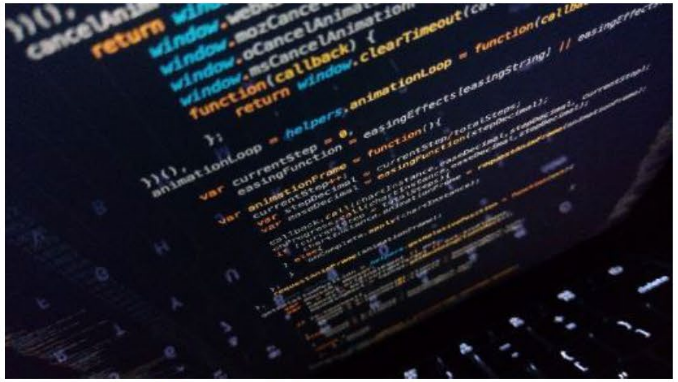


Photo by Irvan Smith on Unsplash

EQUAL1 QUANTUM TECHNOLOGY
Overview

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Commercial CMOS process

Patented quantum dot structures in form of lateral 2D confinement wells

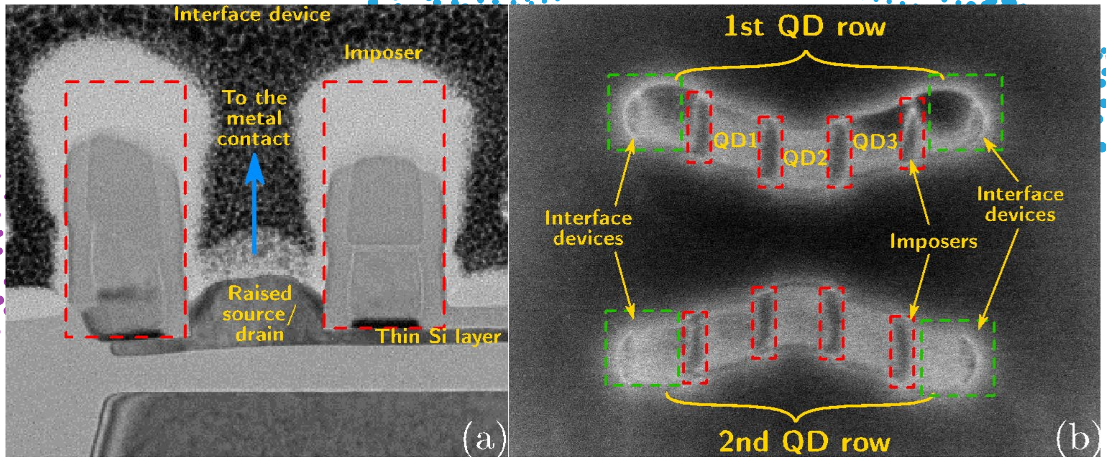
Floating source/drain contacts to inject and detect charge & electrostatic gate control

Quantum dot 2D arrays of different shapes and sizes optimising quantum performance

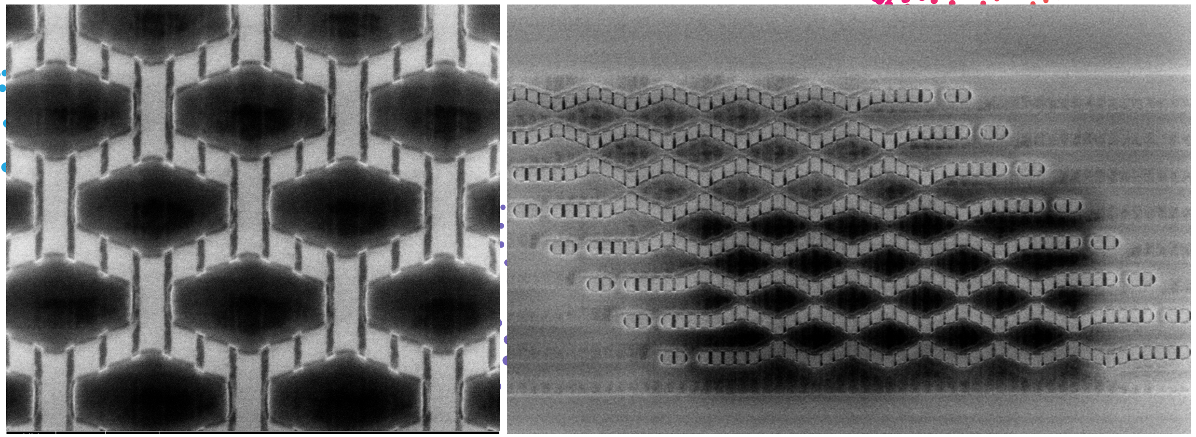
Signature staircase (V-shape) structures to modulate electrostatic interaction

Readily scalable to million of quantum dots

Signature double staircase structure



Two-dimensional quantum dot arrays



EQUAL1 QUANTUM TECHNOLOGY
Alpha Test Chips

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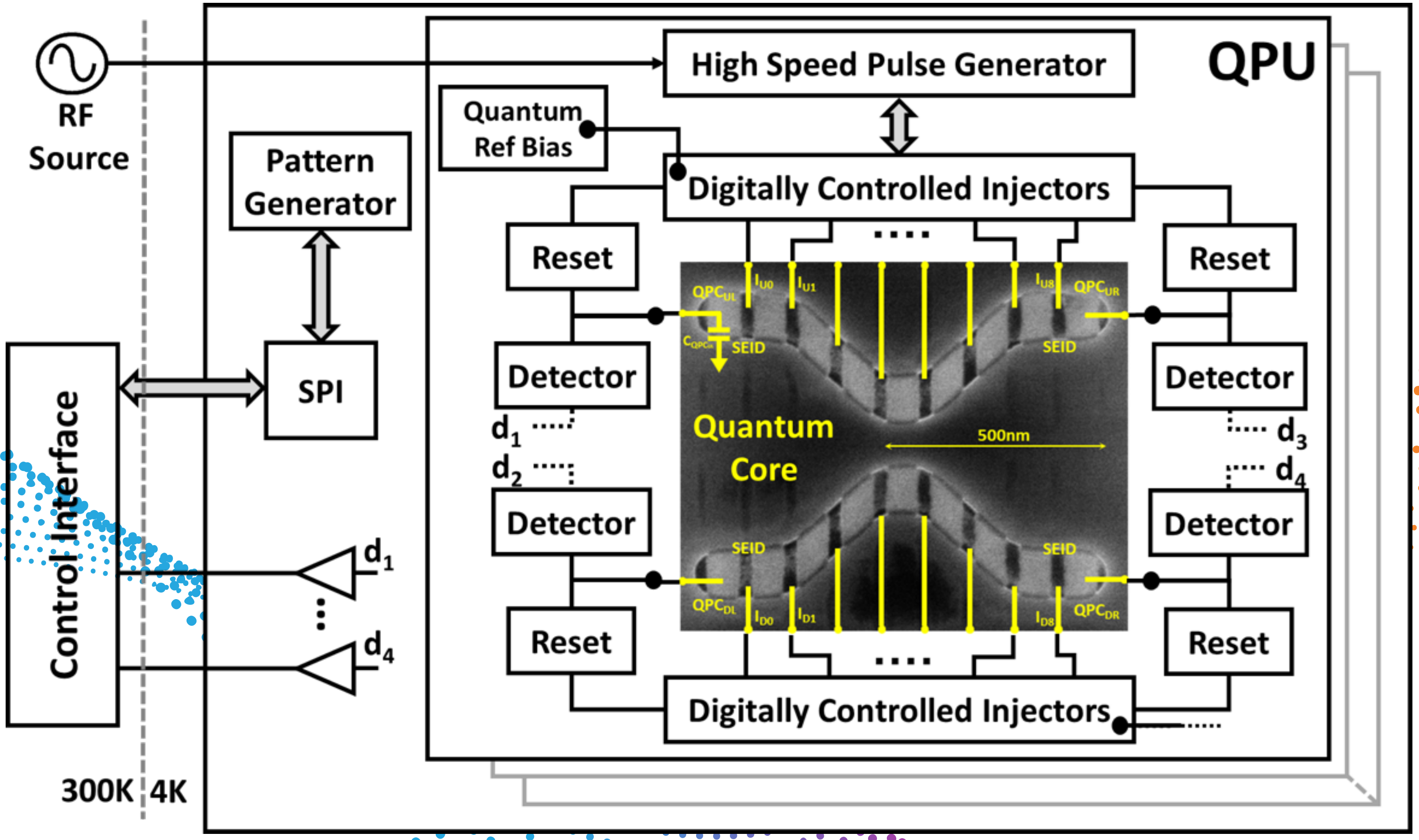
Fully integrated Quantum Processor Unit comprising a quantum core co-located with control + detection circuitry

- Three 1st time successful test chips completed to date
- 22nm FD-SOI from Global Foundries "Plain Vanilla" commercial process
- Multiple Quantum Experiment Cells: 6 physical qubits (min) to 424 physical qubits (max)
- Hybrid qubits added in Alpha3 (2021)
- High-speed pulse generator
- Pattern Generator as command-and-control for all electronics in the QPU
- Quantum Reference Bias Circuit generates all biases for the quantum structure from a single input reference



Sample Quantum Experiment Cell: 4 Injectors/detector & 12 imposers

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EQUAL1 QUANTUM TECHNOLOGY

Three generations ultra-compact quantum machines

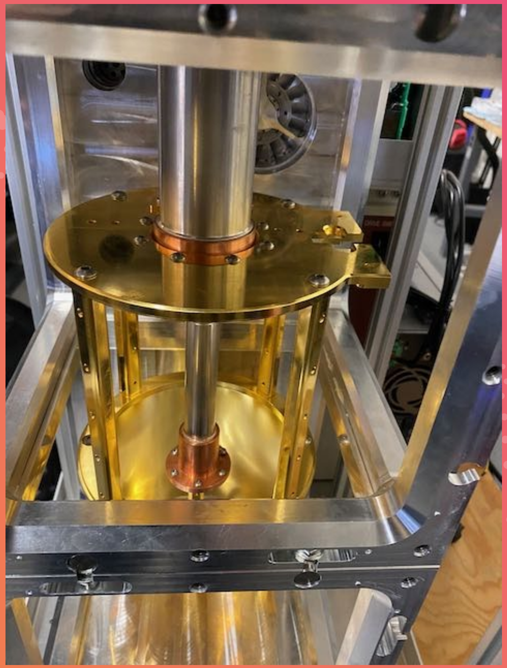
2020

Alice MK1

Initial Test Platform

Two prototypes running at 3 kelvin for over 2 years

2021



Alice MK2

Experimental Physics Qubit Test Platform

2022

Aquarius

Workstation sized machine prototype with all necessary cryo components inside 130x size reduction over competition

BLUEFIN QPU

Quantum tile with adaptive error correction

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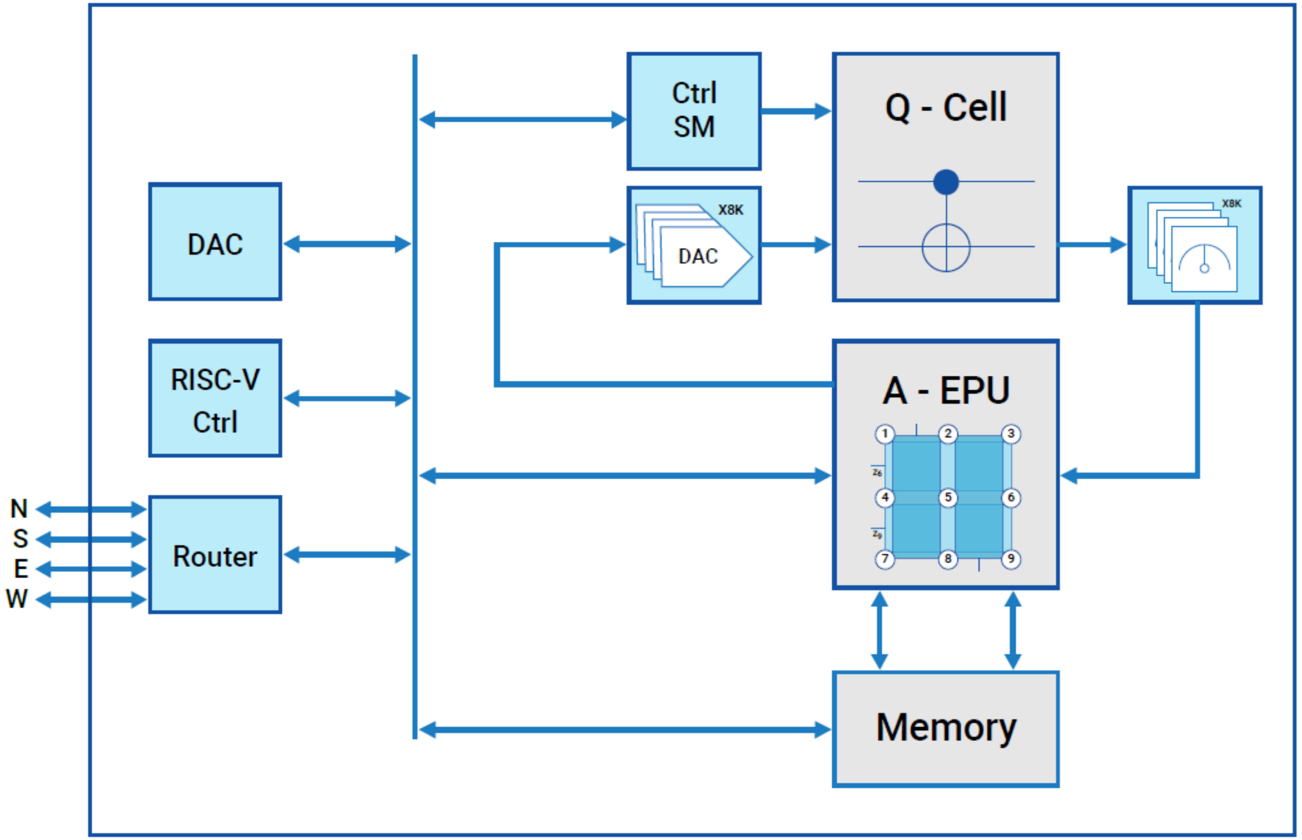
8K physical qubits + adaptive EPU resulting in 2 high quality qubits per tile

Patented A-EPU feedback applies active correction

Quantum experiments used to energise error tensor

Proprietary training strategy

Federated learning model to improve error correction over time



Q-cell: Quantum Cell Array

A-EPU: Adaptive Error Processing Unit

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Quantum Technologies

roadmap, trends, challenges

Market trends & Strategic Industry Roadmap

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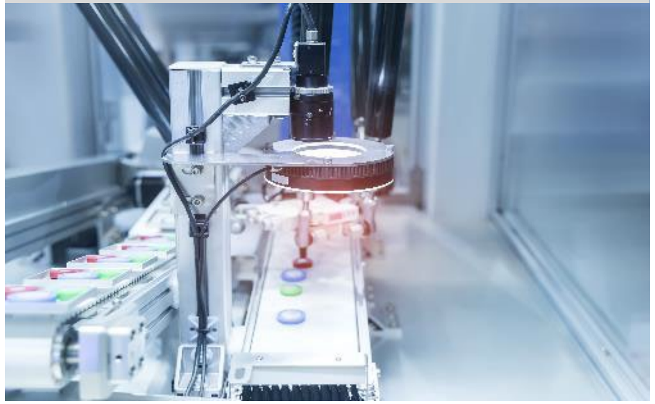
Quantum Computing

Quantum Communications

Quantum Sensing & Metrology



Education & skills

Standards

Intellectual Property

Governance Principles

QuIC
European Quantum Industry Consortium

Market trends & Strategic Industry Roadmap

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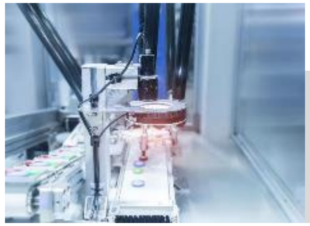
Quantum Computing

- Enormous potential to solve problems and be disruptive
- **Geopolitical race to scale up, number, quality and speed of qubits**
- European sovereignty needs 2 functional, full-stack quantum computing solutions based entirely on European-made components

Quantum Communications

- Able to provide "perfect security" and are important from both a political and commercial perspective
- **Expected to grow almost exponentially**
- Major QKD manufacturing companies in Europe have significant non-European shareholders
- New start-ups emerging in Europe
- Need to develop quantum repeaters
- Investment is needed to develop and improve the technology



Quantum Sensing & Metrology

- Can improve the sensitivity of sensors and offer new functionalities that classical sensors cannot provide
- **Important pillar of the quantum industry**
- Several enabling technologies that are important for quantum technologies are currently not available in Europe

QuIC
European Quantum Industry Consortium

Market trends & Strategic Industry Roadmap

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Education & skills

- Industry needs training and how to solve business problems using quantum technologies
- **Europe needs to keep pace with industry demand** training a quantum technologies skilled workforce

Standards

- As quantum technologies mature and are more widely adopted, the relevance of standardization increases
- **Although many standards organizations co-exist, the industry is relatively fragmented with few or no standards yet in place**

Intellectual Property

- A well-designed process for managing IP and licensing is fundamental
- **EU should create incentives for the generation of IP** and establish a European-wide technology **transfer process** from R&D to corporations

Governance Principles

- Quantum technology can change the world is and has the potential to affect several economic sectors
- **It can improve healthcare, reduce poverty and enable economic growth**

European Quantum Industry Consortium

The Market Potential

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Spend

Grow from $412 million in 2020 to $8.6 billion in 2027

CAGR (2021-2027) of 50.9%

Investments

Reach c. $16.4 billion by the end of 2027

CAGR (2021-2027) of 11.3%

Drivers

Major breakthroughs in quantum computing technology,

A maturing quantum computing as a service infrastructure and platform market,

Growth of performance intensive computing workloads suitable for quantum technology

SOURCE: IDC **worldwide quantum computing market,**

QuIC
European Quantum Industry Consortium

The Market Potential

33K	4K	11K	10.7K
Job Vacancies	Europe	APAC	US

How we see ourselves (QuIC members)

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MATERIALS & PROCESSES

Rare earth ionized materials
Nitrogen, helium 2 and 3,
Nanocarbon, diamonds,
Specific silicones
Nanostructures
Hi-tech metallurgy
Vacuum generators,
Cryogenics
Photonics...etc.

Quantum computing hardware

IQM
PASQAL

Quantum sensing

iXblue
gmv INNOVATING SOLUTIONS

Quantum comms

LUXQUANTA
QUSIDE
KETS
IDQ
TKQ
KEEQUANT
SYNDESIS

Quantum software

MULTIVERSE COMPUTING
river lane
QuantrolOx
Qu & Co

Enabling ecosystem

Fraunhofer
JÜLICH Forschungszentrum
QUANTONATION
nextnano Software for semiconductor nanodevices
BluSpecs

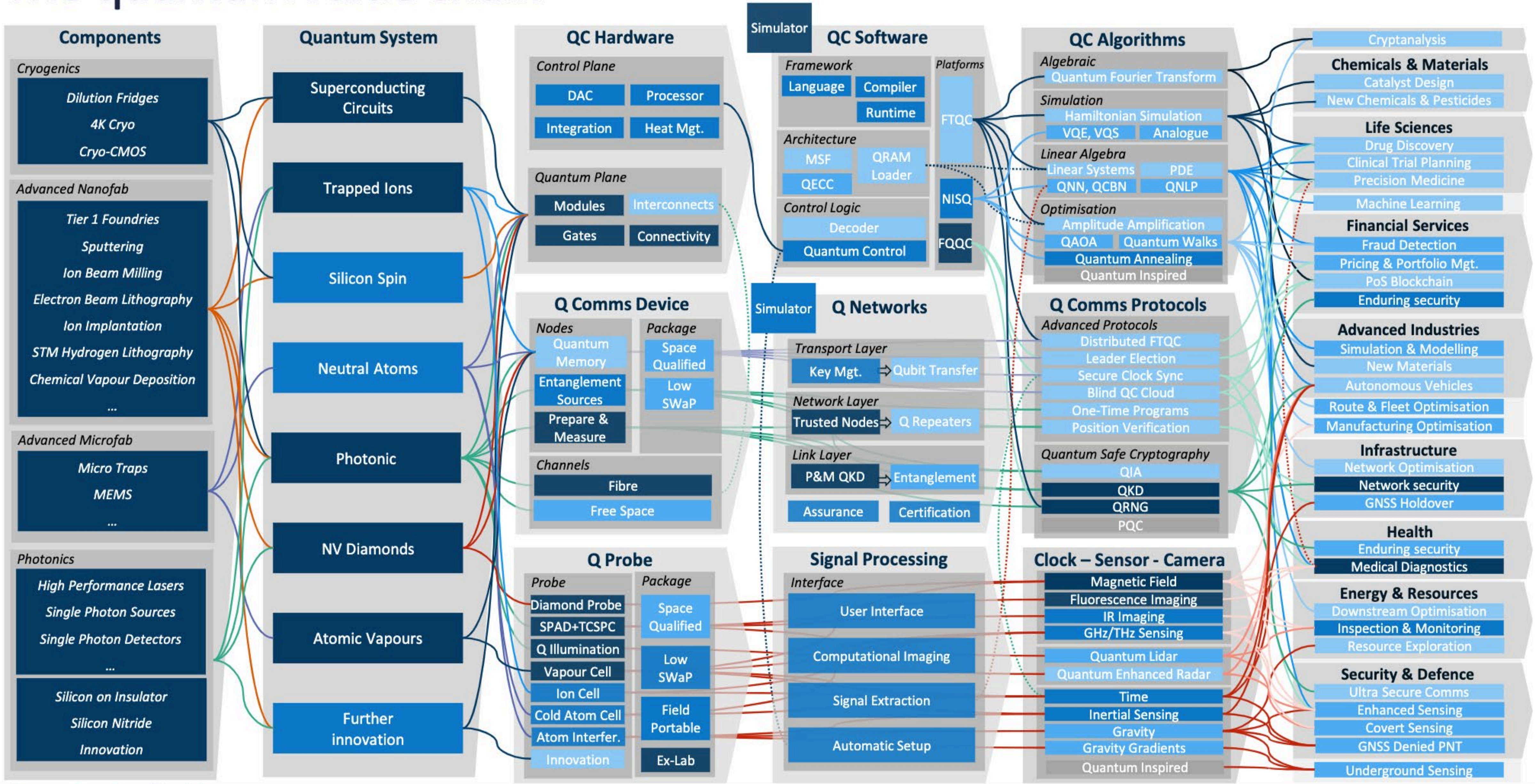
USERS

THALES
BOSCH Invented for life
BASF We create chemistry
MERCK
BBVA

*Indicative only. Non-exhaustive list of members QuIC

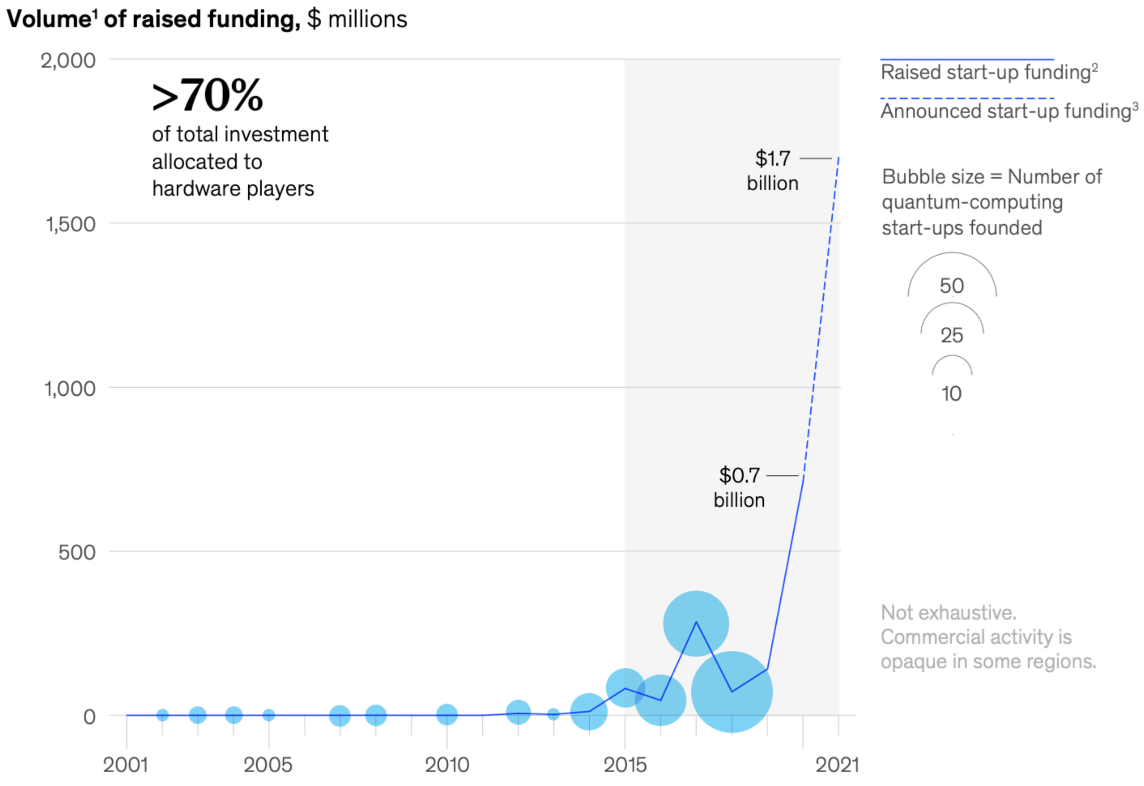
The quantum value chain

Commercial | Prototype | Demonstrator | Academic



Show me the money...

Start-up activity and investments in quantum computing have skyrocketed since 2015.



[1]Based on public investment data recorded in PitchBook; actual investment is likely higher.
[2]Public announcements of major deals; actual investment is likely higher.
[3]Start-ups from 2019 and later are likely still in stealth mode or are not yet recognized as quantum-computing companies by relevant platforms and experts.
Source: PitchBook; McKinsey analysis

Quantum computing: An emerging ecosystem and industry use cases
McKinsey & Co. | Dec 2021

Market development

High capital entry barriers

High R&D entry barriers

Intensive input from academia and RTO

Market currently structured around major corporates but a rich landscape of start-ups is emerging

High reliance on public funding and VCs until the technology stack can be democratised

QuIC in Europe & internationally

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National QT industry groups in Europe

QUANTUM TECHNOLOGY AND APPLICATION CONSORTIUM
QUTAC

UKQuantum

le lab quantique

(and others ...)

QuIC
European Quantum Industry Consortium

International QT consortia

QED-C

Quantum STrategic industry Alliance for Revolution
Q-STAR

QUANTUM INDUSTRY CANADA

IOTWeek

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Thank you!

Find more:

www.euroquic.org

info@euroquic.org