INSTITUT d'OPTIQUE GRADUATE SCHOOL ParisTech

NAQUIDIS CENTER

Quantum Photonics... Every Photon Counts!

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ALPHA RLH

Statement

Optics and photonics are a core enabling element of quantum technologies, as many of the systems require very precise control of light

Quantum technology presents various innovation opportunities for the optics and photonics community, and there is a large ecosystem of component, system, and service players with various requirements for their respective architectures...

Who could be the key players of this QT European Ecosystem?

What is the true market of QT for photonics actors?

How to build together a pereign & mature Quantum Photonics Market

Quantum Computing

There are classes of problems that are exponentially difficult to deal with depending on the number of particles with a classical computer but which can be solved in polynomial time with a quantum computer.

Shor factorization algorithm for example.
Deutsch-Jozsa algorithm.

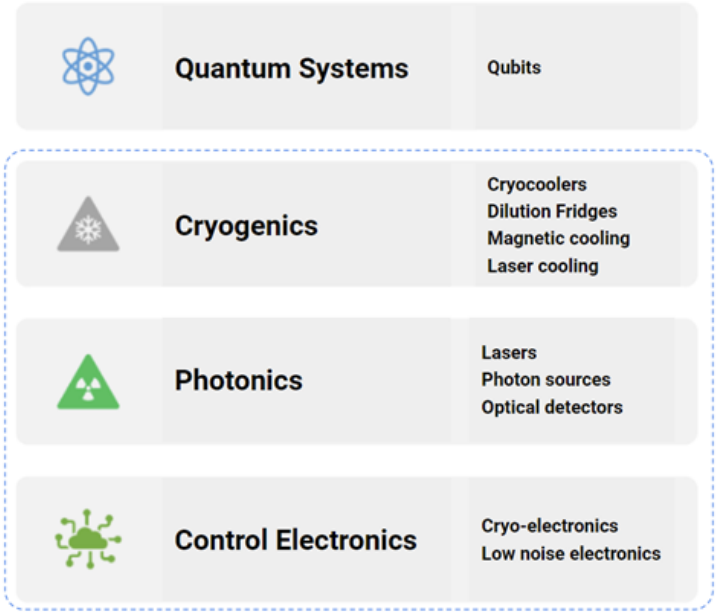
Considerable potential applications in materials science and condensed matter, chemistry, protected communications, etc.

Optimization problems, the traveling salesman,…

Quantum Technology

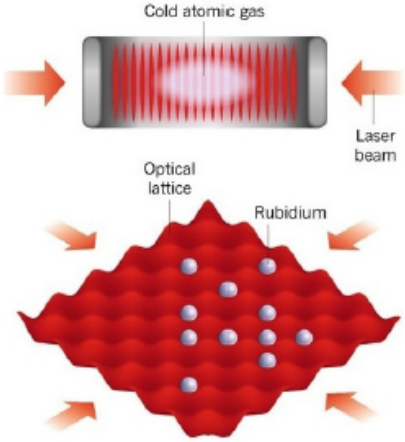
Quantum Systems
- Atoms & Ions
- Superconducting & Semiconductors
- Hybrid
- Topological
- Molecular
- Color Centers
- Photonic

Essential Enabling Technologies
- Cryogenics
- Photonics
- Control Electronics

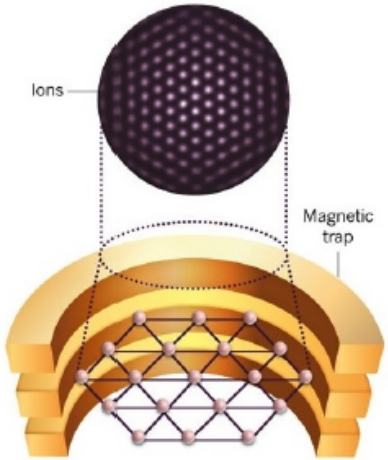


Quantum computing

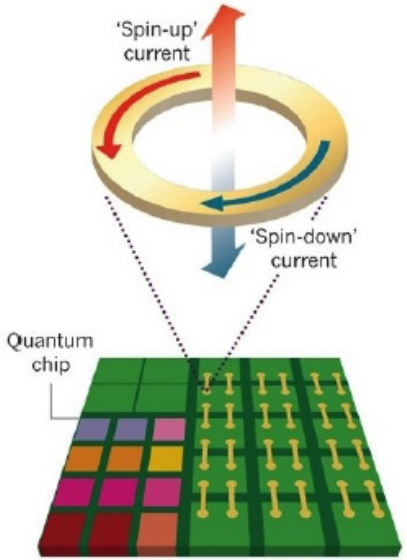
Cold atoms



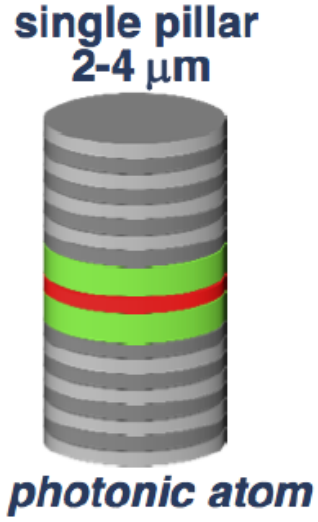
Trapped ions



Superc. loops

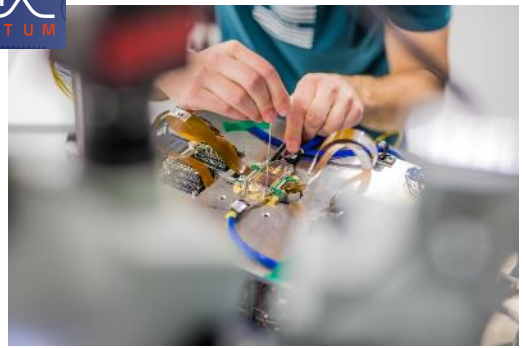


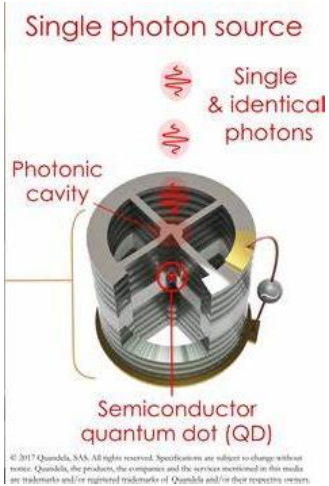
Polaritons

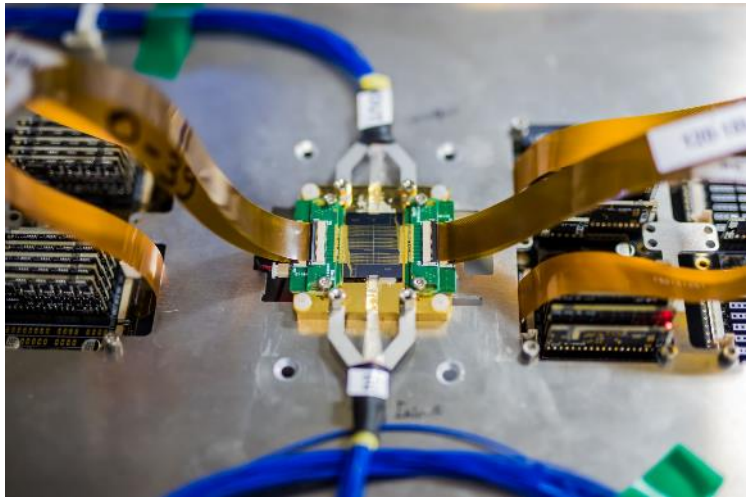


Quantum computing with photons

Photonics integrated circuits & single photon sources







Quantum computing with photons

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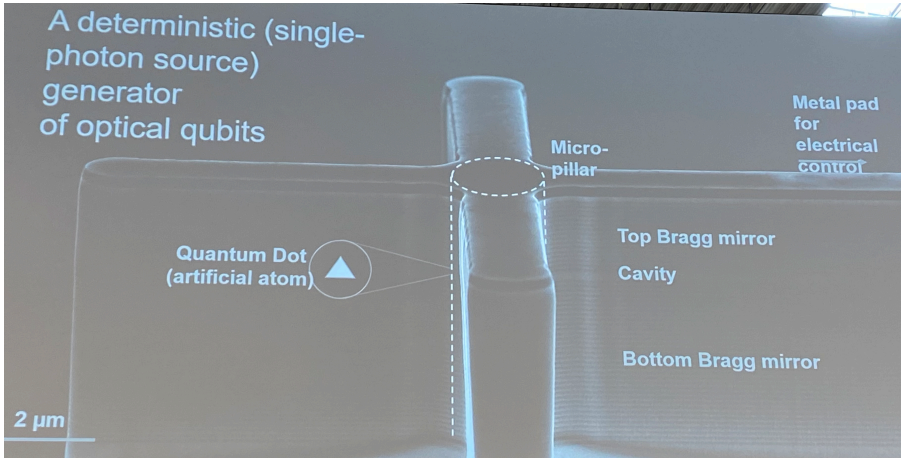
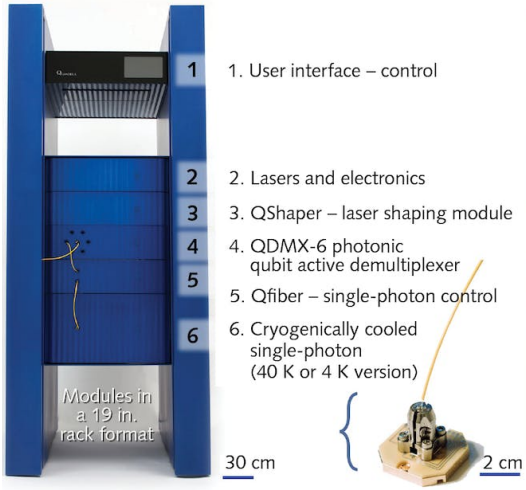
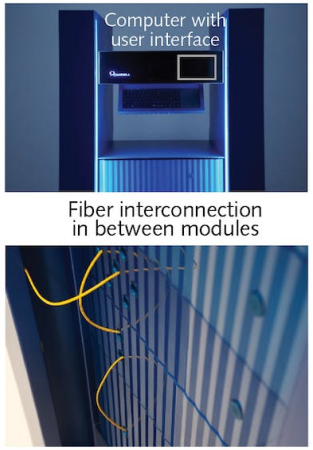
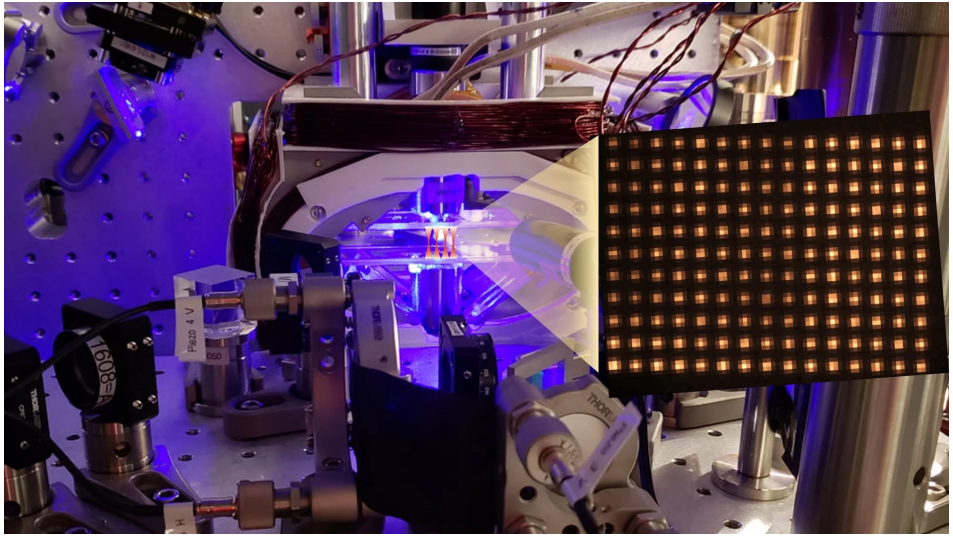
QUANDELA







Quantum computing with atoms



Quantum atom computing : the example of Sr

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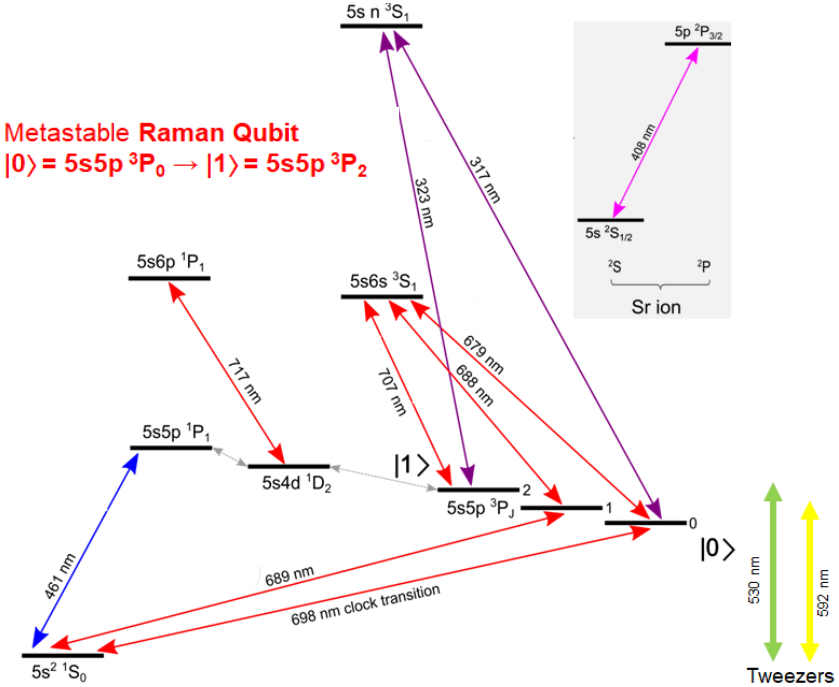
cooling + repumping → optical trapping → optical pumping → 1- or 2-Qubit gate → detection

SPONSORED BY THE Federal Ministry of Education and Research



16 lasers
- 317 nm .. 1550 nm
- power: mW .. 100 W
- frequency stability: Hz .. MHz
- linewidth: Hz .. MHz
- (relative) phase noise: ultralow for high gate fidelity

+ Optical Frequency Comb
+ High Finesse Optical Cavity
+ Wavelength Meter

Other Qubits[**])**
- Other lasers

Quantum computing atoms:
- Rb, Cs, Sr, Yb, …

More lasers & wavelengths!

Photonics as KET : lasers

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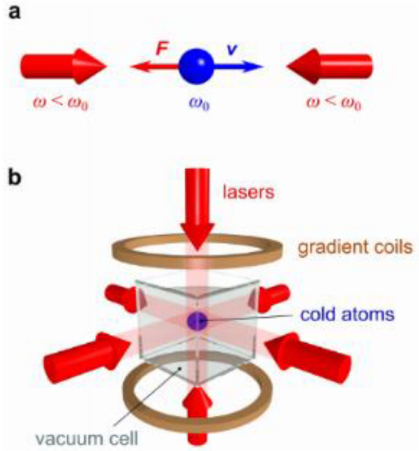
NKT Photonics



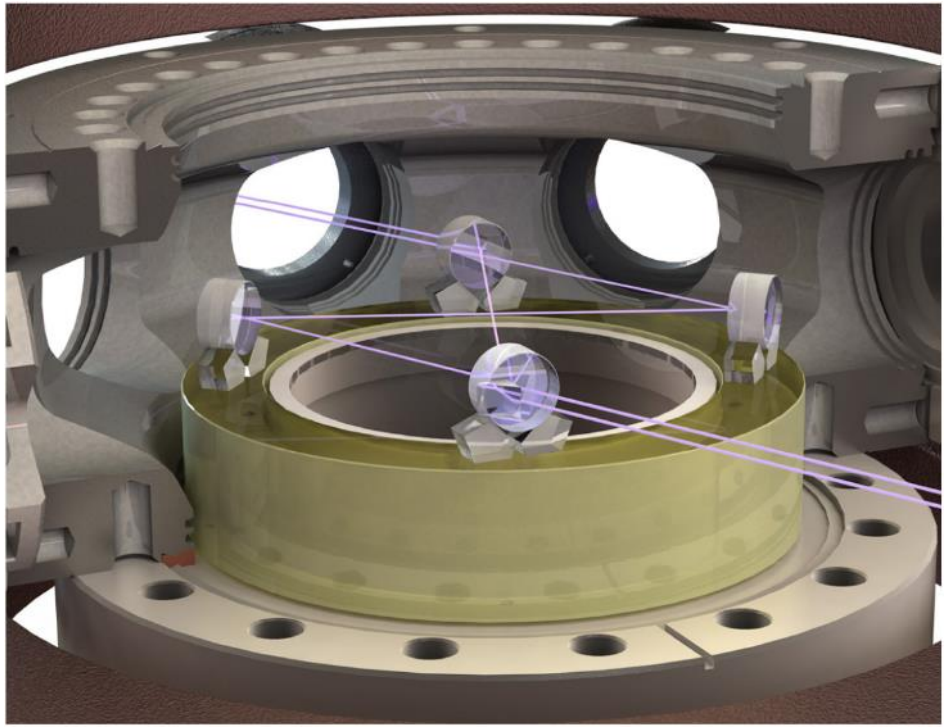
The laser quality and performance are very important:

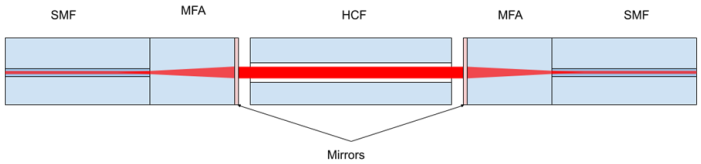
- Wavelength is related to the atomic transition used
- Laser power
- Laser stability and linewidth
- Agility
- Tunability
- …

➔ **$LiNbO_3$ modulators and special fibers are used….**

37 Rb	780 nm 7 W	840 nm 3 W	1064 nm 15 W
38 Sr	317 nm 1 W	813 nm 3 W	
56 Ba	532 nm 7 W	1762 nm 0.5 W	
70 Yb	399 nm 1 W	556 nm 1 W	638 nm 10 W	770 nm 4 W	1064 nm 15 W

Photonics as KET : cavities



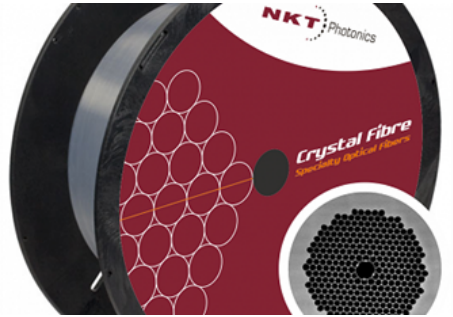


Used as references, exacerbation medium, frequency converter…

Photonics as KET : fibers

- Rare earth doped fibers (for lasers and amplifiers)
- Photonic crystal fibers (PCFs) e.g. for high power light guiding and nonlinear conversion

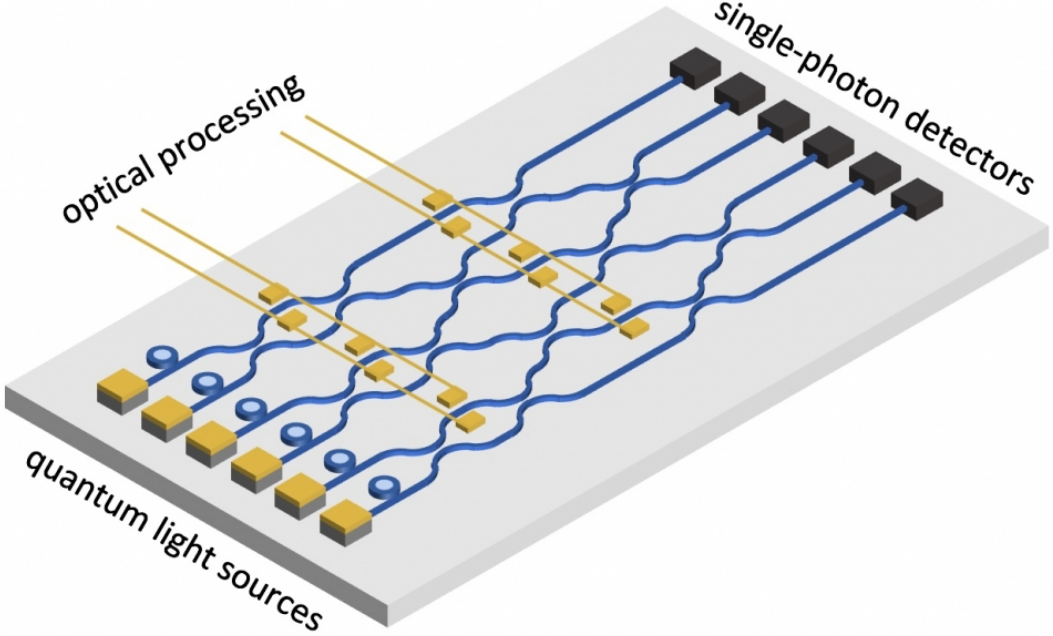
iXblue

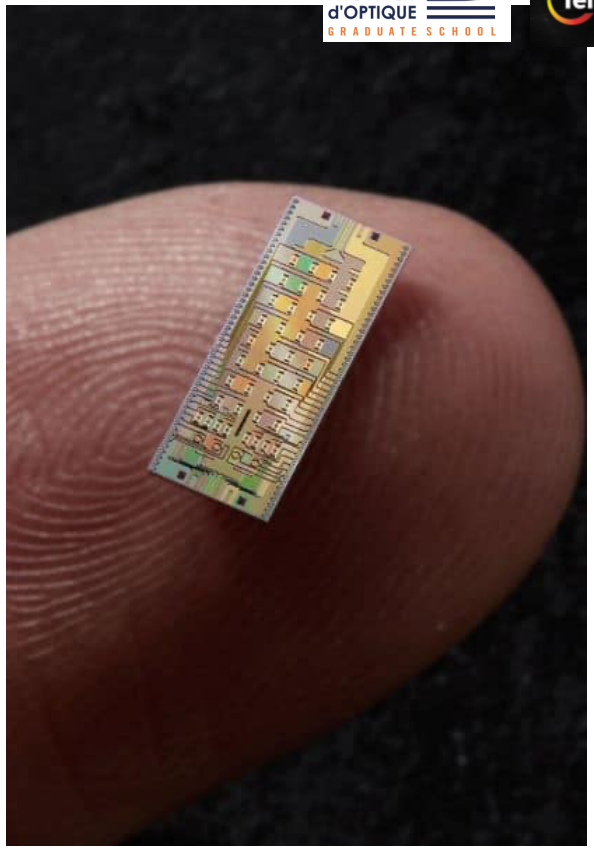


NKT Photonics

… and more

Photonics as KET : PIC





Photonics as KET : detectors

- Single photon detectors (e.g. APD or SNSPD)
- Measurement of single photons / Fock states

ID Quantique

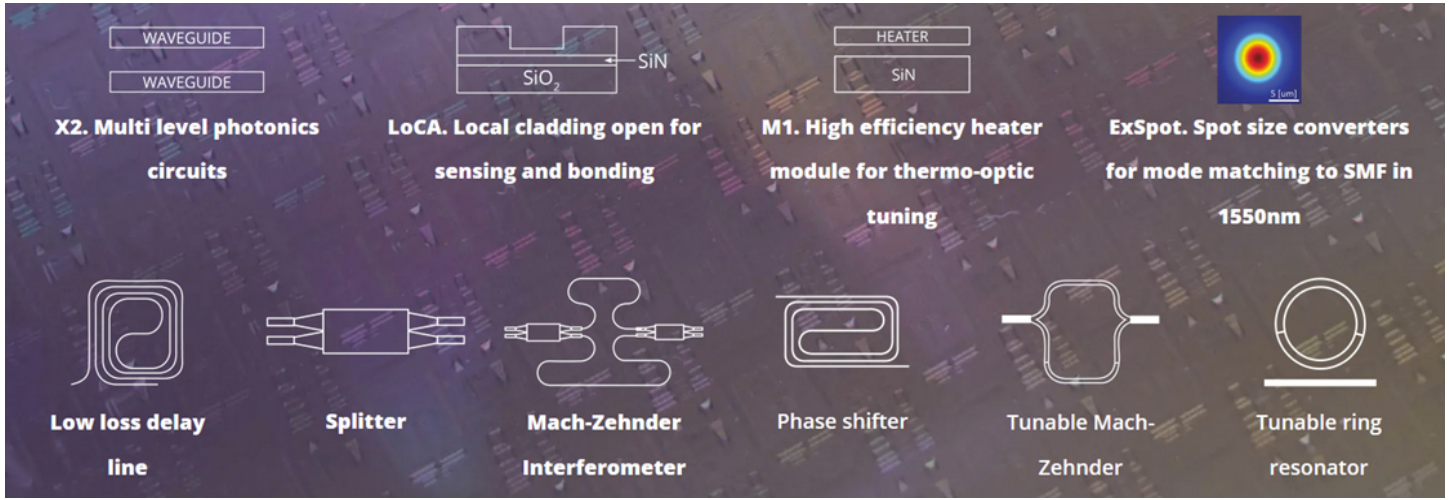
Aurea Technology

Single Quantum

Micro Photon Devices

Integrated Photonics

Photonic Integrated Circuits (PICs) for miniaturization



Ligentec, CEA LETI…

… and more

Road to 2035: Near-Term (2025 – 2029)

Lasers
- Power, wavelength range, low noise etc
- SWAP reduction
- Higher TRL

Single-photon sources
- Higher efficiency sources

Photonics / Optics
- EU sovereignty for components (free space, fiber, crystals, diodes etc)

Advanced optical detectors
- Higher efficiency telecom detectors
- Larger detectors for space

Integrated Photonics
- New production facilities
- Cryogenic compatibility
- Loss reduction
- Source, detector, and modulator integration
- On-chip single photons and squeezed light

Road to 2035: Long-Term (2030 – 2035) but has to start now)

Lasers
- Further SWaP Reduction of lasers, stabilized lasers, optical frequency combs etc
- Cost reduction
- Reduce necessary user interaction

Single-photon sources
- Improve miniaturisation

Advanced optical detectors
- Real photon-number-resolving detectors;
- Higher count rates
- Ultralow time jitter

Integrated Photonics
- High-end foundry fabrication
- Assembly lines photonic integrated circuits

Dual Use of QT : EU recommandation, 10/2023

European Commission - Press release

Commission recommends carrying out risk assessments on four critical technology areas: advanced semiconductors, artificial intelligence, quantum, biotechnologies

Strasbourg, 3 October 2023

Today, the Commission adopted a Recommendation on critical technology areas for the EU's economic security, for further risk assessment with Member States. This Recommendation stems from the Joint Communication on a European Economic Security Strategy that put in place a comprehensive strategic approach to economic security in the EU.

This Recommendation relates to the assessment of one of four types of risks in that comprehensive approach, namely technology risk and technology leakage. The risk assessment will be objective in character, and neither its results nor any follow-up measures can be anticipated at this stage. In the Recommendation, the Commission puts forward a list of ten critical technology areas. These technology areas were selected based on the following criteria:

- Enabling and transformative nature of the technology: the technologies' potential and relevance for driving significant increases of performance and efficiency and/or radical changes for sectors, capabilities, etc.;
- The risk of civil and military fusion: the technologies' relevance for both the civil and military sectors and its potential to advance both domains, as well as risk of uses of certain technologies to undermine peace and security;
- The risk the technology could be used in violation of human rights: the technologies' potential misuse in violation of human rights, including restricting fundamental freedoms.

QT enabling industry needs worldwide market

Recommendations for strengthening the QT market

- Not a **fundamental lack of supply** -> Europe is the home for the best suited laser sources & photonics systems for QT and serves maybe 60 to 80% of the current global market demand for quantum.

- On the other hand, there can be a **fundamental discrepancy between the expectation of the not-laser-savvy quantum customers and their SWaPc requirements** on one side and the existing photonics companies in the field on the other side.

- **Lack of realism on the market size** as far as the transition effort to bridge such discrepancy is concerned.

- Mastering the demand **in small volume today by testing the quality in limited series** is a tricky thing...

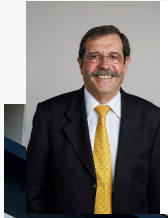
- From small volume and high cost to largest volume and low cost we need a consistent longterm market (not funding alone with its wavy political uncertainties), **in non-European markets**, that we cannot address due to understandable European souvereignity concerns.

- **Capital investment** is needed.

- **Government / European contracts** (compare to USA)

IOGS 2024 :

If I have seen further, it is by standing on the shoulders of giants…
Newton correspondance, 1675)



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De l'animation scientifique à l'impact économique

12 *PROJETS*

+18 *PARTENAIRES ACADEMIQUES ET INDUSTRIELS*

15 *RECRUTEMENTS (PHD, POST-DOCS, IR, CHERCHEURS)*

+9 *MILLIONS D EUROS LEVES*
POUR 3 MEUR INVESTIS PAR LES MEMBRES DU CONSORTIUM

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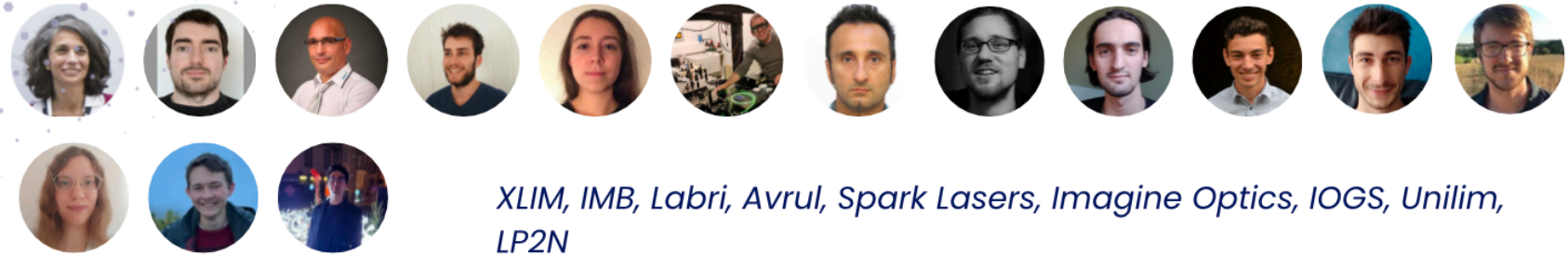
DE LA NECESSITE D'ATTIRER DE NOUVEAUX TALENTS

15 recrutements dans 9 structures



XLIM, IMB, Labri, Avrul, Spark Lasers, Imagine Optics, IOGS, Unilim, LP2N

***Houko-formation**, la plateforme de formation continue en sécurité informatique, cryptographie et informatique quantique.*

atomCtrl

INTRO ACTUALITÉS OPEN JOBS JOIN US

Programme FRANCE 2030

Sécurisation de l'approvisionnement français en lasers pour la manipulation d'atomes pour les technologies quantiques

The french initiative for Atom-based Quantum Technologies Dedicated Lasers

AVEC LE SUPPORT DE

RÉPUBLIQUE FRANÇAISE
Liberté Égalité Fraternité

anr agence nationale de la recherche

FRANCE 2030

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TEAMWORK MAKES THE DREAM JOB

WE WELCOME NEW OPPORTUNITIES TO EXCHANGE IDEAS AND TO EXPLORE COLLABORATIONS.

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