

15/03/2019

Iñigo Artundo

# Estado del arte de la fotónica integrada para aplicaciones de cuántica

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Quantum technologies in Spain

**secpho**  
collaborate to innovate

**VLC**  
PHOTONICS

# 1

## Photonic Integration

Company introduction

Introduction to photonic integrated circuits

# 2

## PICs for Quantum Optics

Integration of quantum optics systems

Quantum PIC requirements

Quantum PIC examples

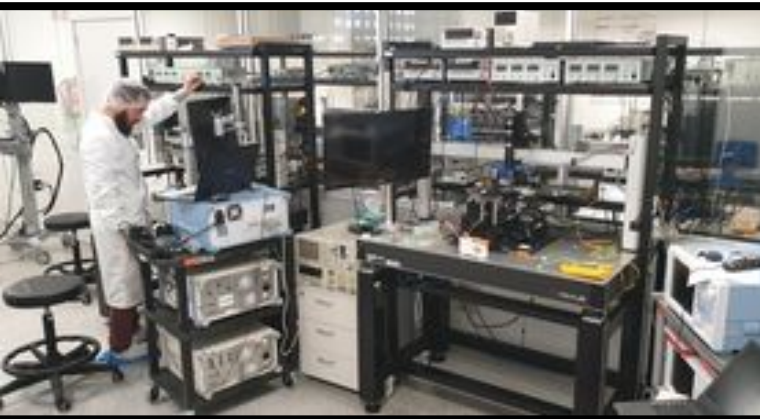
Market status

# 3

## Summary & take-aways

# Company Introduction

- Founded in 2011.
- Offices in Spain, with agents in USA, the Netherlands and China.
- 14 members of extensive academic and industrial experience.
- 20+ years in the field of integrated optics and photonics.



# Photonic Integrated Circuits

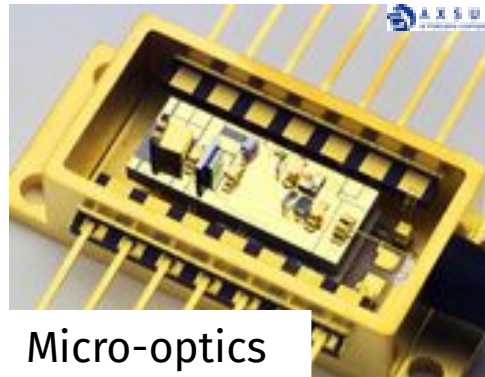
Multiple components of a system into a single monolithic chip.

**Integrated  
Circuits**

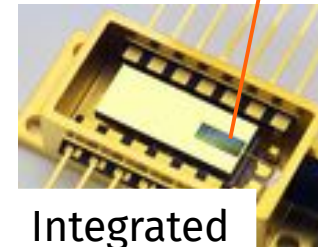


Transistors  
Capacitors  
Resistors  
Inductors  
etc.

**Same evolution path as electronics:**



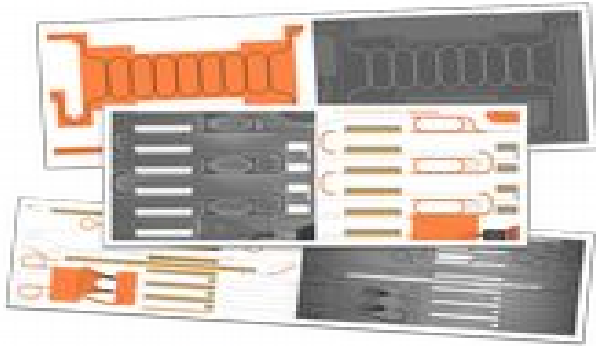
Micro-optics



Integrated optics

Lasers/LEDs  
Photodetectors  
Modulators  
Optical Filters  
Couplers/Splitters  
Multiplexers  
Interferometers  
etc.

Provide services for the development of



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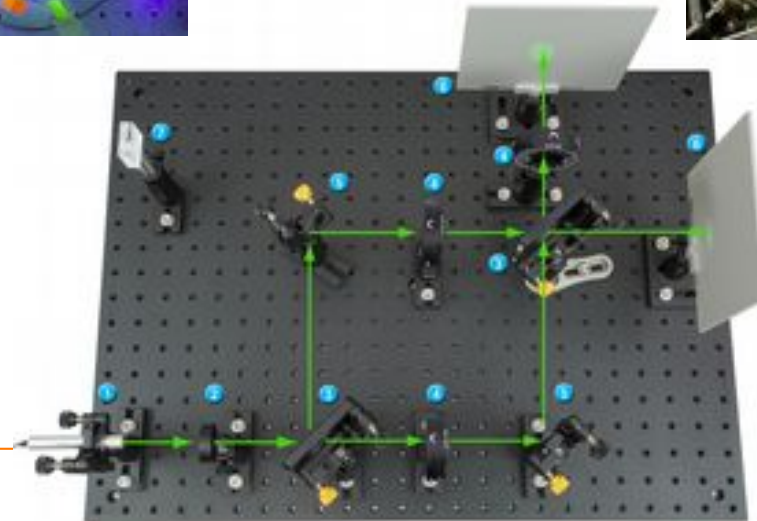
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## Summary & take-aways



# Quantum optics systems



## Advantages:

- Compact, scalable.
- Robust, working at ambient conditions.
- Mature telecom technology in volumes.



## Disadvantages:

- Performance trade-offs
- Integration of single and entangled photon sources is highly complex.
- Single-photon detectors not yet on PICs.

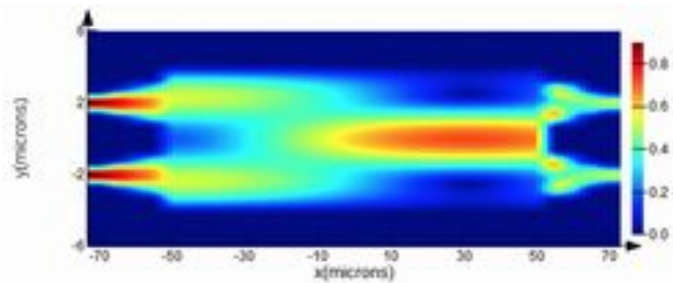
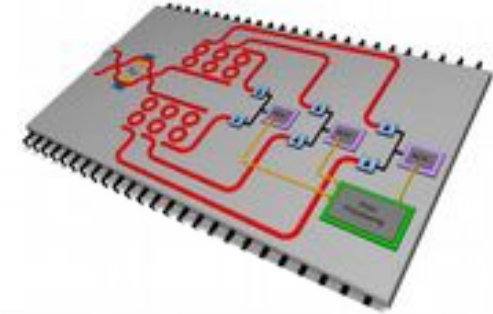




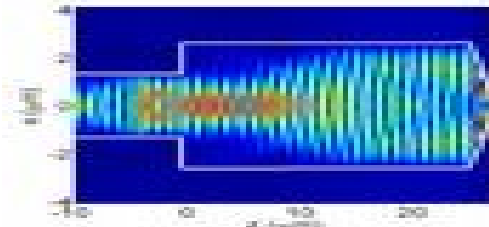
# Quantum PIC requirements

## To integrate quantum optic applications:

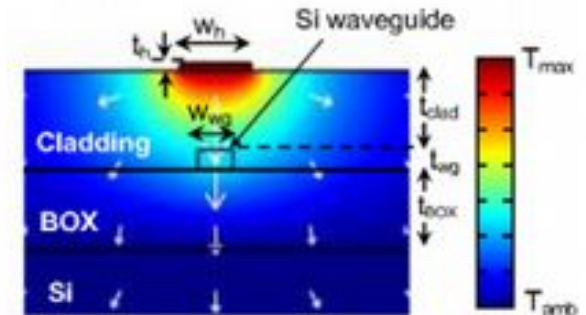
- Very low-loss waveguides
- Photonic passive components
- Transparent at certain wavelengths
- Accurate and repeatable process



50:50 couplers



Mirrors



Phase shifters

# Quantum PIC examples

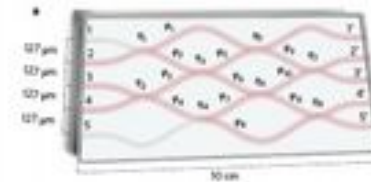
## Security:

- Quantum key distribution
- Quantum random number generation



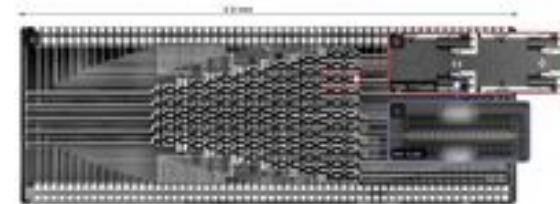
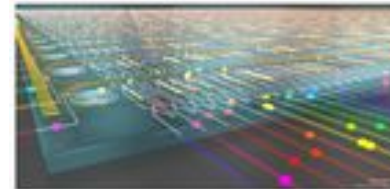
## Quantum signal processing:

- Boson sampling
- Linear optical quantum computing



## Quantum sources:

- Single photon generation
- Photon pair generation



- Sibson, P. et al. "Chip-based Quantum Key Distribution" Nature Comm., 8, 13984 (2017)  
Tillmann, M. et al., "Experimental Boson Sampling", Nature Phot. Lett., 7, 7, 540-554 (2013)  
Crespi, A et al. "Integrated multimode interferometers with arbitrary designs for photonic boson sampling", Nature Phot., 7, 7, 545-549 (2013)  
Taballione, C. et al. "8x8 Reconfigurable Quantum Photonic Processor based on silicon nitride waveguides" Arxiv. 2018. <https://arxiv.org/1805.10999>  
Harris, N.C. et al. "Bosonic transport simulations in a large scale programmable nanophotonic processor", Nature Phot., 11, 7, 447-452 (2017)  
Silverstone, J.W. et al. "Silicon Quantum Photonics", IEEE JSTQE, 22, 6, 390-402 (2016)



## Quantum entropy source on an InP photonic integrated circuit for **QRNG**

*C. Abellan et Al., Optica 3-9, 2016.*



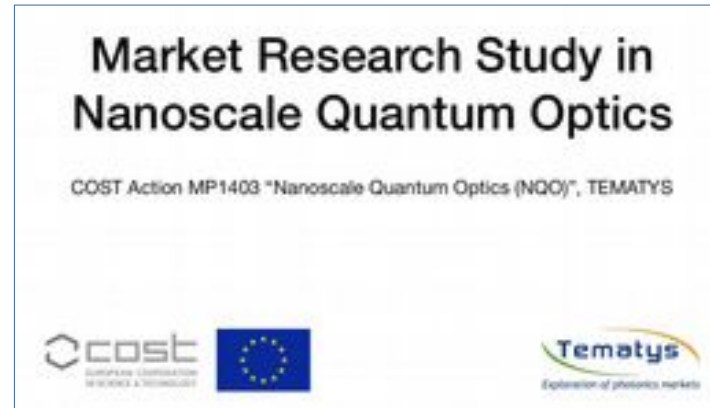
### **Eurostars:**

- **QuPIC** – On discrete variable **QKD**

### **EU H2020 – Quantum Flagship:**

- **CiViQ** – On continuous variable **QKD**
- **S2QUIP** – Integration of 2D **single photon sources**





**Available for free download: [www.cost-nqo.eu](http://www.cost-nqo.eu)**

## **Companies developing or using (integrated) quantum systems:**

- 13+ in Quantum Random Number Generation (QRNG)
- 18+ in Quantum Key Distribution (QKD)
- 19+ in quantum sensing
- *55+ in quantum computing*

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**Many quantum systems use optics  
and can be integrated into a photonic circuit.**

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**Many quantum systems use optics  
and can be integrated into a photonic circuit.**

**PIC integration enables industrialization.**

2

3

**Many quantum systems use optics  
and can be integrated into a photonic circuit.**

**PIC integration enables industrialization.**

**Technology is evolving very quickly.**

4

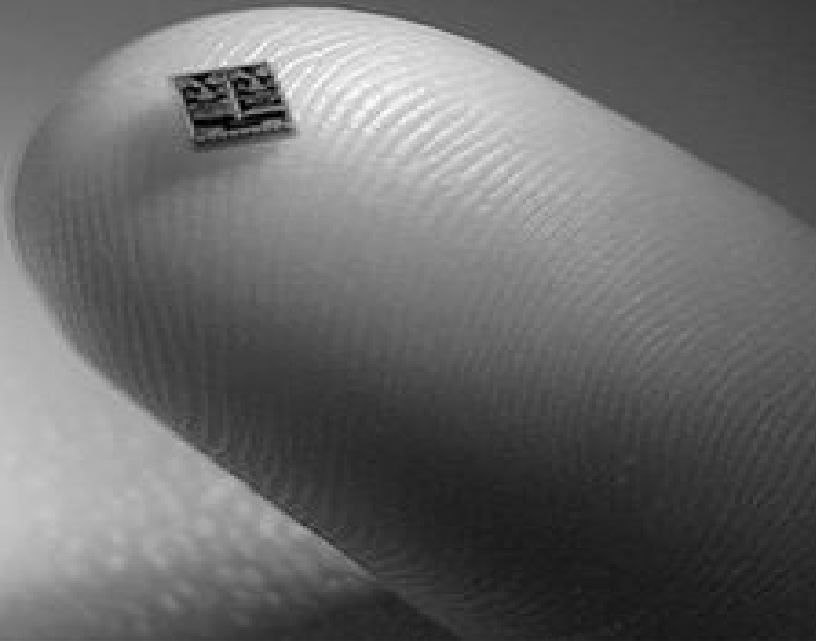
**Many quantum systems use optics and can be integrated into a photonic circuit.**

**PIC integration enables industrialization.**

**Technology is evolving very quickly.**

**Market is taking off since the last 2 years, and it will be exploding soon.**

**Thank you for  
your attention!**



## Contact details

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