

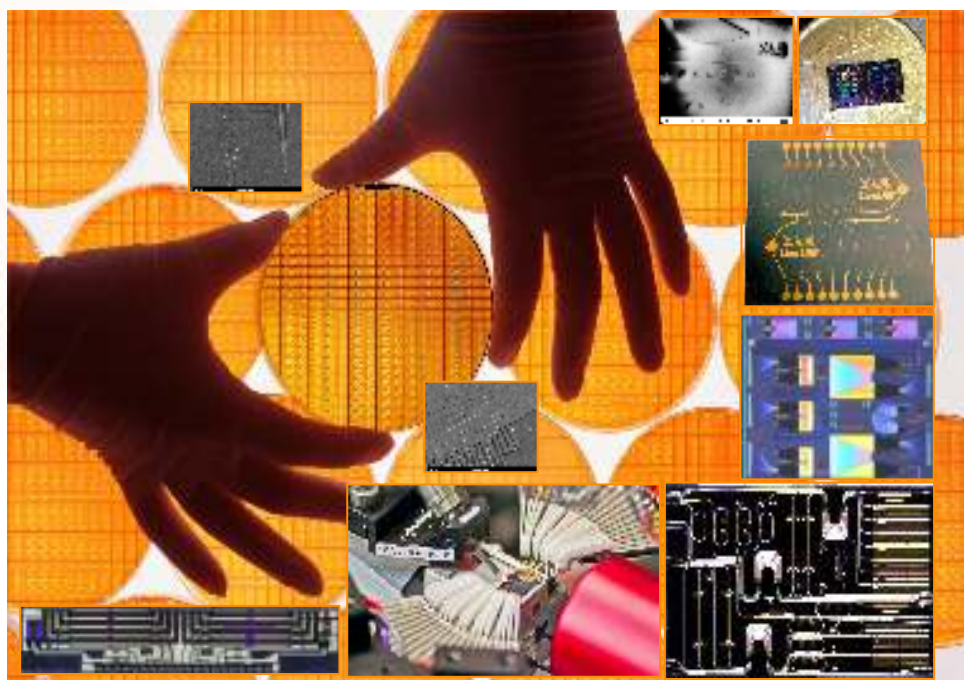


PHOTONIC INTEGRATED CIRCUITS FOR QUANTUM OPTICS APPLICATIONS

3^{er} Foro Tecnologías Cuánticas – QUINFOG
CSIC Campus (Madrid) - November 3rd, 2016



Outline



COMPANY OVERVIEW

- THE PROBLEM & THE SOLUTION
- THE BUSINESS MODEL
- TECHNOLOGIES & LIBRARIES
- INTERNAL AND COLLABORATIVE R&D

QUANTUM OPTICS & PHOTONIC CHIPS

- Q-ENTROPY SOURCE PHOTONIC CHIP
- PROGRAMMABLE HEXAGONAL MESHES

CONCLUSION



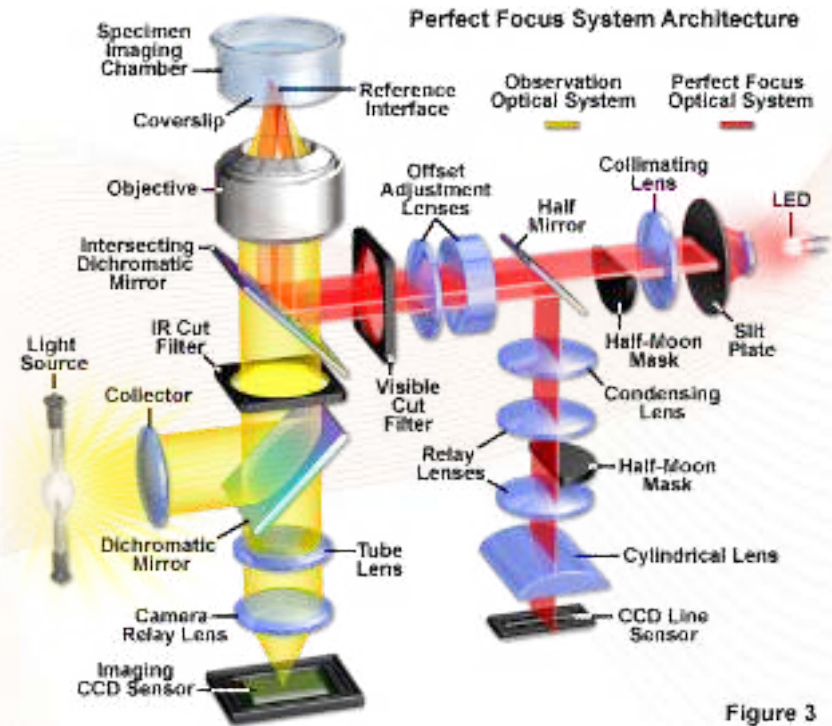
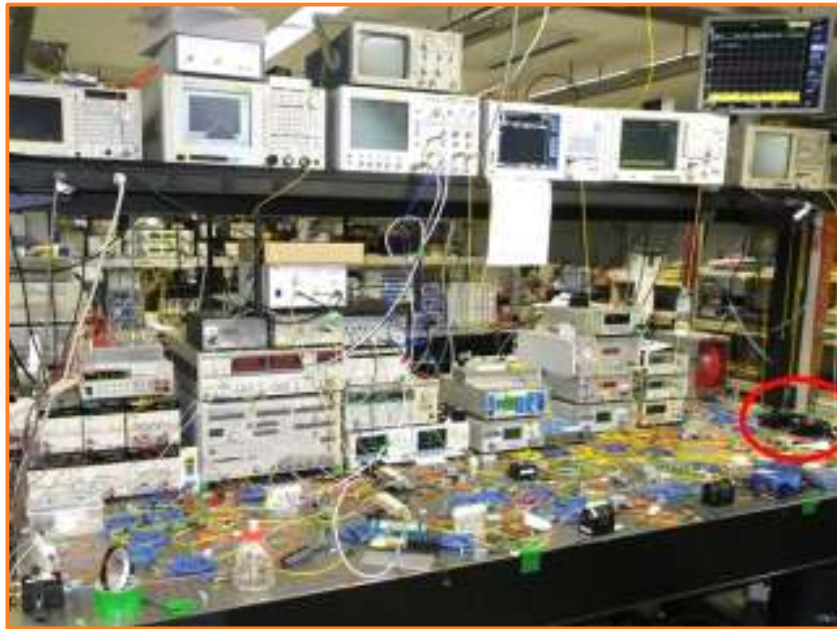
Company Overview

- VLC Photonics is a **Photonic Integrated Circuit (PIC) DESIGN HOUSE**
 - Established in 2011 as spin-off from the Technical University of Valencia (UPV)
 - From photonic integration expertise acquired through competitive R&D
 - The founding team has 15+ years of experience in photonics and integration
- The company **headquarters are in Valencia (Spain)**
 - The office is at the UPV campus, in the Business Development Center
 - The company has direct access to UPV Photonics Labs & Experts
 - It serves customers worldwide, mainly Europe, USA, Asia and Australia





The problem: bulk, heavy, complex & expensive optics





The solution

VLC addresses the needs of system integrators which use aggregation of discrete photonic components to build their products

VLC outsources fabrication to chip manufacturers that provide generic processes, which can be employed to serve a wide range of applications

VLC provides a solution with the advantages of integration: size, cost, power, scalability & performance

System Integrator

Specialized market
Advanced functionality
Small/Medium volume



System concept

VLC Photonics

PIC dev know-how
Building block library
Design/Prototype/Test



Chip Manufacturer

Generic components
Simple functionality
Large volume



Self fabrication

Size
Cost
Power
Scalability
Performance

Integrated Solution

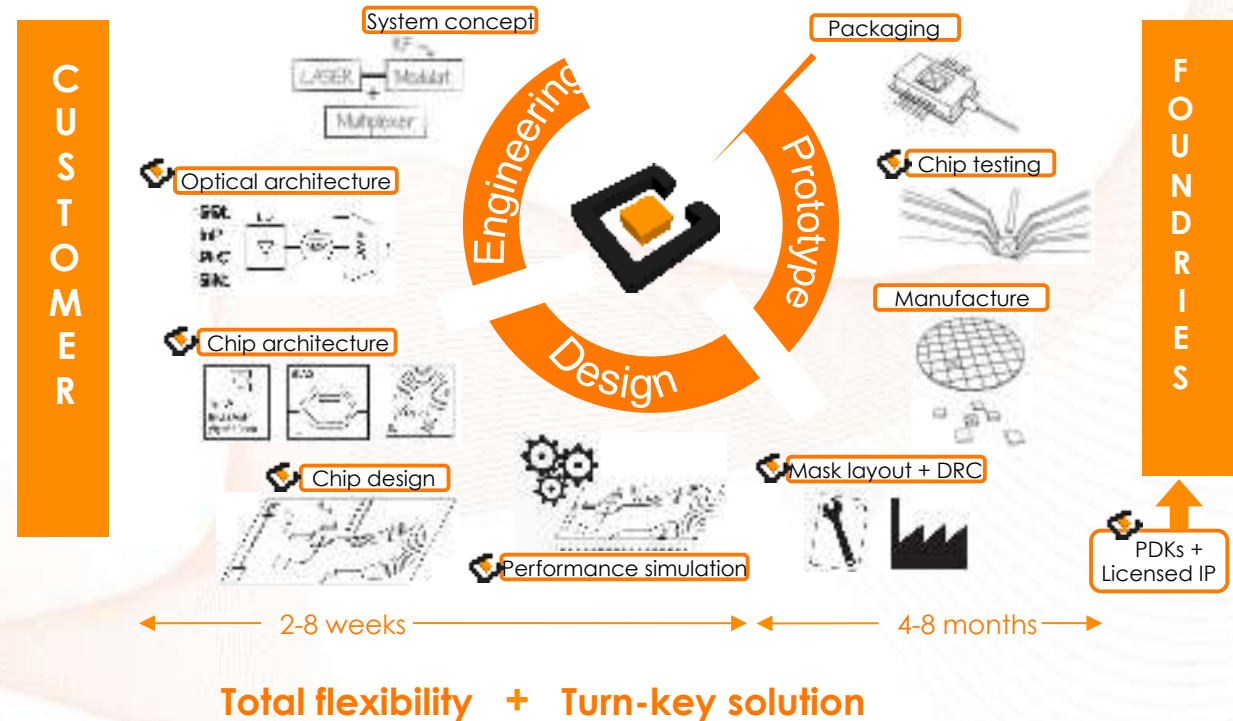
High yield commercial process

Capacity outsourcing



The business model: general view

- VLC translates (photonic) system concepts into photonic chips
- Selects the best suited optical architecture & technology
- Addresses the PIC design and performance simulation
- Generates the PIC layout for manufacturing following the design rules of the selected foundry
- Outsources the PIC manufacturing
- Validates experimentally the manufactured PICs





Technologies

Silicon on Insulator

Indium Phosphide

Si Nitride/PLC

Best Technology Features

- Low propagation loss
- Good coupling to fibers
- Good electro-optic effect
- Good thermo-optic effect
- Good electro-absorption effect
- Light generation / regeneration
- Small footprint
- Compatibility with electronics

	SOI	SiO ₂ /Si	Si ₃ N ₄ /SiO ₂	InP/GaAs
Low propagation loss		Yes	Yes	
Good coupling to fibers		Yes	Yes	
Good electro-optic effect				Yes
Good thermo-optic effect	Yes	Yes	Yes	Yes
Good electro-absorption effect				Yes
Light generation / regeneration				Yes
Small footprint	Yes		Yes	Yes
Compatibility with electronics	Yes			

VLC Photonics operates fabless
The technical team masters the most relevant integration technologies on the market



Library of components vs foundries

Broker		europractice-IC			IME	JePPIX				VLC Photonics
Foundry	Technology	IMEC	CEA LETI	IHP	IME	III-V	Oclaro	SmartPhotonics	LibriX	IMB CNM
		SOI	SOI	SOI	SOI	InP	InP	InP	BIN ^x	BIN ^x
BUILDING BLOCKS										
Waveguide	SHWVG									
	DEWVG									
	WVGX									
Couplers	Y-B									
	DC									
	MMI									
Optical I/O	SPGC									
	PSGC									
	SSC									
Modulation	EO-MOD									
	TO-MOD									
	PN-MOD									
Filter	RR									
	AWG									
	DBR / DFB									
Active	SOA									
	DFB Laser									
	DBR Laser									
	PD									
	BPD									

Color code: Green=Available / Possible, Grey=Not Available / Possible.. Abbreviations: SHWVG Shallow waveguide, DEWVG Deeply etched waveguide, WVGX Waveguide crossing, Y-B Y-branch, DC Directional coupler, MMI Multi-Mode Interference coupler, SPGC Single Polarization Grating Coupler, PSGC Polarization Splitting GC, SSC Spot-Size Converter, EO-MOD Electro-Optic Modulator, TO-MOD Thermo-Optic Modulator, PN-MOD PN Junction Modulator, RR Ring Resonator, AWG Arrayed Waveguide Grating, DBR Distributed Bragg Reflector, SOA Semiconductor Optical Amplifier, PD Photo-Detector, BPD Balanced PD



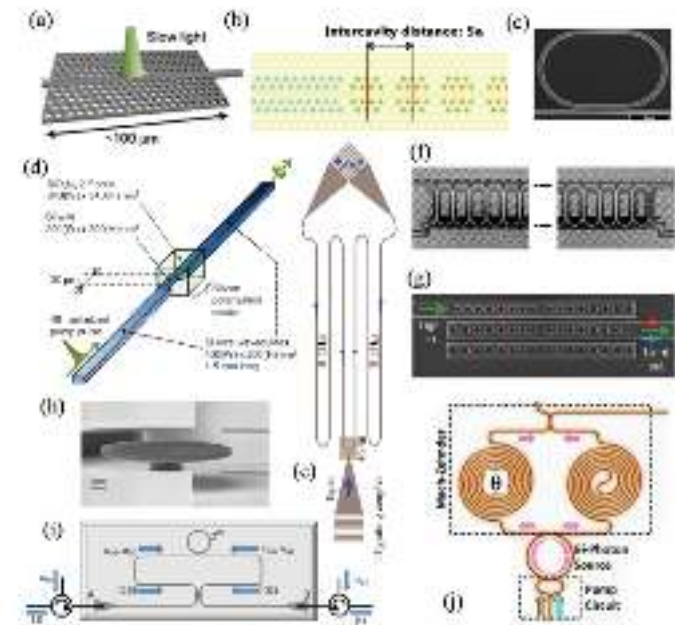
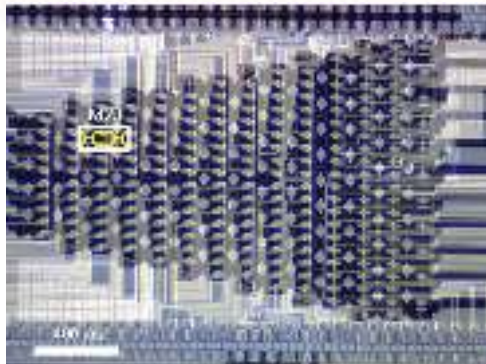
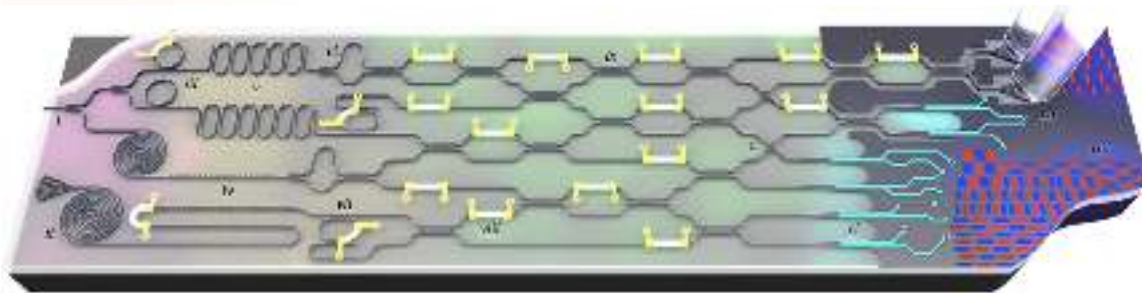
R&D Photonic Integrated Circuits, internal and external collaborations

YEAR	DESCRIPTION	TECHNOLOGY
2012	Microwave Photonics (MWP) beamformer	InP
2013	Wavelength tracker, modulators and filters	Thin SOI
2013	Arrayed waveguide gratings (AWGs)	TripleX
2014	AWGs, Echelle Gratings and MWP filters	Thick SOI
2014	Quantum Random Number Generator + Comb lasers	InP
2014	FTTH transceiver	InP
2014	Arrayed waveguide gratings	TripleX
2014	External cavity laser and filters to combine with InP chip	TripleX
2014	Echelle Gratings	InP
2015	Opto-electronic oscillators	InP
2015	Quantum Random Number Generator, (SG)DBR lasers	InP
2015	Silicon nitride process development & Multi-Project Wafer runs	SiNx
2012-16	Other than cannot be disclosed due to confidentiality	All of them



Quantum Optics & Photonic Chips

- There is an unprecedented opportunity for integrated photonics in quantum information



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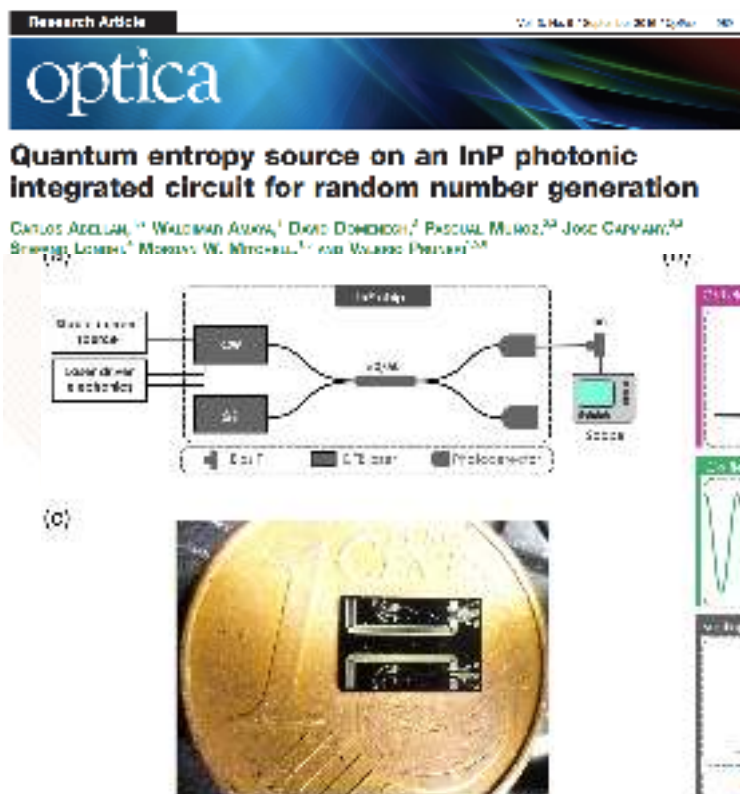
Silicon Quantum Photonics

Joshua W. Silverstone, Damian Bonneau, Jeremy L. O'Brien, and Mark G. Thompson

(Invited Paper)



Quantum Entropy Source on a Photonic Chip



Collaborative work with ICFO, UPV and Politécnico di Milano

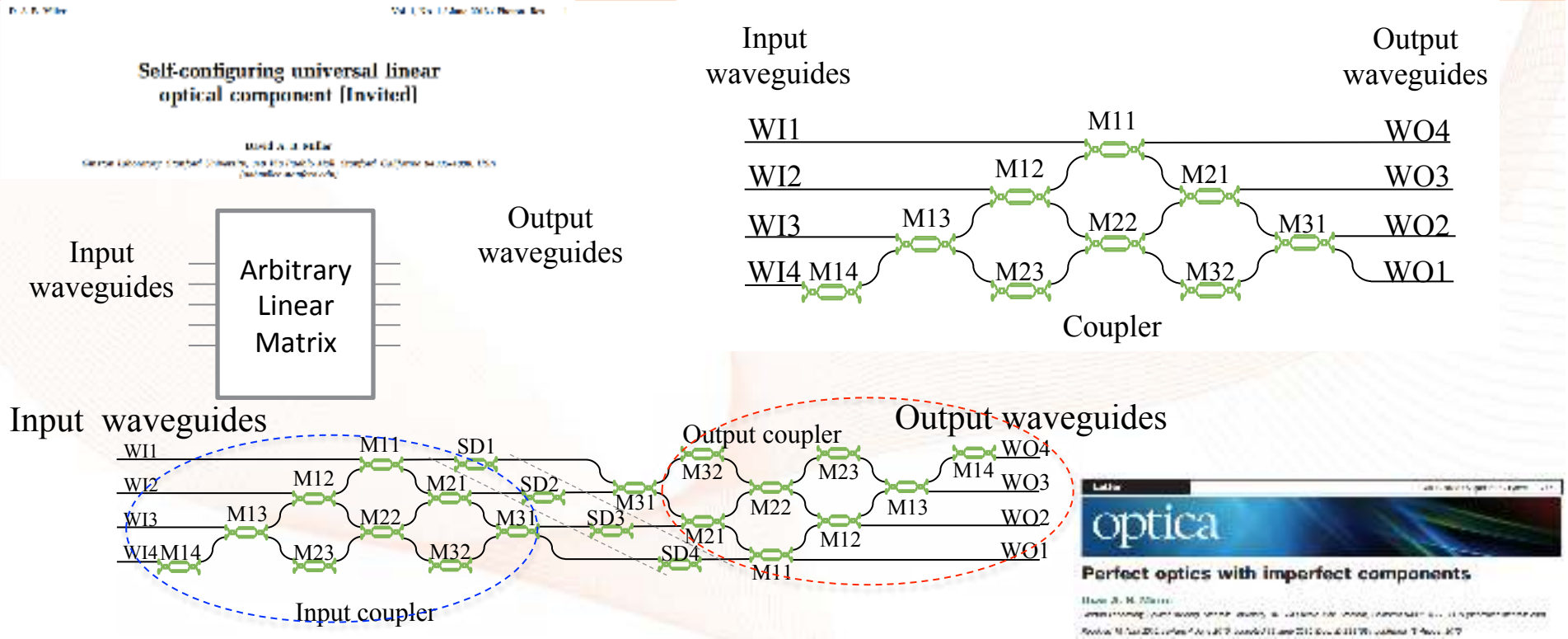


UNIVERSITAT POLITÈCNICA DE VALÈNCIA



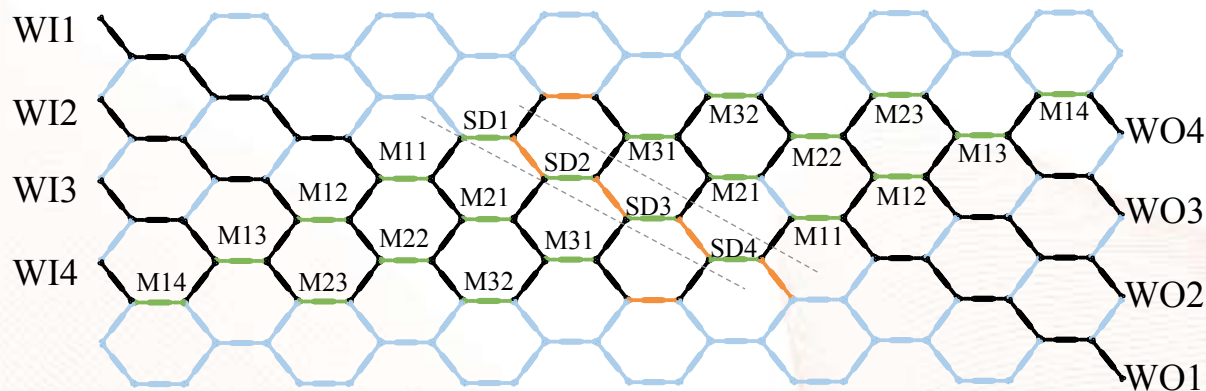


Programmable hexagonal meshes

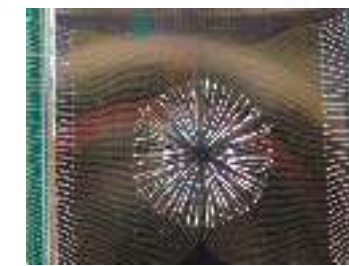
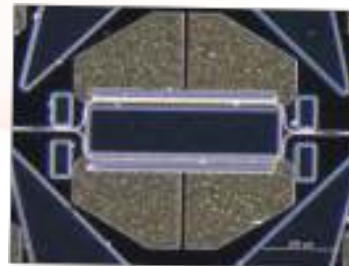
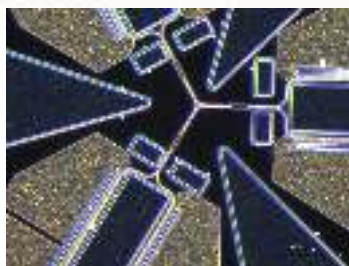




Programmable hexagonal meshes (collab with UPV and ORC)



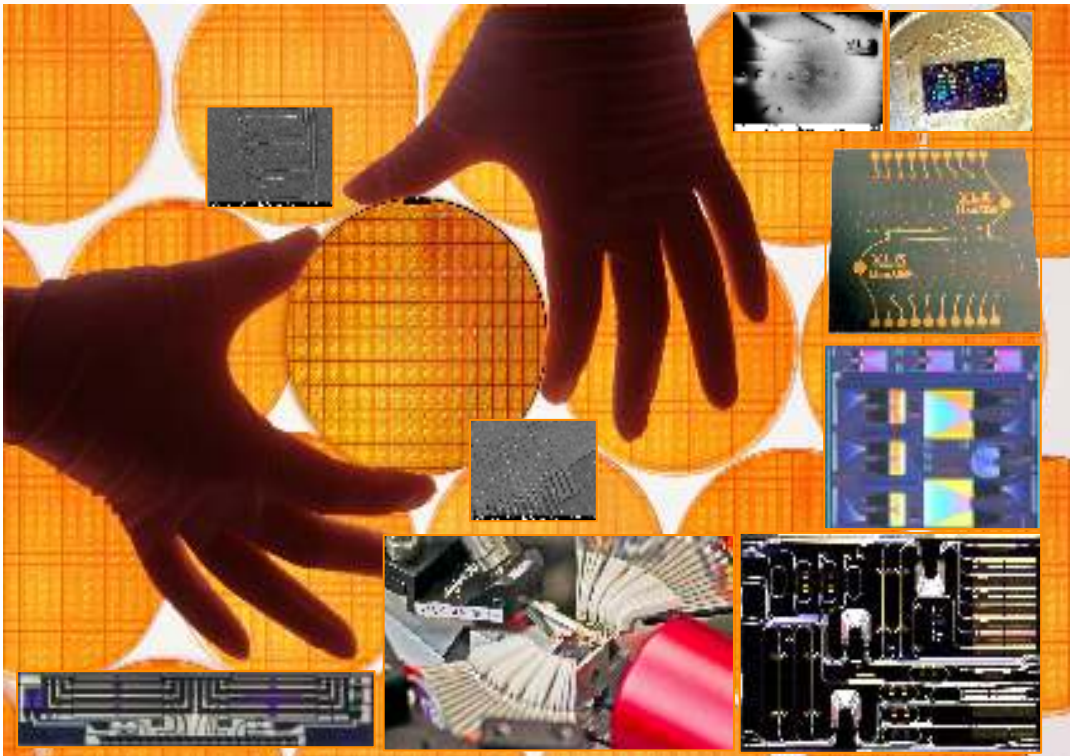
— Cross State — Not used (available) — Bar State — Tunable Coupler





Conclusion

- VLC Photonics has been operating **on market for 5 years**
 - Holds a very strong widely recognized brand as independent PIC design house
 - Has a growing, solid and diversified customer base, industry & academics
 - Track on market indicates more opportunities can be turned into customers
- Strong interest in application of photonic chips in Quantum Optics :
 - There is a **huge potential** for integrated photonics (leveraging on its unique properties)
 - Photon sources
 - Other Application Specific Photonic Circuits (Detectors, Switches, Bell states, QKD integrated transceivers etc..)
 - Reconfigurable processors (i.e quantum FPGa)



**We are in the high level
committe to serve the
community!!**

**All your comments, inputs &
suggestions are wellcome!**

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THANK YOU!

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