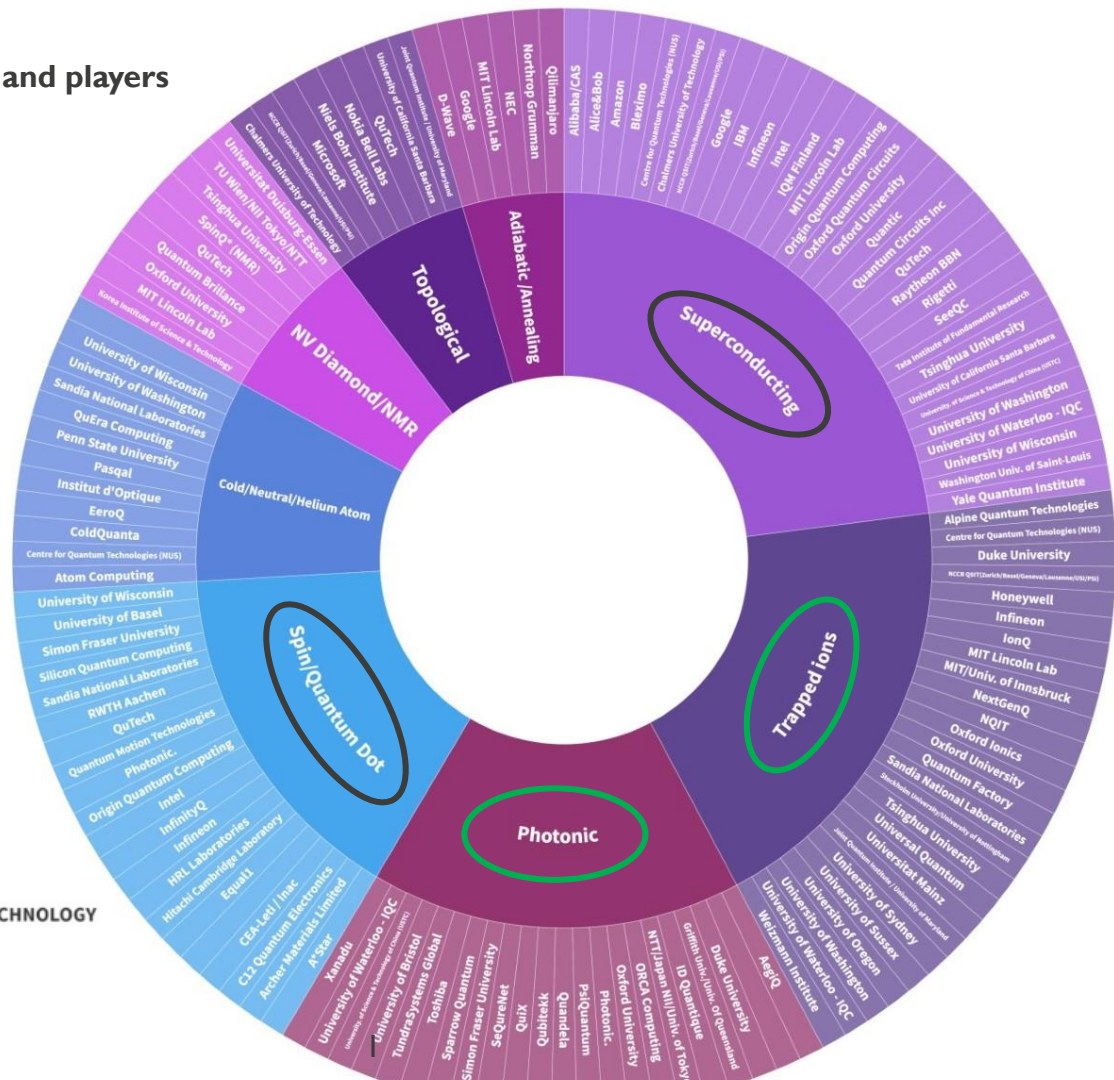


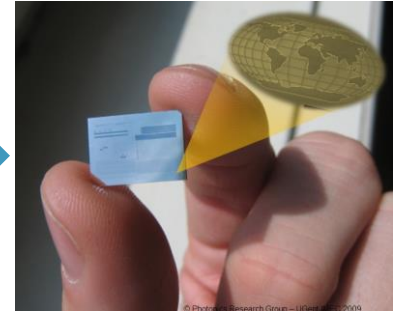
# Quantum computing technologies and players



ORGANISATIONS QUBIT TECHNOLOGY  
(c) Michel Kurek

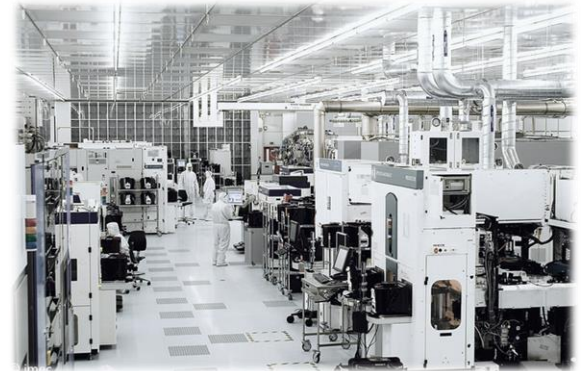
# SCALABILITY CONCERN

Moving from 10s qBit toward 1000s, 10K, ...



H. Zhong, et al, "Quantum computational advantage using photons", Science, 2020.

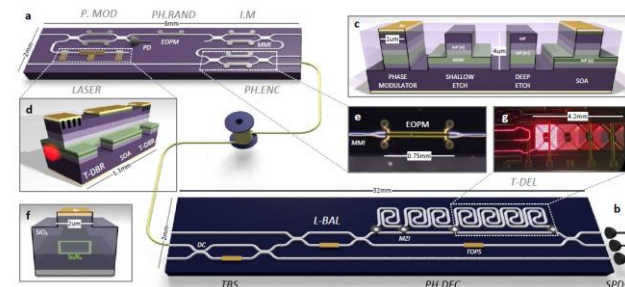
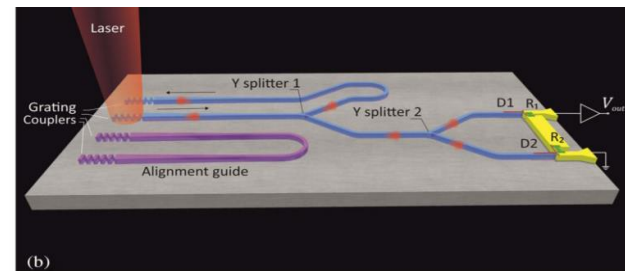
# 200 MM & 300 MM CLEANROOMS (24/7 OPERATION)



# QKD: USING PHOTONICS



- Ultrafast quantum random number generation (QRNG)
- Entangled photonic integrated sources
- Inter-connection (3D integration) between multiple chips



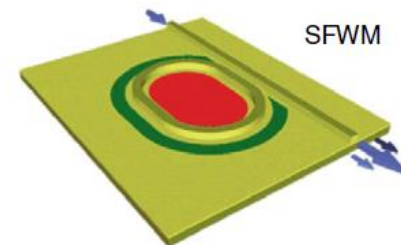
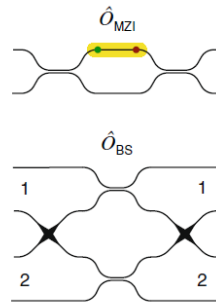
A. Gaggero, Amp-multiplexed readout of single photon detectors superconducting nanowires, 2019.

P. Sibson, et al, "Chip-based Quantum Key Distribution", 2015.

# SiN IS THE ENABLER TECHNOLOGY FOR QC

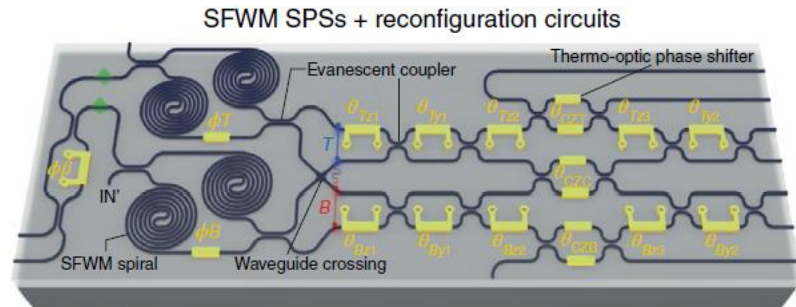
## Basic building blocks

- PIC based quantum processor
- High Q ring resonators
- MZ interferometer-switch
- Phase shifters (Thermal, LiNbO<sub>3</sub>, etc.)
- In-out coupling interfaces



## SiN features

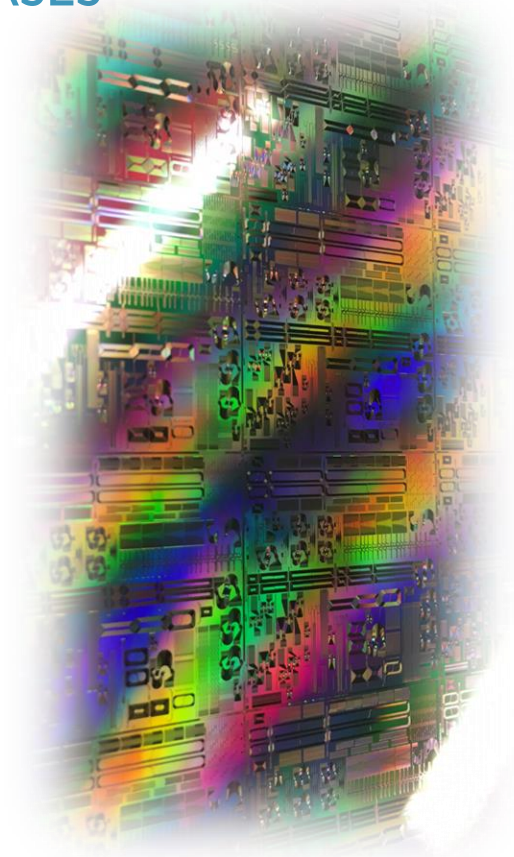
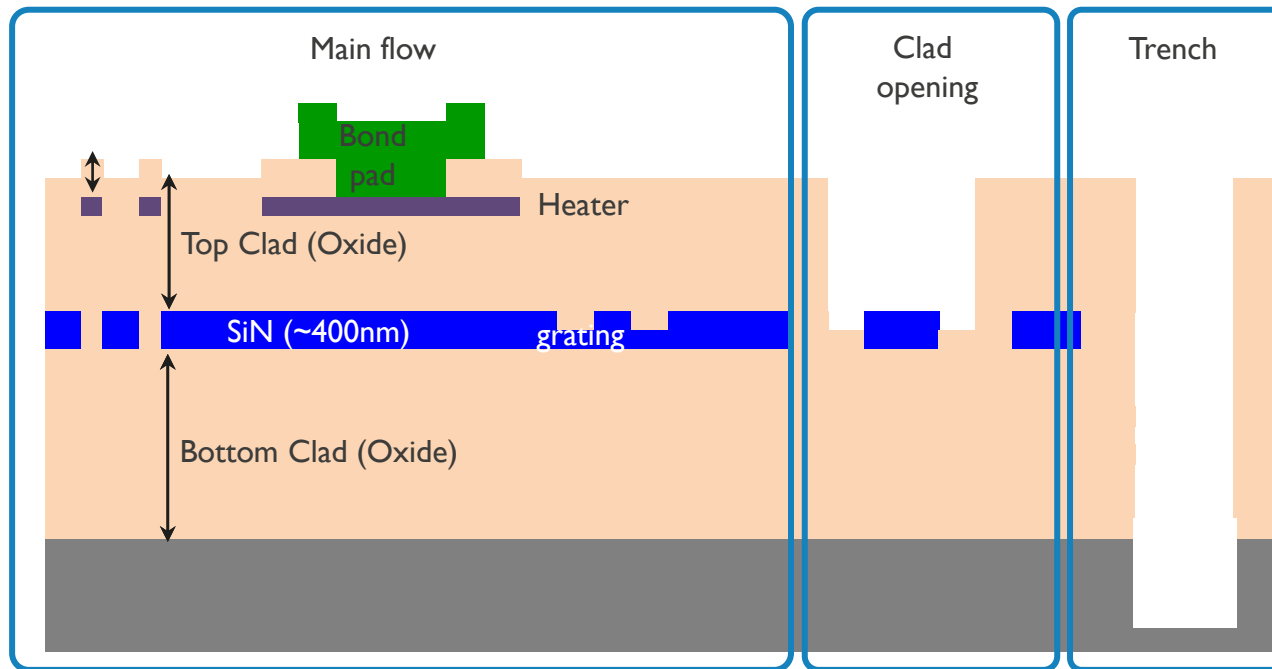
- Scalable 200/300 mm wafer production
- Extremely low loss (down to few dB/m)
- Low phase noise
- Transparent at visible wavelength (ion-trapping)
- High power handling



J. Wang, et al, "Integrated photonic quantum technologies", Nature communication, 2020.

# FLEXIBLE CROSS SECTION FOR DIFFERENT USE-CASES

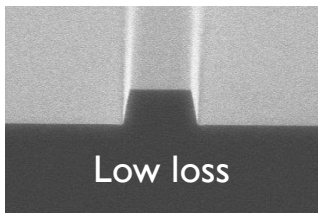
## HIGH VOLUME MANUFACTURING



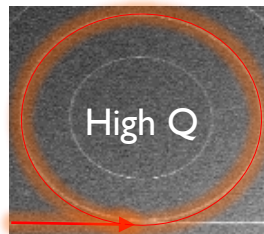
# SIN PHOTONICS PLATFORM @ IMEC

A large library of experimentally verified components is available

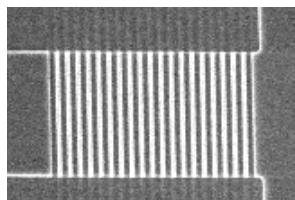
Waveguides



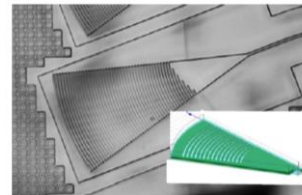
Ring Resonators



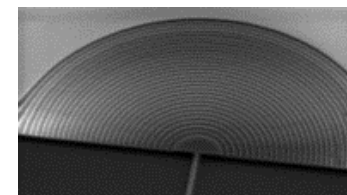
Fiber-to-WG



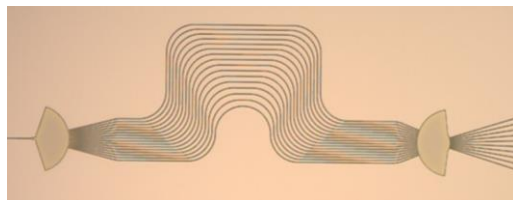
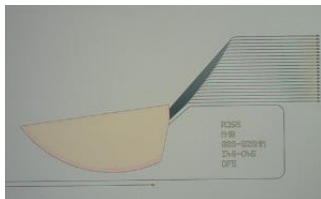
Low reflection



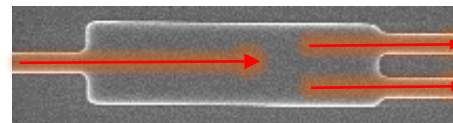
Focusing



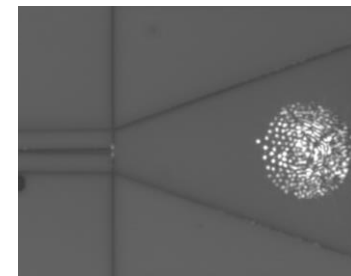
Basic spectrometers



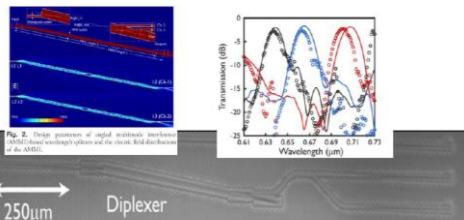
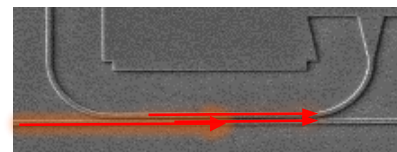
Multi-mode interferometer



Pseudo-random

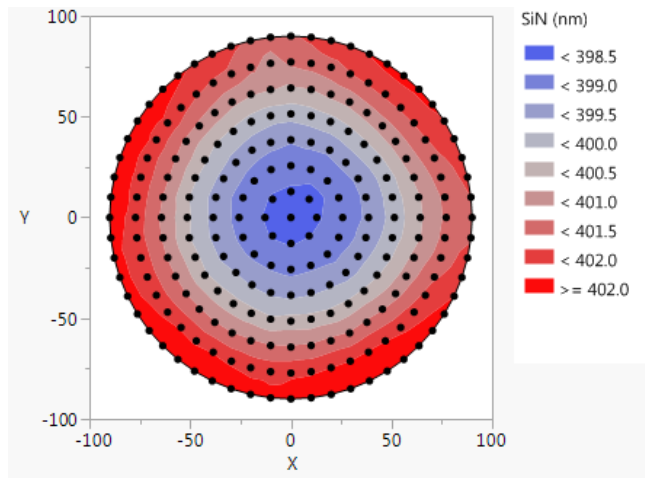


Evanescent coupler

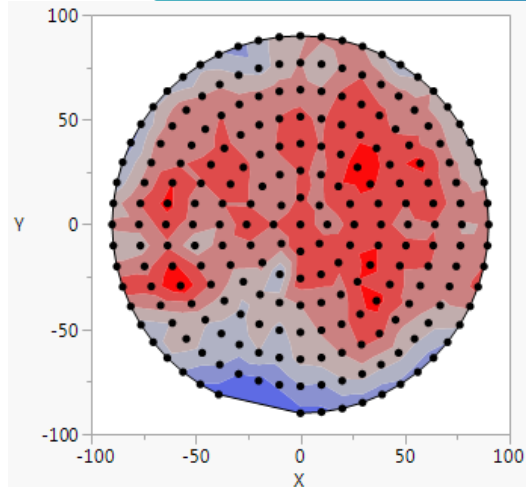


# UNIFORMITY ON 200MM WAFER

## LPCVD-SiN



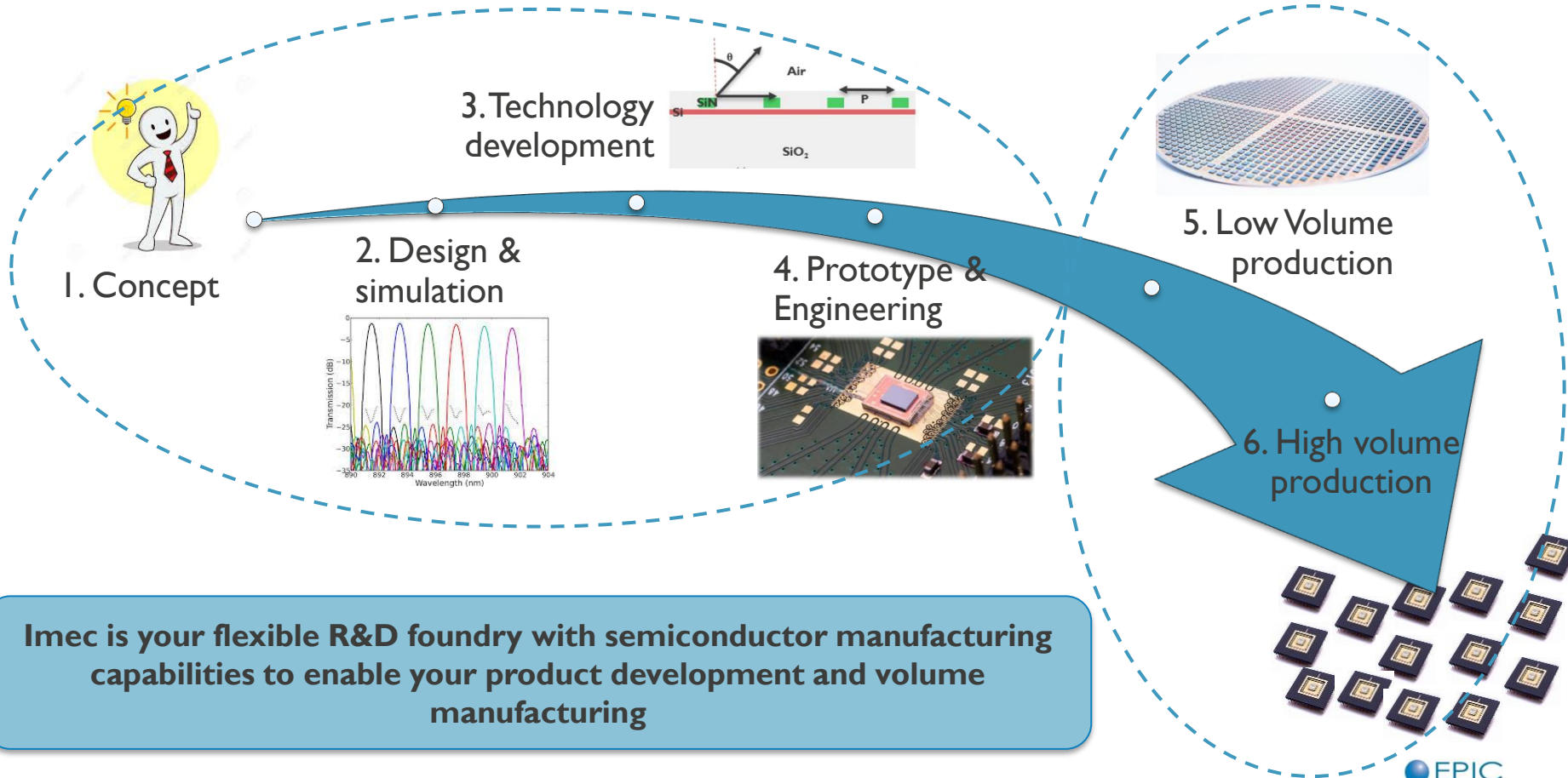
## Advanced SiN film



225 data points	PECVD	LPCVD	Advanced layer
Range (nm)	26	4.3	1.0
% th/std dev	2.85	0.58	0.06



# R&D INDUSTRIAL HUB DEDICATED TO OPTICAL BEAM FORMING





# imec

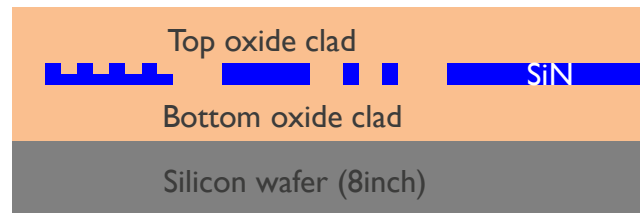
embracing a better life

[Amin.Abbasi@imec.be](mailto:Amin.Abbasi@imec.be)

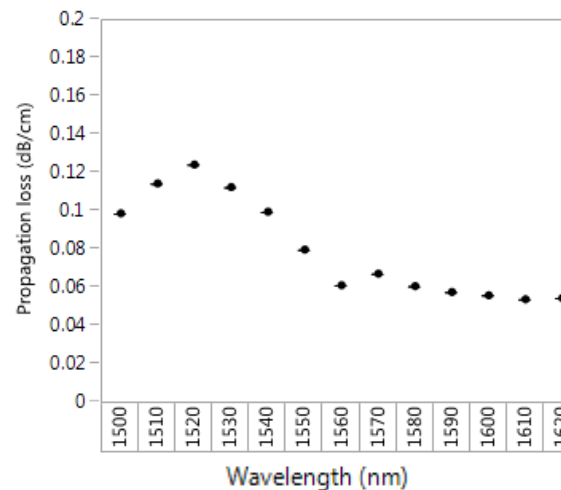
# SiN PHOTONICS PLATFORM

## HIGH VOLUME MANUFACTURING

- Extremely low propagation loss
  - Annealing of silicon nitride
  - Low waveguide sidewall roughness
- SiN layer
  - LPCVD stoichiometric film
  - Hydrogen content control
  - Refractive index uniformity
  - Thickness uniformity
  - Shallow & full SiN etch
- Oxide layer
  - Refractive index uniformity



Propagation loss of a single mode waveguide



Higher absorption loss at 1520nm linked to N-H bond  
reduced from 3dB/cm (standard processing) down to 0.125dB/cm

# ACTIVE DEVICE HYBRID INTEGRATION

- Hybrid integration enables to use the best features of each technology
  - SiN or Si for passive, switching, routing, coupling, etc.
  - IIIV for active devices, e.g. laser, modulator, photodiode
- Prototype could be developed via R&D contract
  - Technology-transfer to an industrial fab for production

