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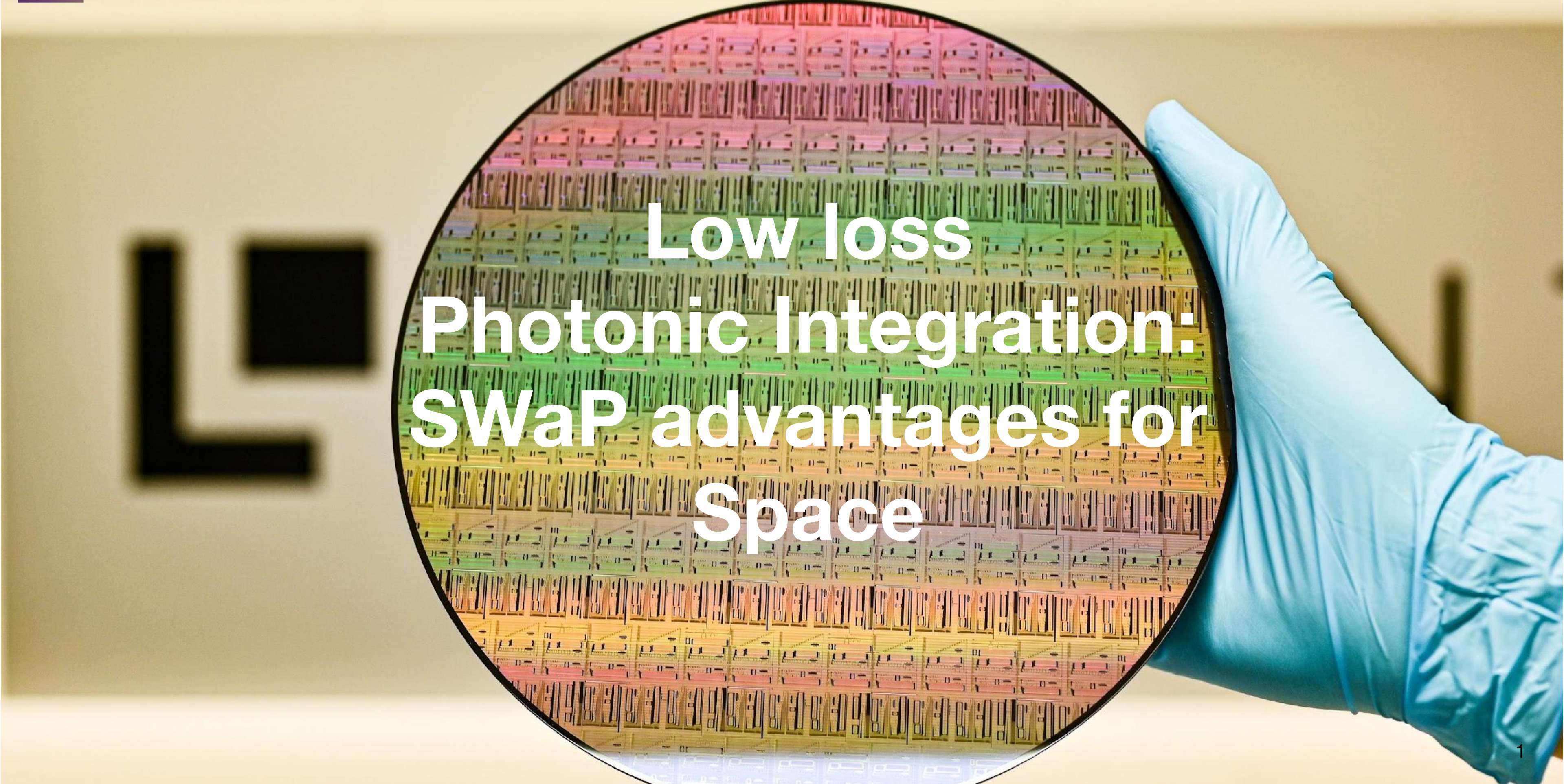
Low loss Photonic Integration: SWaP advantages for Space



Photonic integrated circuits

Size, Weight and Power (SWaP) reduction

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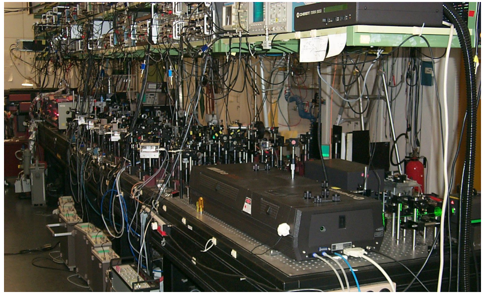
MAX-PLANCK-INSTITUTE OF QUANTUM OPTICS GARCHING MPQ

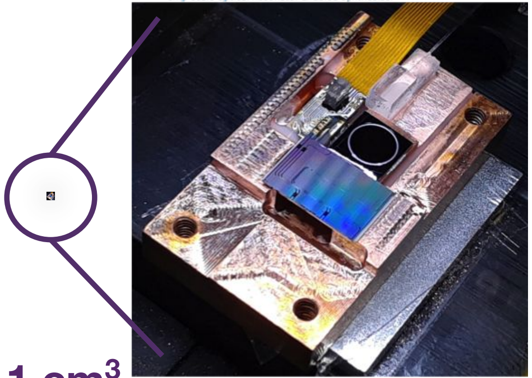


4 m^3

MenloSystems

1 m^3

CORES
Chip-scale Optical Resonator Enabled Synthesizer



1 cm^3

- ✔ Less complexity
- ✔ Power efficient
- ✔ Small size
- ✔ No movable parts

1998 2008 2019

Material Choice

Benefits of Silicon Nitride

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Large transparency window: 400 – 4’000 nm
Reference Silicon: 1’100 – 4'000 nm

Low propagation loss: < 1dB/m
Reference Silicon: 50-1000 dB/m

High optical power: > 5 W per waveguide (10^9 W/cm^2)
Reference Silicon: 0.1 W per waveguide

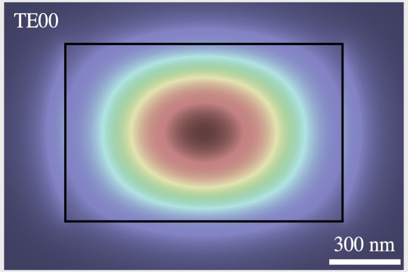
Scalable to volume
Non exotic material

Radiation hardness proven
Space compatible

required for many applications

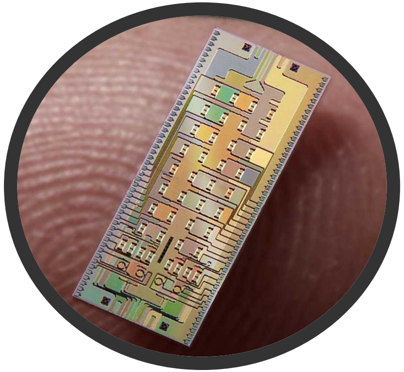
We deliver PICs

Thick SiN – the game changer



90% of the light is confined

- Low propagation loss
- Small chip size
- Dispersion engineering
- High Power, VIS to IR

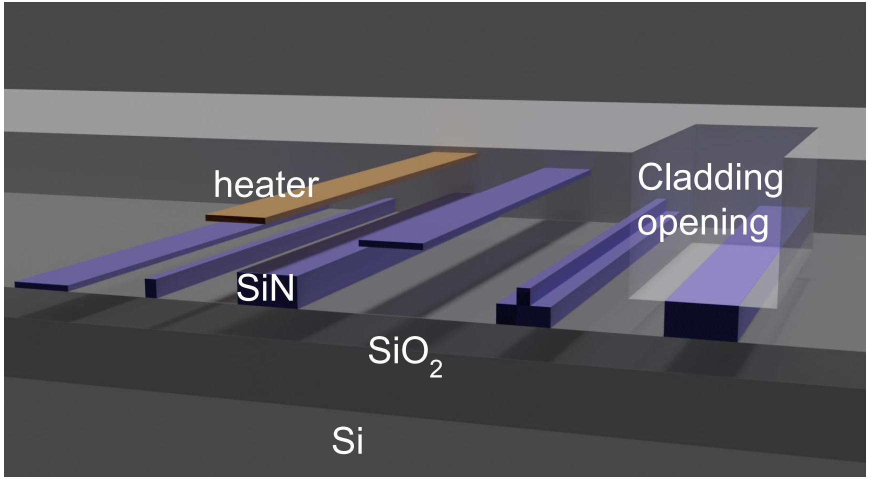


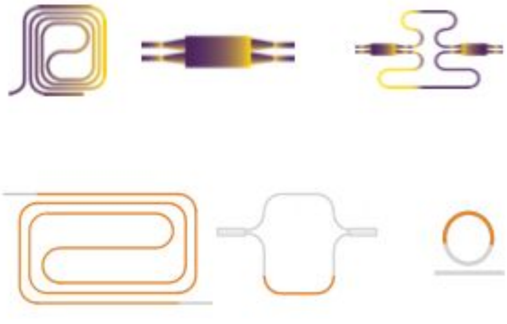
A base to build on

Versatile Platform

3+ thicknesses	10+ process modules	Extensive PDK

- 800 nm
- 350 nm
- 150 nm
- custom





High throughput optical testing

PDK Development and Quality Control

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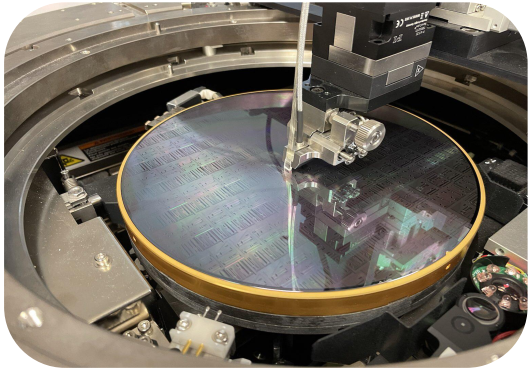
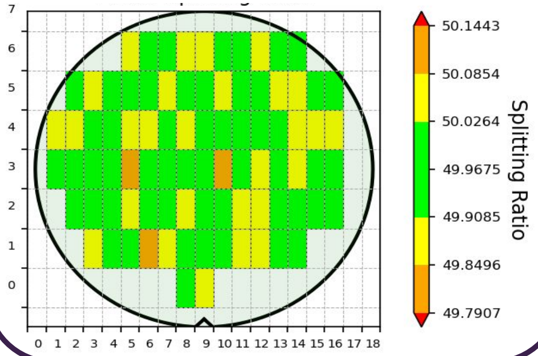
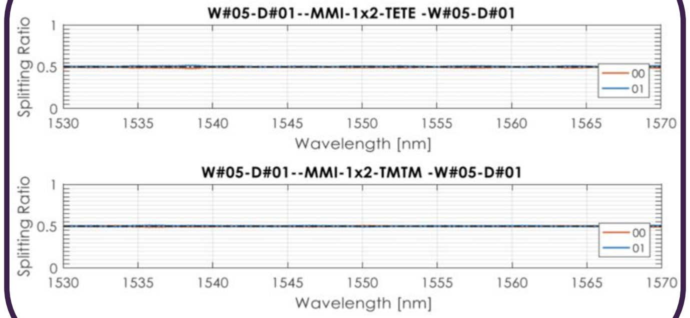
TE / TM





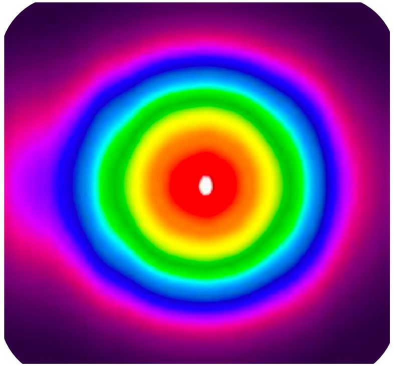


Reproducible

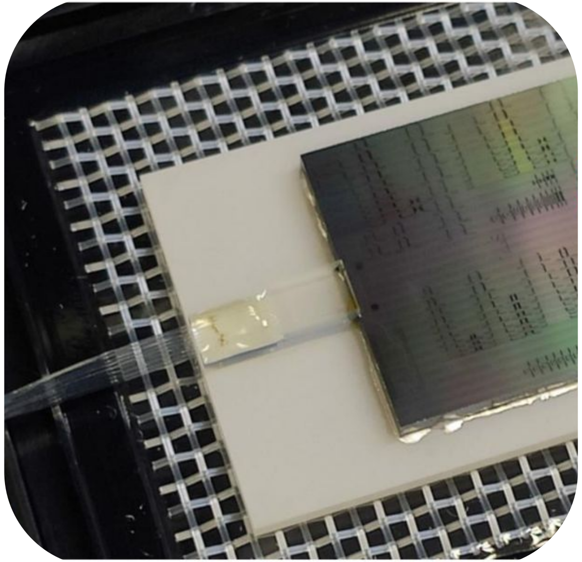
Broadband

High performance optical I/O

Proven track-record in development of efficient optical I/O interfaces



MFD [µm]	9.7
M^2	1.06



Commercial Offering

Seamless journey from Idea to Volumes

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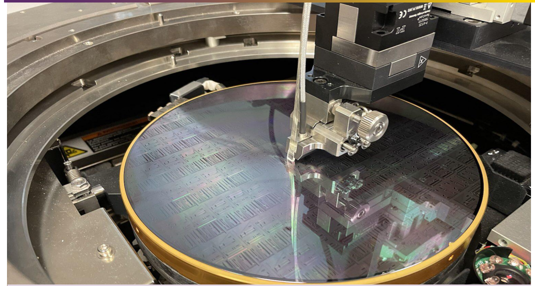
Entry: R&D & Prototyping
Open access, low barrier

Fast prototyping

- Established technology
- Fixed layer stack
- Extensive PDK
- **Regular MPW runs**
- Custom runs
- Design / layout support
- Characterization
- Packaging support

Optimize: Development
High flexibility & competence



Custom PIC Developments

- Engineering studies
- Layer stack adaptation
- Custom integrations

Ligentec Labs

- Early technology access

Manufacturing: Supply
Quality and guarantee

Pilot Fabrication

- Pilot and niche quantities

Volume Fabrication

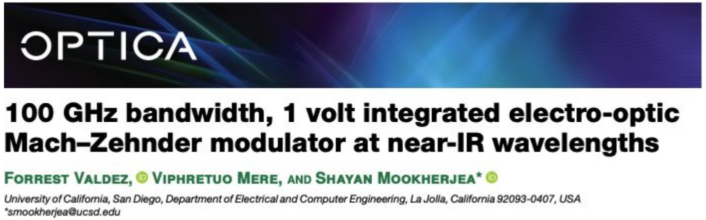
- Large volumes
- High-capacity wafer fab
- Fully automated testing
- Automotive quality system

The next step – enhance the SiN PIC platform

SiN – The platform for heterogeneous integration

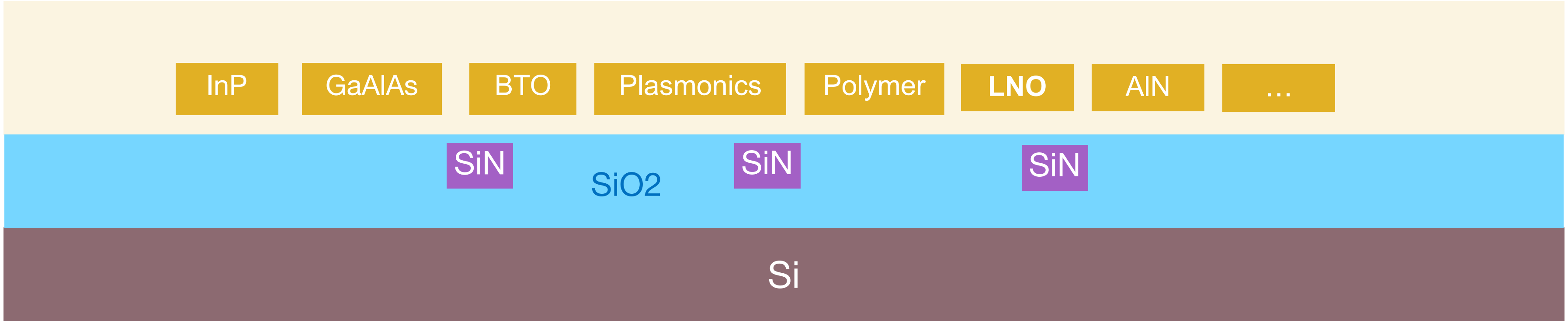
Use SiN as base platform for general circuitry
- Comprehensive PDK
- Standard I/Os
- Scalable to volume

Add materials as required by application


OPTICA

100 GHz bandwidth, 1 volt integrated electro-optic Mach–Zehnder modulator at near-IR wavelengths

FORREST VALDEZ, VIPHRETUO MERE, AND SHAYAN MOOKHERJEA*
University of California, San Diego, Department of Electrical and Computer Engineering, La Jolla, California 92093-0407, USA
*smookherjea@ucsd.edu



The next step – enhance the SiN PIC platform

Heterogeneous integration of modulators

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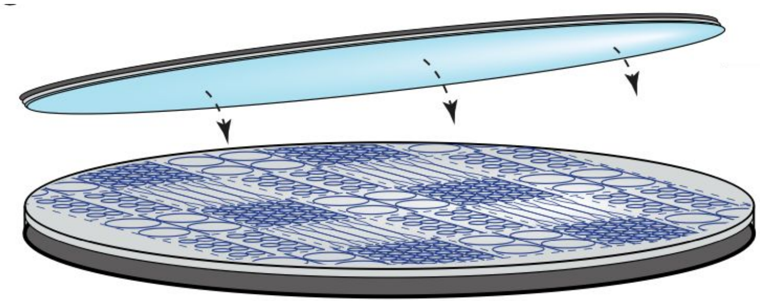
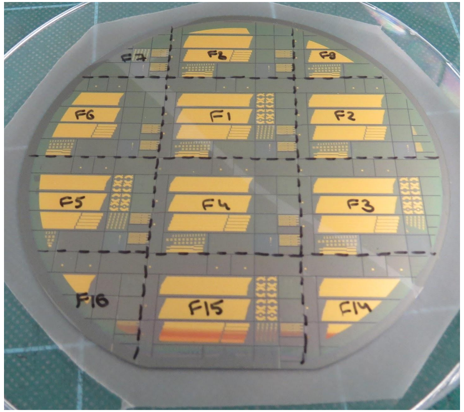
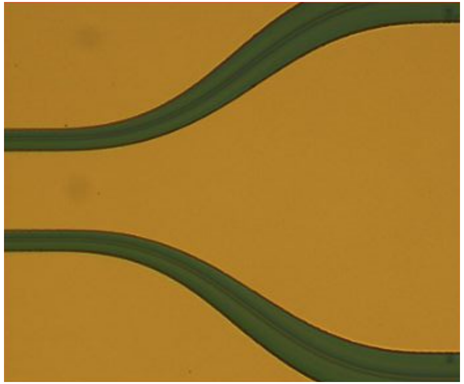
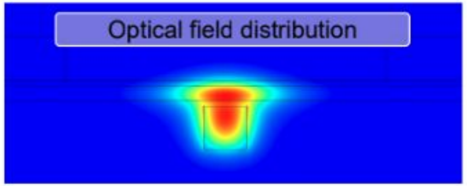
LiNbO3

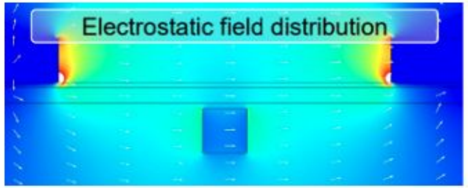


SiN



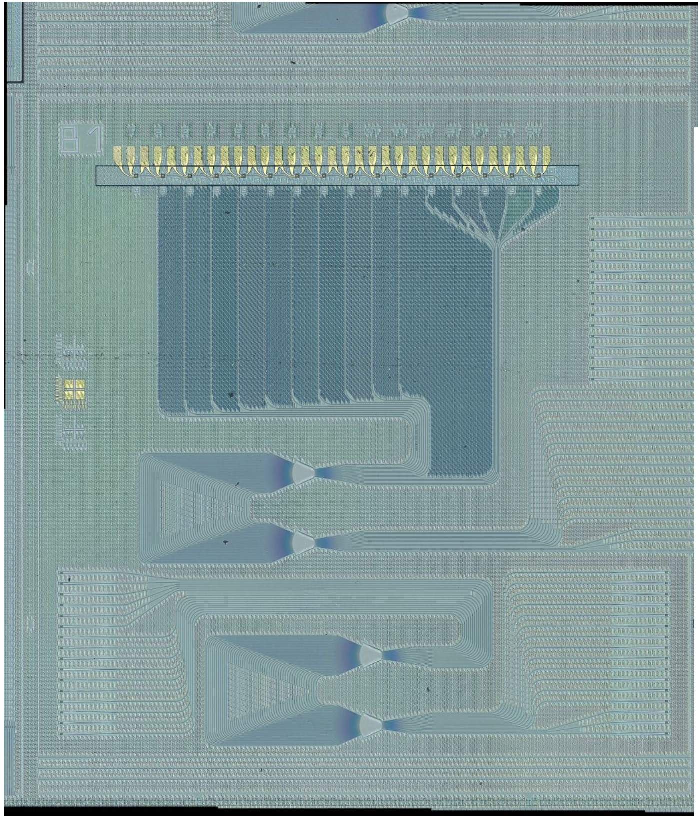


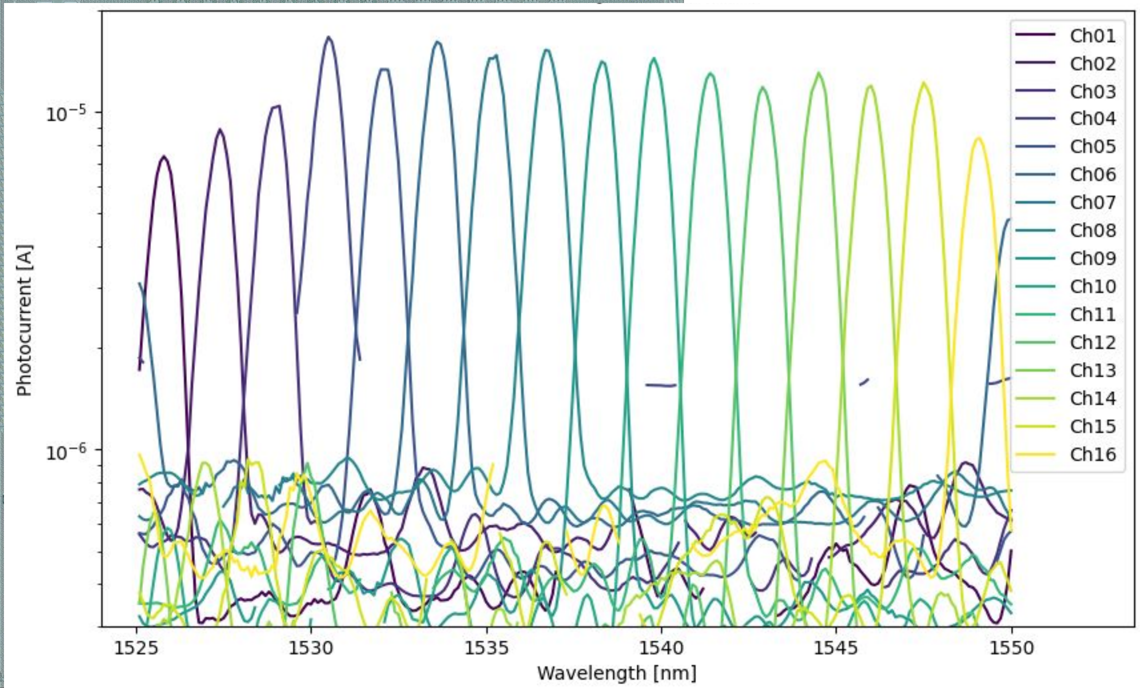




The next step – enhance the SiN PIC platform

Heterogeneous integration of photodiodes



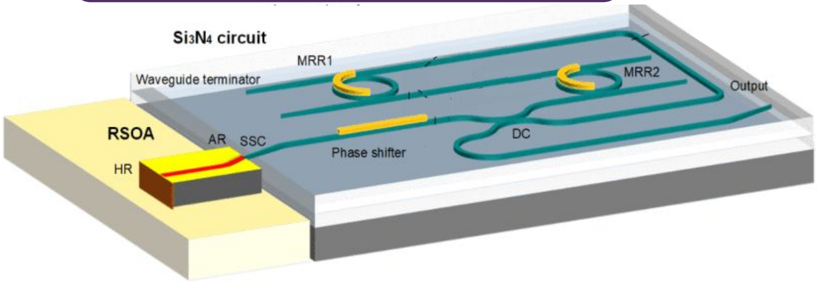


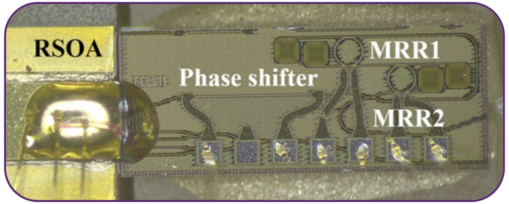
Y.Guo et al., IEEE Photonics Journal (2021)
C.Liu et al., JLT (2022)

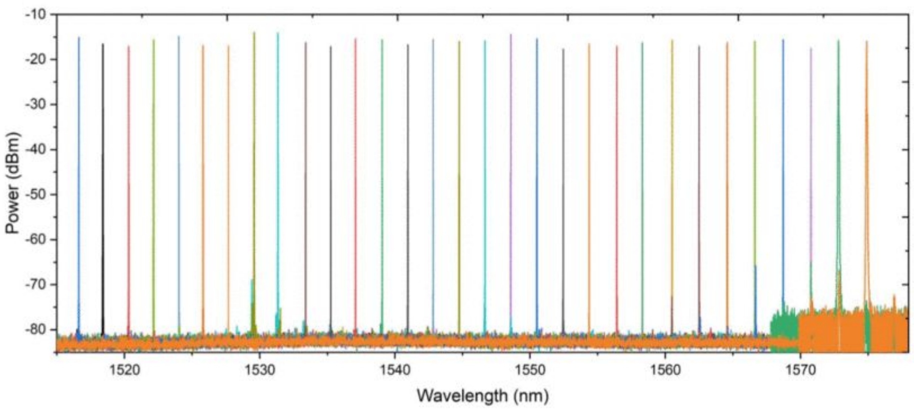
The next step – enhance the SiN PIC platform

Hybrid integration of lasers

LIGENTEC design, layout and fabrication capability







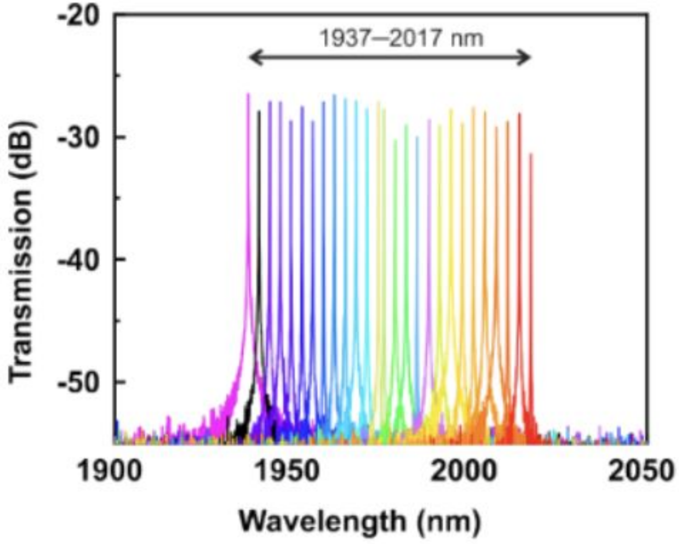
Narrow Linewidth External Cavity Lasers

Linewidth: <3kHz
SMSR: -70dB
Max power: 34mW
Tuning: 58.5nm

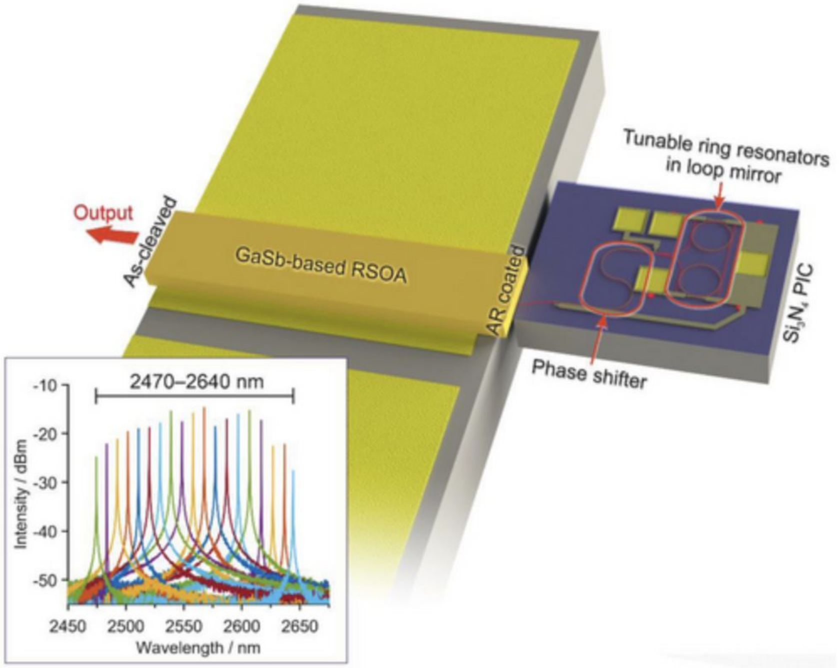
The next step – enhance the SiN PIC platform

GaSb/Si3N4 hybrid laser at 2 µm and 2.5 µm

LIGENTEC

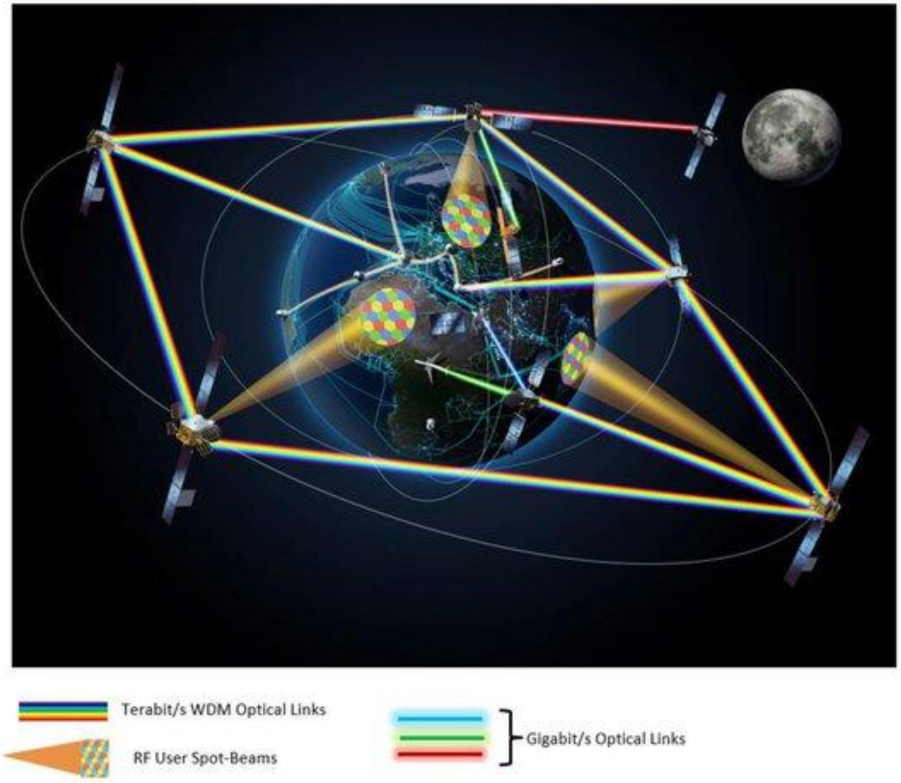


Zia et al., arXiv 2211.02135 (2022)



Ojanen et al., Laser&Photonics Review (2023)

Space Adaptive Photonics Phased Array IR Feeder Link



Artist Impression of HydRON Vision of an all optical space network integrated into terrestrial network infrastructures. **Image credit: ESA**

Space Adaptive Photonics Phased Array IR Feeder Link

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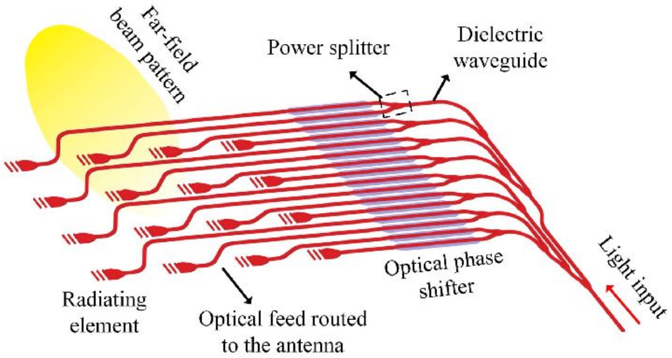
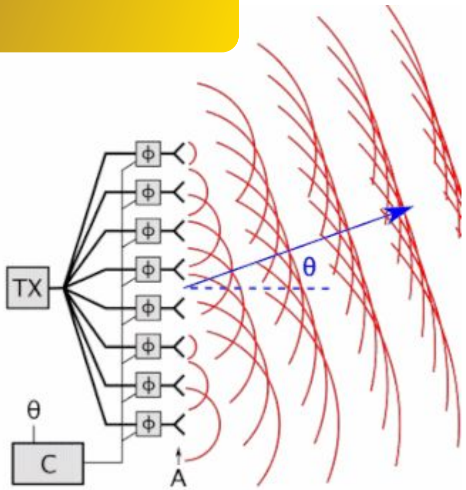
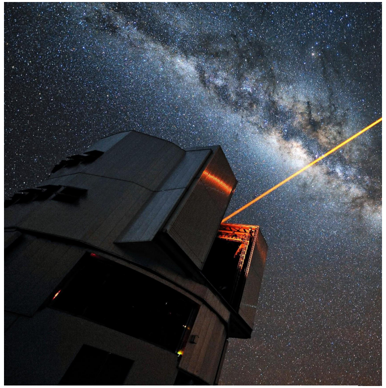
- **Need for more bandwidth (intra-satellite and satellite to earth)**
- **High power light propagation**
- **Low loss optical phase shifter**







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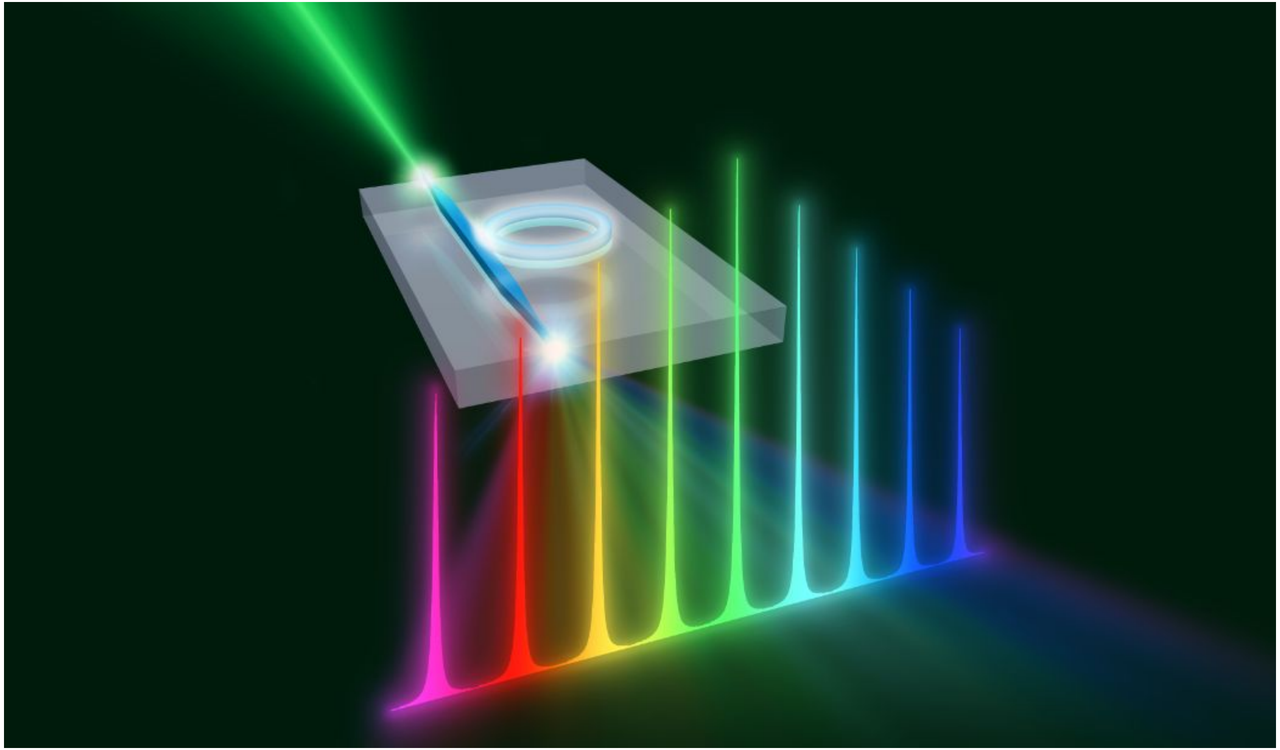
ESA SAPPHIRE SCYLIGHT

mbryonics

scylight

Generation of on chip frequency comb



Frequency comb generation on chip

Space Spectrograph Design to Calibration

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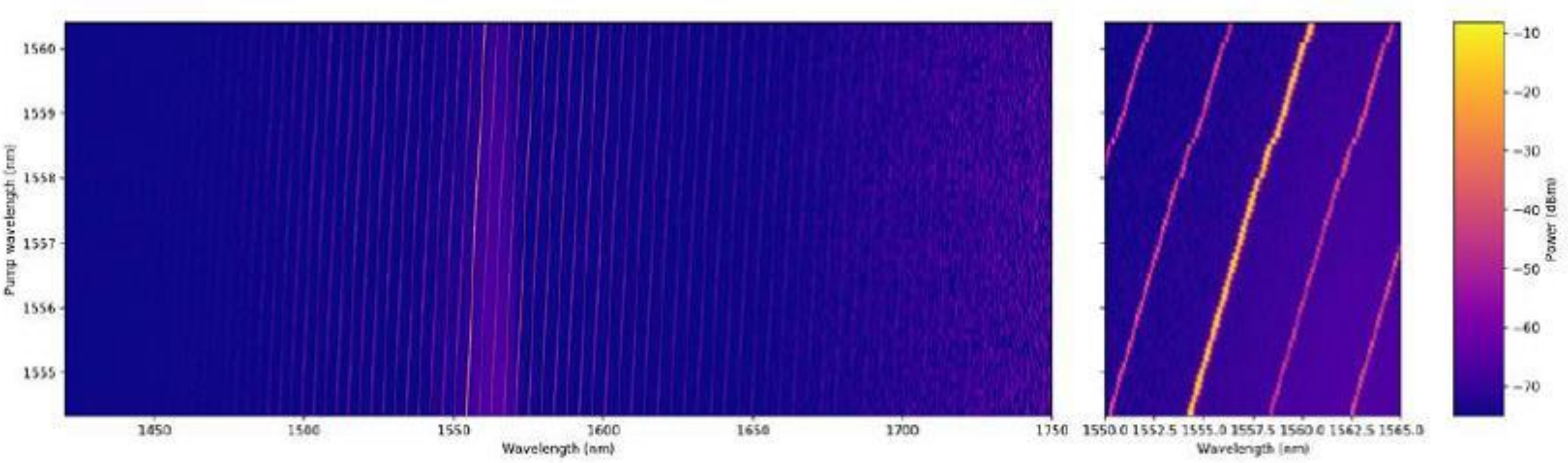
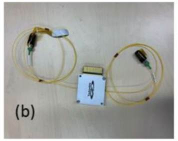
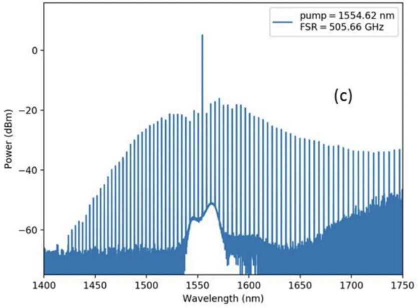


Full 500GHz tuning of a ring resonator

esa

AIRBUS DEFENCE & SPACE





Riviere et al., ICSO (2020)

FGU: RF Frequency Generation Unit for Telecommunication Payloads

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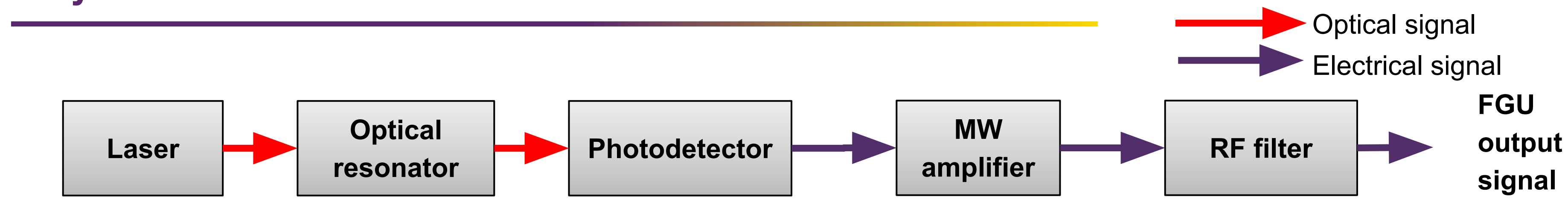
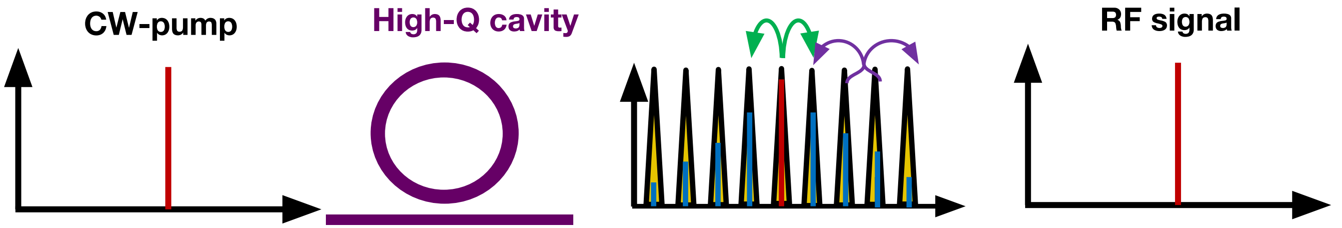
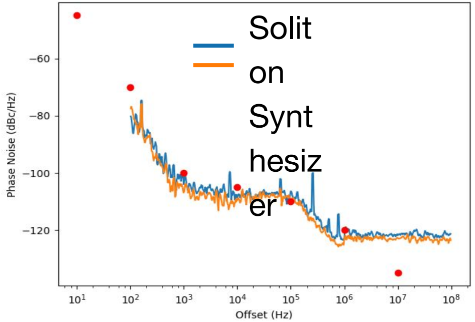
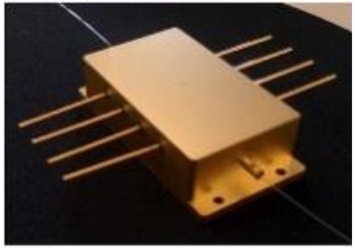






complex modulation and multiple frequency conversion require:
ultralow phase noise reference LO (8-10GHz)

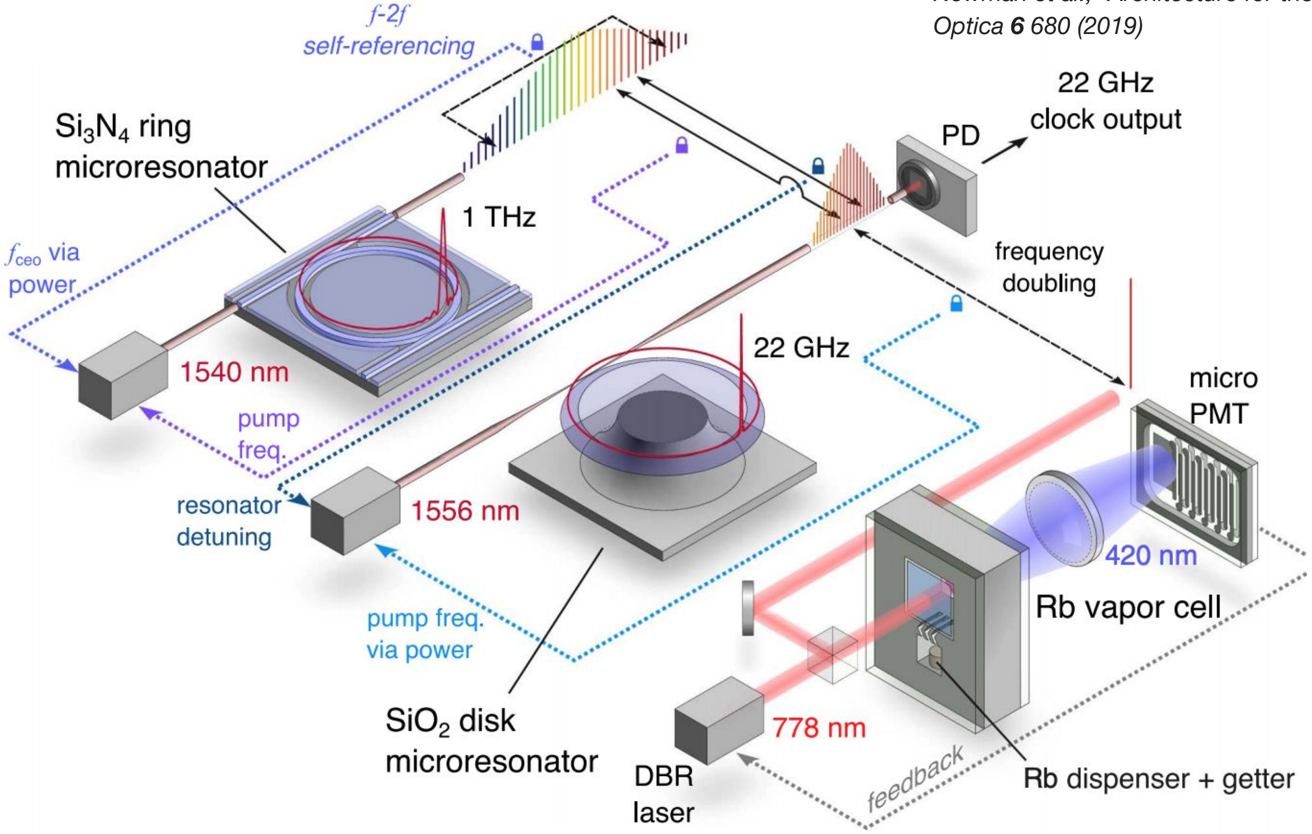


Pulsed soliton regime:
no excess phase noise

esa csem EPFL

Building blocks for optical atomic clocks

Newman et al., "Architecture for the photonic integration of an optical atomic clock", Optica ***6*** *680 (2019)*



Summary

Low Loss SiN - Platform Overview

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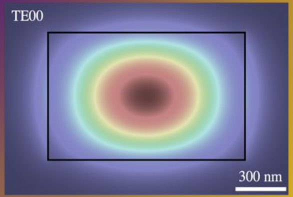
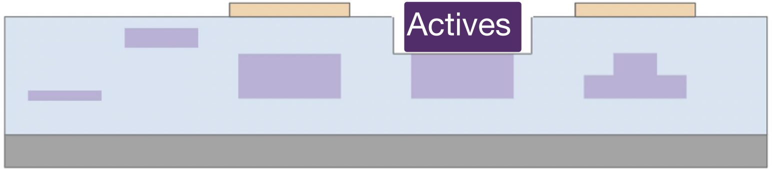
Low loss waveguides

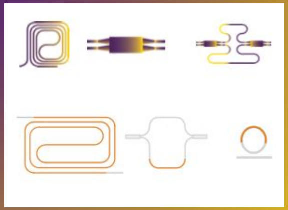


MPW / Dedicated runs
Short turn around

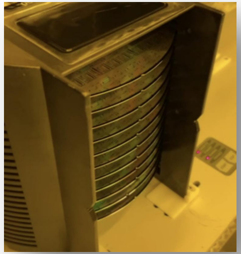
Flexible R&D line
Volume line



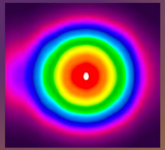
Extensive PDK



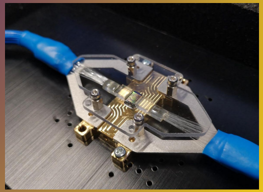
Actives Integration



Low loss optical I/O



MFD [µm]	9.7
M^2	1.06



This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement #954530, #863322, #812818, #780537, #871658, #965124, #101070342, #101111896, and by BPI France. Co-funded by Innosuisse - Swiss Innovation Agency, and by the Swiss State Secretariat for Education, Research and Innovation (SERI)