



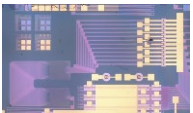
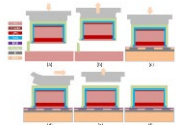
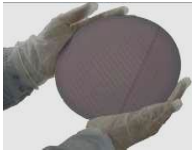
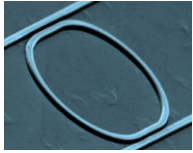
Integrated photonics:  
Towards on-chip lasers for quantum applications

**Photonics Research Group**

K. Van Gasse

9 March 2026 - Workshop BTFS 2026

# Photonics Research Group of Ghent University and imec



## ■ Research focus

- Silicon photonics and novel materials
- Heterogeneous integration of novel materials
- Micro-transfer printing on a wafer scale
- Photonic integrated systems on a chip

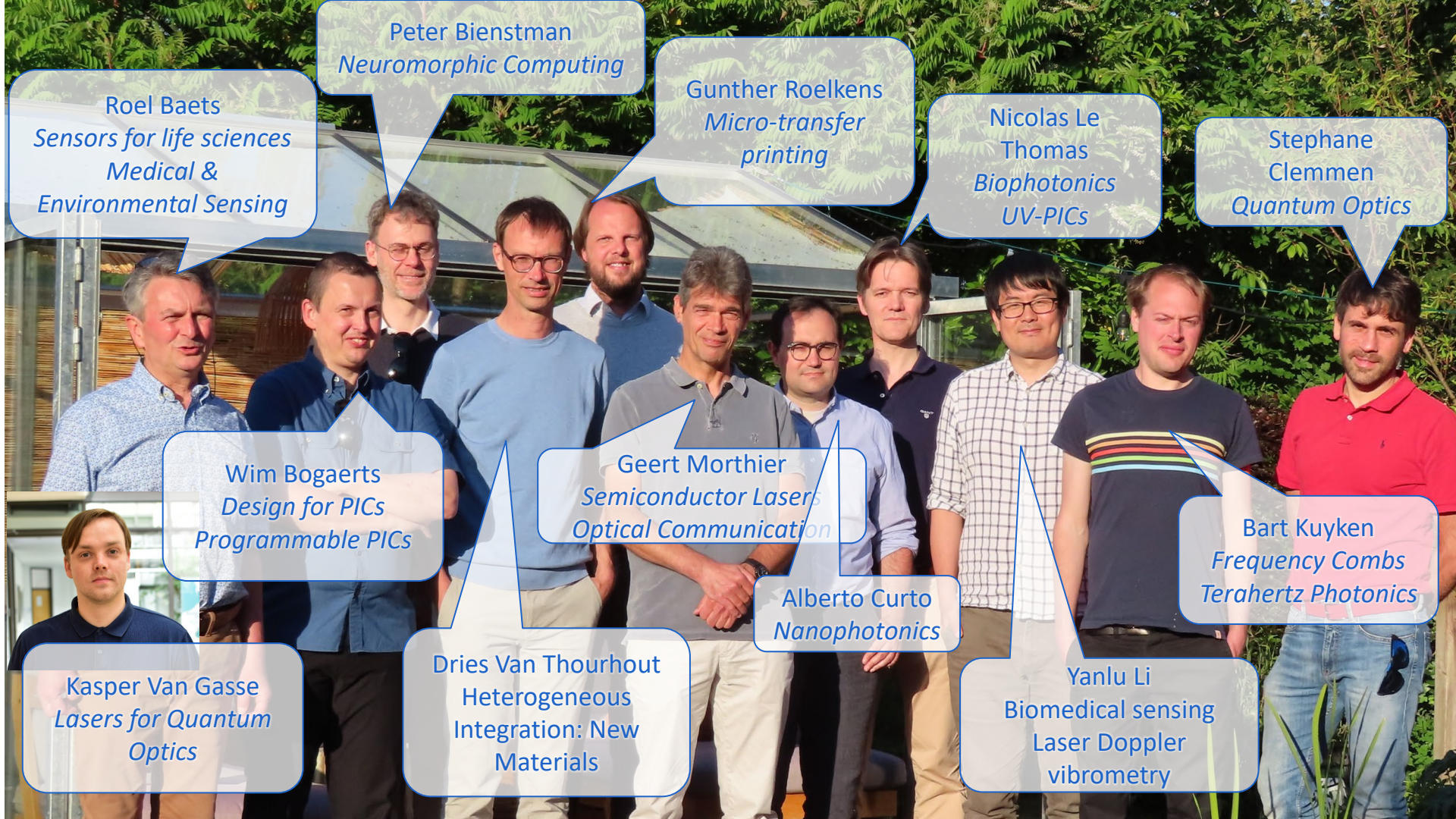
## ■ Applications

- Datacom and transceivers
- Sensing for life sciences
- Optical information processing
- On-chip quantum optical systems

12 Professors  
27 postdocs  
64 PhD students  
15 support staff

20+ nationalities  
9 ERC grantees  
6 spin-off companies  
50 journal papers/year  
Class 100 clean rooms  
M.Sc. Photonics program





**Peter Bienstman**  
*Neuromorphic Computing*

**Roel Baets**  
*Sensors for life sciences  
Medical &  
Environmental Sensing*

**Gunther Roelkens**  
*Micro-transfer  
printing*

**Nicolas Le  
Thomas**  
*Biophotonics  
UV-PICs*

**Stephane  
Clemmen**  
*Quantum Optics*

**Wim Bogaerts**  
*Design for PICs  
Programmable PICs*

**Geert Morthier**  
*Semiconductor Lasers  
Optical Communication*

**Alberto Curto**  
*Nanophotonics*

**Bart Kuyken**  
*Frequency Combs  
Terahertz Photonics*

**Kasper Van Gasse**  
*Lasers for Quantum  
Optics*

**Dries Van Thourhout**  
*Heterogeneous  
Integration: New  
Materials*

**Yanlu Li**  
*Biomedical sensing  
Laser Doppler  
vibrometry*



GHENT  
UNIVERSITY

→ Top 100 university.

→ Since 1817

→ 11 faculties

50,000  
STUDENTS



15,000  
EMPLOYEES



in Belgium



1<sup>st</sup> European university  
in South Korea



GHENT UNIVERSITY  
GLOBAL CAMPUS



+200 programmes

68 English-taught  
master's programmes



2,250

Ghent University  
students abroad



7,300

International students  
at Ghent University

140 ERC projects  
assigned

1,356

Patents

84

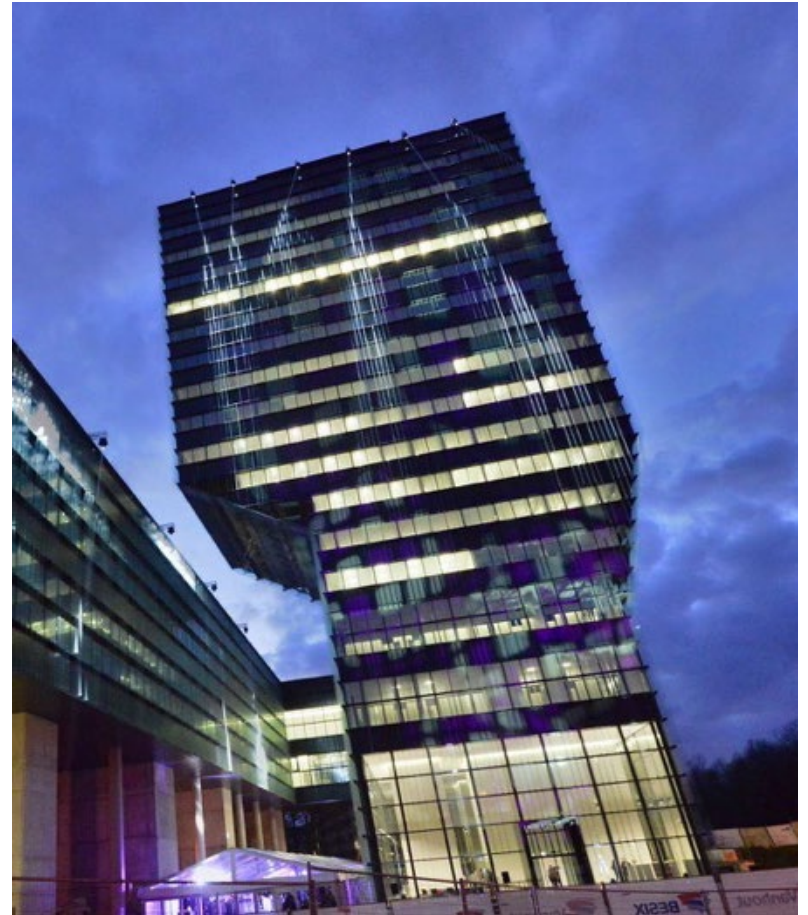
Spin-offs

# imec: Interuniversity Microelectronics Centre

A unique infrastructure that includes a 2.5-billion-euro 300mm semiconductor pilot line

More than 5,500 expert scientists from over 96 countries

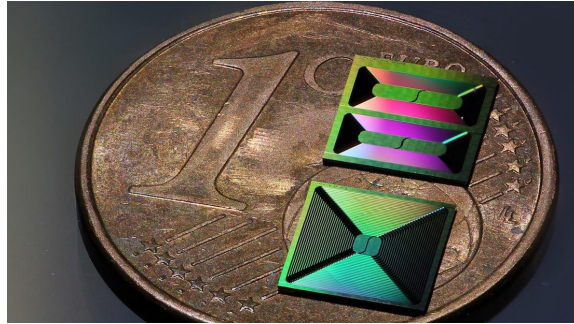
An ecosystem of more than 600 world-leading industry partners and a global academic network



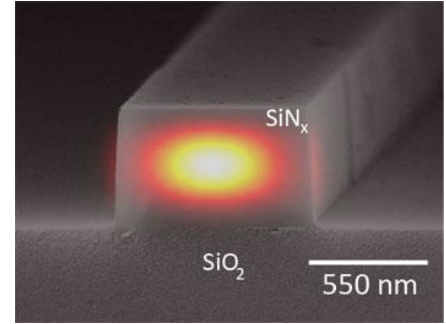
# What are photonic integrated circuits?



Integrated circuits fabricated with mature semiconductor fabrication technologies



Photonic integrated circuits can contain optical components such as: waveguides, splitters, filters, detectors, lasers



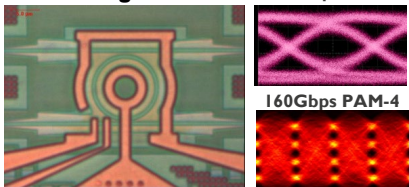
Sub-micrometer-sized dielectric waveguides

# Photonic integrated platform: imec silicon photonics platform – iSiPP200

56-160Gbps

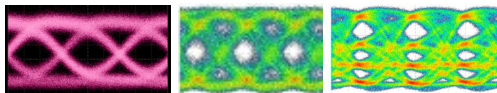
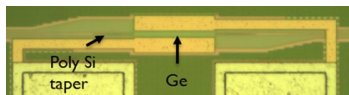
**Silicon Ring Modulator**

56Gbps NRZ



Y. Tong et al., PTL 2020

**56-128Gbps GeSi Electro-Absorption Modulator**

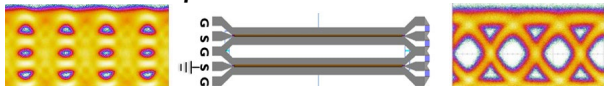


56Gbps NRZ

100Gb/s NRZ

128Gb/s PAM-4

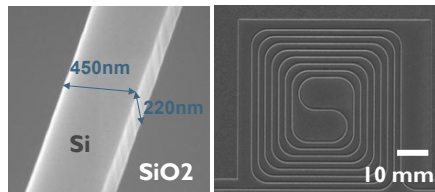
**56-106Gbps Silicon Mach-Zehnder Modulator**



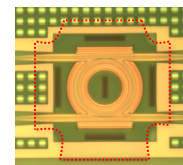
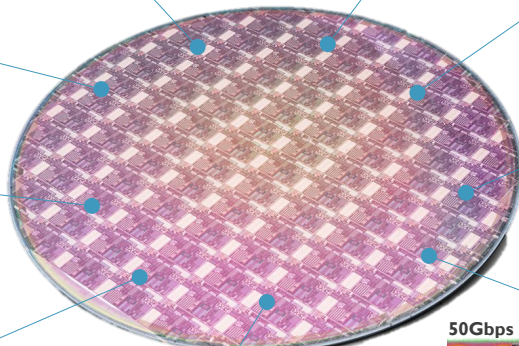
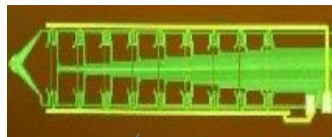
106Gbps PAM-4

56Gbps NRZ

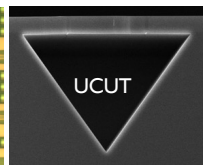
**High-density Si Waveguides (0.5-2dB/cm)**



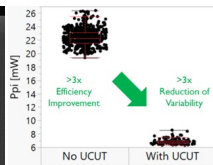
**Silicon WDM filters**



**Efficient Thermo-Optic Phase Tuners**



Undercut

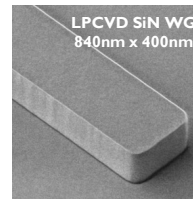


**Low Thermo-Optic Power Consumption**

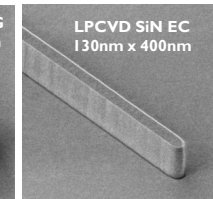
**Integrated LPCVD SiN Waveguides**



**SiN Edge Coupler**  
9um MFD (<3dB)

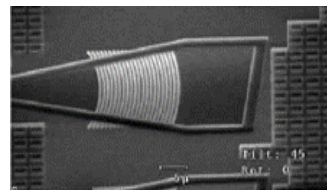


LPCVD SiN WG  
840nm x 400nm

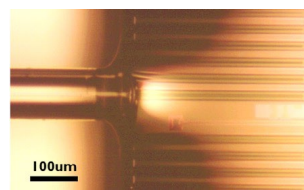


LPCVD SiN EC  
130nm x 400nm

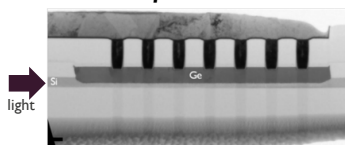
**SMF Grating Coupler (<2dB)**



**High-NA (<2dB) & SMF Edge Couplers (<3dB)**



**56-128Gbps Ge Photodetector**



50Gbps NRZ

128Gbps PAM-4

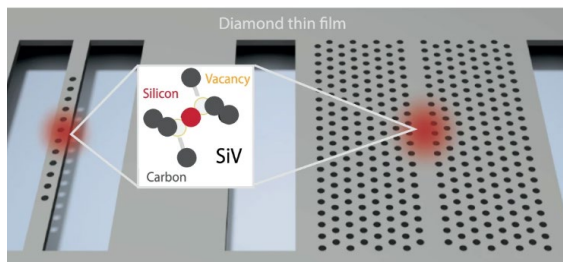
100Gb/s NRZ

56Gbps NRZ

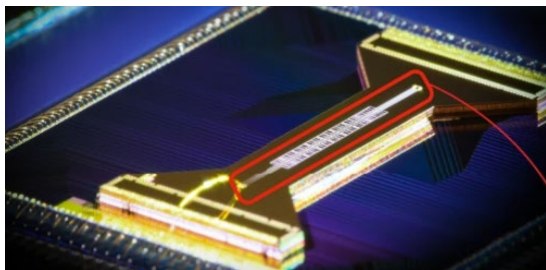
# Can photonic integration help scale quantum systems?

## Quantum hardware

### Solid-state qubits



### Trapped-ion qubits



...

## Applications

Quantum networks

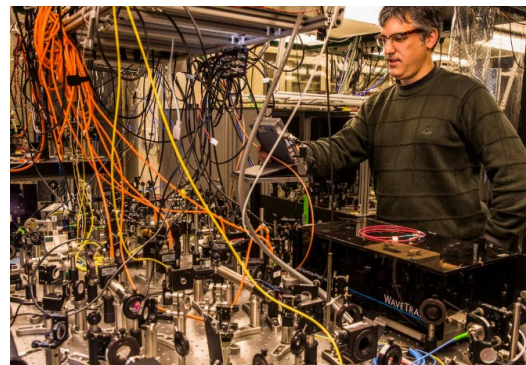
Quantum sensing

Timekeeping  
(optical atomic clocks)

Quantum simulations

Quantum computing

## Scaling challenge: laser systems

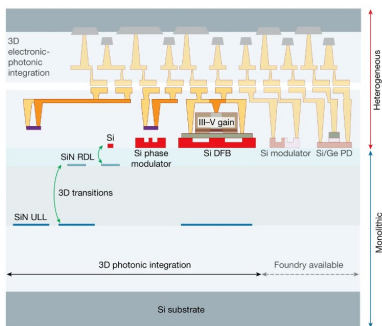


Current laser systems needed for qubit control are not scalable

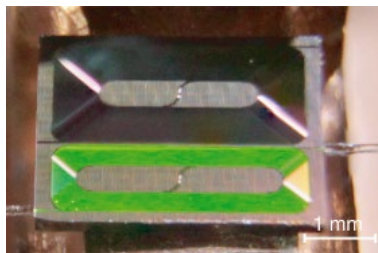
Can we realize laser systems on-chip with sufficient performance?

# Overview: photonic integration of lasers and amplifiers

## Extremely mature in C-band

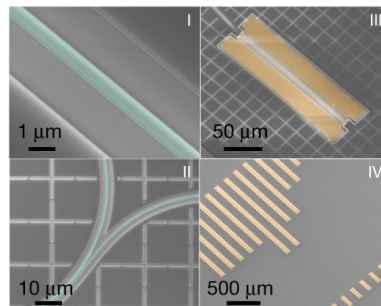


Xiang, C., Jin, W., Terra, O. *et al.* 3D integration enables ultralow-noise isolator-free lasers in silicon photonics. *Nature* **620**, 78–85 (2023).

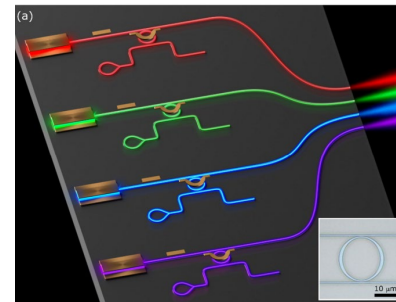


Kippenberg *et al.*, A photonic integrated circuit-based erbium-doped amplifier, *Science* **376**, 2022.

## Novel platforms in visible to NIR for optical clocks, quantum systems and AR/VR

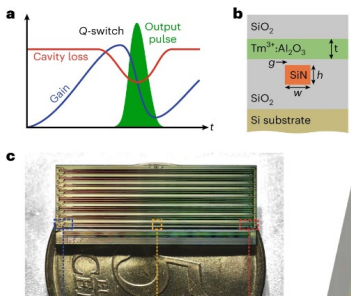


M. Tran *et al.*, Extending the spectrum of fully integrated photonics to submicrometre wavelengths. *Nature* **610**, 54–60 (2022)

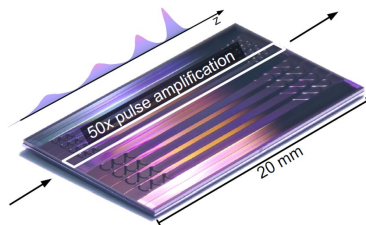


M. Corato-Zanarella *et al.* Widely tunable and narrow-linewidth chip-scale lasers from near-ultraviolet to near-infrared wavelengths. *Nat. Photon.* (2022).

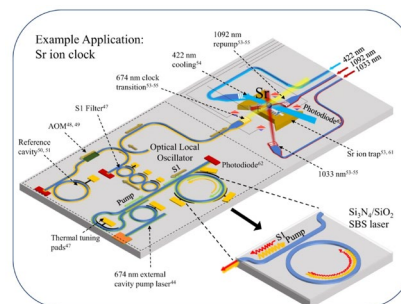
## Rare-earth systems using $Tm^{3+}$



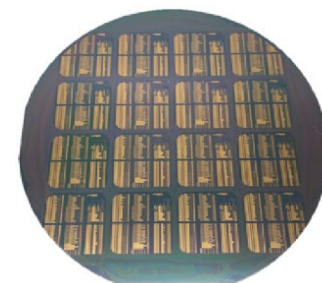
N. Singh *et al.* Silicon photonics-based high-energy passively Q-switched laser. *Nat. Photon.* (2024)



M. Gaafar *et al.*, Femtosecond pulse amplification on a chip, arXiv:2311.04758 (2023)



Chauhan, N., Isichenko, A., Liu, K. *et al.* Visible light photonic integrated Brillouin laser. *Nat Commun* **12**, 4685 (2021).



Zeyu Zhang *et al.*, "Photonic integration platform for rubidium sensors and beyond," *Optica* **10**, 752-753 (2023)

# Titanium-sapphire: A benchmark for high-performance lasers for quantum optics

Host: crystalline sapphire ( $\text{Al}_2\text{O}_3$ )  
Extremely low material absorption  
Excellent thermal conductivity  
Mature technology (Blue LED)

Dopant: Titanium ( $\text{Ti}^{3+}$ )  
4-level laser system  
Transparent at lasing wavelength  
( $< 0.1 \text{ dB/cm}$ )



<https://www.crylink.com/product/ti-sapphire/>

Unparalleled laser performance

Commercially available, widely tunable  
lasers (650 nm – 1100 nm)  
Femtosecond mode-locked lasers

Workhorse quantum optics, two-photon  
microscopy, AMO, metrology, ...

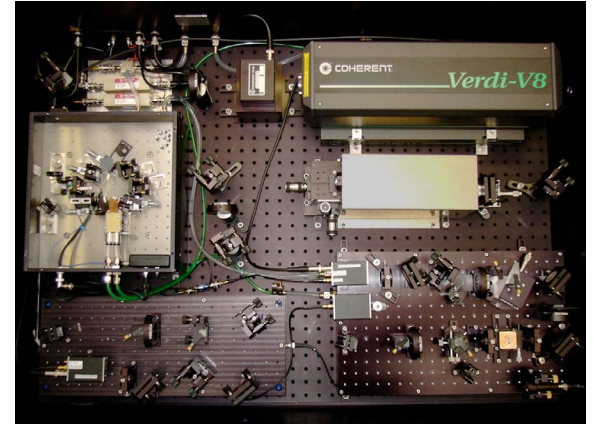


<https://m2lasers.com/lasers.html>



<https://www.spectra-physics.com/en/f/mmai-tai-ultrafast-laser>

Key-enabling laser system for the first optical  
frequency comb.



Nobel Prize 2005 lecture "Passion for precision", T. Hänsch



Photo: Sears\_P.Studio  
John L. Hall



Photo: F.M. Schmidt  
Theodor W. Hänsch

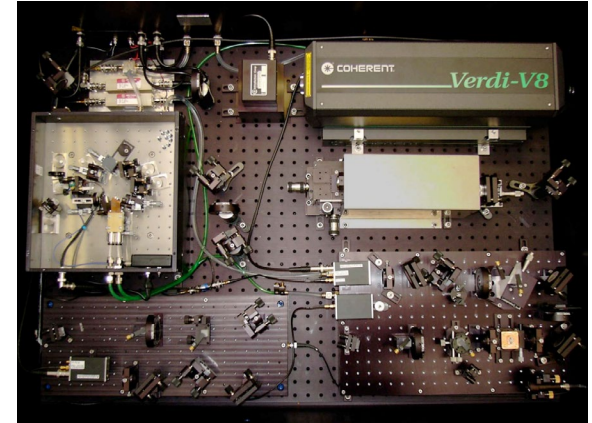


High-performance lasers but bulky and expensive!

# Enhancing pump efficiency in titanium-sapphire with waveguides

The need for very high pump powers ( $> 1 \text{ W}$ ) is a major driver for cost and size of current titanium-sapphire lasers

The need for high-power pump sources can be significantly reduced by using waveguides for pump and lasing wavelength!

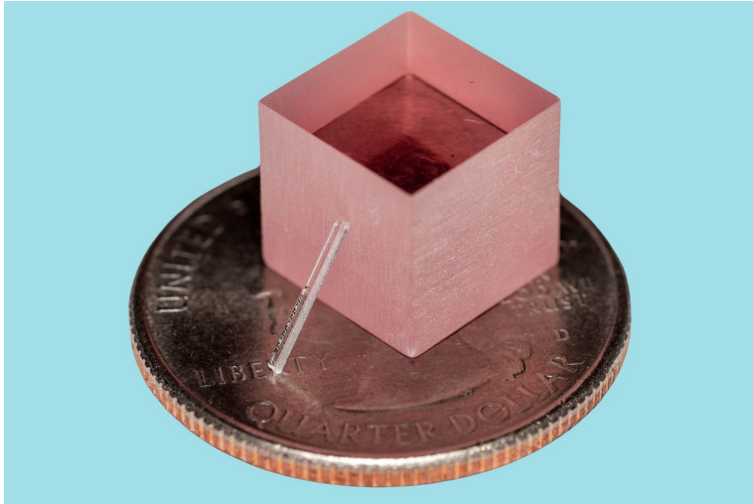


Nobel Prize 2005 lecture "Passion for precision", T. Hänsch

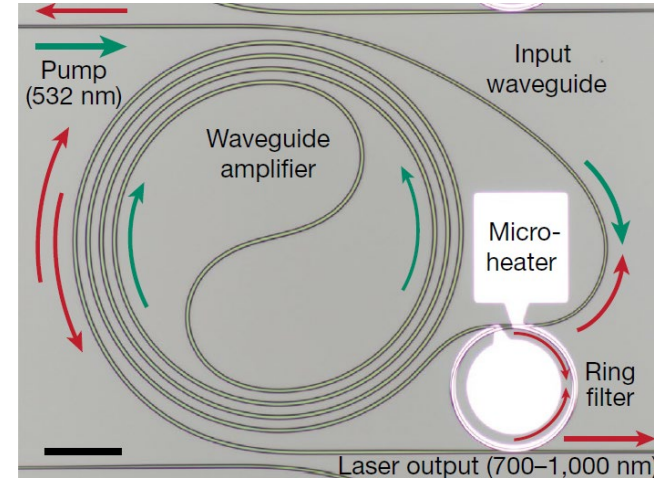
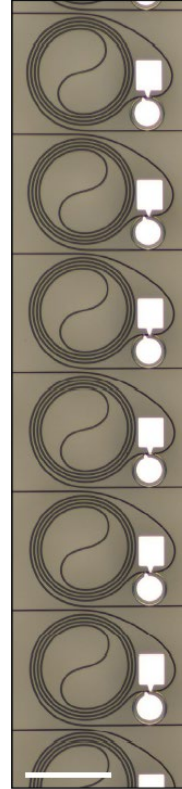
	<p>□ Ti:Sa 50 <math>\mu\text{m}</math></p>	<p>□ Ti:Sa □ Sapphire 10 <math>\mu\text{m}</math></p>	<p>□ Ti:Sa □ Sapphire 10 <math>\mu\text{m}</math></p>	<p>□ Ti:Sa 5 <math>\mu\text{m}</math></p>	<p>□ Ti:Sa □ SiN □ Sapphire 500 nm</p>
Platform	Free space	Channel waveguide	Microfibre	Bulk WGM	Microring resonator
$A_{\text{eff}}$ ( $\mu\text{m}^2$ ), typical	$>200$	55–230	130–250	20	1.5
Threshold (mW)	$>100$	72–230	120–250	14	6.5

Wang, Y., Holguín-Lerma, J.A., Vezzoli, M. *et al.* Photonic-circuit-integrated titanium:sapphire laser. *Nat. Photon.* **17**, 338–345 (2023).

# Example of new generation on-chip solid-state laser: Ti:SaOI



J. Yang\*, K. Van Gasse\*, D. Lukin\*, et al. Titanium:sapphire-on-insulator integrated lasers and amplifiers. *Nature* **630**, 853–859 (2024).

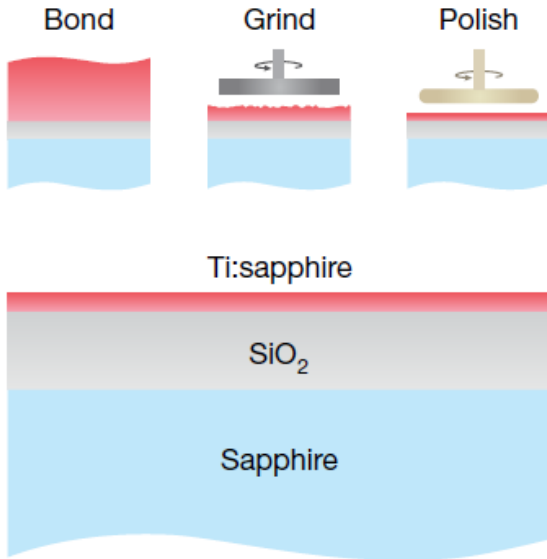


# Ti:SaOI nanophotonic waveguide fabrication

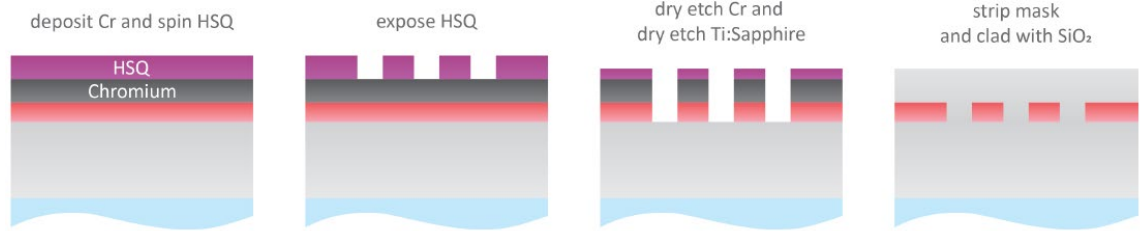
Bonding and thinning

Preserve bulk-performance in nanophotonics

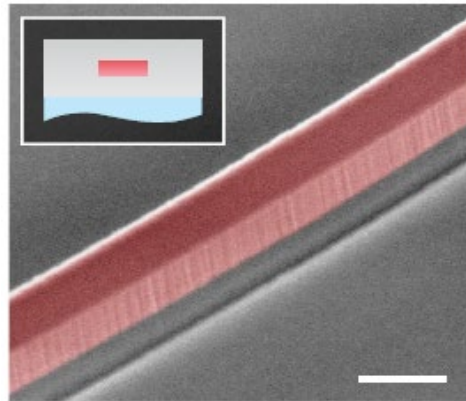
Approach developed in Vuckovic group



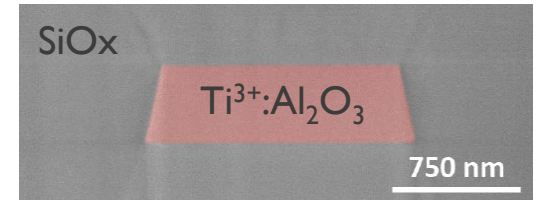
Waveguide definition with standard lithography and dry-etching



False coloured SEM image of uncapped waveguide



SEM cross-section of capped  $\text{Ti}^{3+}:\text{Al}_2\text{O}_3$  waveguide

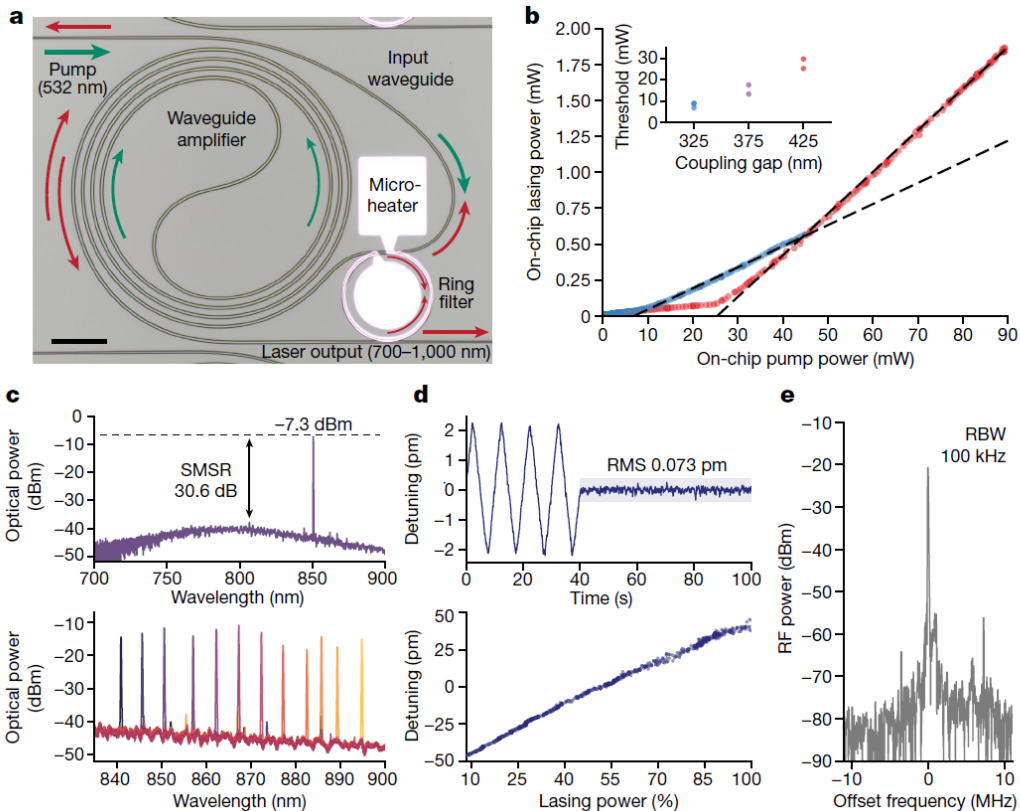


# Our work: Titanium-sapphire-on-insulator tuneable laser

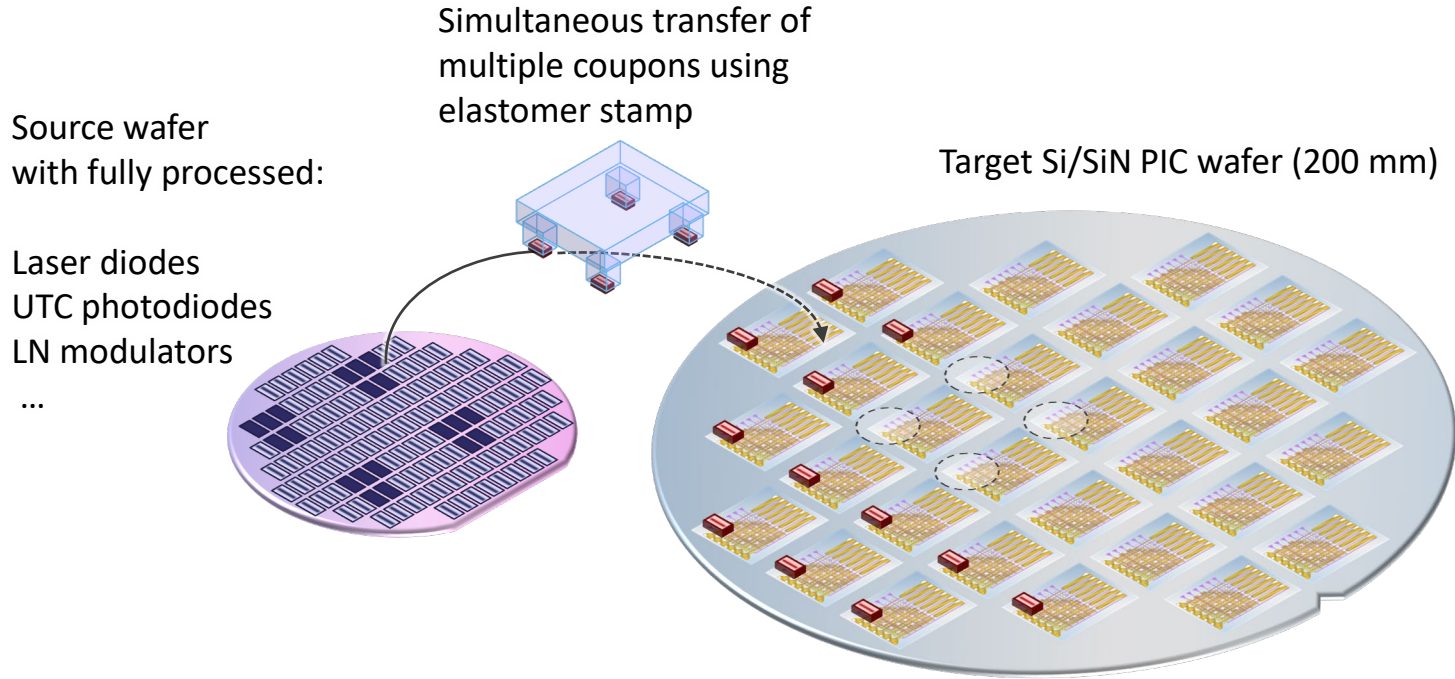
A nanophotonic waveguide platform made from titanium-sapphire crystal allows to miniaturize laser systems to sub-mm size.

Chip enables widely tunable laser at 840 nm to 900 nm

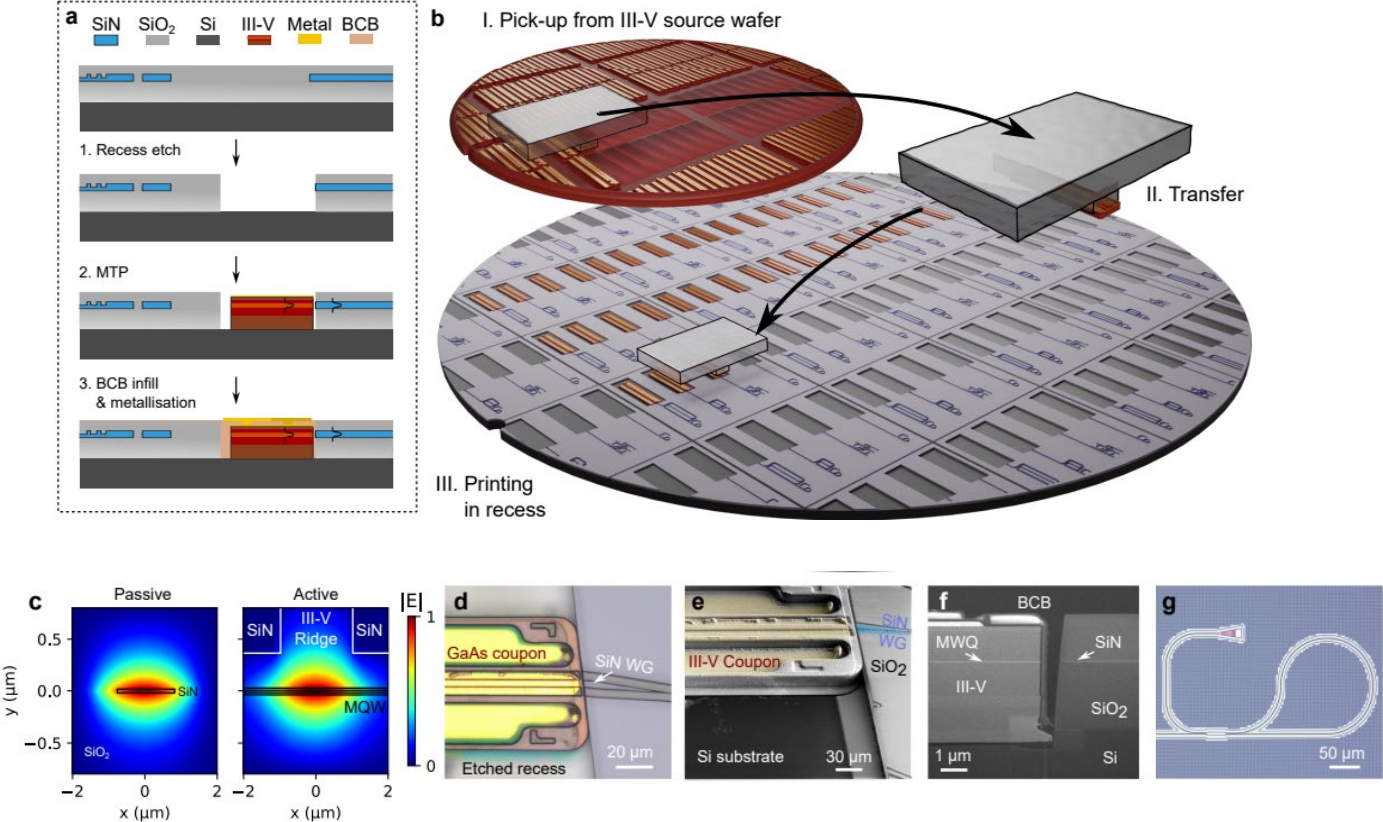
Other wavelengths achievable using newer on-chip laser cavities



# Laser diode integration at Photonics Research Group of Ghent University: uTP



# Laser diode integration at Photonics Research Group of Ghent University



M. Kiewiet, S. Cuyvers, M. Billet, K. Akritidis, V. Bonito Oliva, G. Jeevanandam, S. Saseendran, M. Reza, P. Van Dorpe, R. Jansen, *et al.*, "Micro-transfer printed continuous-wave and mode-locked laser integration at 800 nm on a silicon nitride platform," *Laser Photon. Rev.*, p. e00956, 2025.

# Conclusion

At Ghent University, we investigate how on-chip lasers and amplifiers may improve the scalability of quantum systems.

Integrated photonics can enable more compact, robust, and manufacturable laser sources.

Recent results such as Ti:SaOI are promising first demonstrations, but substantial further development is still needed.

This remains a young and rapidly developing field with many open opportunities.

