Micro transfer printing for integrated photonics at scale

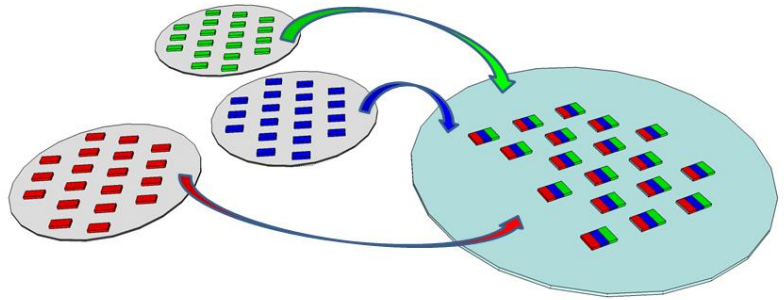
We create advanced micro assembly solutions

EPIC online Technology Meeting on Hybrid Photonic Integrated Circuits
16/09/2024

Company Introduction

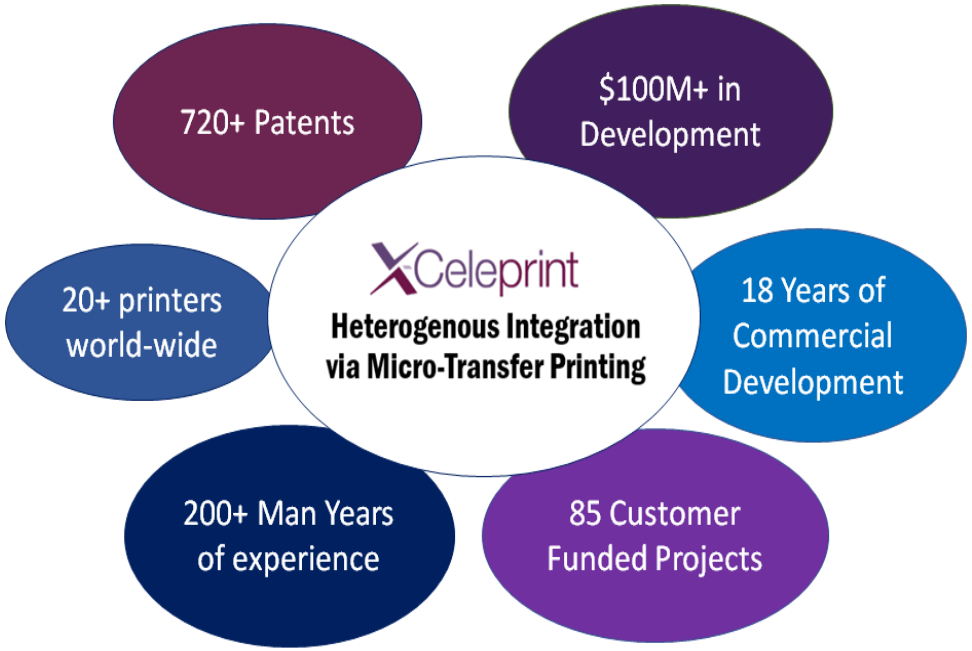
Core technology: Micro-Transfer Printing (MTP)

- **Wafer scale pick and place** of micro-components exploit visco-elastic property of PDMS stamps



Business Model: Licensing of the technology

- Development of micro-transfer printing solutions for specific applications
- MTP prototype services



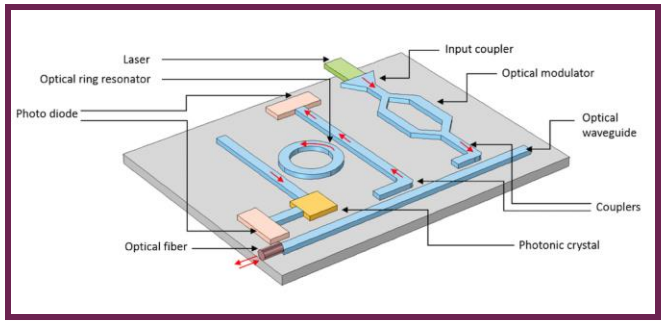
Monitoring MTP projects

- Closed projects: Top-hit, Micro-prince, Caladan, **DTIF,** MORPHIC

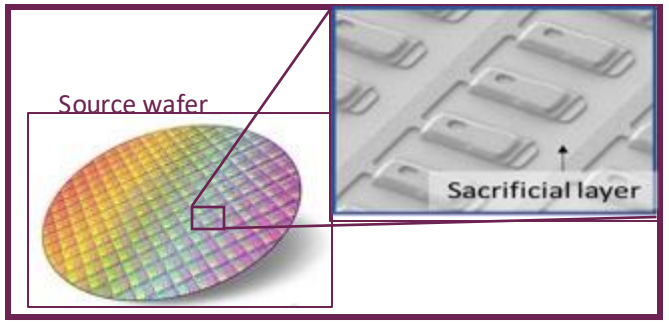
- **Active projects XCEL is directly involved:**
  - INSPIRE (EU, 4.9M): InP photonics and SiN silicon photonics by MTP
  - AMBROSIA (EU, ~5M): InP components on SiN photonics for sepsis diagnosis
  - BAMBAM (EU, 4.3M): uLED and uIC mass transfer
  - M-Engine: Microcomb Photonic Engine
- **Other projects involving MTP:**
  - **EU**: PATTERN, PHORMIC, PUNCH, VISSION, AMICA, LOLIPOP
  - **NON-EU**: TRANSVERSE,
- **EU non-EU Pilot lines and consortia including MTP:**
  - PhotoniXFAB, Photon Delta, Lightup, Medphab, Jeppix

- **Customer active projects: ~20 ->** more in the queue

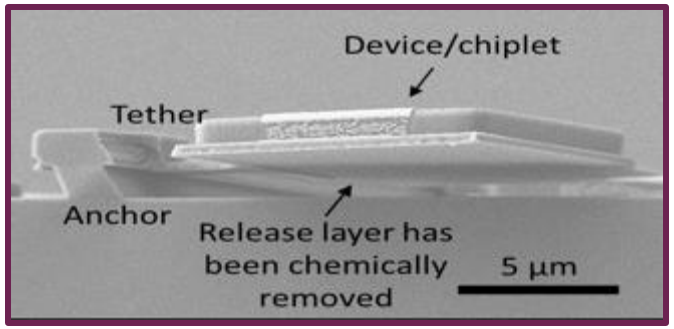
Step 1: choose target layout



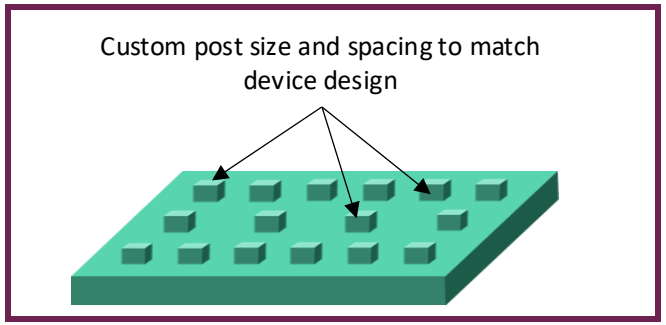
Step 2: Fabricate source wafer to match target layout



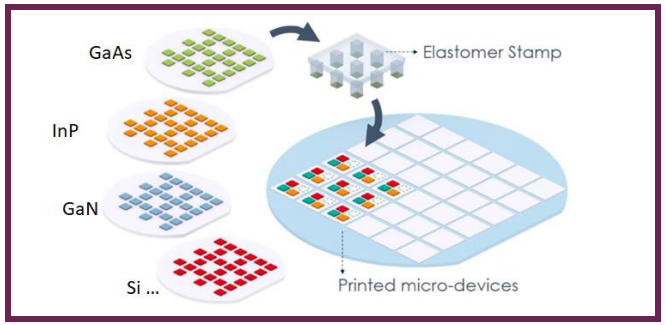
Step 3: Release devices on source



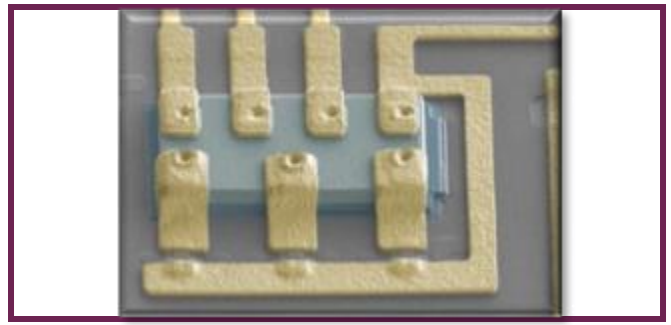
Step 4: create stamp to match target



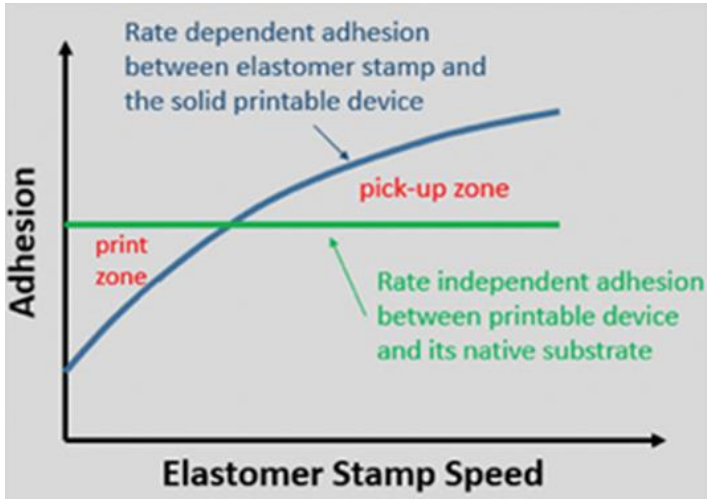
Step 5: micro transfer printing



Step 6: connect devices

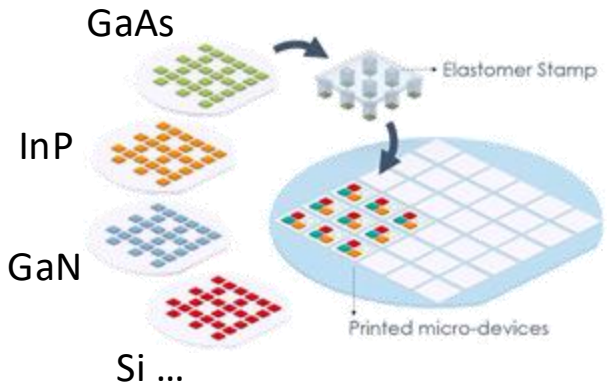


MTP of 20x28 array of 40x40um^2 GaAs devices onto a silicon substrate.



Why MTP for integrated photonics?

Multiple components integration



Manipulate fragile components

Tolerant to Wafer size mismatch

Versatile Material Sets and Substrates

Main features	Benefits
Starting wafer	**Starting wafer**
• Dense component arrays • Pre/post fabrication	• Source wafer exploitation • known good die
Transfer	**Transfer**
• Scalable using parallel transfer • Chips from different wafers	• Throughput • Flexibility • Mix and match approach
Print	**Print**
• passive alignment: - <0.5µm • **roadmap: <0.1 µm alignment**	• Throughput • Enable III-V onto SiPh

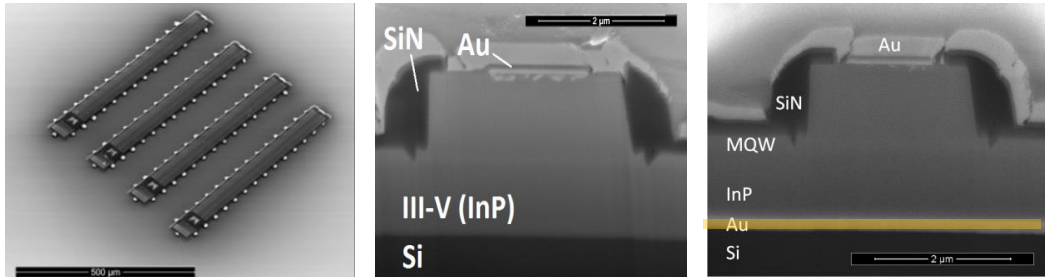
1. Micro Transfer Printing for Micro Assembly of Heterogeneous Integrated Compound Semiconductor Components, CS MANTECH Conference, 2022.

III-V MTP onto SiPh substrates:

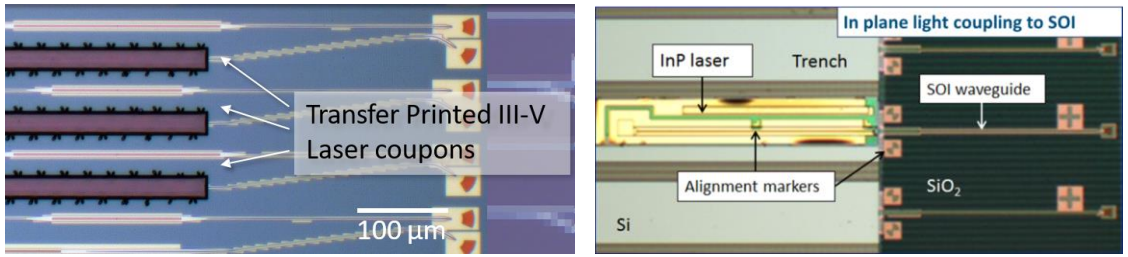
- Operational devices & coupons of material
- Single posts & arrays printing
- Type of substrates:
  - Si, SiO2, glass, GaAs, InP
  - SOI, SiN (Top, buried oxide, substrate, inside recess)
- interfaces:
  - Adhesive layers: Intervia // BCB
    - Super-thin-adhesive (<30nm)
  - Adhesive-less to engineered layers

- Different light coupling configurations:
  - **edge, evanescent**, grating

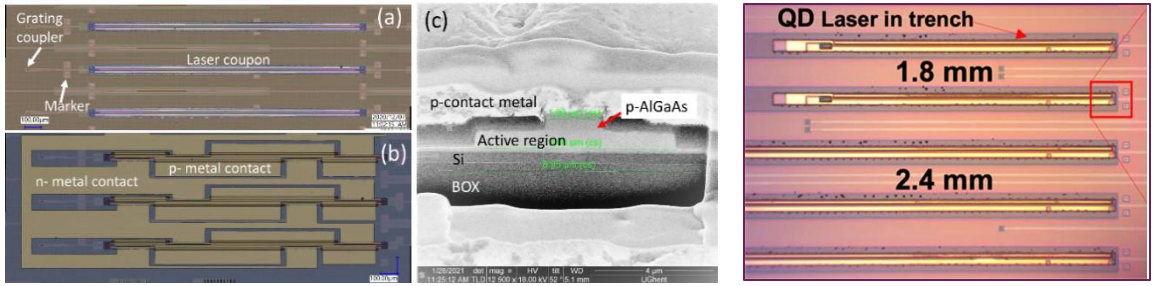
InP lasers MTP on Si substrate with / without interface layers



InP lasers MTP on Silicon photonics – Top SOI - In a recess



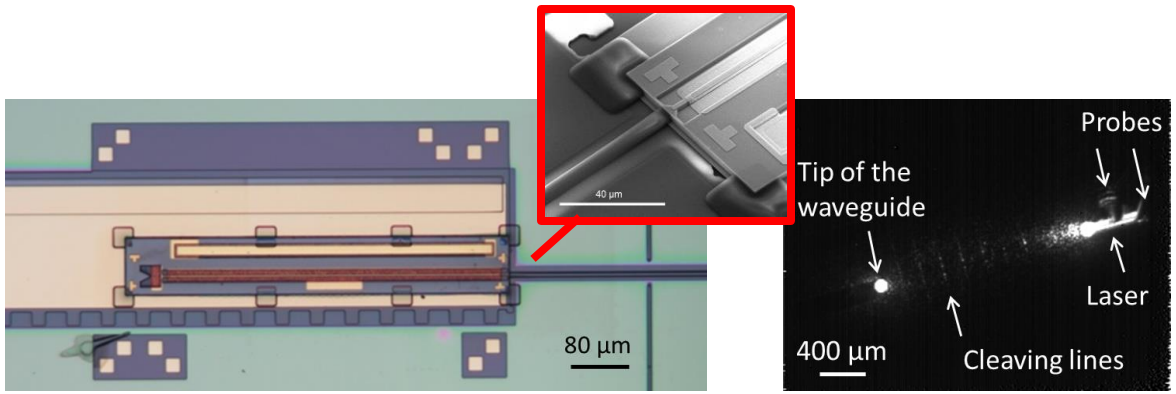
GaAs QD lasers MTP on Silicon photonics – Top SOI - In a recess



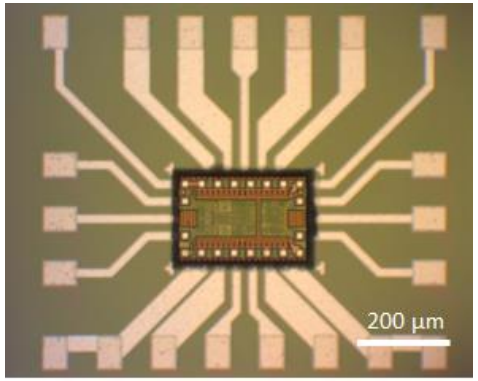
1. Transfer Printing of AlGaInAs/InP Etched Facet Lasers to Si Substrates. 2016. IEEE Phot. Journ.
2. Micro Transfer Printing for Micro Assembly of Heterogeneous Integrated Compound Semiconductor Components, CS MANTECH Conference, 2022.
3. Micro-transfer printing for advanced scalable hybrid photonic integration. May 30, 2018. European Conference on Integrated Optics (ECIO 2018).
4. Integration of Edge-Emitting Quantum Dot Lasers with Different Waveguide Platforms using Micro-Transfer Printing, JSTQE 2023

Other examples of integrated photonics using MTP

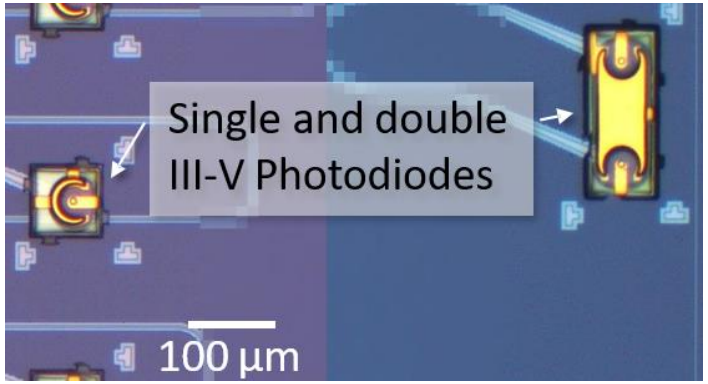
InP lasers MTP in a recess on SiPh edge coupled to polymer waveguide + SOI



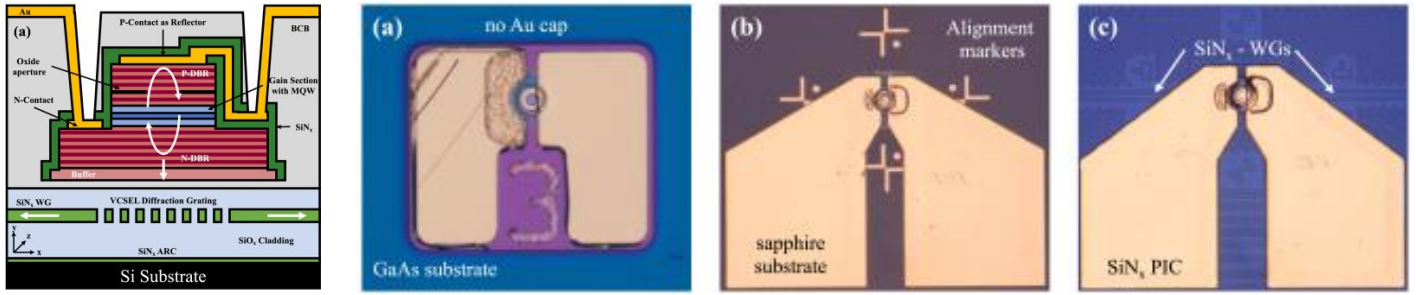
EIC on SiPh interposer



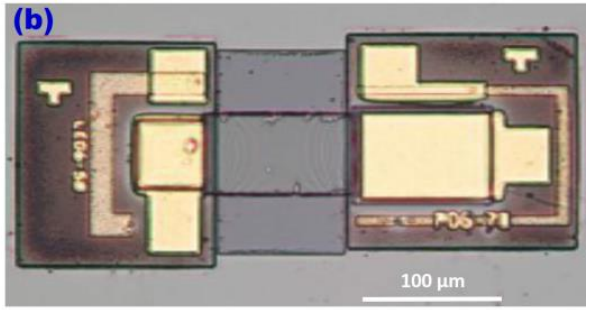
PD on SiPh



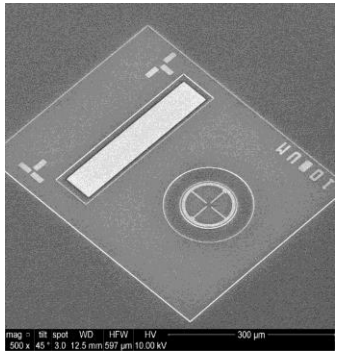
VCSELs on Sapphire and SiPh



LED+PD interconnect on Si



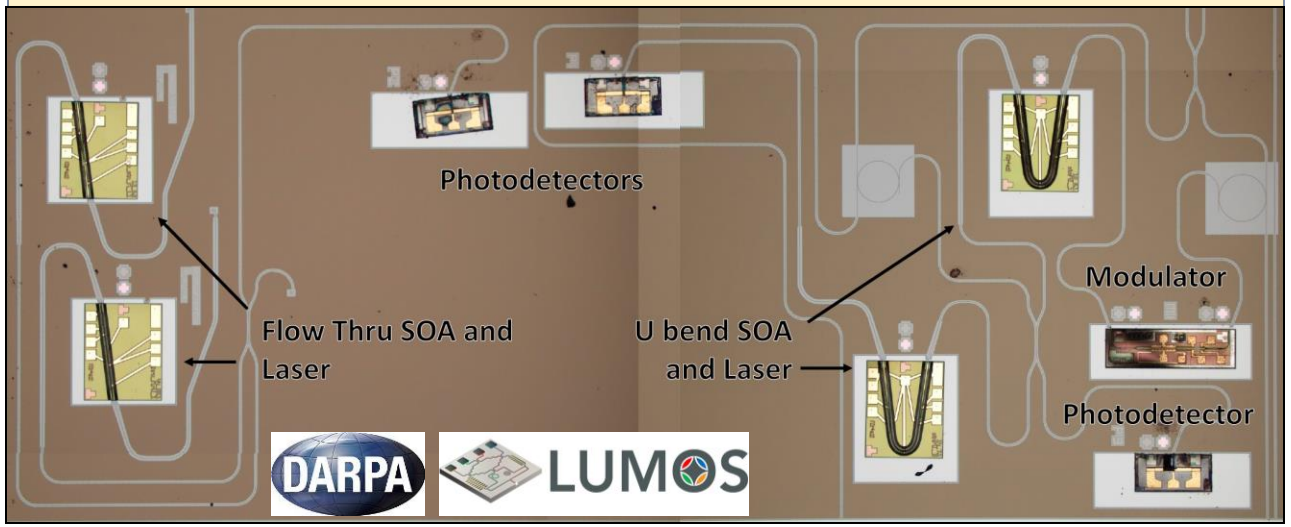
PV-Cell on Si



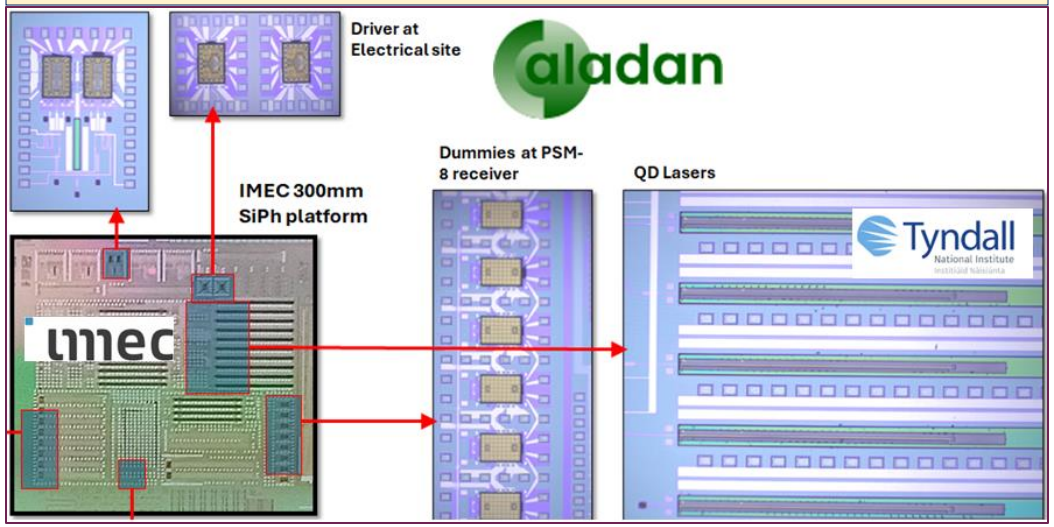
1. Edge-Coupling of O-Band InP Etched-Facet Lasers to Polymer Waveguides on SOI by Micro-Transfer-Printing, in *IEEE Journal of Quantum Electronics*, 2020
2. R. Loi et al., "Micro transfer printing of electronic integrated circuits on Silicon photonics substrates," in ECIO 2022 conference. May, 2022.
3. Top-hit EU project
4. Enabling VCSEL-on-silicon nitride photonic integrated circuits with micro-transfer-printing." Optica 8.12 (2021): 1573-1580.
5. Low-power-consumption optical interconnect on silicon by transfer-printing for used in opto-isolators." Journal of Physics D: Applied Physics 52.6 (2018).
6. Microtransfer Printing High-Efficiency GaAs Photovoltaic Cells onto Silicon for Wireless Power Applications." Advanced Materials Technologies 5.8 (2020): 2000048.

Last demos

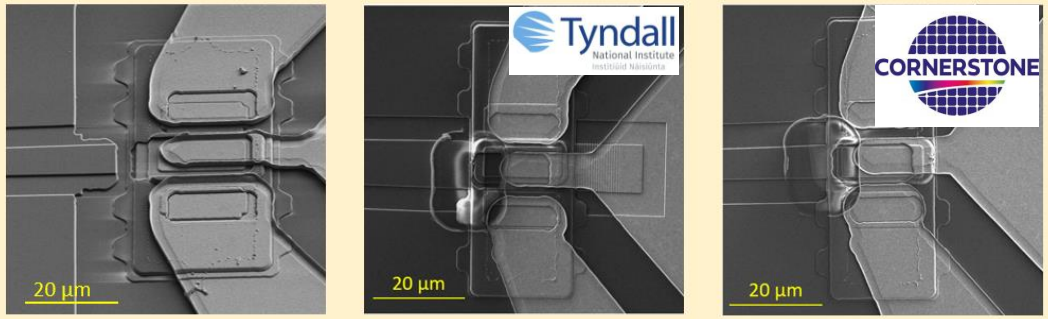
LUMOS: Different GaAs components integrated on PICs



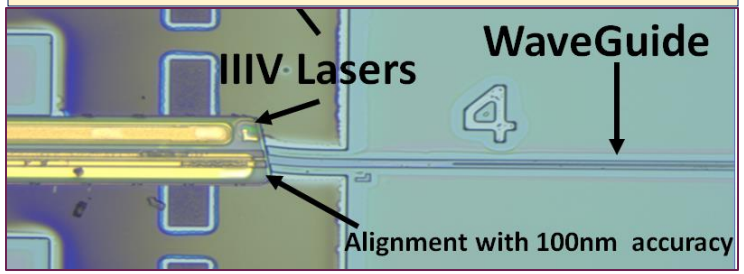
CALADAN: wafer scale MTP of EICs and lasers on SiPh



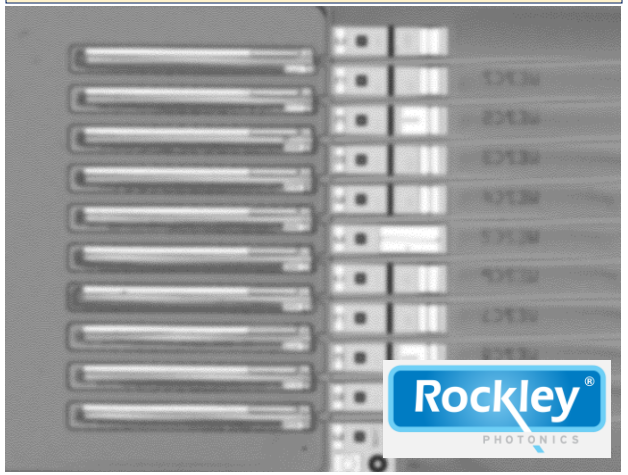
Tyndall's O-C-band PDs on SiPh from Cornerstone



InP laser edge coupling with **<100nm overlay**



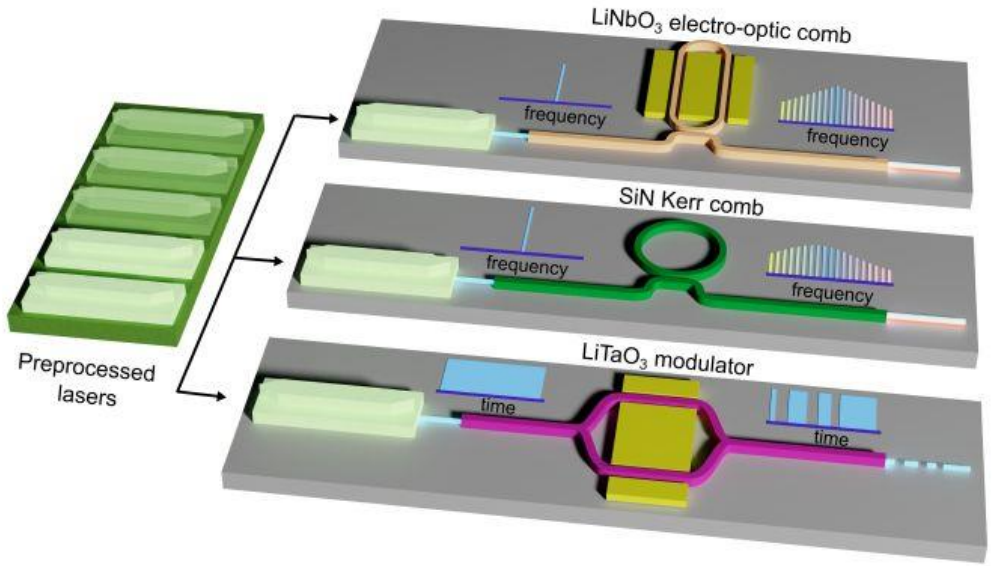
Array of 10 laser MTP in a recess in the SOI

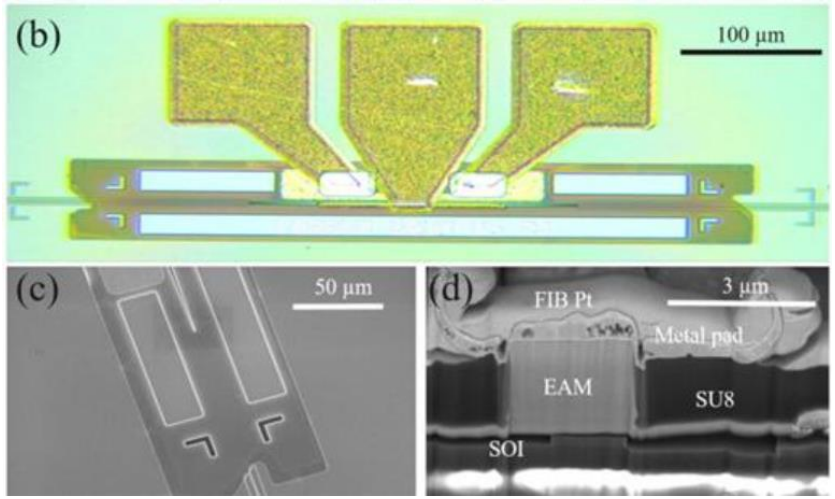


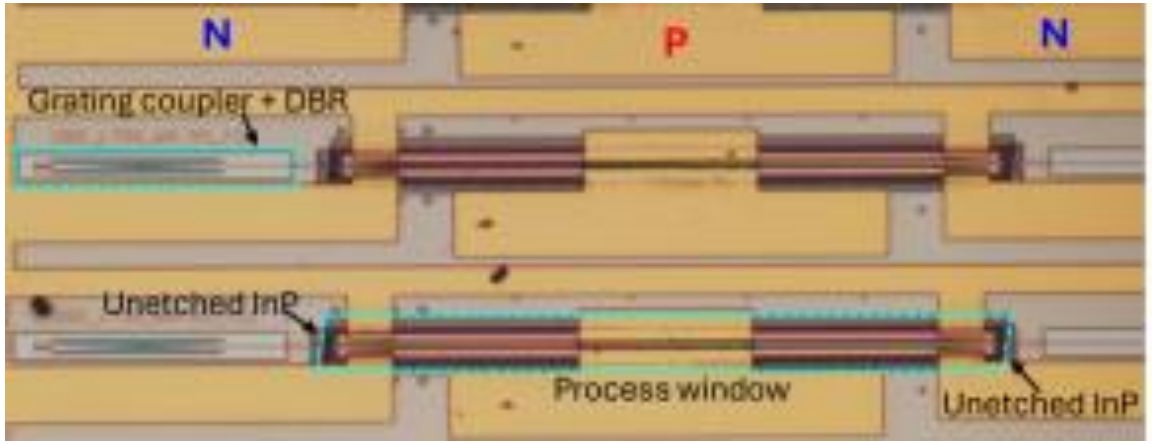
1. Micro Transfer Printing for Micro Assembly of Heterogeneous Integrated Compound Semiconductor Components, CS MANTECH Conference, 2022.
2. Aaron Zilkie et al. "High-Performance Micro-Transfer-Printed Silicon Photonic DBR Laser, in , in *ECOC 2023 conference*
3. H. Mathuganesan, "100 Gbps PAM4 ultra-thin photodetectors integrated on SOI platform by micro transfer printing," Opt. Express 31, 36273-36280 (2023)

Last results

- PRG platform agnostic III-V laser on LiNb, SiN;
- TYN-INTEL O-band DBR lasers MTP onto SiPh;
- TYN high-speed InP-based EAM on SiPh;







1. I. Luntadila Lufungula, et. al, "Integrated Resonant Electro-Optic Comb Enabled by Platform-Agnostic Laser Integration", *Laser Photonics Rev* 2024.
2. S. Ghosh et. al, "Scalable transfer printing approach to heterogeneous integration of InP lasers on silicon-on-insulator waveguide platform." Appl. Phys. Lett. 19 August 2024;
3. Owen Moynihan, et.al "Micro-transfer printed high-speed InP-based electro-absorption modulator on silicon-on-insulator." *Appl. Phys. Lett.* 29 July 2024

Supply chain of MTP for integrated photonics

Objectives:

I. Accelerate MTP into production

- Path to production: **Prototypes -> Pilot volume -> High volume**

II. PICs at large volume

- An ecosystem of suppliers is currently in development
- A standardization process is required

Supply chain leverages:

- Partners/customers from previous/active projects
- Photonics consortia / pilot-lines

Activities:

I. **Monitor** TRL, Readiness, standardization
II. **Support** improvement of parameters above
III. **Facilitate networking, reduce overlap**

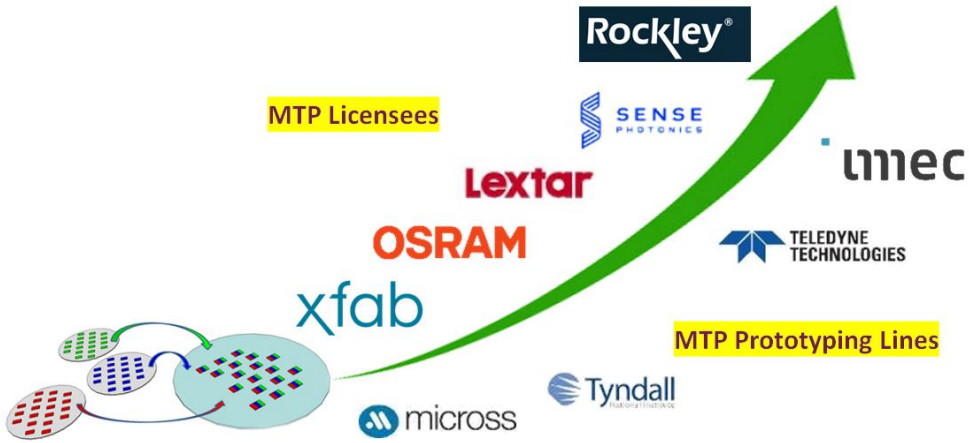
Suppliers are grouped in **prototyping** and **production** per each area of the SC

feel free to get in touch If you want to know more about the MTP supply chain and how to work with it

Supply chain 8 areas (50+100 suppliers)

III-V or Si Components	Silicon photonics	MTP Printing Sites	Thin Film Interconnect
Design	Packaging	Testing	Equipment

- **MTP is a key enabling technology for integrated photonics**
- Multiple licensees are moving into commercialisation
- High volume products will be out end of 2024 /2025



Contact us with any questions

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