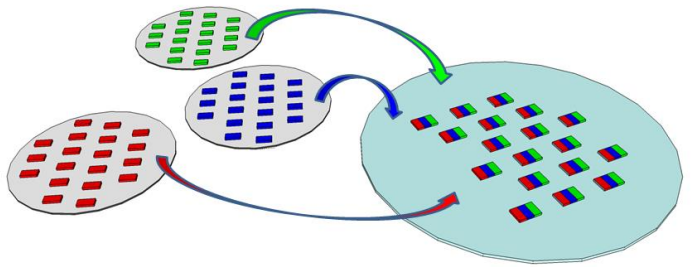
Micro-transfer-printing for Integrated Photonics

We create advanced micro assembly solutions

Company Introduction

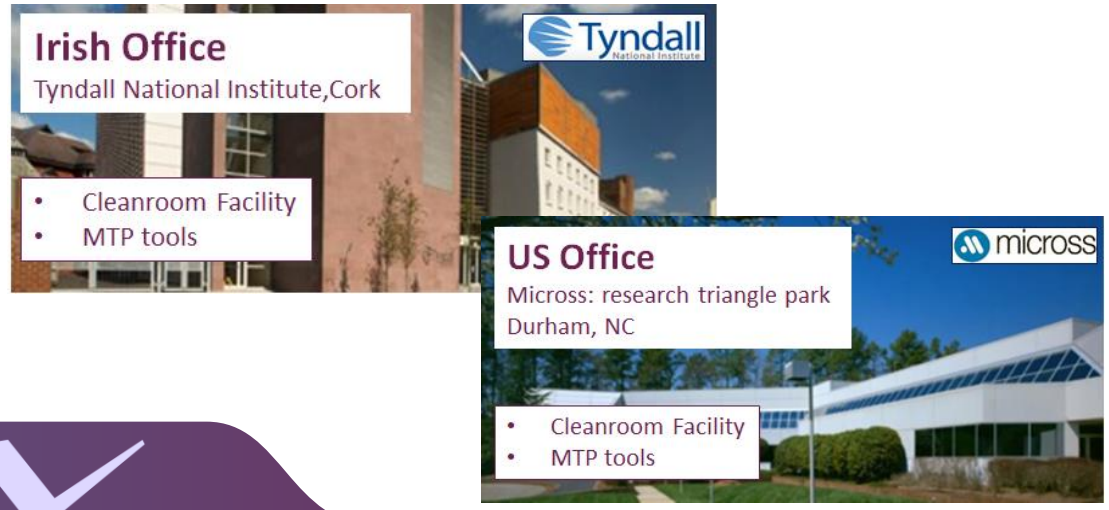
Core technology: Micro-Transfer Printing (MTP)

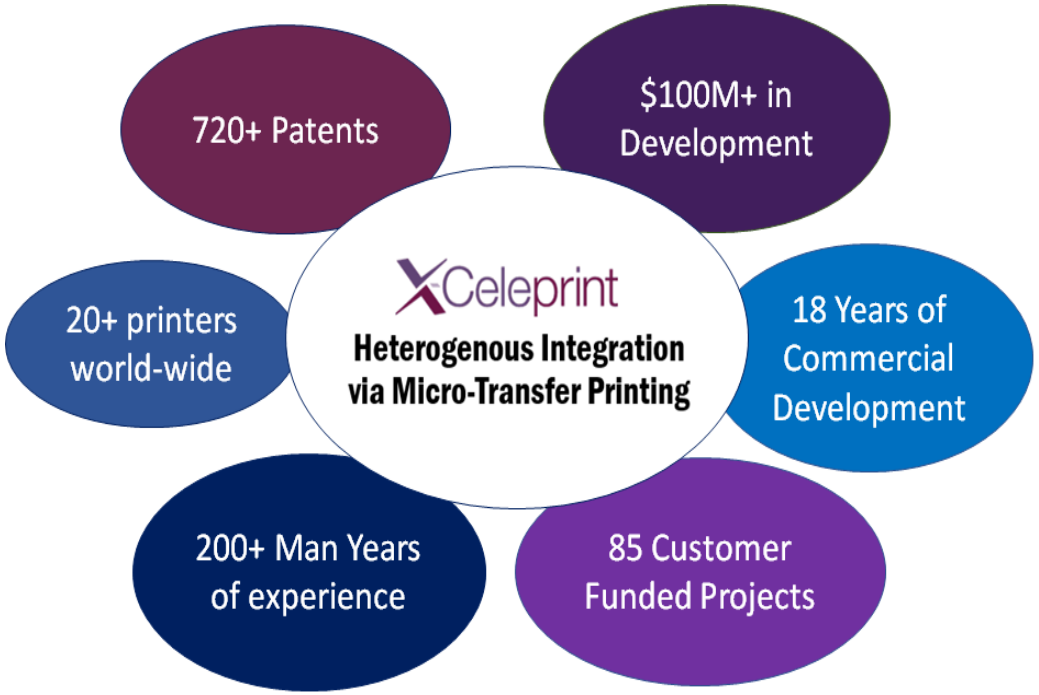
- **Wafer scale pick and place** of micro-components exploit visco-elastic property of PDMS stamps



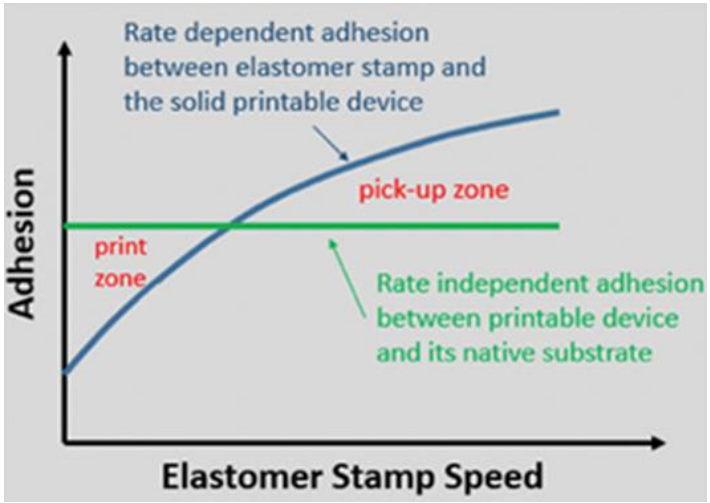
Business Model: Licensing of the technology

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



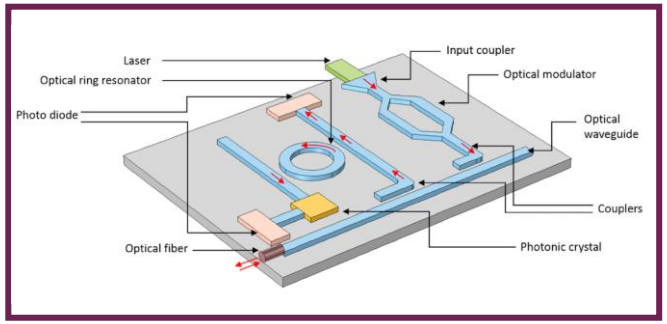


MTP of 20x28 array of 40x40um^2 GaAs devices onto a silicon substrate.

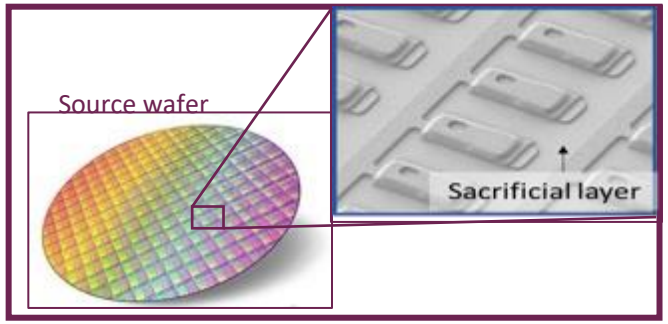


1. Micro Transfer Printing for Micro Assembly of Heterogeneous Integrated Compound Semiconductor Components, CS MANTECH Conference, 2022.

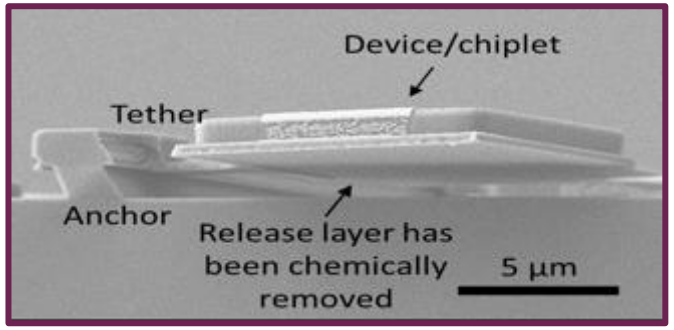
Step 1: choose target layout



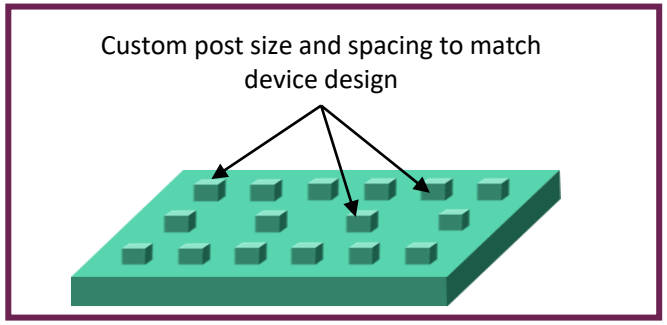
Step 2: Fabricate source wafer to match target layout



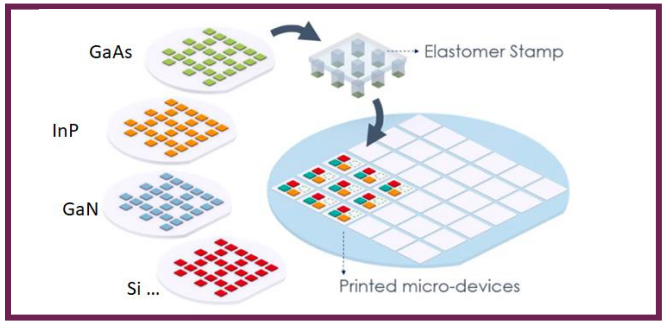
Step 3: Release devices on source wafer



Step 4: create stamp to match target layout



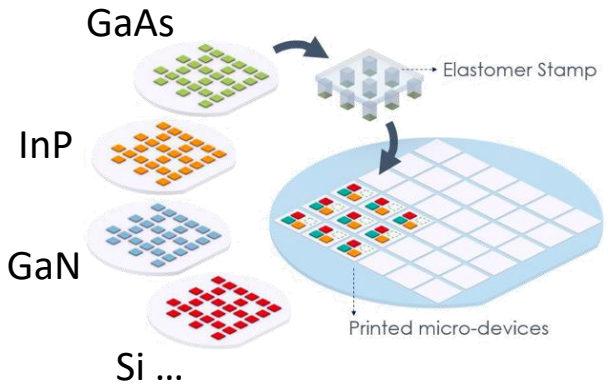
Step 5: micro transfer printing



Step 6: connect devices

Why MTP for integrated photonics?

Multiple components integration



Manipulate fragile components

Tolerant to Wafer size mismatch

Versatile Material Sets and Substrates

Starting wafer

- Dense component arrays
- Pre/post fabrication

Benefits

- Source wafer exploitation
- known good die

Transfer

- Scalable using parallel transfer
- Chips from different wafers

- Throughput
- Flexibility
- Mix and match approach

Print

- passive alignment:
  - <0.5µm

- Throughput
- Enable III-V onto SiPh

- **roadmap: <0.1 µm alignment**

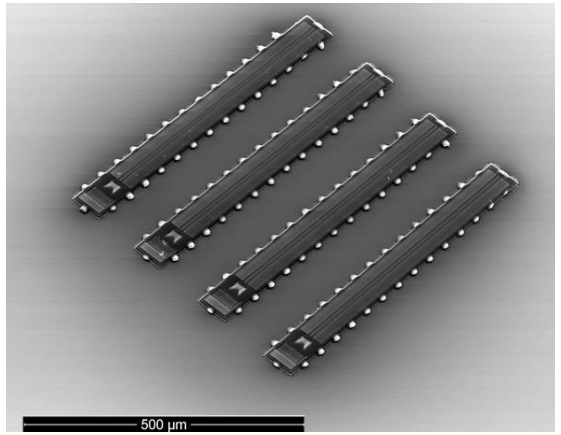
1. Micro Transfer Printing for Micro Assembly of Heterogeneous Integrated Compound Semiconductor Components, CS MANTECH Conference, 2022.

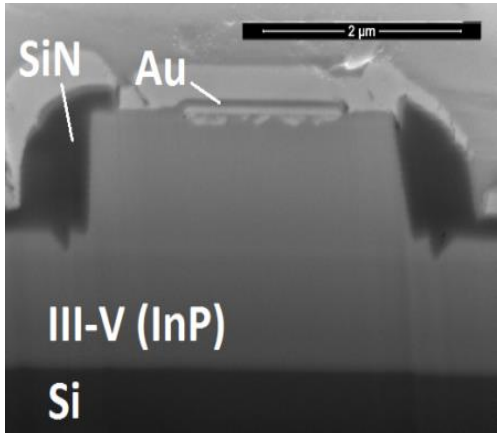
III-V MTP onto SiPh substrates:

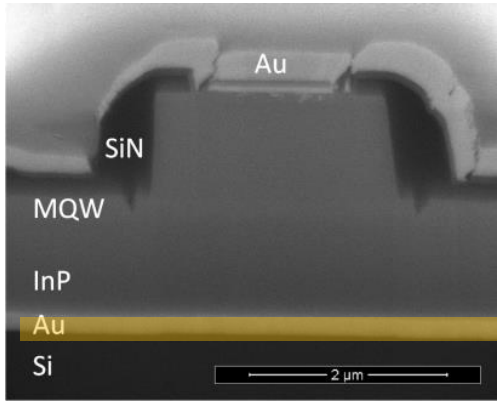
- Operational devices & coupons of material
- Single posts & arrays printing
- Type of substrates:
  - Si, SiO2, glass, GaAs, InP
  - SOI, SiN (Top, buried oxide, substrate, inside recess)
- interfaces:
  - Adhesive layers: Intervia // BCB
    - Super-thin-adhesive (<30nm)
  - Adhesive-less to engineered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

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

C-band InP lasers MTP on Si substrate with / without interface layers



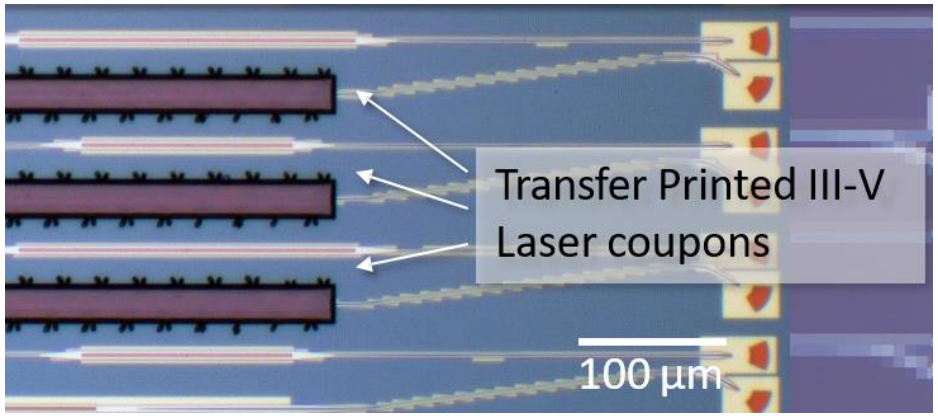


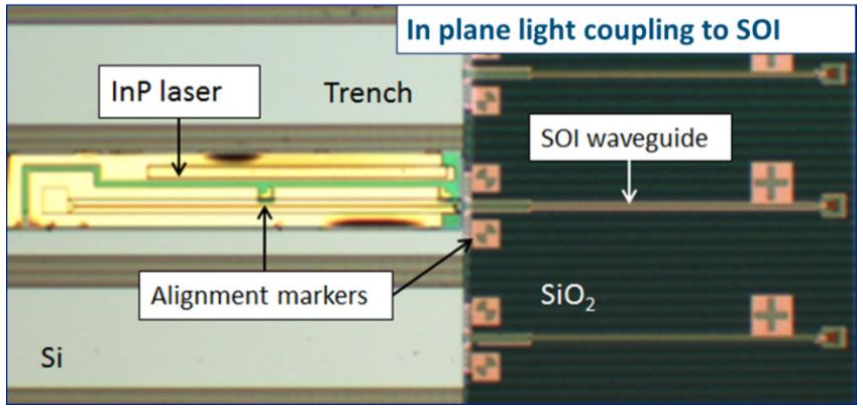


1. Transfer Printing of AlGaInAs/InP Etched Facet Lasers to Si Substrates. 2016. IEEE Phot. Journ.

Examples of integrated photonics using MTP

C-band InP lasers MTP on Silicon photonics – Top SOI (evanescent light coupling) - In a recess (edge coupling)





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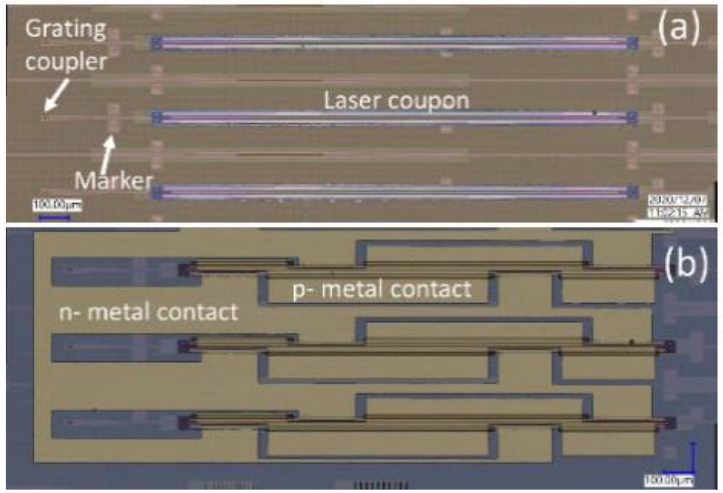
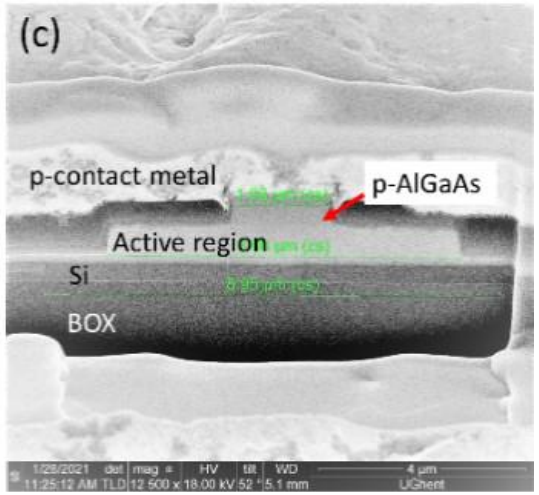
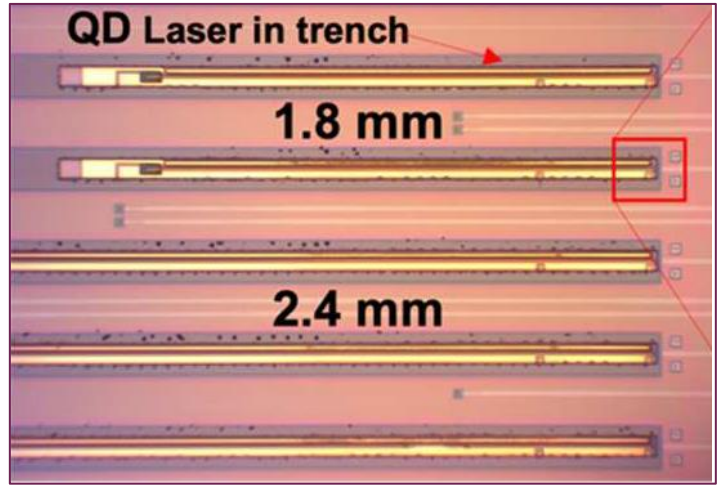
GaAs O-band QD lasers MTP on Silicon photonics – Top SOI - In a recess



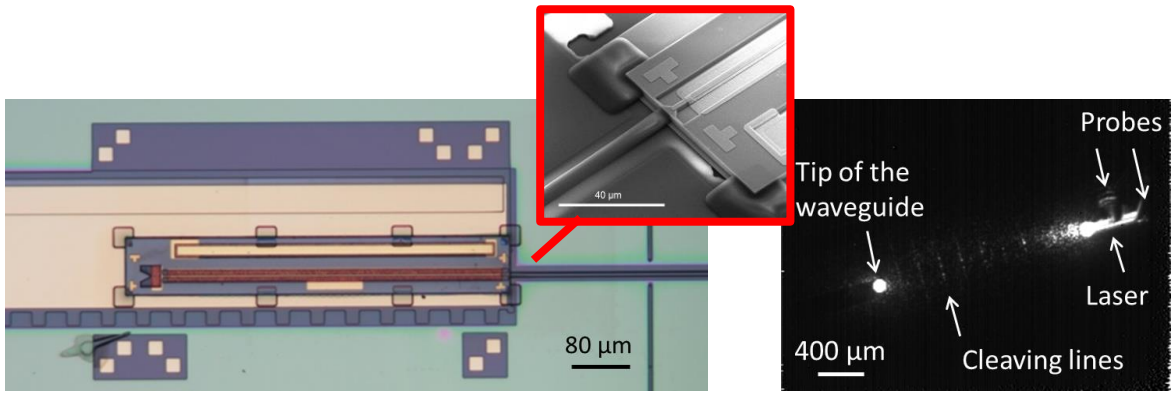




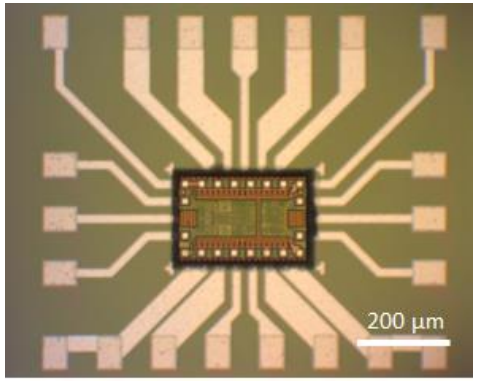
1. Micro Transfer Printing for Micro Assembly of Heterogeneous Integrated Compound Semiconductor Components, CS MANTECH Conference, 2022.
2. Micro-transfer printing for advanced scalable hybrid photonic integration. May 30, 2018. European Conference on Integrated Optics (ECIO 2018).
3. Integration of Edge-Emitting Quantum Dot Lasers with Different Waveguide Platforms using Micro-Transfer Printing, JSTQE 2023

Other examples of integrated photonics using MTP

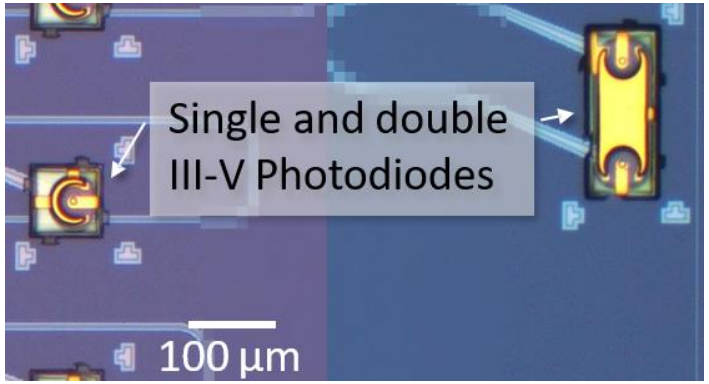
InP lasers MTP in a recess on SiPh edge coupled to polymer waveguide + SOI



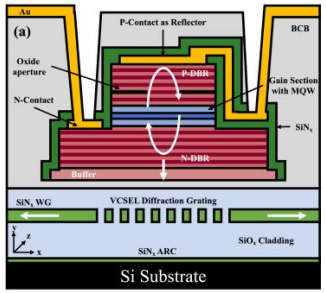
EIC on SiPh interposer

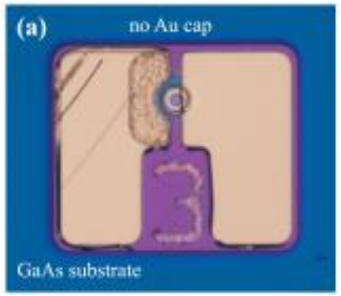


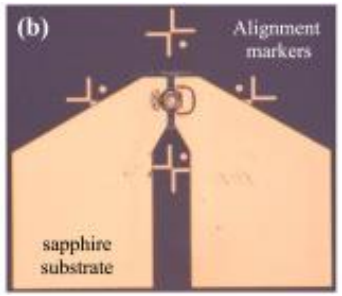
PD on SiPh

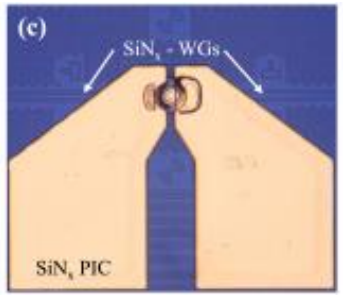


VCSELs on Sapphire and SiPh

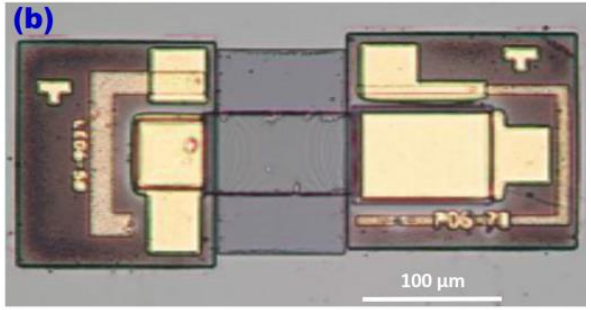




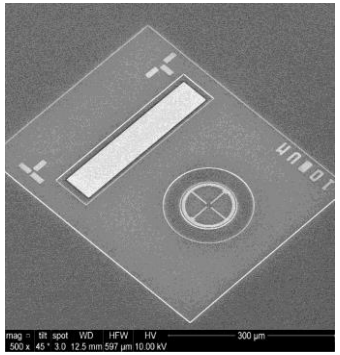




LED+PD interconnect on Si

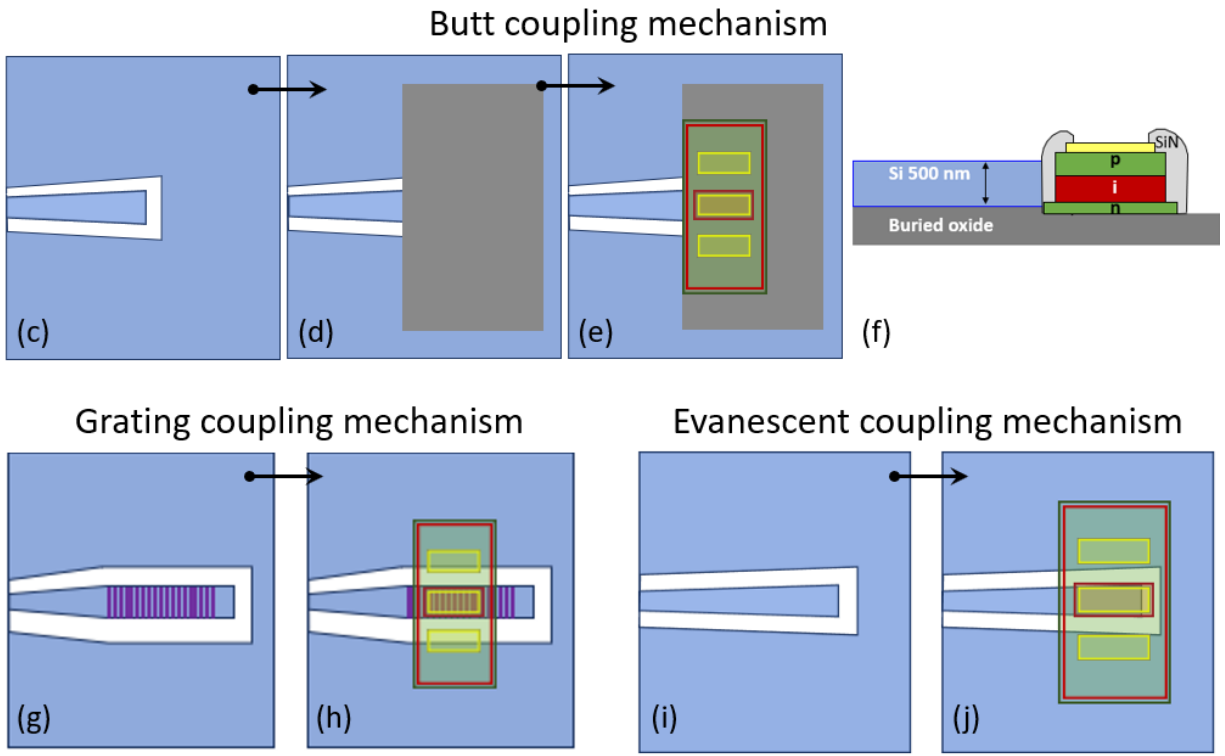


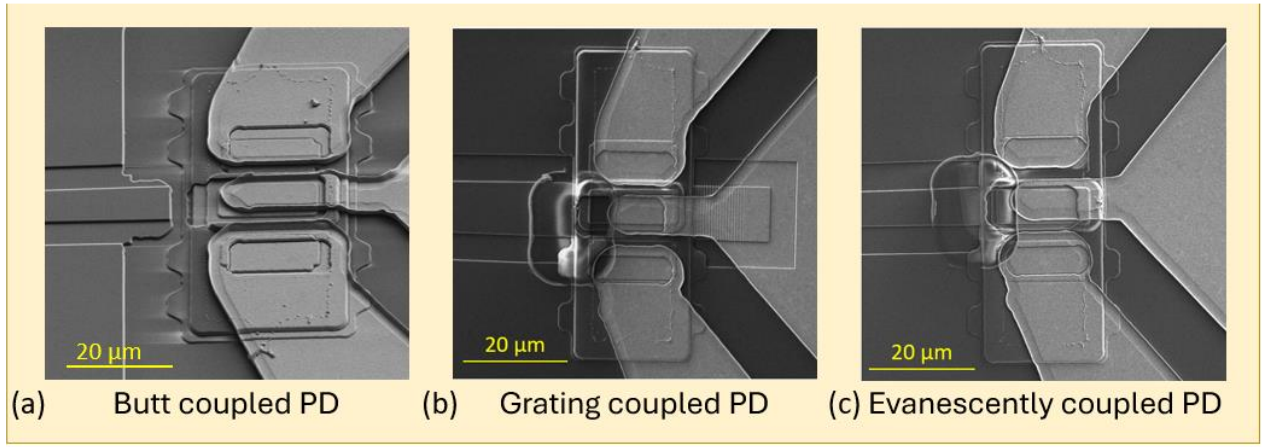
PV-Cell on Si

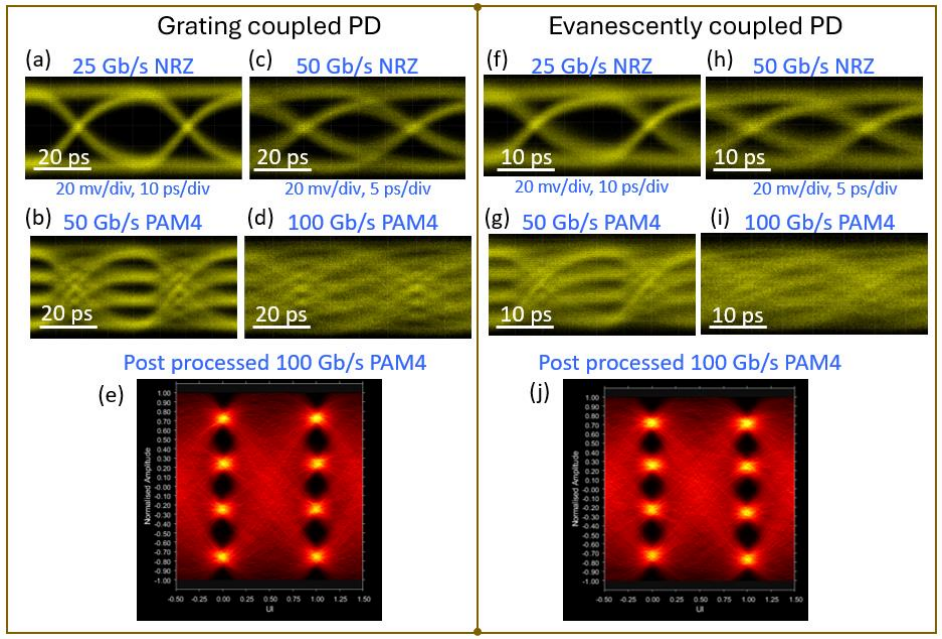


1. Edge-Coupling of O-Band InP Etched-Facet Lasers to Polymer Waveguides on SOI by Micro-Transfer-Printing, in *IEEE Journal of Quantum Electronics*, 2020
2. R. Loi et al., "Micro transfer printing of electronic integrated circuits on Silicon photonics substrates," in ECIO 2022 conference. May, 2022.
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.

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



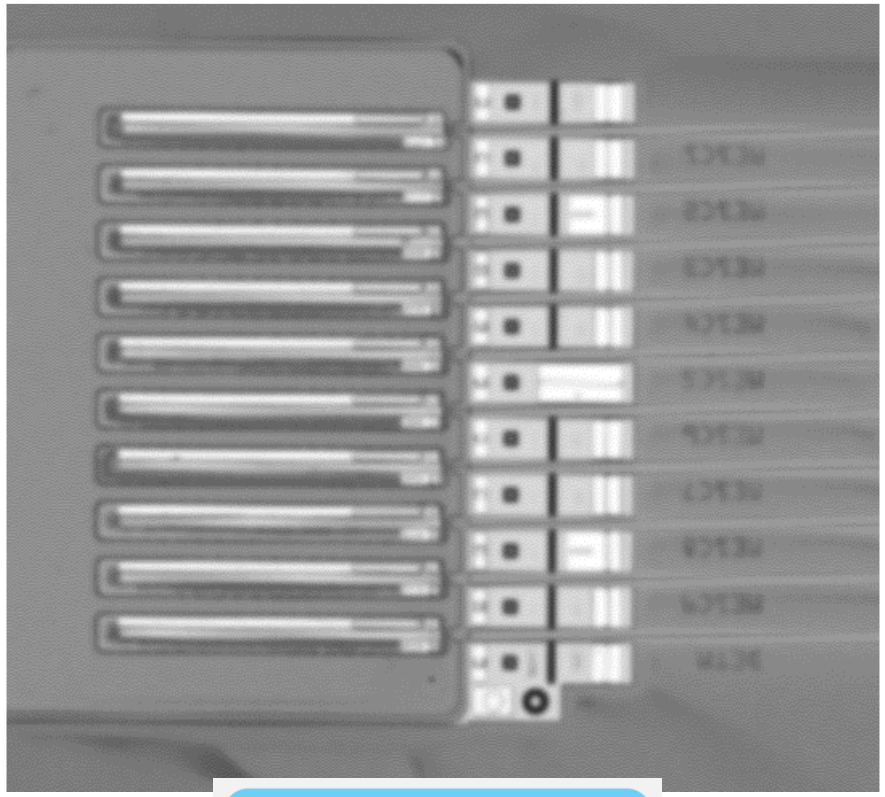


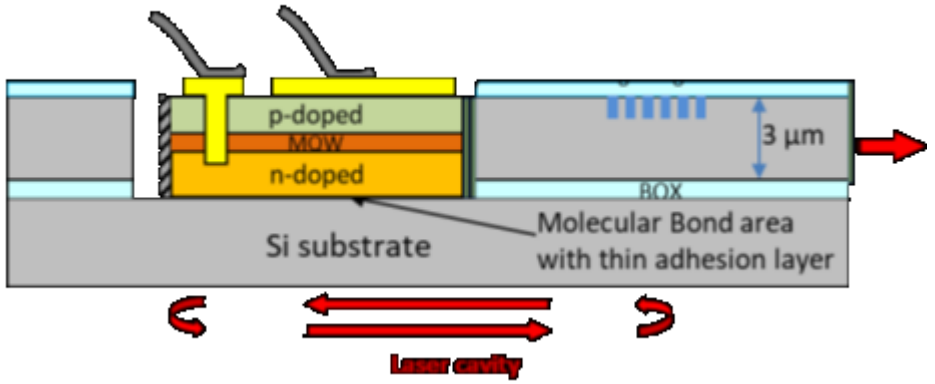


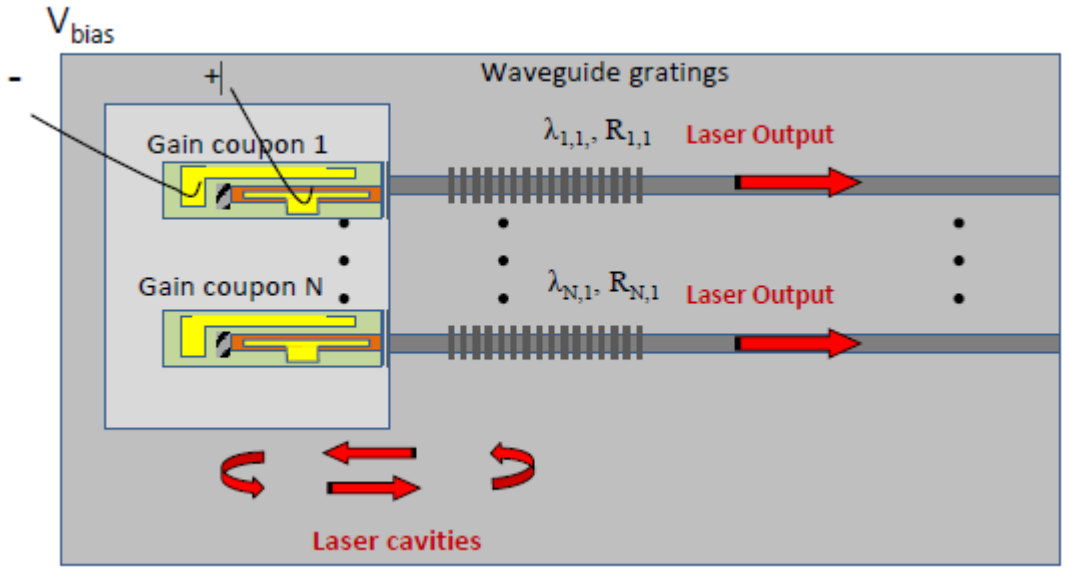
1. H. Mathuganesan, "100 Gbps PAM4 ultra-thin photodetectors integrated on SOI platform by micro transfer printing," Opt. Express 31, 36273-36280 (2023)

Rockley C-band DBR Laser to thick SOI

Array of 10 laser MTP in a recess in the SOI







1. Aaron Zilkie et al. "High-Performance Micro-Transfer-Printed Silicon Photonic DBR Laser, in , in *ECOC 2023 conference*

development of MTP in research projects

- Completed >3 EU projects: TOP-HIT, MICROPRINCE, HIPERION
- **Active projects XCEL is directly involved:**
  - **CALADAN (EU,** 6M): wafer scale assembly of Terabit/s optical engines by MTP
  - **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
  - **DTIF, M-Engine, …**
  - …more proposals submitted
- **Other >5 EU projects involving MTP:**
  - MORPHIC, PATTERN, PHORMIC, PUNCH, TRANSVERSE, VISSION
- **EU non-EU Pilot lines and consortia including MTP:**
  - PhotoniXFAB, Photon Delta, Lightup, Medphab

- **~20 photonics customer active projects**

Supply chain of MTP for integrated photonics

Objectives:

I. **We want to accelerate use of MTP into production**
- Path to production: **Prototypes -> Pilot volume -> High volume**

II. **We want be ready for PICs at large volume**
- An ecosystem of suppliers is currently in development
- A standardization process is required

Actions:

I. **Increase TRL + standardization**
II. Create **demos**
III. Build **PDKs,**

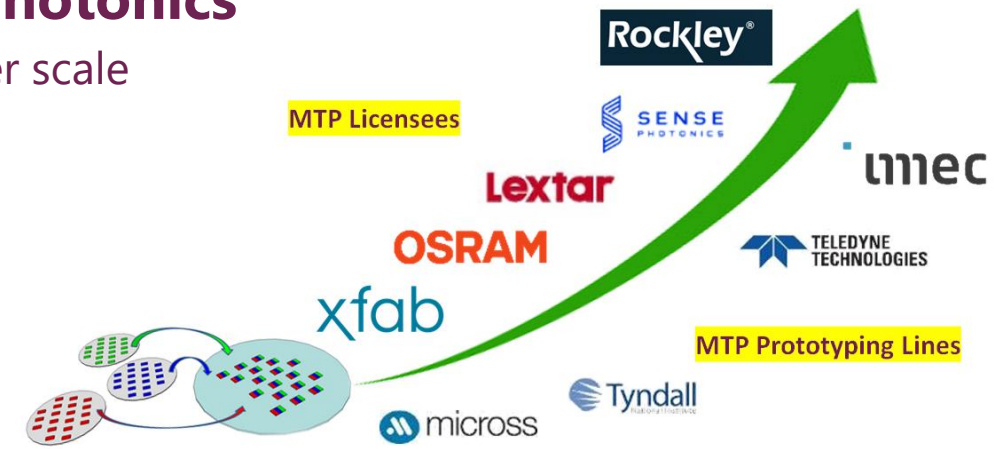
Supply chain leverages:

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

Supply chain 7 areas (70 suppliers)

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

- **MTP is a key enabling technology for integrated photonics**
  - Different functionalities integrated on the same platform at wafer scale
  - <0.5 um alignment, Edge/evanescent light coupling
- Multiple licensees are moving into commercialisation
- High volume products will be out in 2024 /2025



Contact us with any questions

Supply Chain Scientist
Ruggero Loi: rloi@x-celeprint.com

Director - IP
Ron Cok: rcok@x-celeprint.com

Sr. Dr. Technology / Business Dev - GM Supply Chain / Commercialization
David Gomez: dgomez@x-celeprint.com