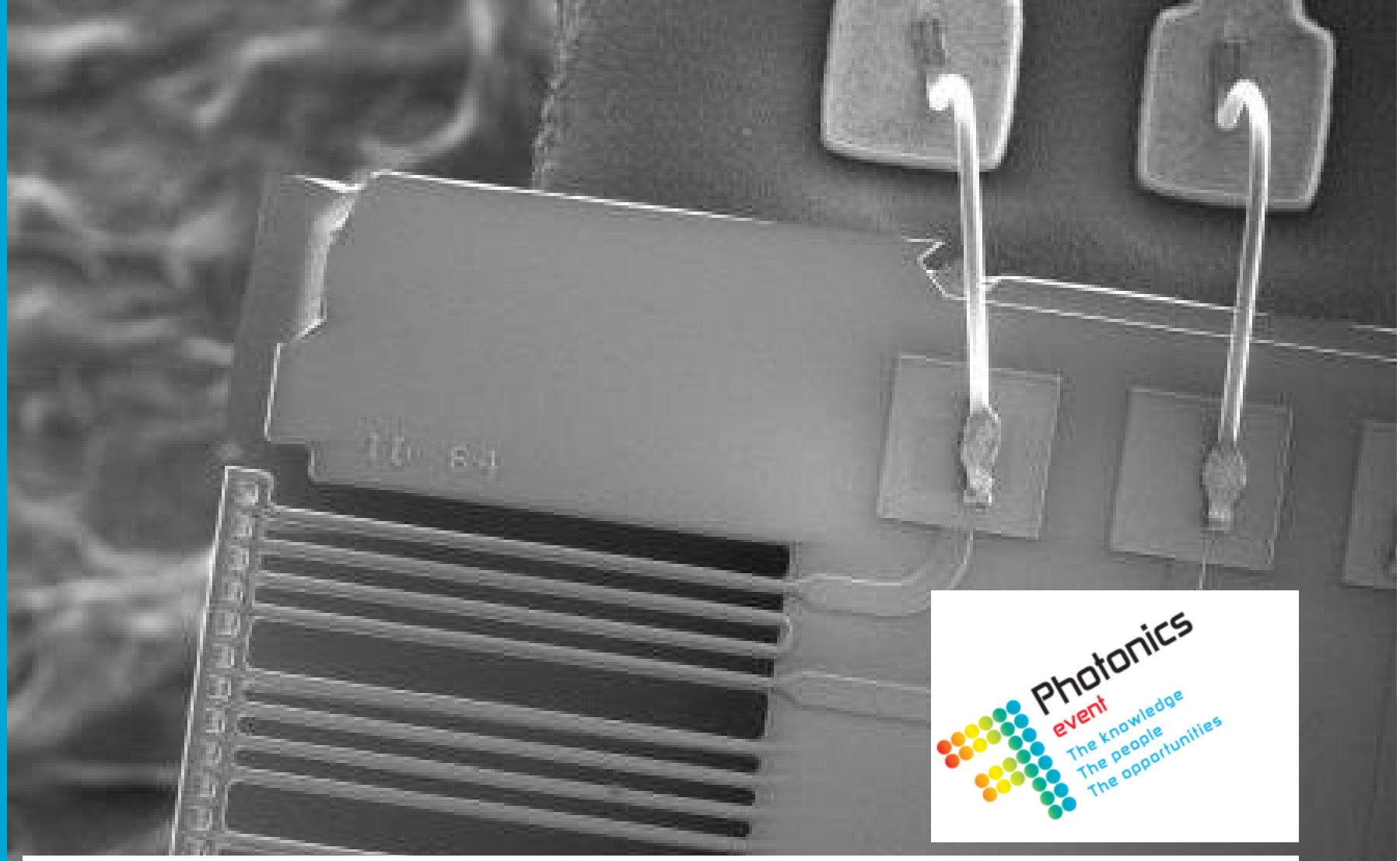


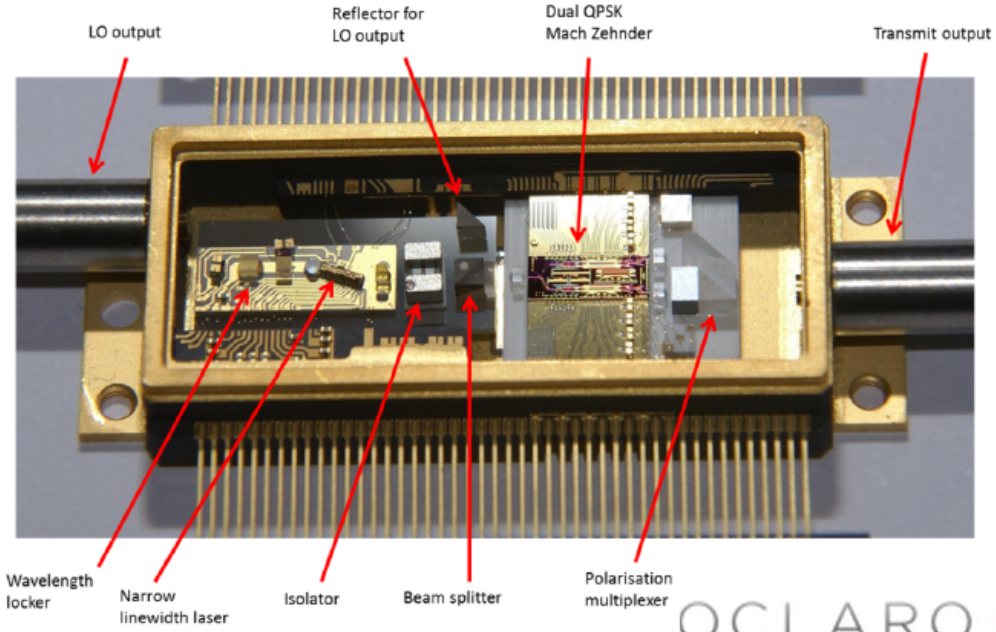
On-chip MEMS for automated chip-to-chip assembly

Dr. Ir. Marcel Tichem, *Ir. Tjitte-Jelte Peters, Kai Wu MSc*
TU Delft, Precision and Microsystems Engineering
Photonics Event, Koningshof, Veldhoven, 2 June 2016

TU Delft

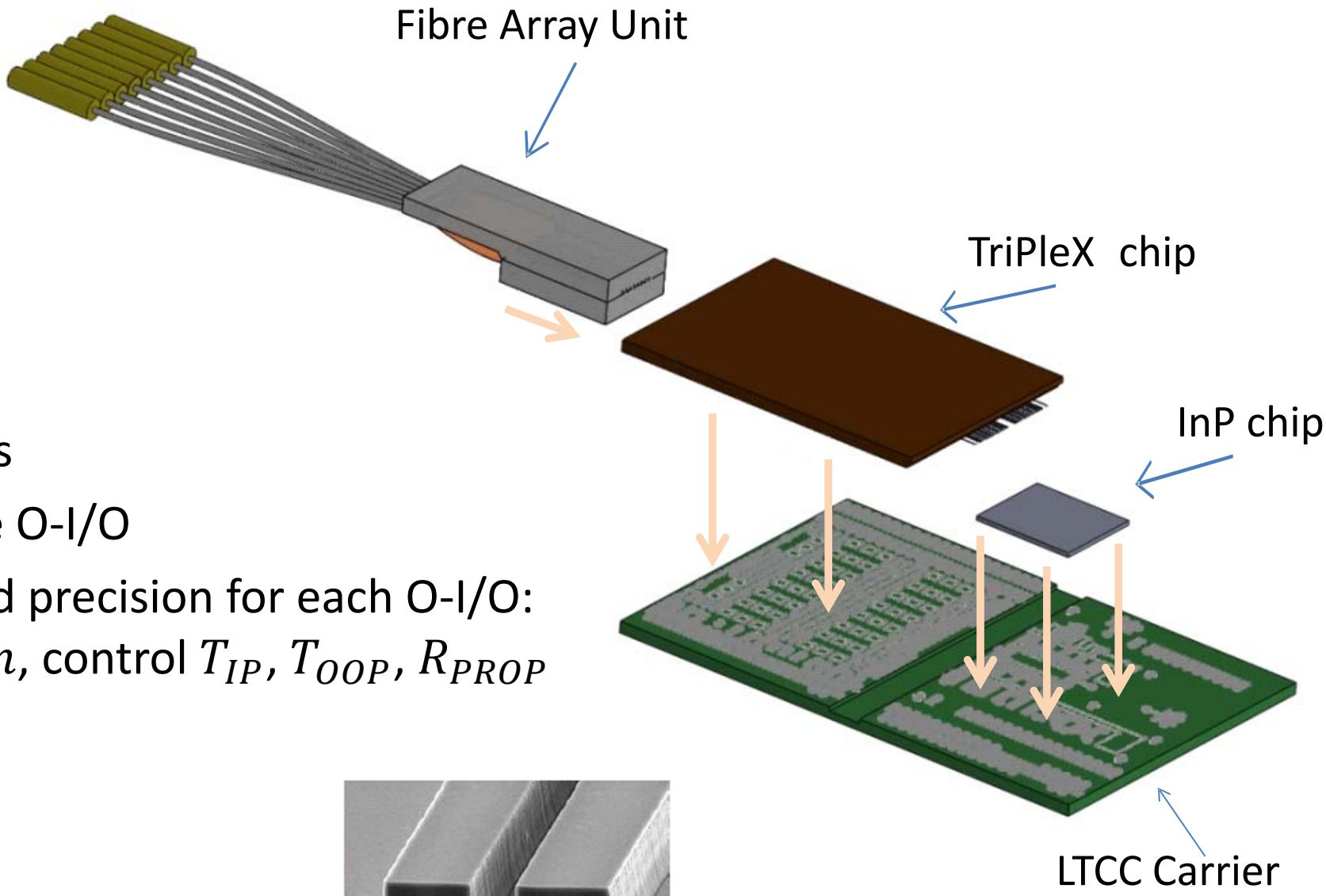
Photonics for data communication

- Photonic packages to enable massive data communication
- Complex packages, containing: Photonic Integrated Circuit (PIC), micro-optics, electrical components
- Integration is a key challenge
  Technology exists for assembly, however:
  - Labour intensive
  - Expensive

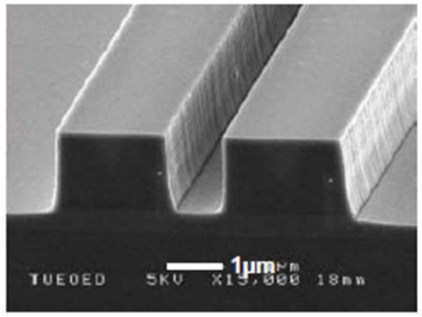


1st generation 40G package

Case: multi-chip photonic package



- Two PICs
- Multiple O-I/O
- Required precision for each O-I/O: $\pm\, 0.1\mu m$, control T_{IP}, T_{OOP}, R_{PROP}

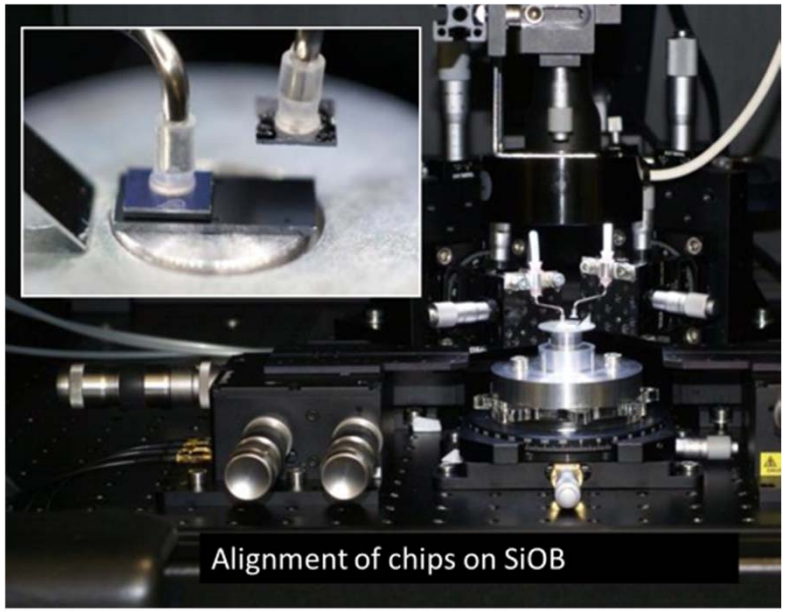


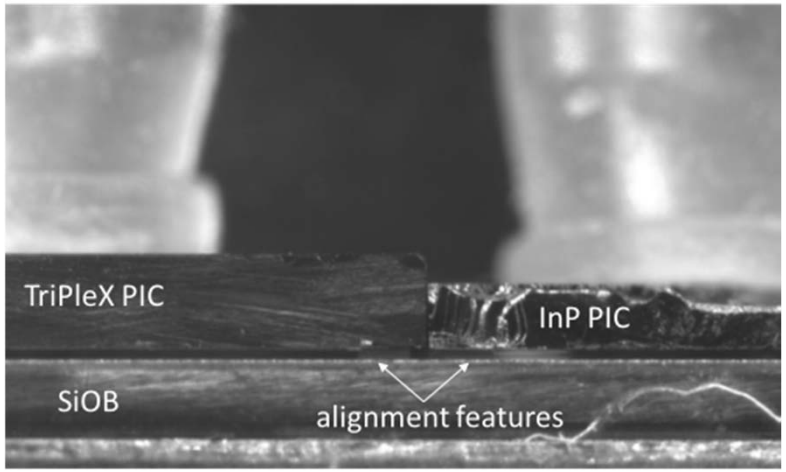
Courtesy:

COBRA

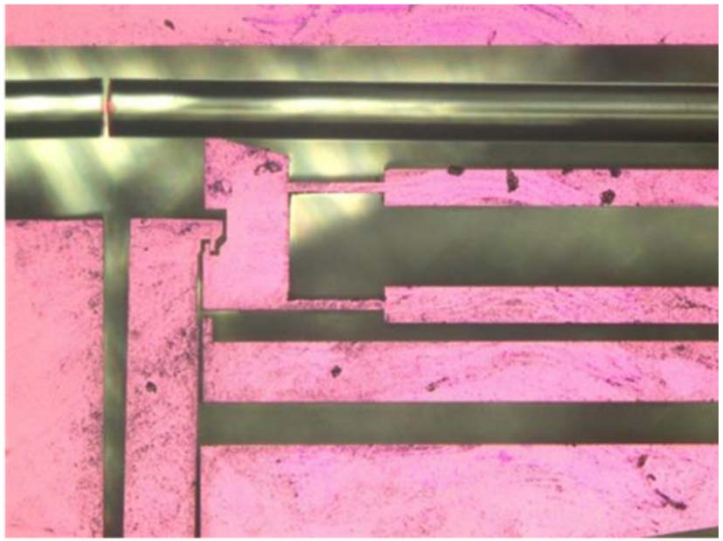
TU/e Technische Universiteit Eindhoven University of Technology

Enabler: microfabrication and MEMS

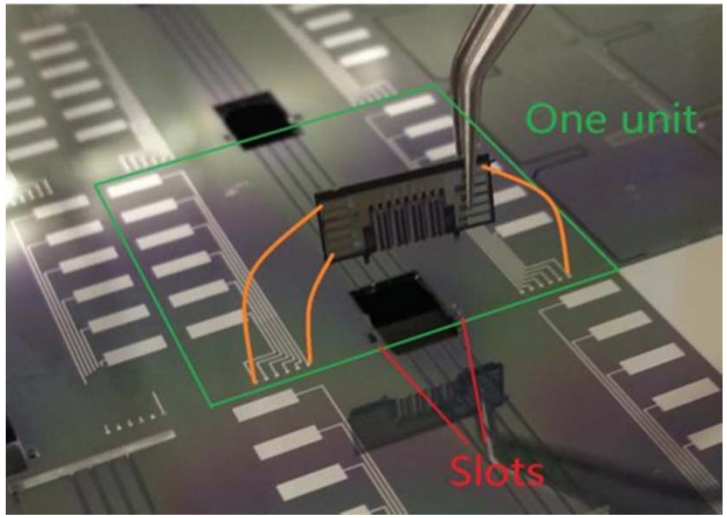




- **Passive alignment**: geometric mating features



Single fibre

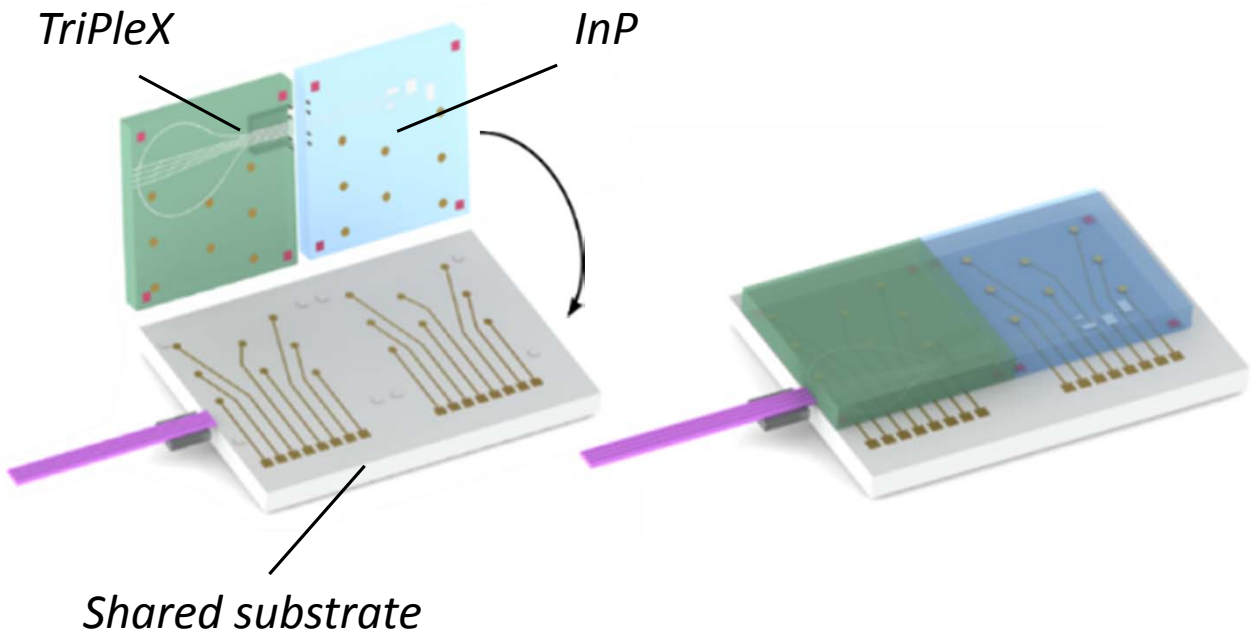


Fibre array

- **Active alignment**: use of **MEMS**

The concept

- Integrate an “assembly machine” into one of the photonic chips for fine alignment: on-chip MEMS
- Two-stage process



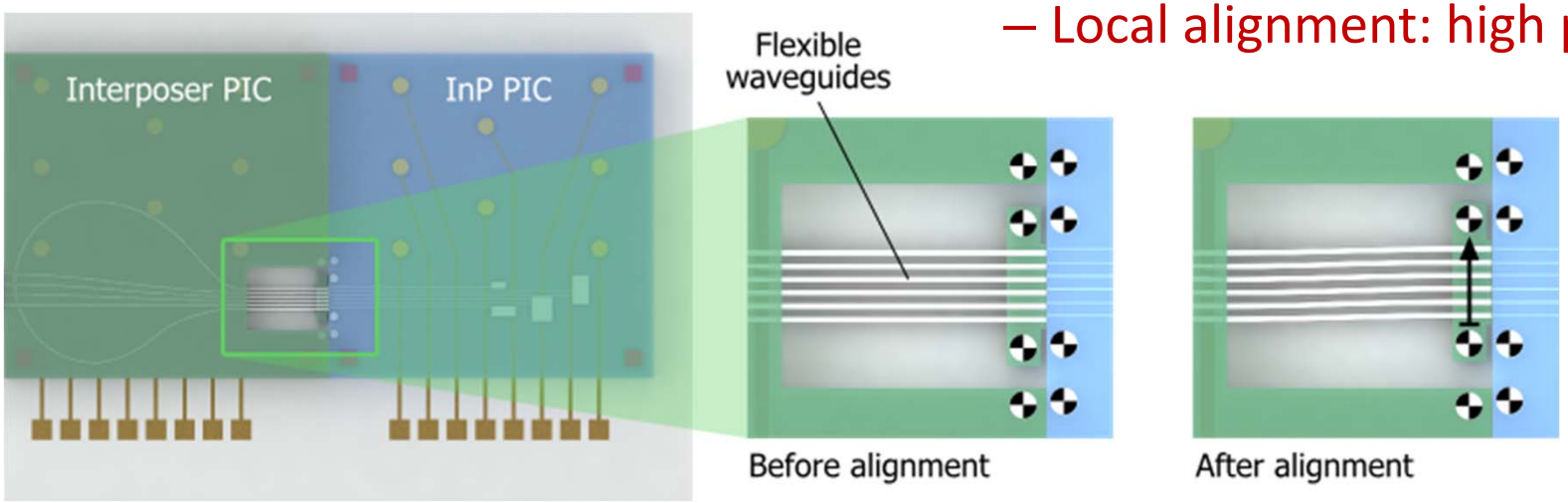
Step 1: pre-assembly of photonic chips on common carrier, flip chip bonding

Peters, Tichem, SPIE Photonics West 2014, doi: 10.1117/12.2052430
Wörhoff et al, SPIE Photonics Europe, 2016 doi: 10.1117/12.2227814

The concept

- Integrate an “assembly machine” into one of the photonic chips for fine alignment: on-chip MEMS
- Two-stage process

- The potential:
  - Increased assembly automation, cost reduction
  - Local alignment: high precision



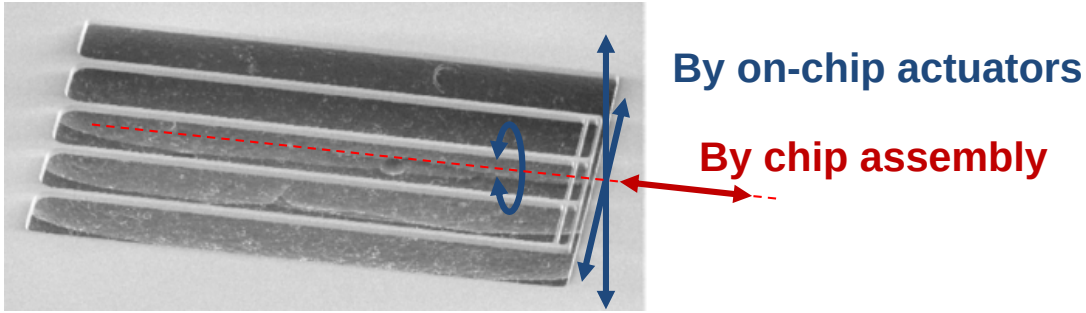
Step 2: Fine alignment of flexible waveguide structures using on-chip MEMS

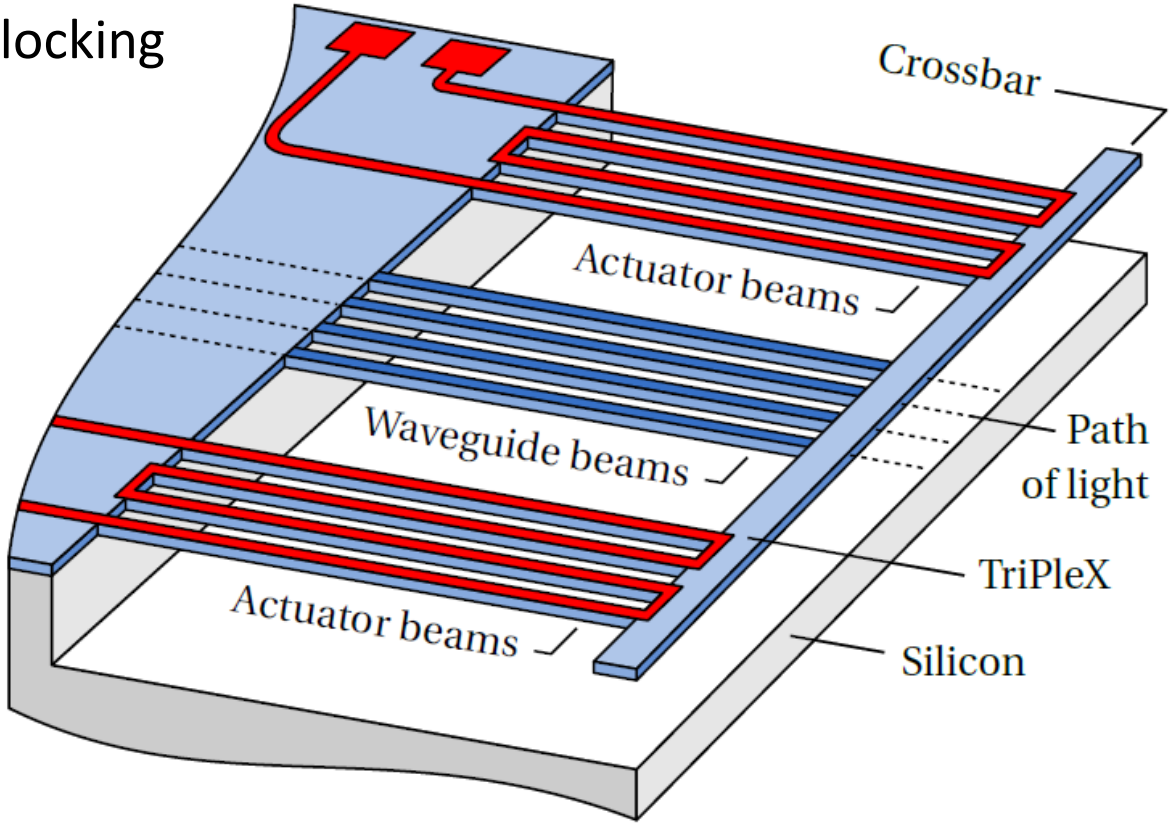
MEMS = MicroElectroMechanical System

Peters, Tichem, SPIE Photonics West 2014, doi: 10.1117/12.2052430
Wörhoff et al, SPIE Photonics Europe, 2016 doi: 10.1117/12.2227814

On-chip functions

- Functions:
  - Flexible waveguide beams, coupled by cross-bar
  - Actuators
  - Waveguide beam locking





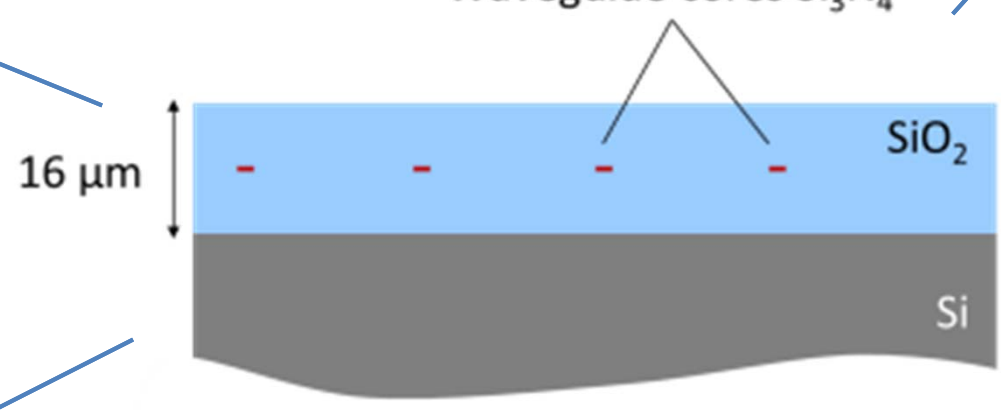
SiO_2 photonic MEMS

Challenges

- Functionality realised in TriPleX material platfor:

Deformation
Residual stress in multi-material layers

Fabrication
Compressive stress in thick SiO_2



TriPleX™ platform

Actuation range
All relevant motion direction
CTE of SIO_2 (thermal actuators)

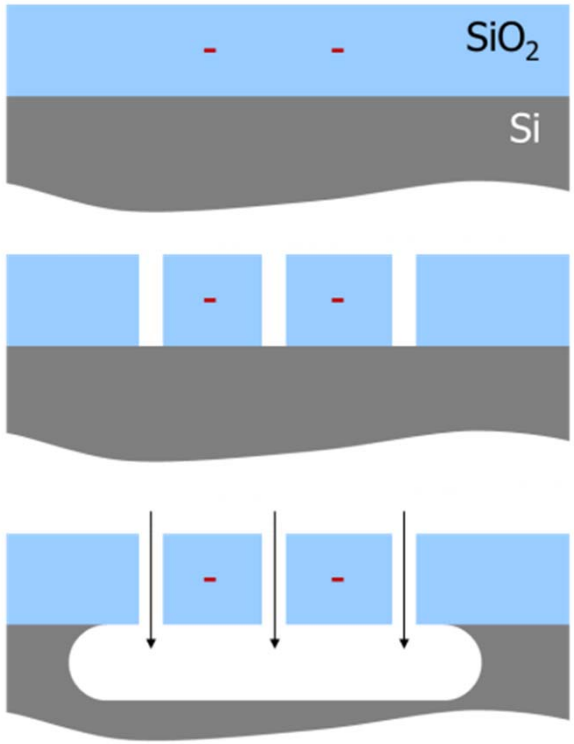
Locking precision
Maintain position

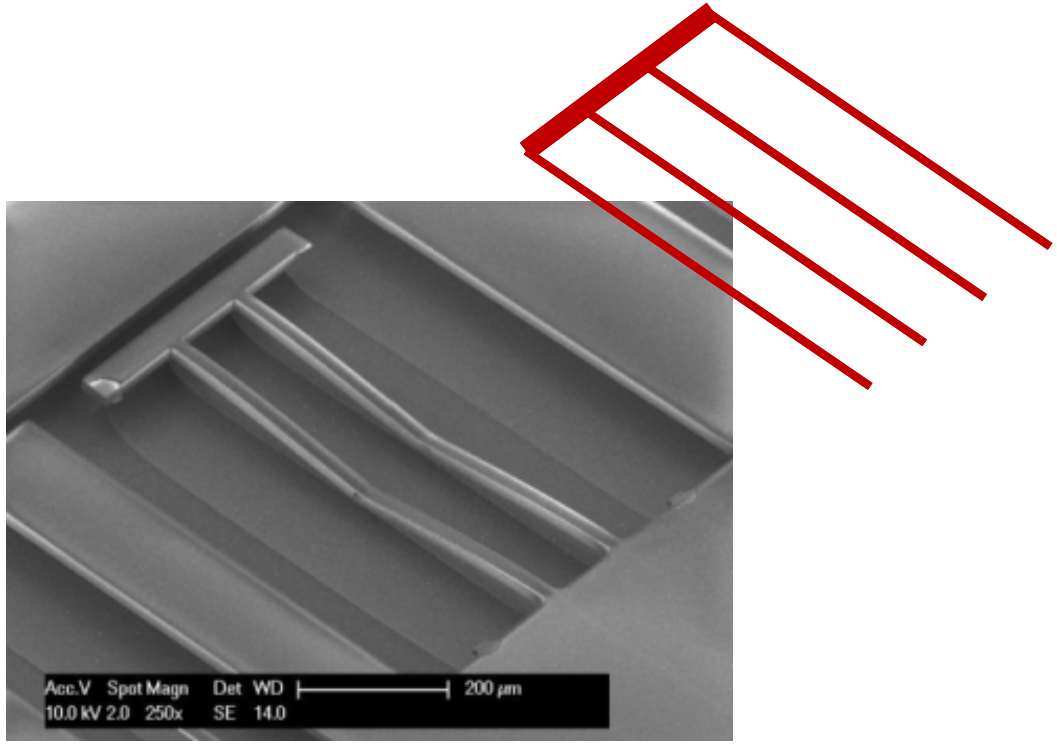
Design integration
All functions cooperating, space consumption

Fabrication and results

Fabrication in TriPleX material platform

- Frontside release
  - Structuring of photonic layer (plasma etch)
  - Release by underetching Si (isotropic plasma etch)

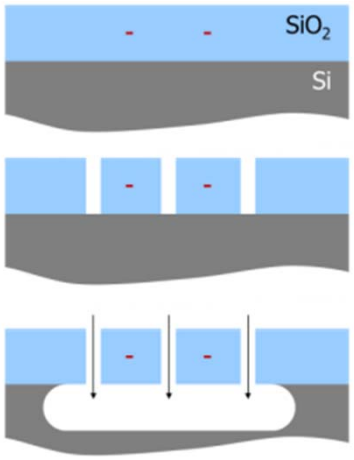


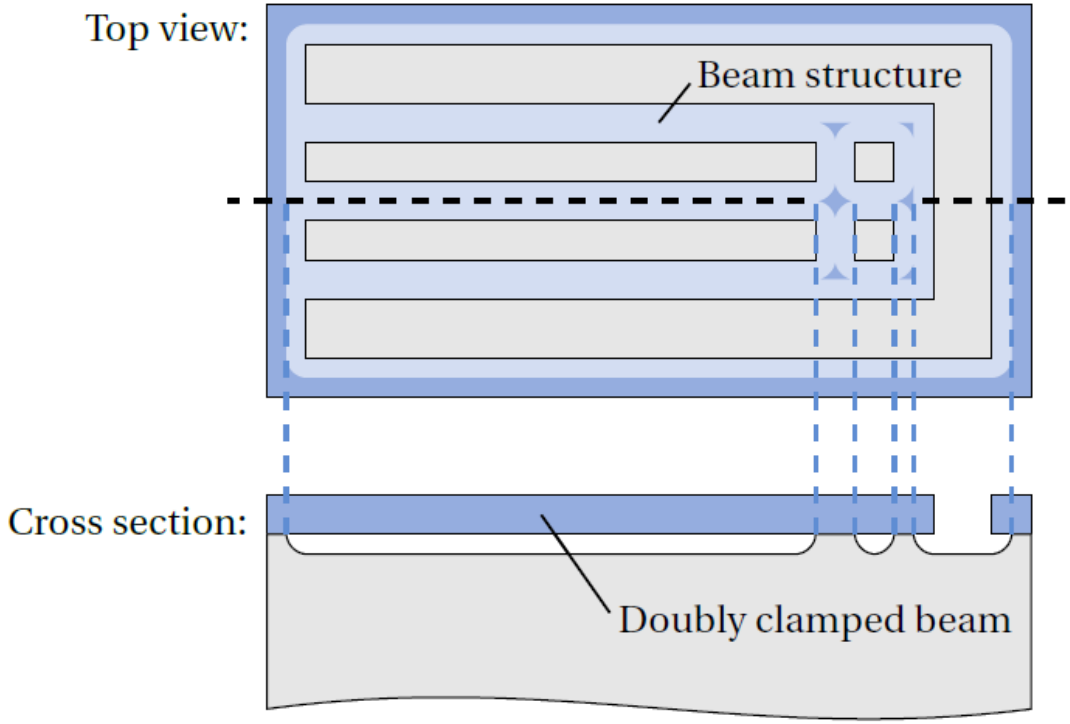


Peters, Tichem, J. Micromech. Microeng. **25** (2015) 105003

Fabrication in TriPleX material platform

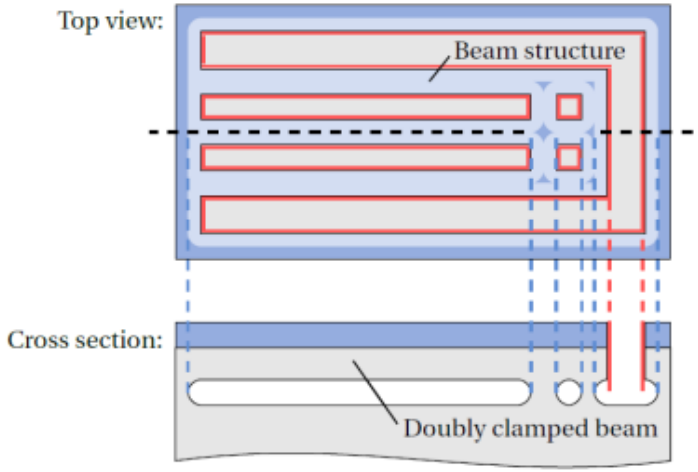
- Poor yield
  - SiO_2 under compressive stress
  - Clamped-clamped beam situations





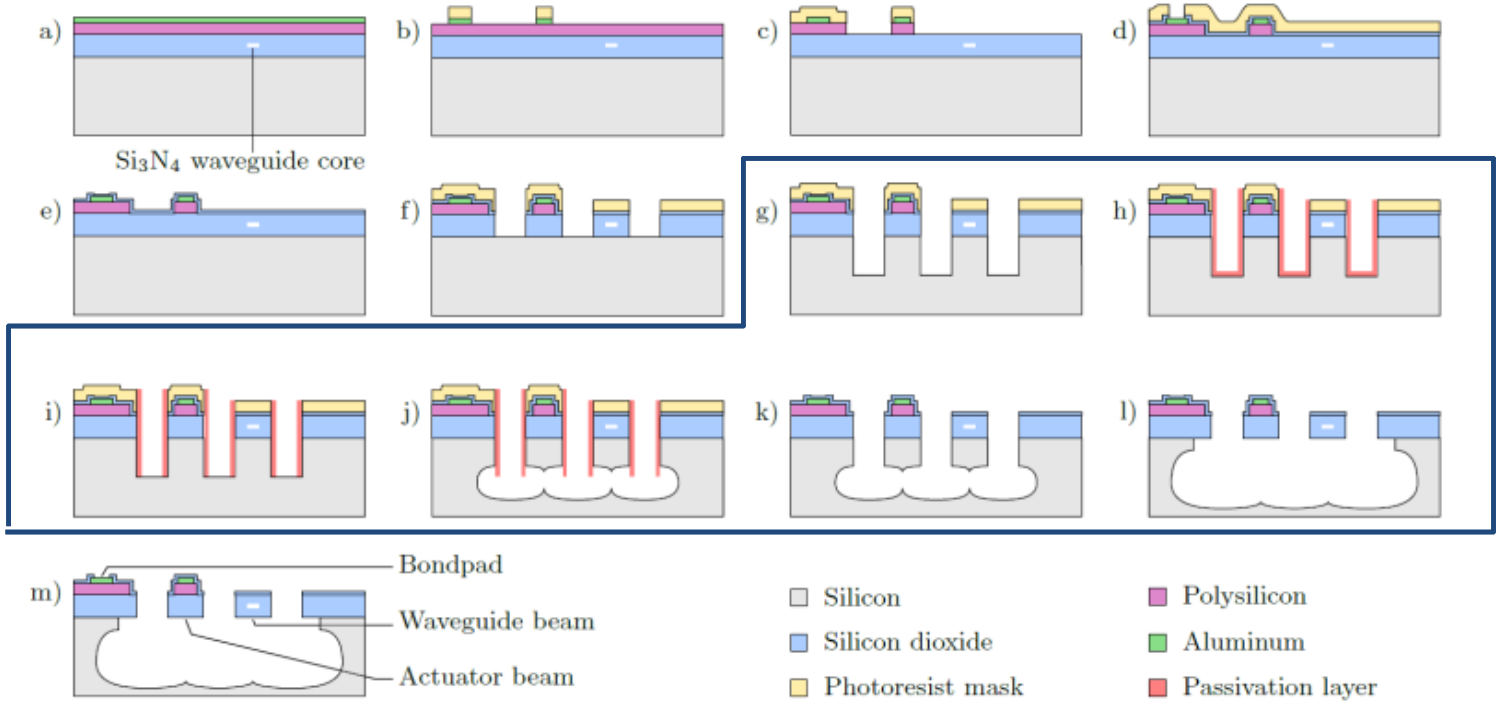
Peters, Tichem, J. Micromech. Microeng. **25** (2015) 105003

Fabrication in TriPleX material platform



- Improved process: “Si-reinforced”
- 98% yield (single cantilevers)

Fabrication process for reliable structure release



Peters, Tichem, J. Micromech. Microeng. **25** (2015) 105003

Fabrication in TriPleX material platform

- Improved process: “Si-reinforced”
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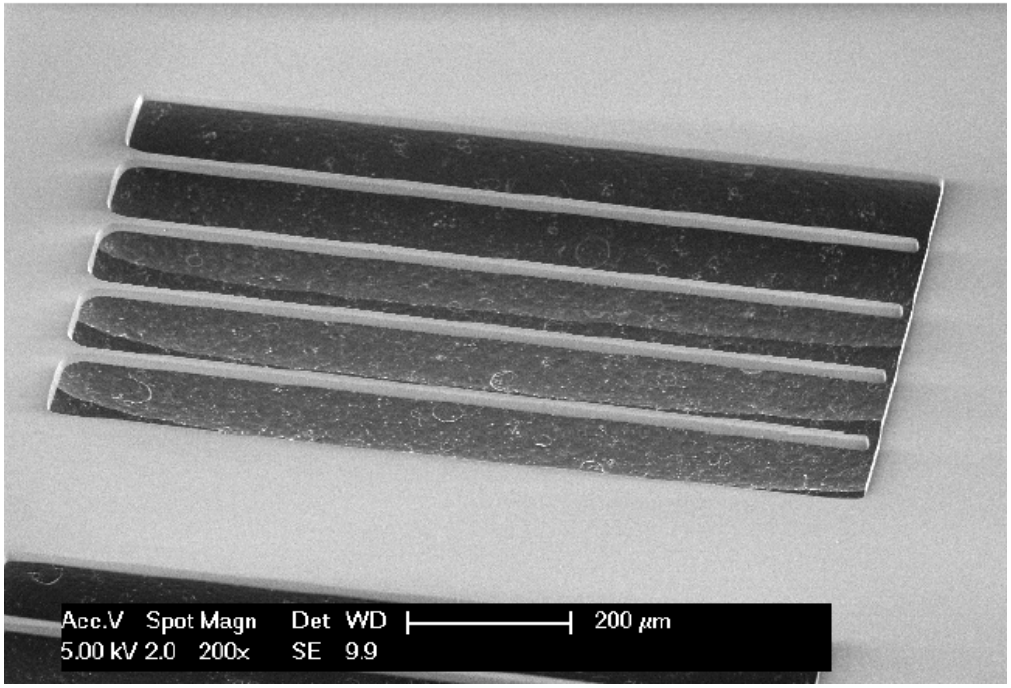
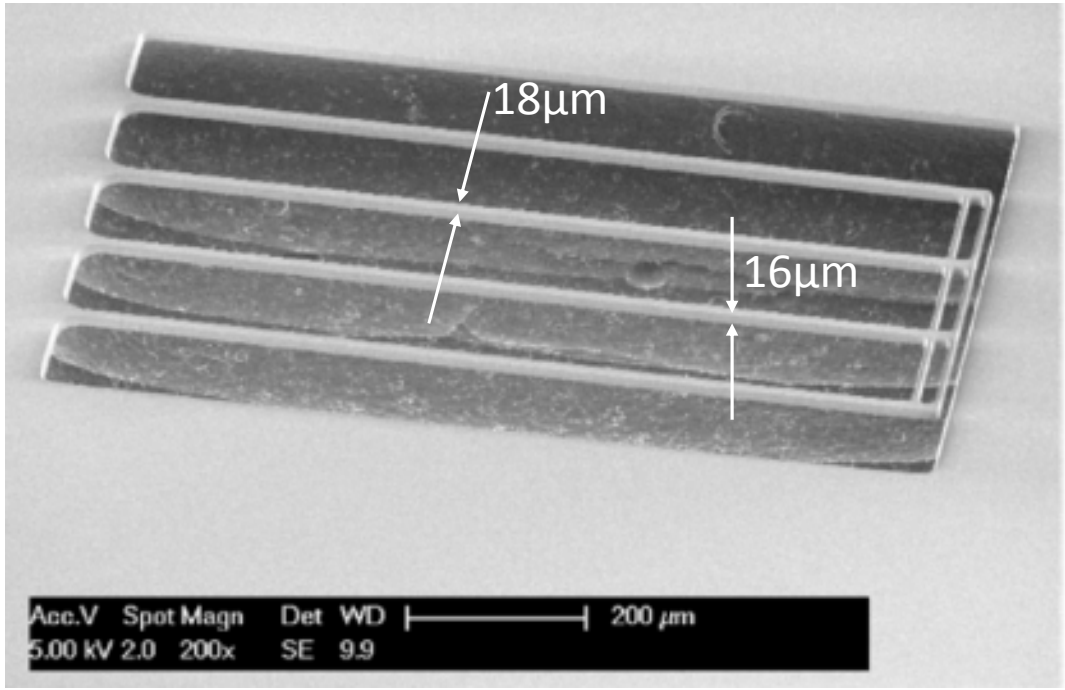


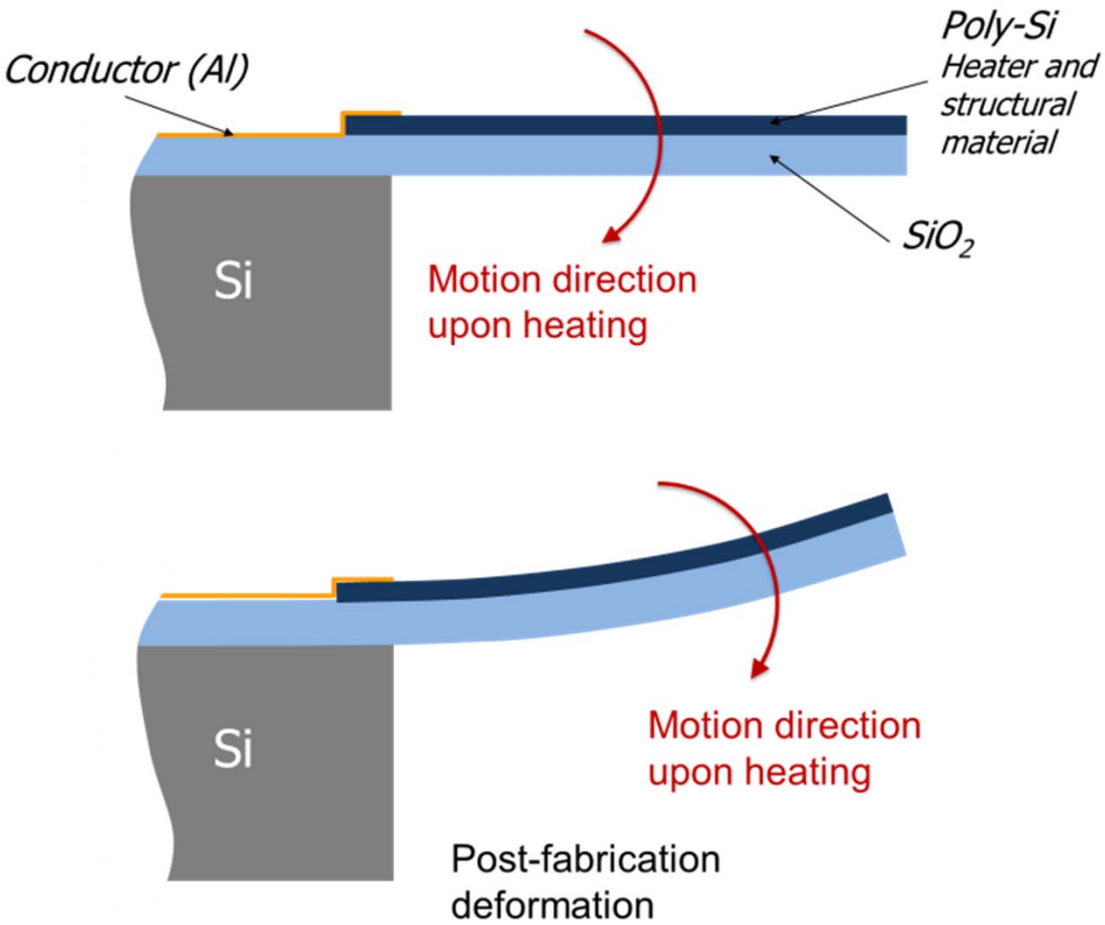
Cantilevers

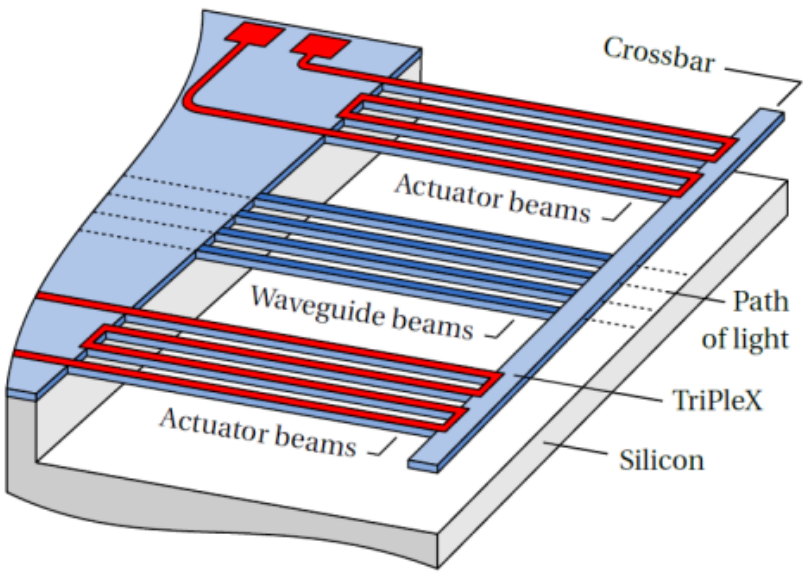


4-WG beam structure

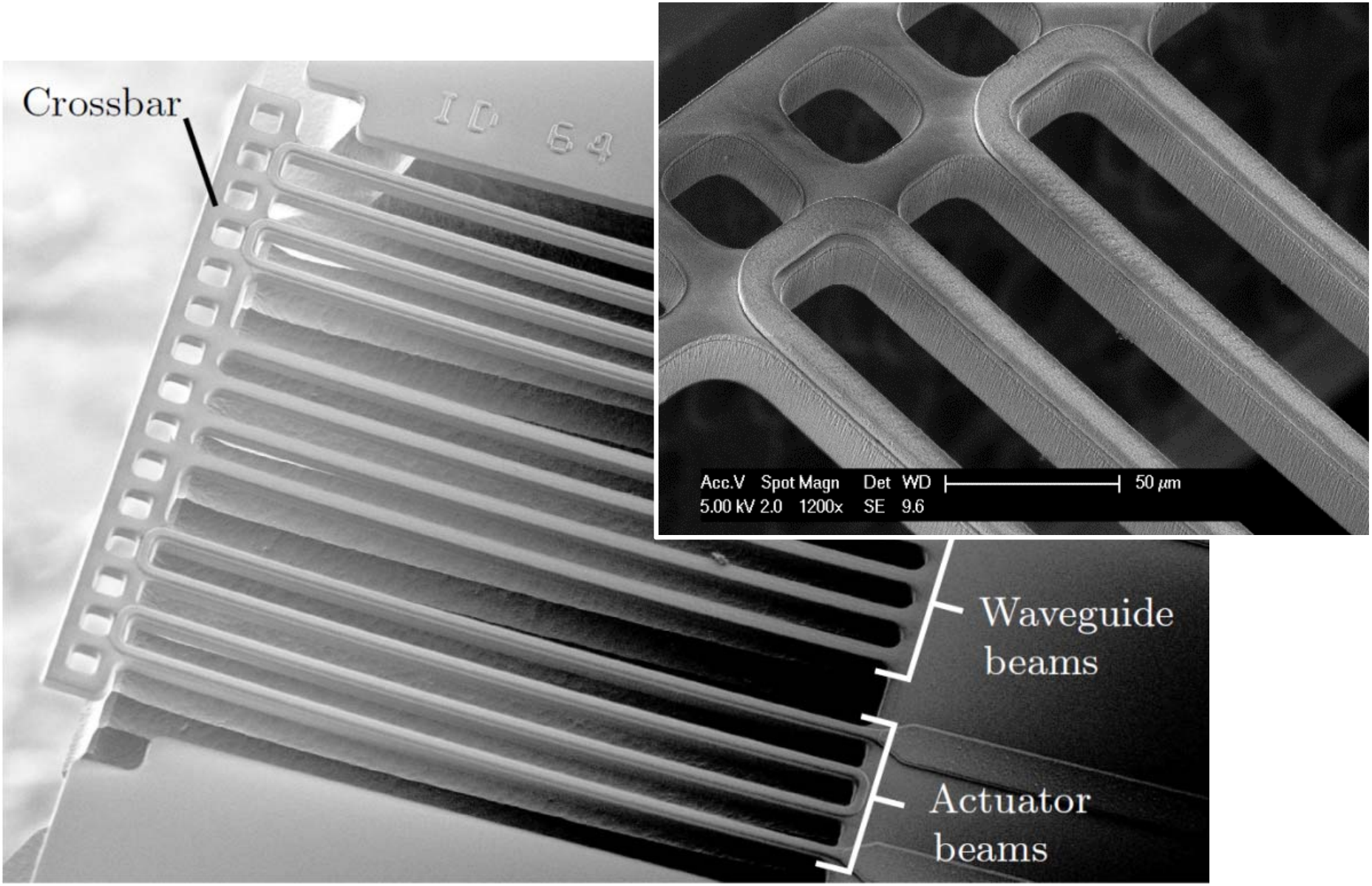
Peters, Tichem, J. Micromech. Microeng. **25** (2015) 105003

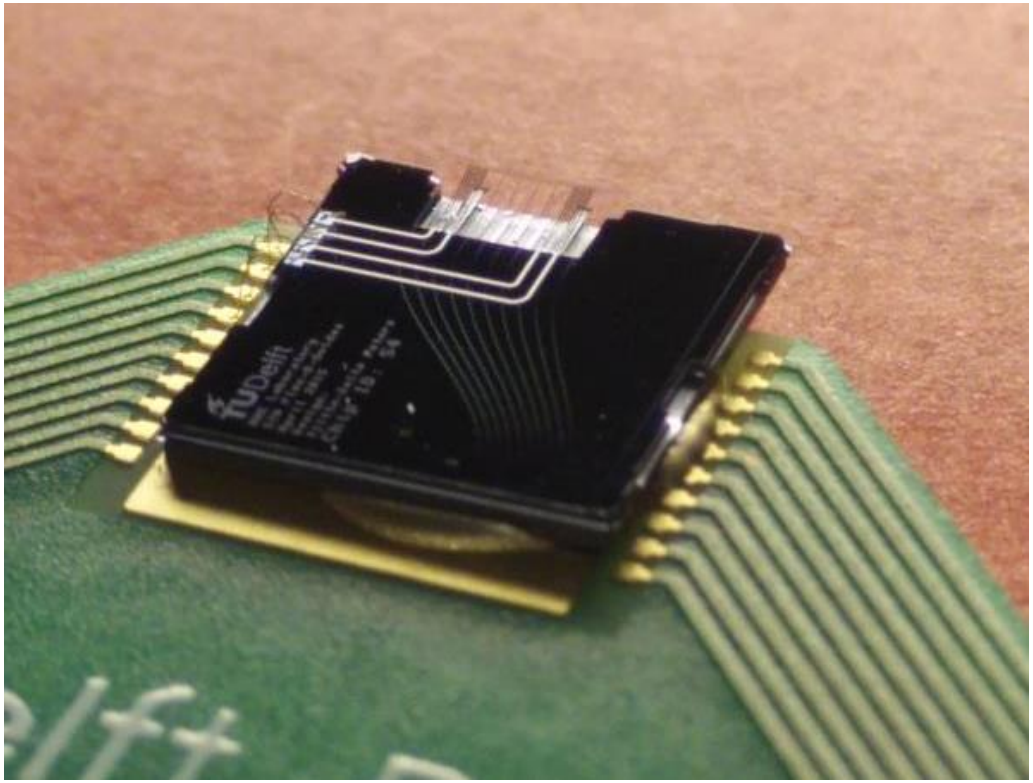
Thermal bimorph actuators

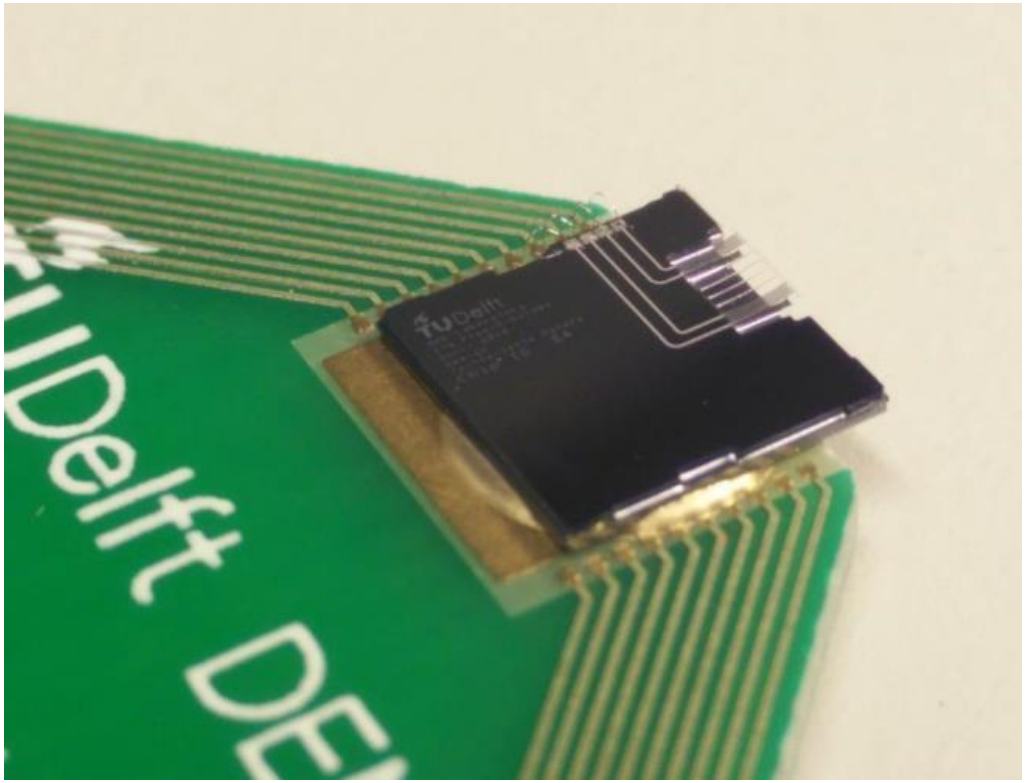


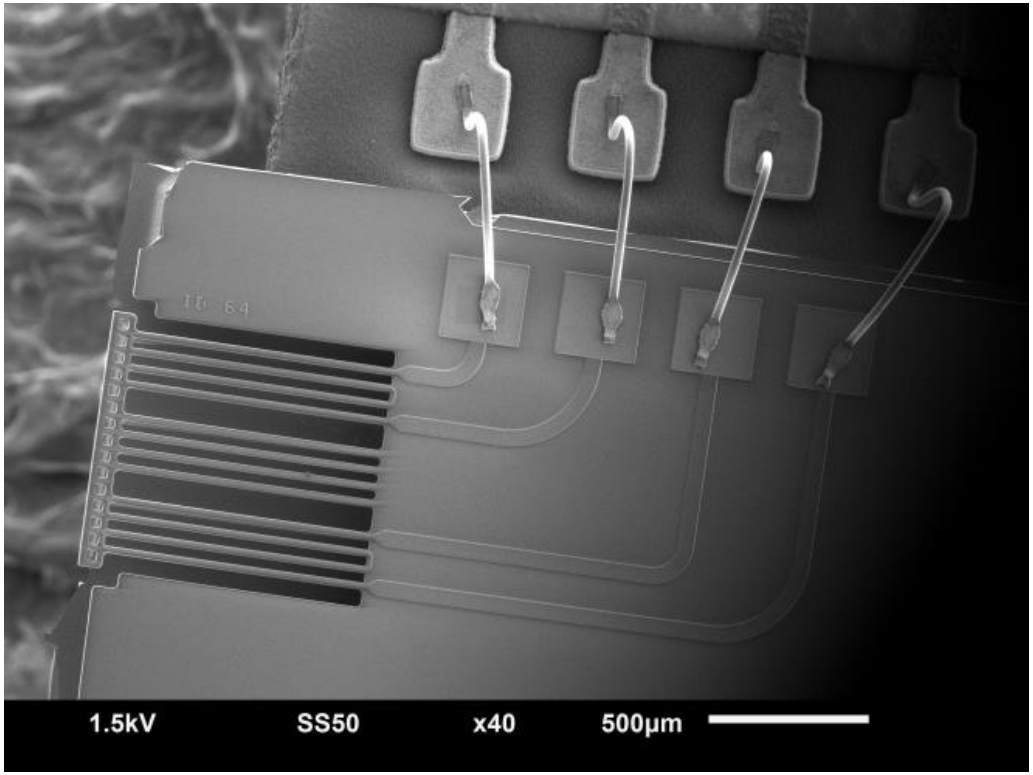


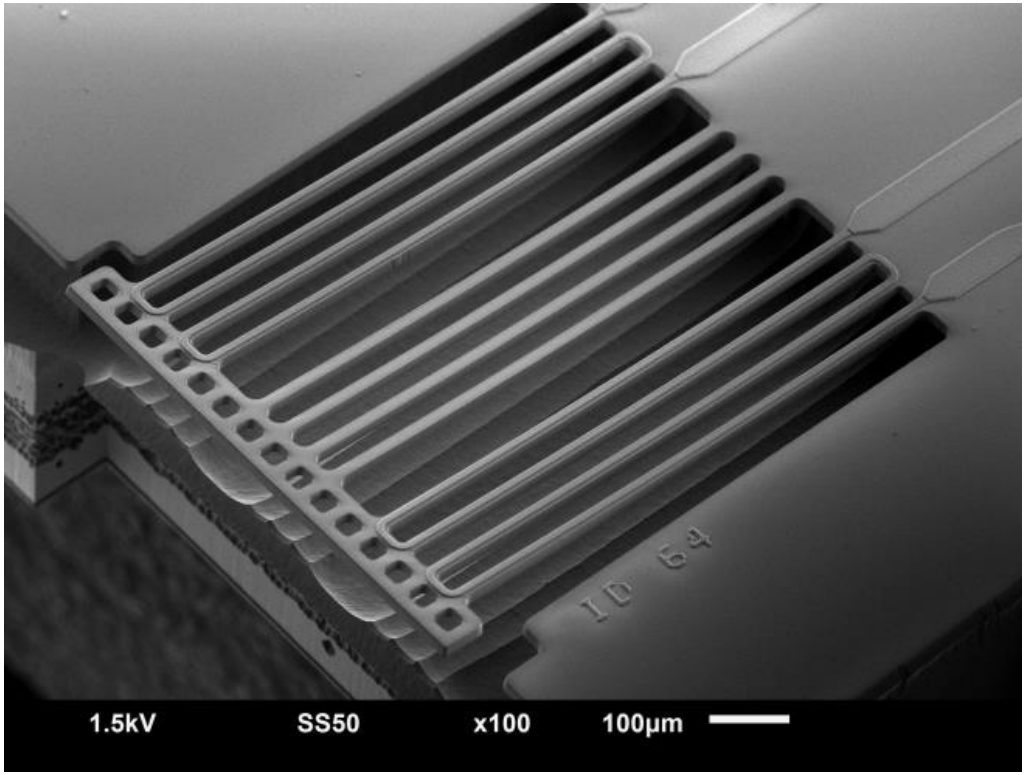
Example structure



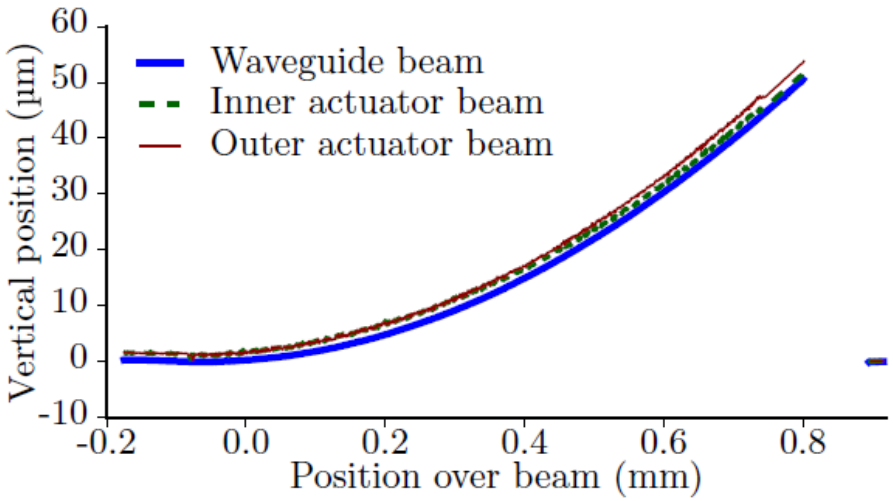


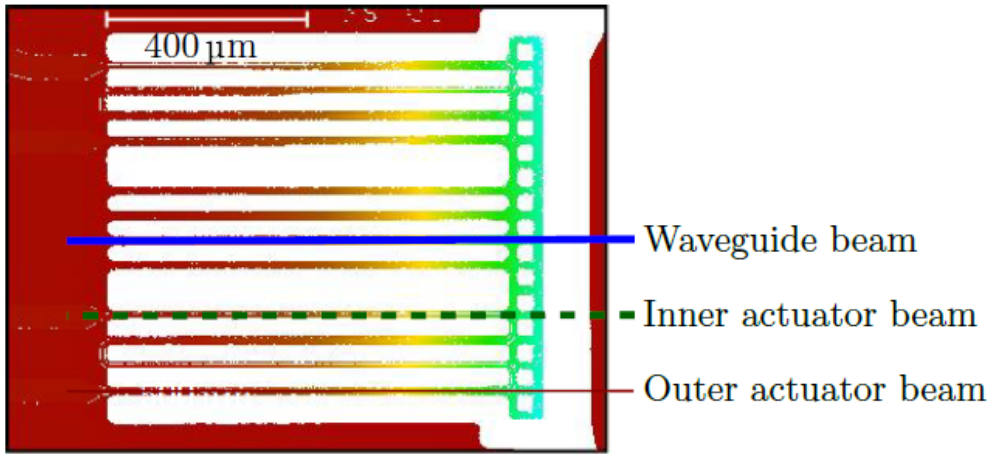

TuDelft


1.5kV SS50 x40 500µm


ID 64
1.5kV SS50 x100 100µm

Post-fabrication deformation



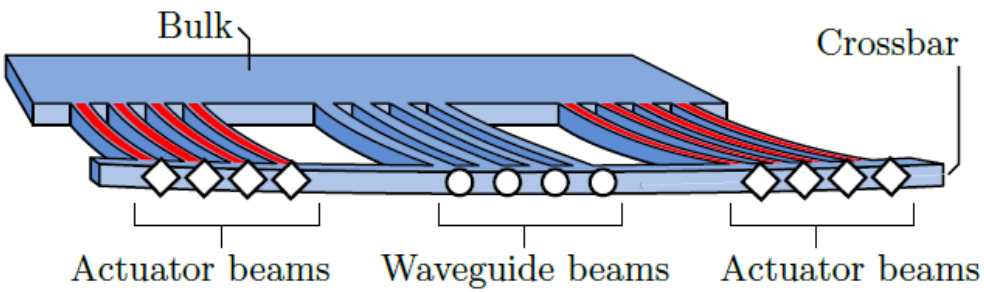


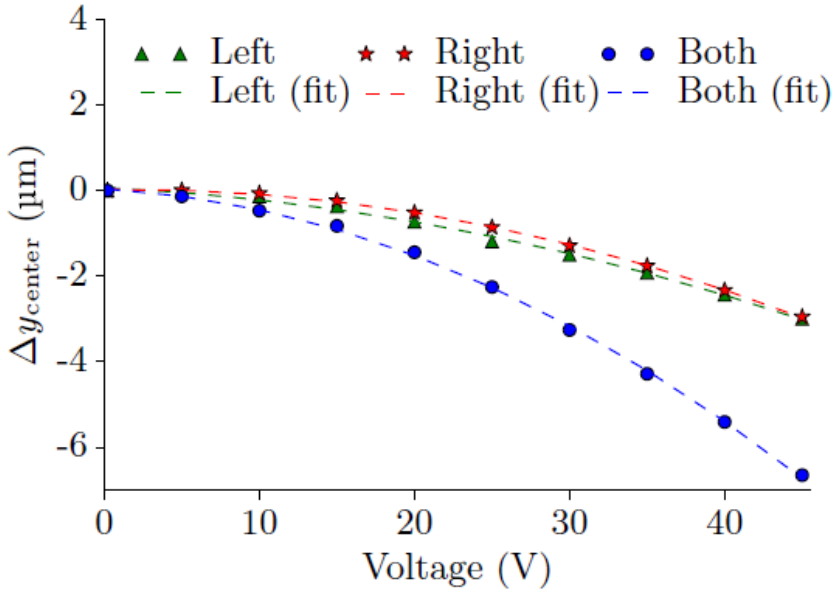
Peters, Tichem, SPIE Photonics Europe, Brussels, 2016, doi 10.1117/12.2222512
Peters, Tichem, Journal paper under preparation

Waveguide motion

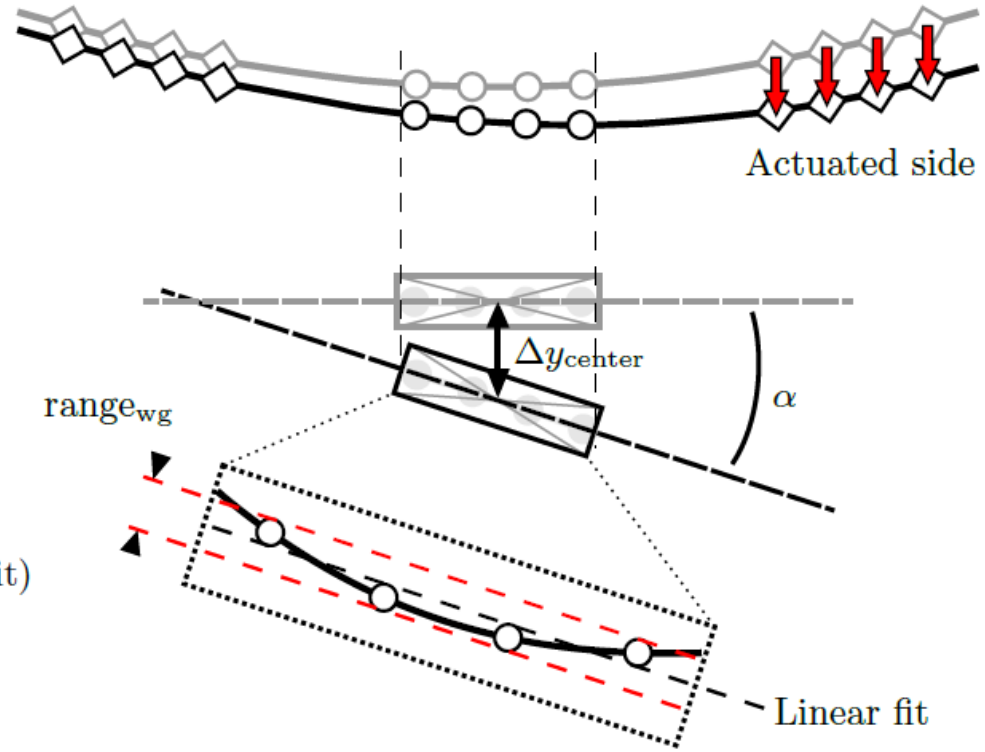
Side view of bimorph actuator

Motion measurements



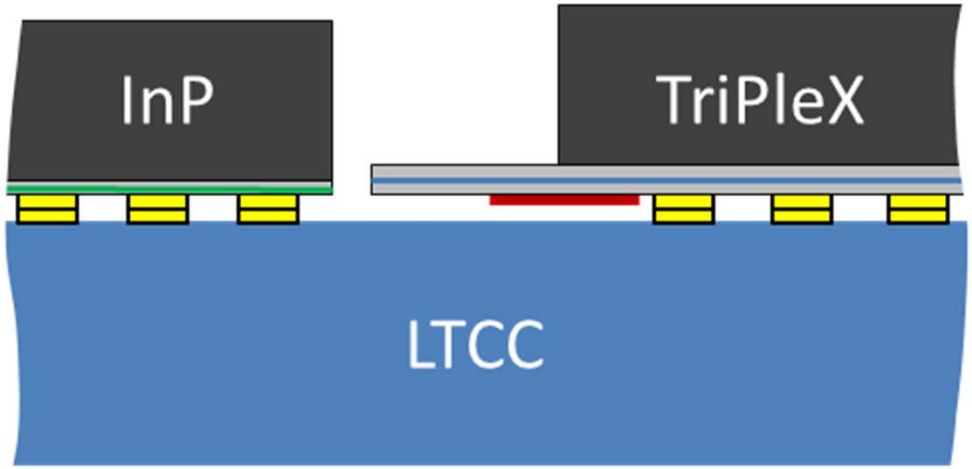


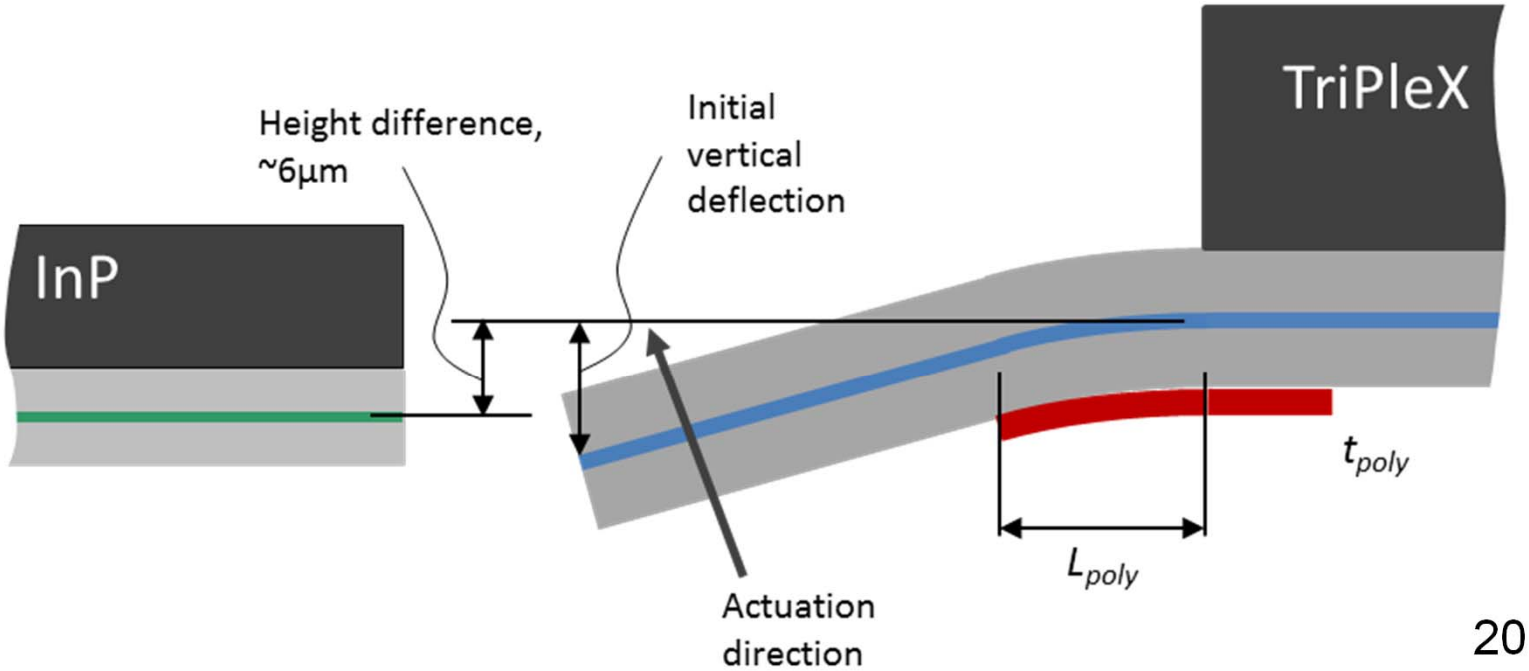
(a) Δy_{center} plotted as a function of voltage



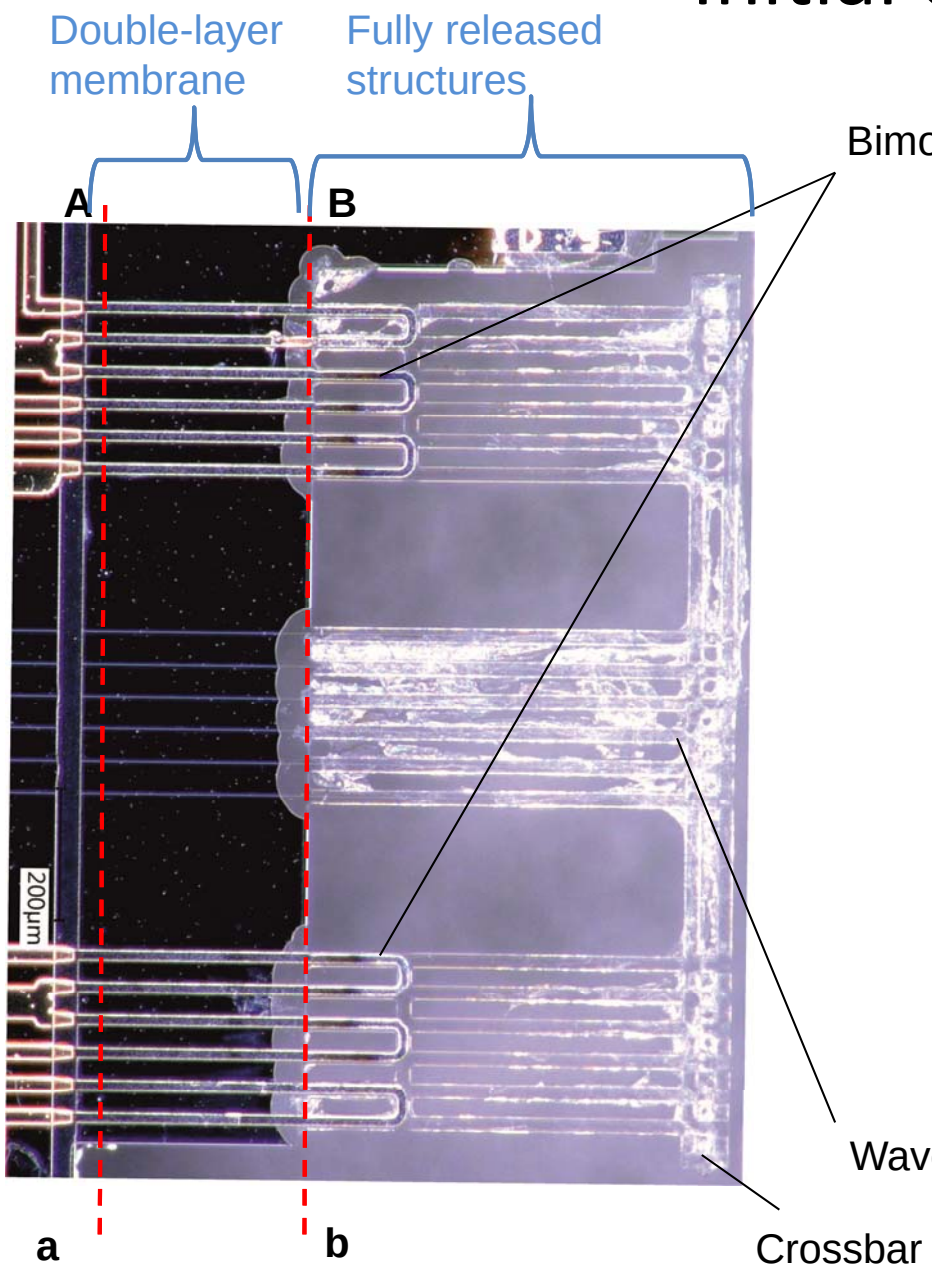
Peters, Tichem, SPIE Photonics Europe, Brussels, 2016, doi 10.1117/12.2222512

Height compensation *and* actuation range using *short loop bimorph actuators*





Initial deflection

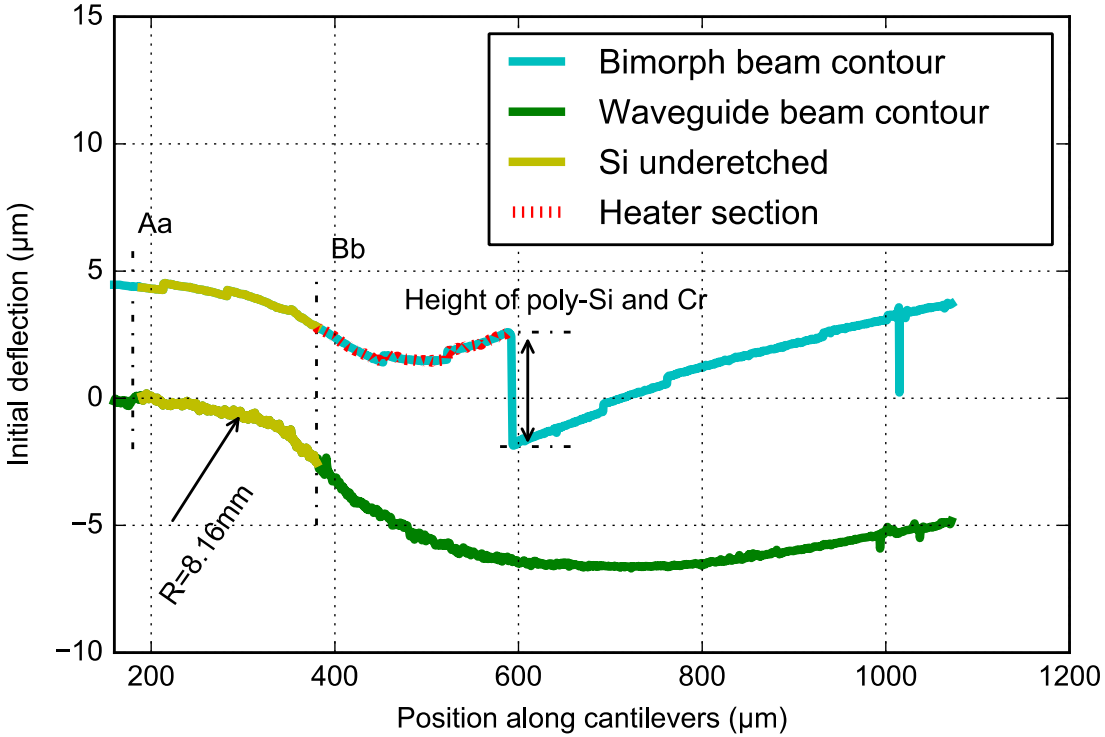


Bimorph actuators (short loop)

Waveguide beams

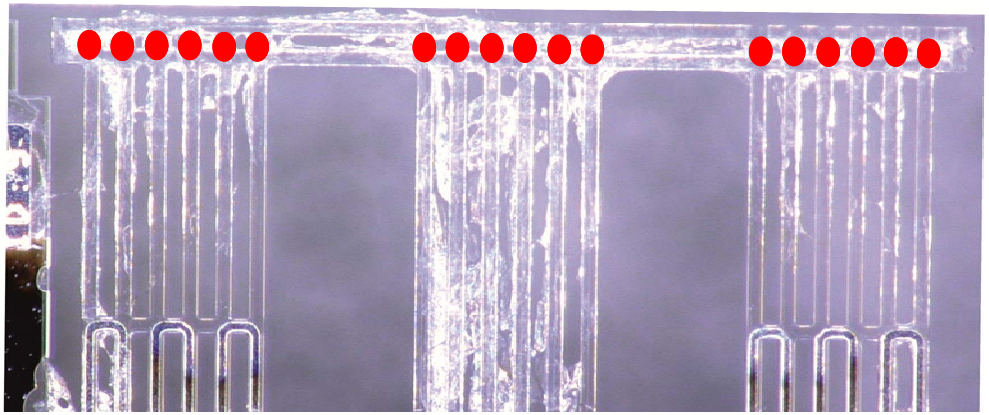
Crossbar

Chip150 (short-loop poly-Si):
L_{ox}=650µm, L_h=150µm



Wu, Tichem, SPIE Photonics West 2016, doi: 10.1117/12.2209499

Motion measurement



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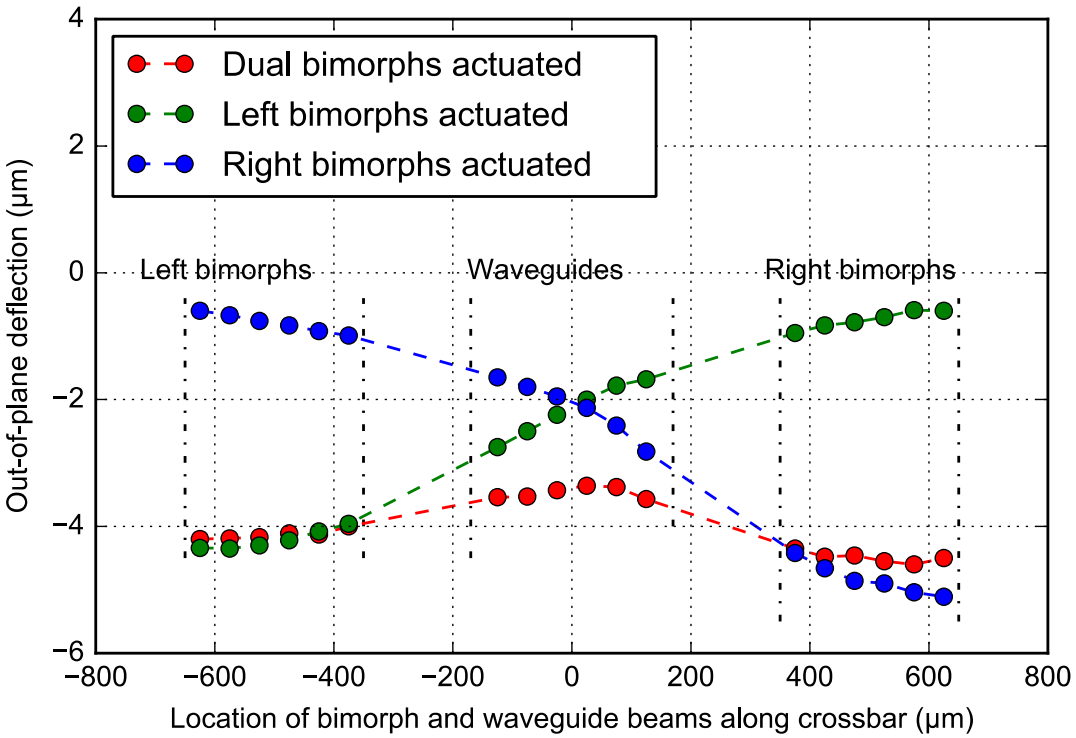
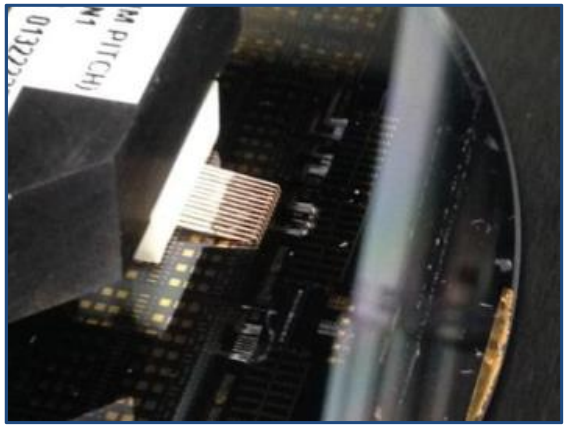


Laser vibrometer measurement
Amplitude: 4V,
Offset: 2V,
Frequency: 2Hz



Wu, Tichem, SPIE Photonics West 2016, doi: 10.1117/12.2209499

Conclusions

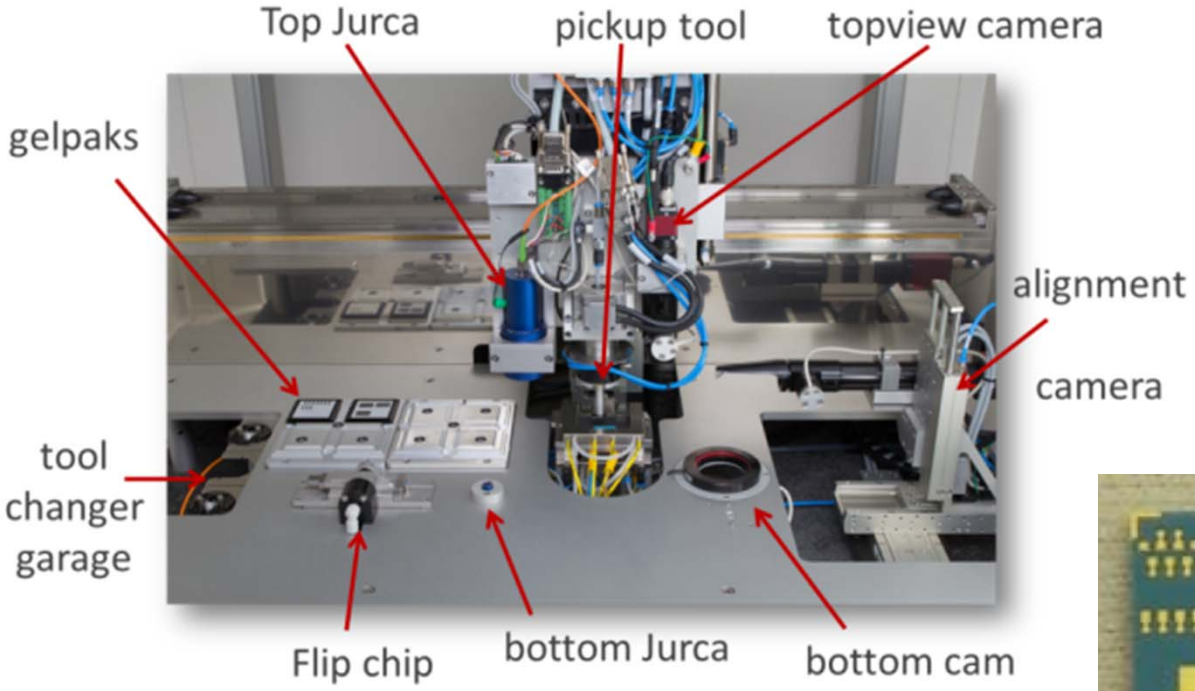
- Concept proposed for highly automated, high-precision, multi-port chip-to-chip alignment, exploiting MEMS

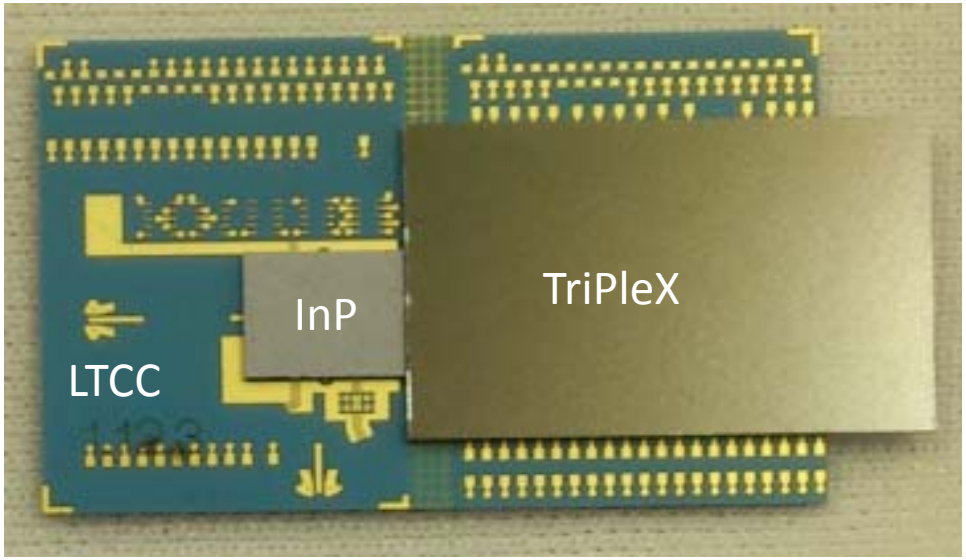
- Implementation of concept is challenged by thick ($\approx 16\mu m$) SiO_2 material, and requires smart designs:
  - Reliable fabrication is feasible with proper process design (make use of supportive Si) and chip design (prevent clamped-clamped beam situation)
  - Short-loop actuator design to use post-fabrication deformation for height compensation and have motion ranges in order of few μm

- Basic functions demonstrated, currently working on in-plane actuation, locking, optical coupling experiments and integration into overall concept

Towards a complete process

EU FP7 PHASTFlex





First proof of assembly
TriPleX chip w/o MEMS

PHASTFlex

TU Delft

ficonTEC

AIFOTEC fiberoptics

IMST

Acknowledgement

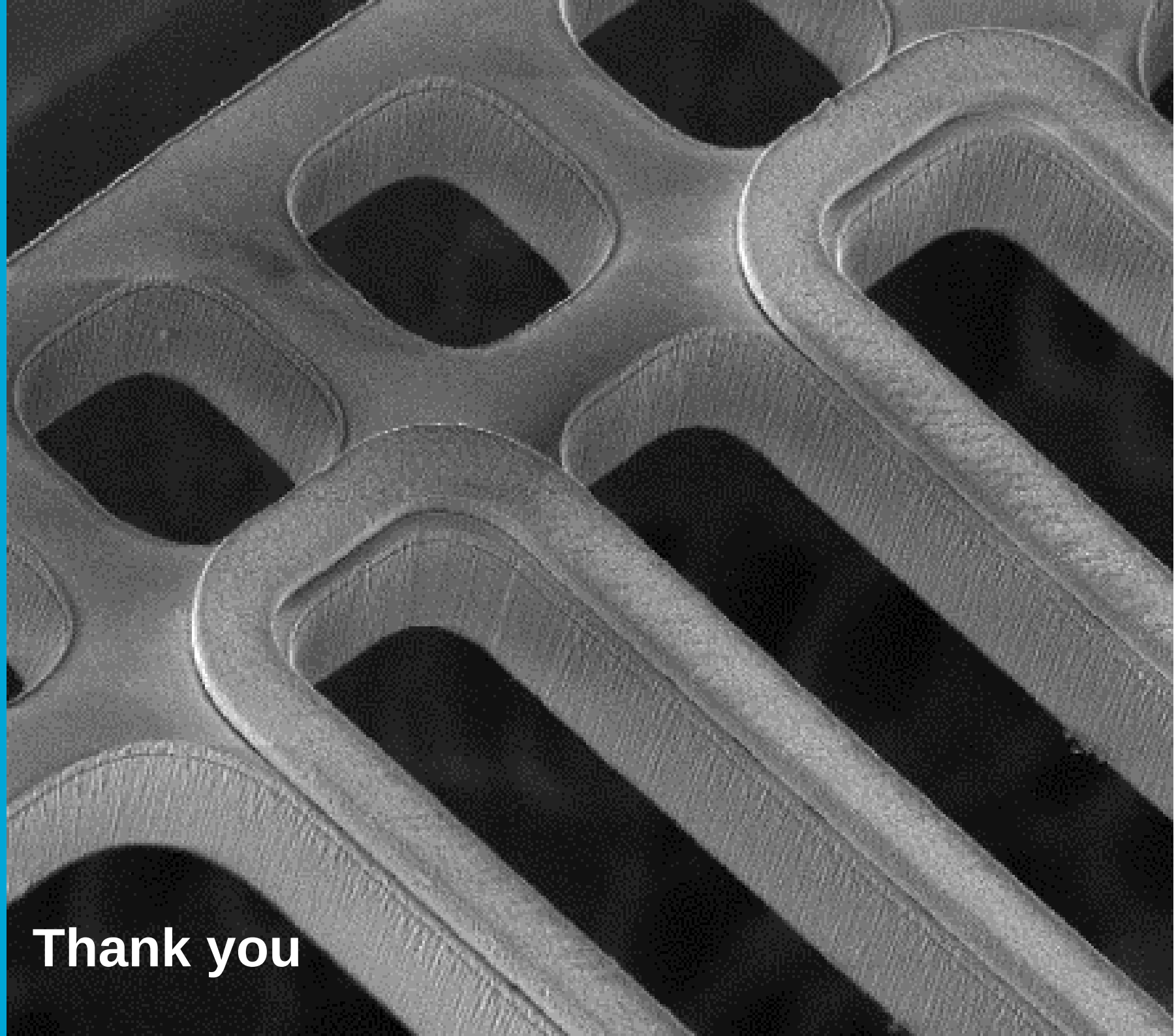
TU Delft co-workers

Tjitte-Jelte Peters, Kai Wu, Alexandre Beck

Funding

- STW GTIP grant 11355 , Flex-O-Guides
- EU FP7 grant 619267, PHASTFlex, www.phastflex.eu

Collaborators from partners, user committee members



Thank you

TU Delft