The Abdus Salam International Centre for Theoretical Physics
50th Anniversary 1964-2014

2572-10

Winter College on Optics: Fundamentals of Photonics – Theory, Devices and Applications

10 – 21 February 2014

Photonic packaging and integration technologies II

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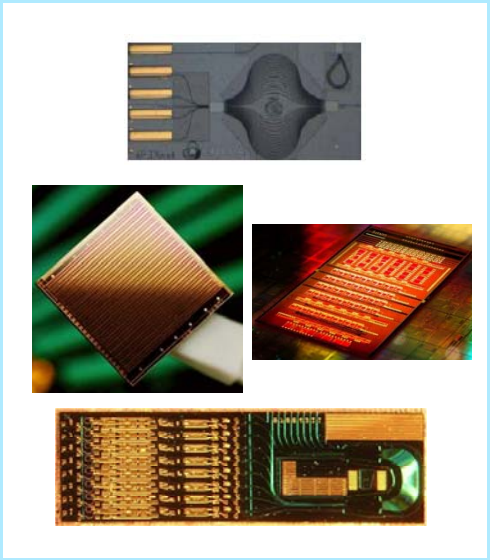
Winter School on Optics

ICTP, Trieste, February 2014

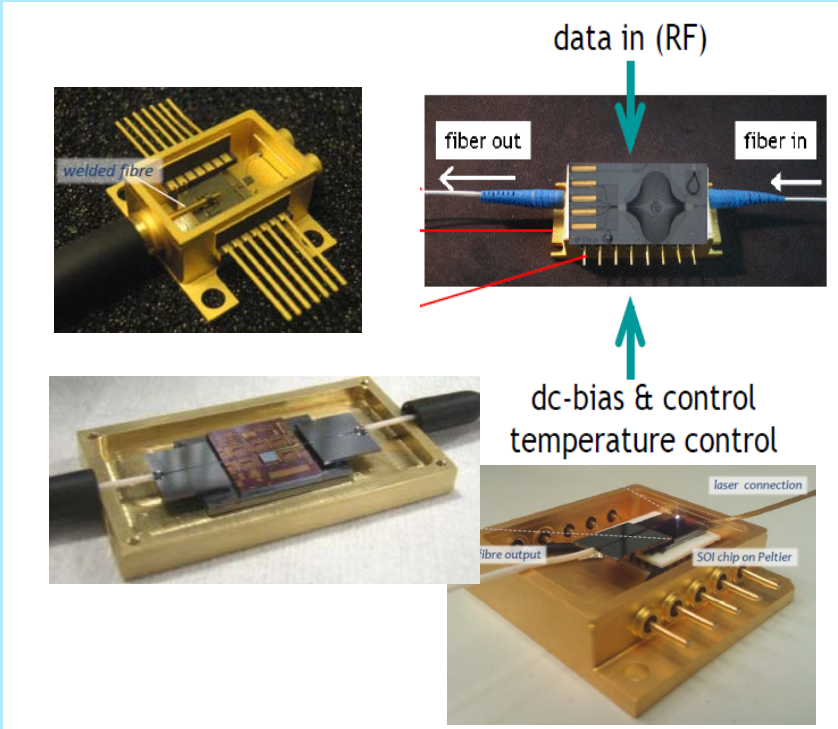
Sonia M. García Blanco, University of Twente

PHOTONIC PACKAGING AND INTEGRATION TECHNOLOGIES

Bare photonic dies



Packaged dies



[Lars Zimmerman, Helios, Silicon Photonics course]
[P. O'Brien, Tyndall National Institute, Cork, Ireland]

OUTLINE

1. Packaging of LEDs, detectors and image sensors
2. Packaging of photonic devices
3. Hybrid and heterogeneous integration technologies

HYBRID INTEGRATION

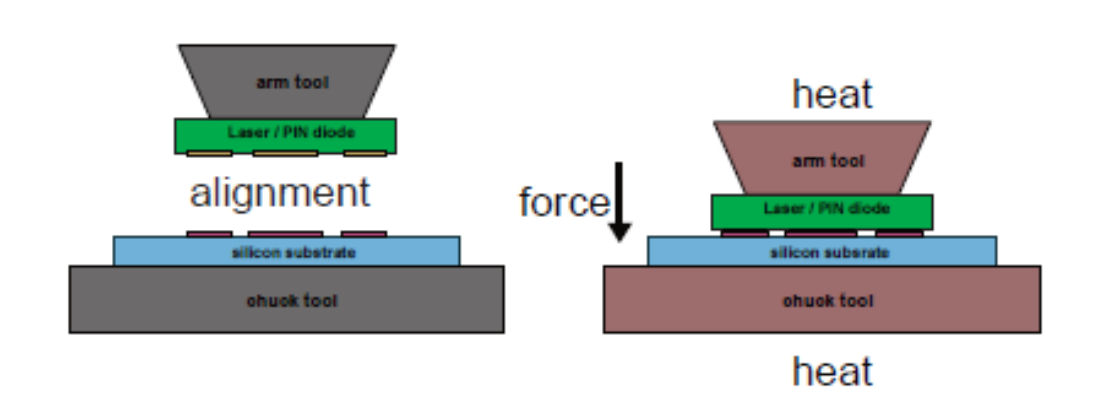
CONCEPT: "To develop a motherboard onto which the different optical components are passively assembled

Passive assembly:
- Purely visual
- V-grooves
- Solder self alignment
- Solder self alignment with mechanical stops
- With MEMS or with micromachines

Examples of optical benches:

- Axsun
- Tyndall
- Mycraline
- Kaiam
- CPI
- INO

“VISUAL” PASSIVE ASSEMBLY



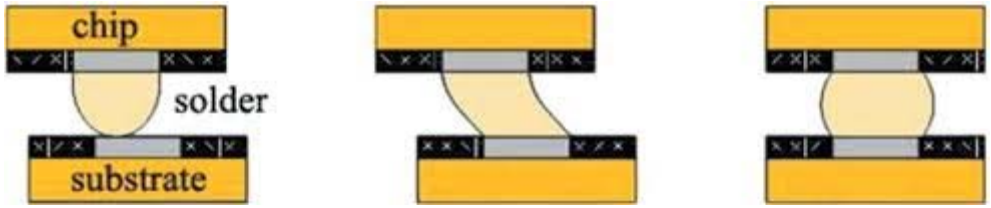
[H. Oppermann, IZM]

- Metal thermocompression bonding or solder (AuSn)
- Alignment using a very accurate flip-chip bonder

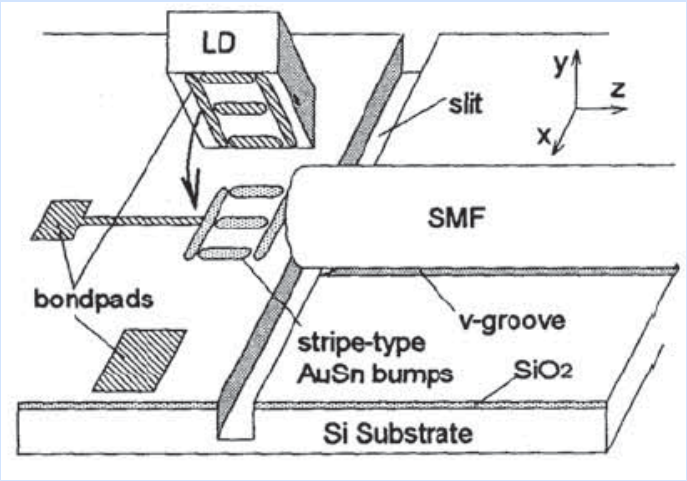
Finetech Lambda: Δx, Δy (post-bond) < 1 μm

SET FC150: Δx, Δy (post-bond) < 1 μm

SOLDER “SELF-ALIGNMENT”

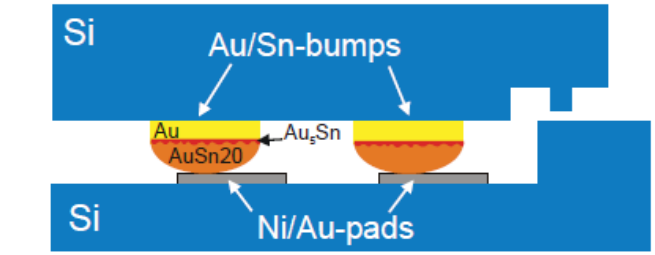


EXAMPLE:

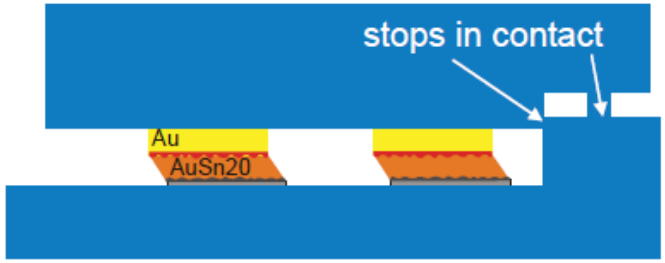


- Long solder stripes aligned in the x and z directions
- Stripes along x → self-alignment in z
- Stripes along z → self-alignment in x
- x-z positioning accuracy <1μm
- y positioning → volume of solder

SOLDER "SELF-ALIGNMENT" WITH MECHANICAL STOPS



After pick & place: bumps and pads are misaligned to each other (90 µm)

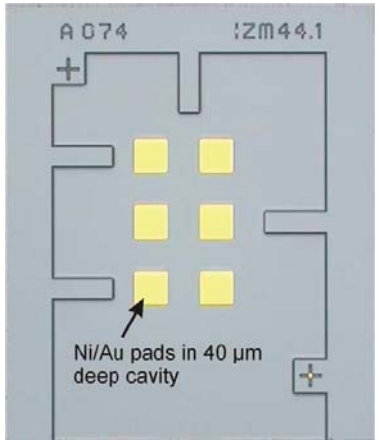


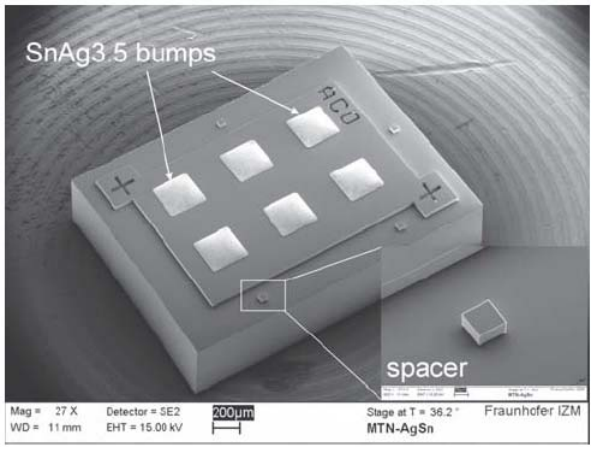
After reflow soldering: chip has reached its final position, bumps and pads are still misaligned to each other

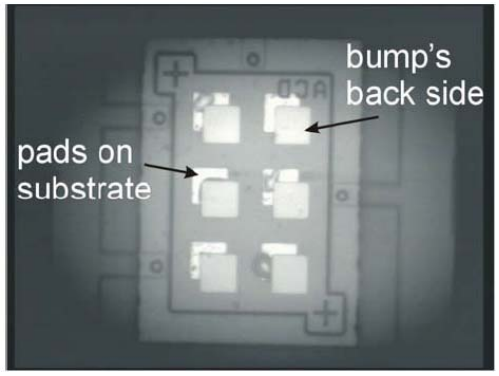
- Restoring force is proportional to initial misalignment → 90 mm produces enough force to move the top die against the stops
- In final positions misalignment of pad and stud ensures force against stops
- Low accuracy pick-and-place equipment (~10-20 µm)

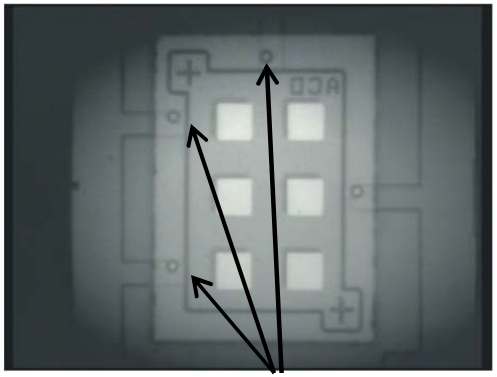
[Hutter et. al., Proc. ECTC 2006]

SOLDER “SELF-ALIGNMENT” WITH MECHANICAL STOPS







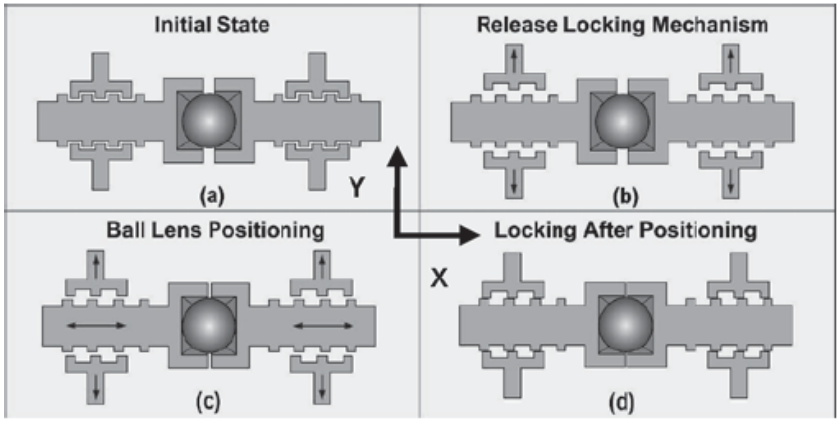


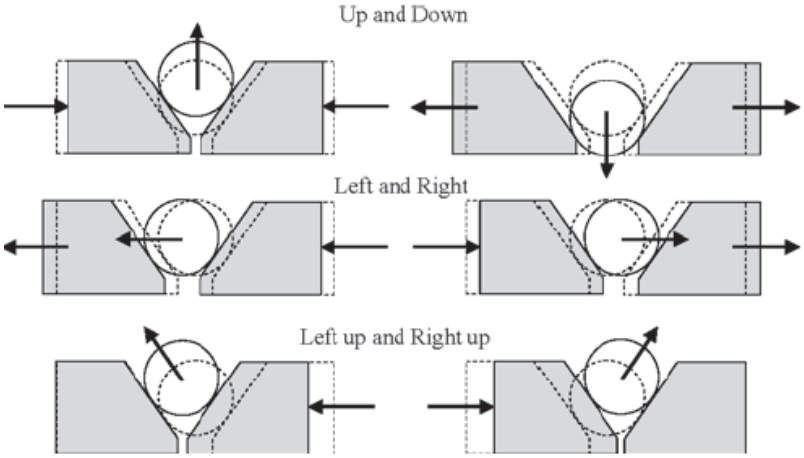
Placement before reflow

After reflow chip is against the stops

[Hutter et. al., Proc. ECTC 2006]

ALIGNMENT WITH MEMS

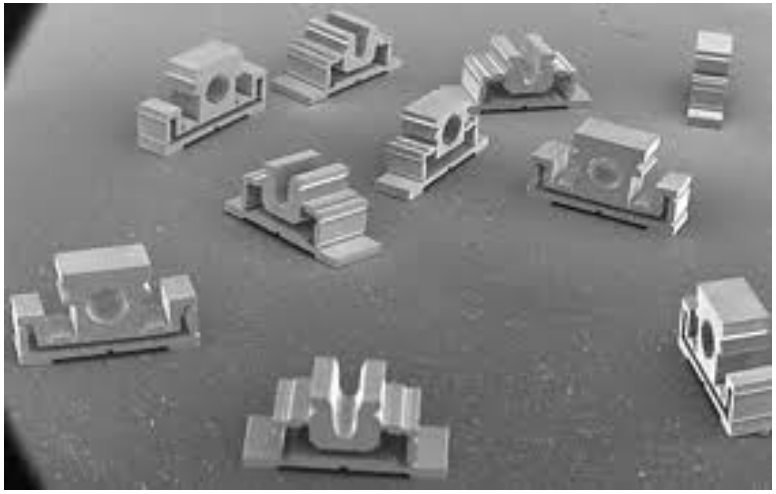


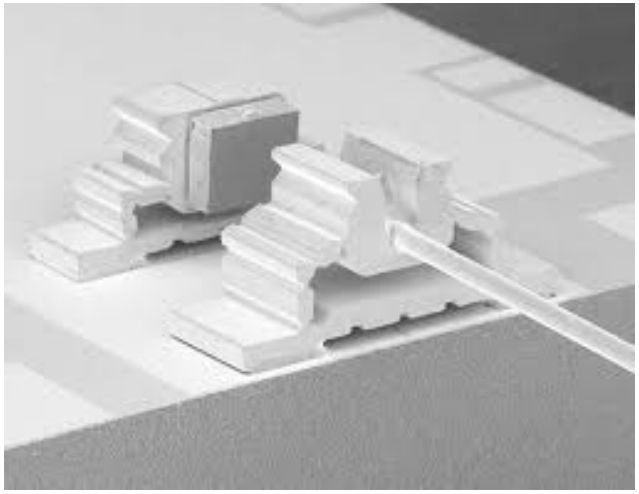


- Ball lens alignment in 2-axes by lateral movement of slope wedges
- Fixed in aligned position by locking mechanism of MEMS structure

[Zhang et. al., JSTQE, 2010]

ALIGNMENT WITH MICROMACHINES





- Metallic “micromachines” made with the LIGA process
- Positioned with very high accuracy on the substrate

[Axsun]

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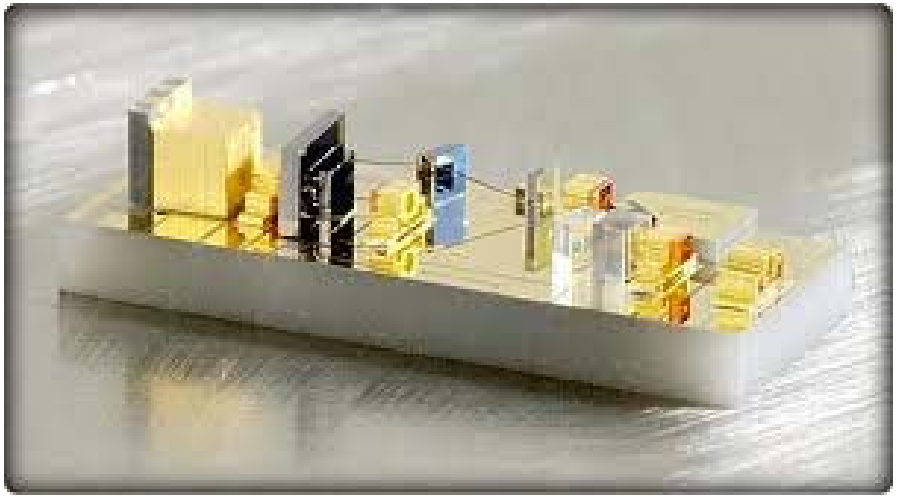
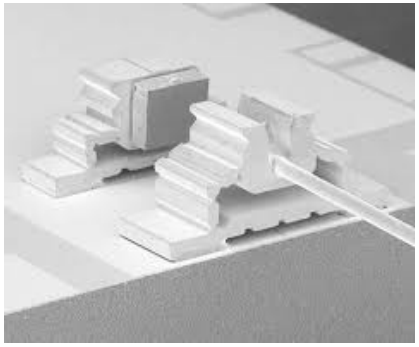
- Mycraline
- Kaiam
- CPI
- INO

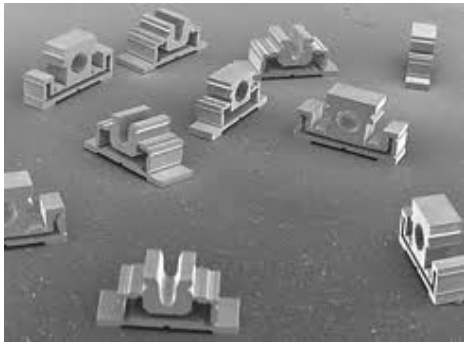
AXSUN OPTICAL BENCH



Electroplated LIGA mold

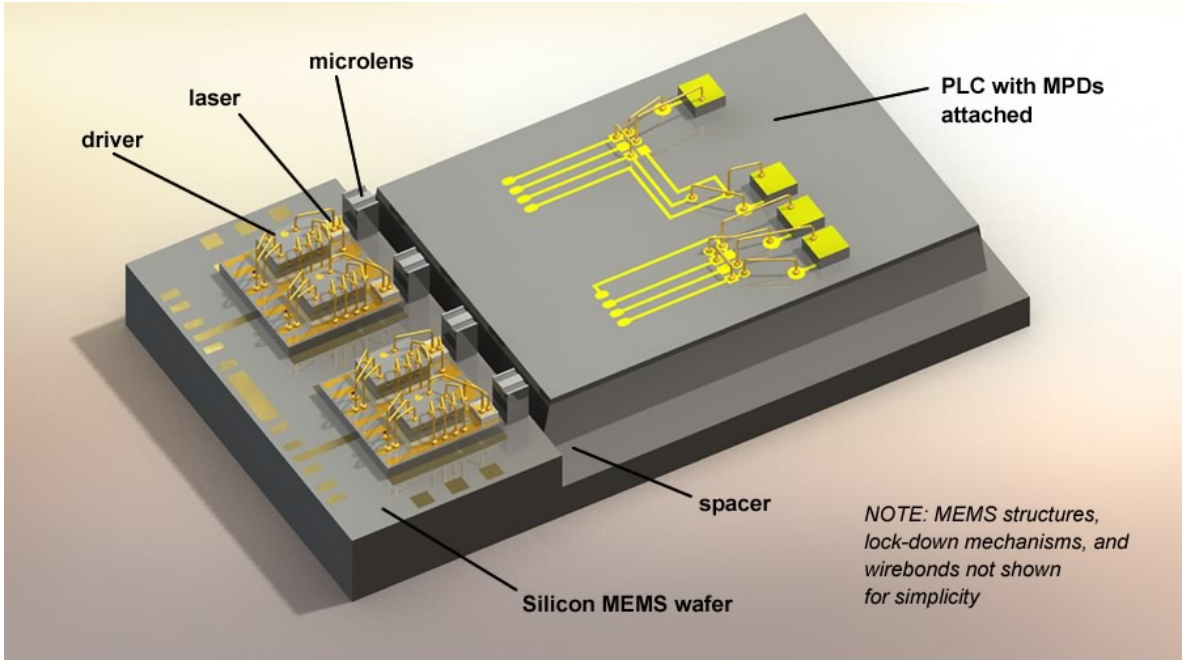


Fibre gripper



Various structures

KAIAM HYBRID INTEGRATION PLATFORM

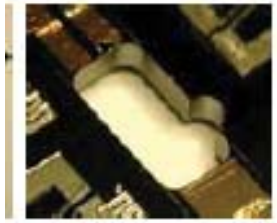


[Kaiam Corp]

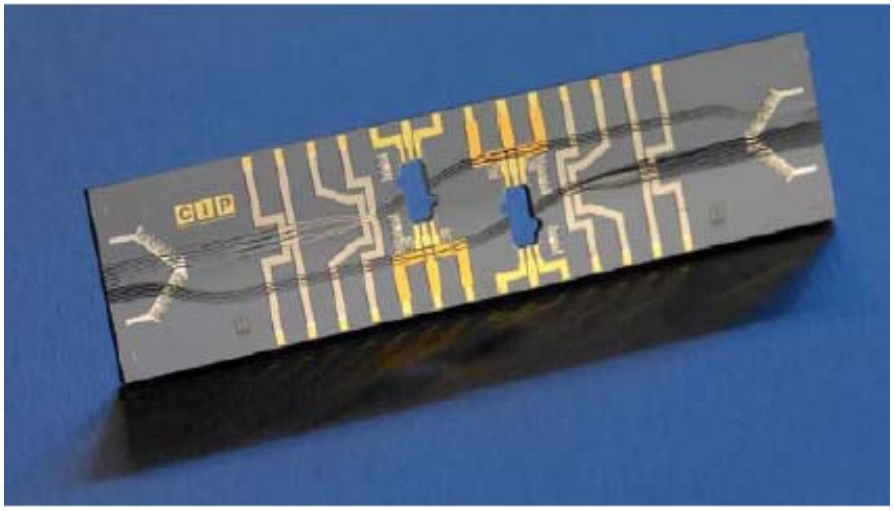
CIP OPTICAL BENCH

[InP devices]

[Mech stops]



[Cavity]



[Fibre array]

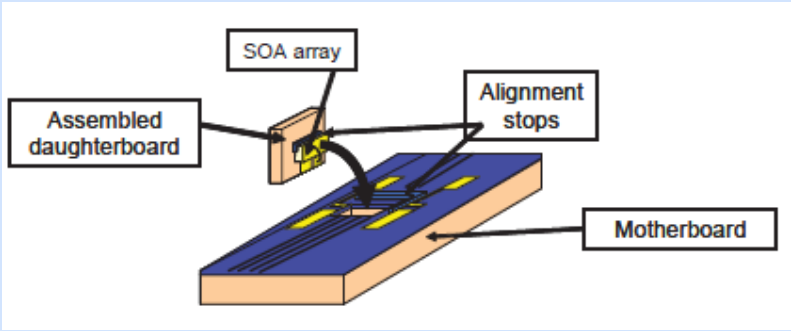
[Si daughter board]

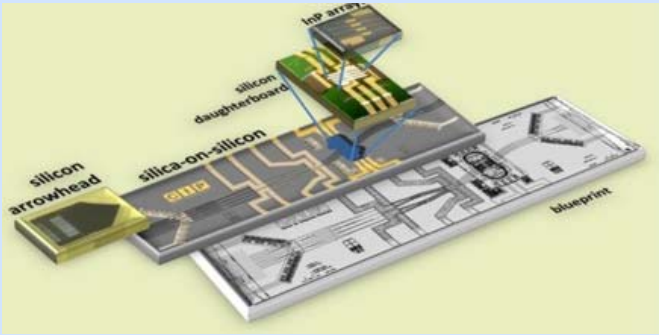
[Silica-on-silicon motherboard]

[Isolator]

[CIP (now Huawei)]

CIP OPTICAL BENCH





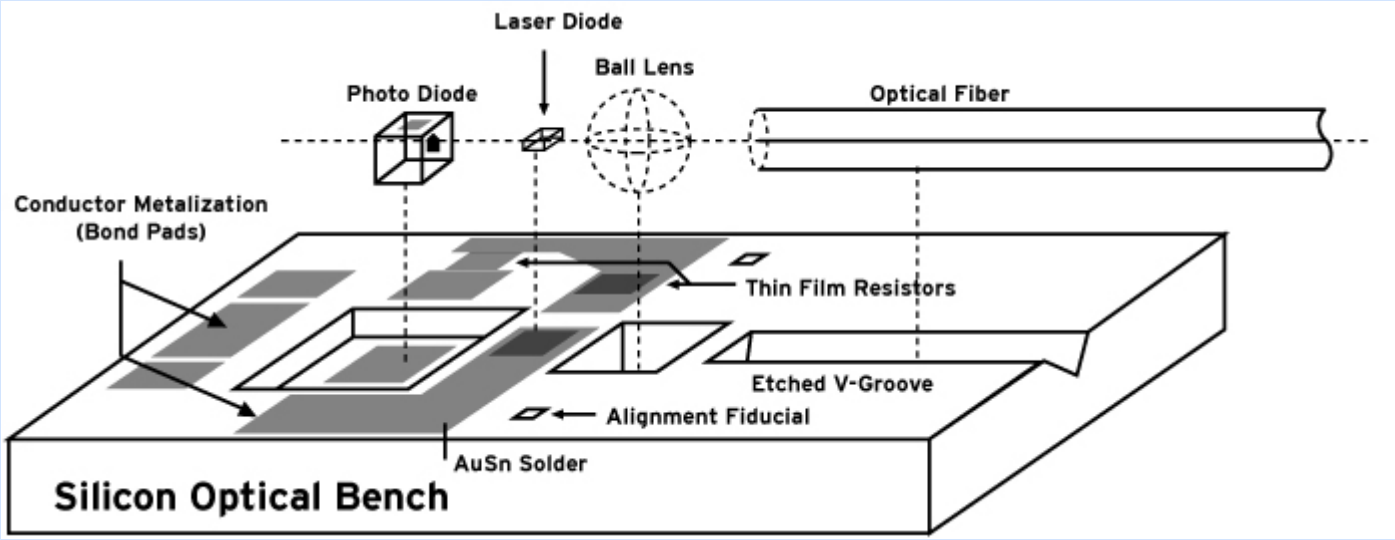
[CIP (now Huawei)]

- Motherboard: low loss silica waveguide platform.

- Silicon daughter boards: InP chips with mode converters are passively attached.

- Cavities in motherboard + polymer alignment stops + control of thickness of silica clad → precise alignment

MICRALYNE OPTICAL BENCH



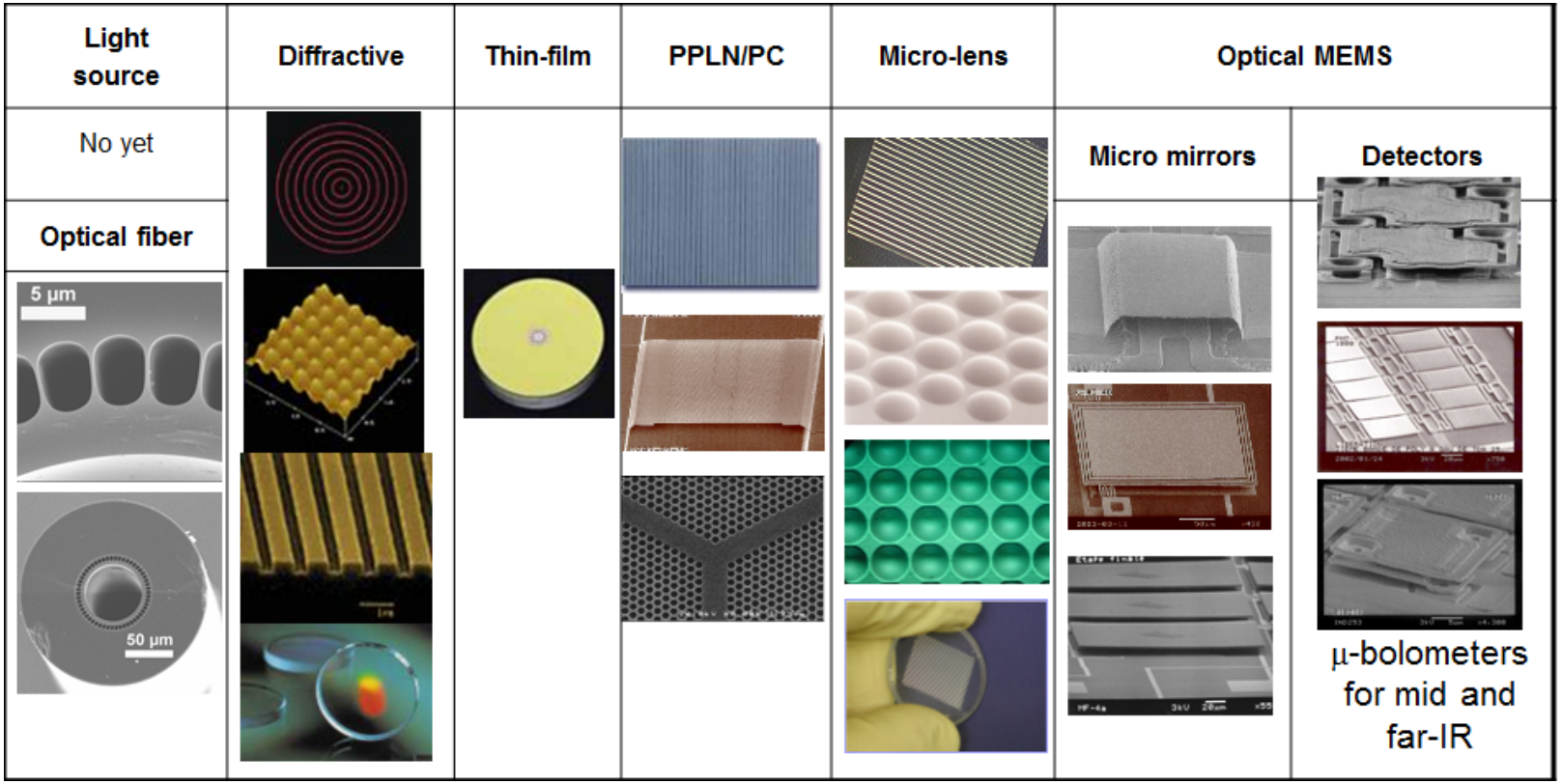
[Mycraline]

INO OPTICAL BENCH: MINIATURIZATION OBJECTIVE

Traditional optical toolbox to be miniaturized …

INO OPTICAL BENCH: MINIATURIZATION OBJECTIVE

… into INO's toolbox of micro-components …

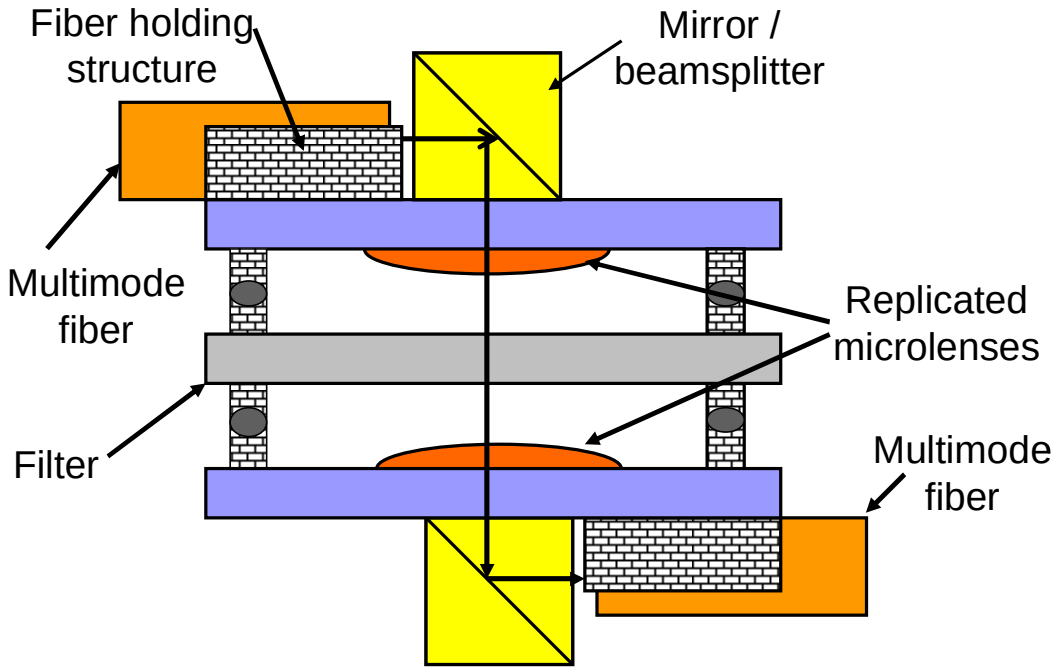


… integrated using INOs 3D microbench technology

S. García-Blanco, et. al., "Photonics integration, micro-assembly and packaging technologies at INO", SPIE Photonics North, 2010 (Invited Presentation)

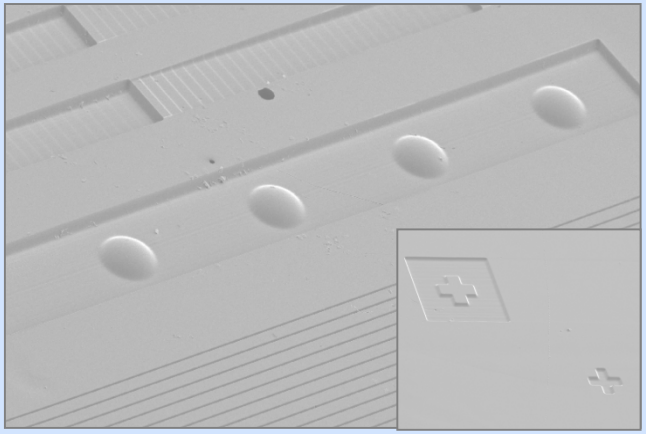
GENERAL OVERVIEW

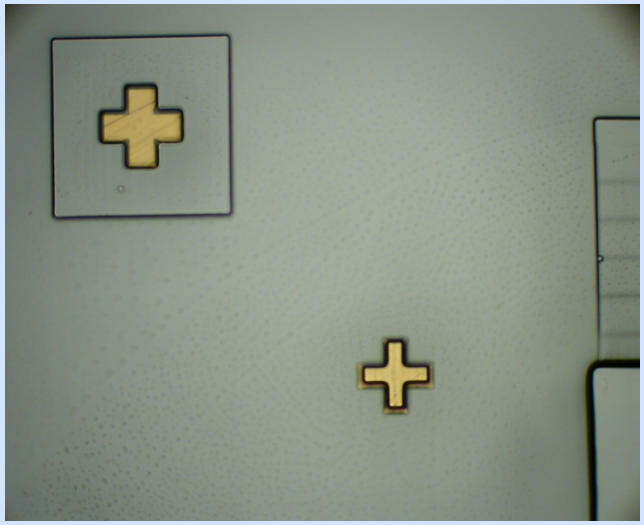
"Integration MEMS-based micro-optical components and macro COTS components on a 3-D multilevel configuration"



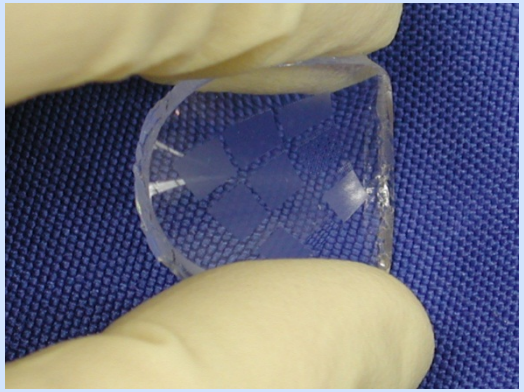
S. García-Blanco et. al., "3D MOEMS-based micro-bench platform for the miniaturization of sensing devices", Proc. SPIE, 68870F, 2008

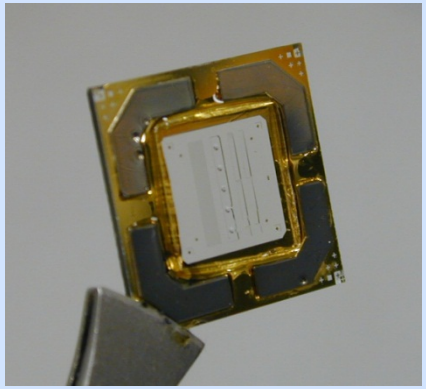
MICROLENSES INTEGRATION





Current technology: replication in sol-gel materials (visible)

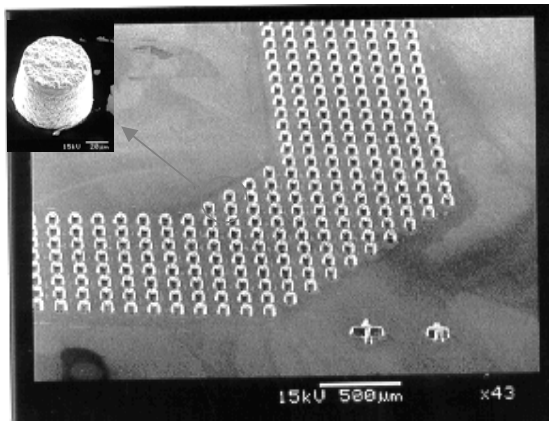


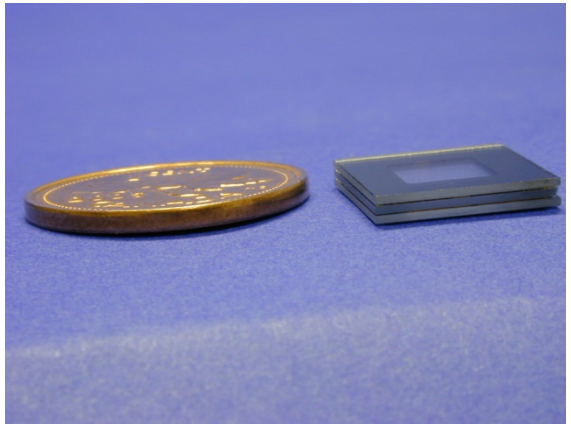


- Technology to fabricate microlenses in materials suitable for other wavelength ranges can be developed (mid and far-IR)

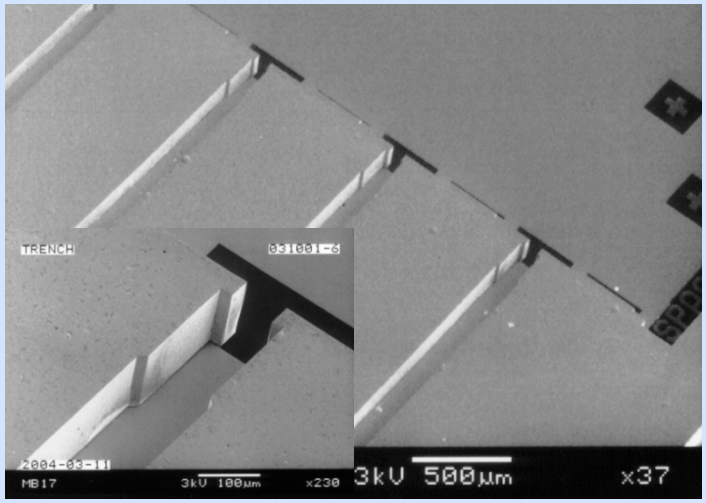
COMPONENTS INTEGRATED IN THE PLATFORM

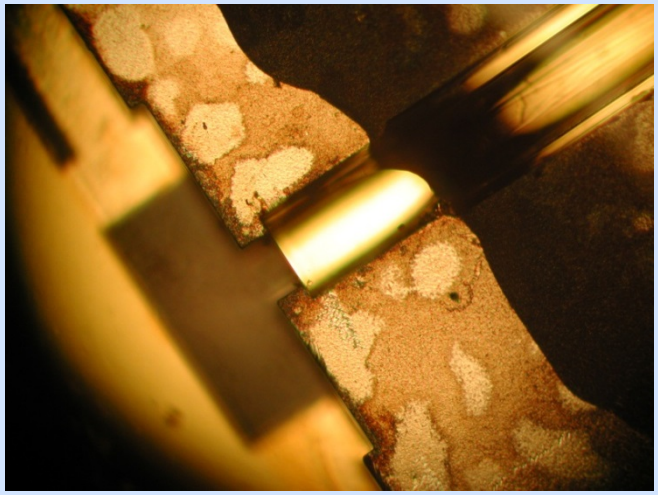
1. Optical components wafer-level microfabricated on both sides of intermediate layers
    - Replicated microlenses
    - Apertures, thin films filters, gratings
2. Wafer-level assembly of different levels
    - Solder ball self-alignment
    - Adhesive bonding

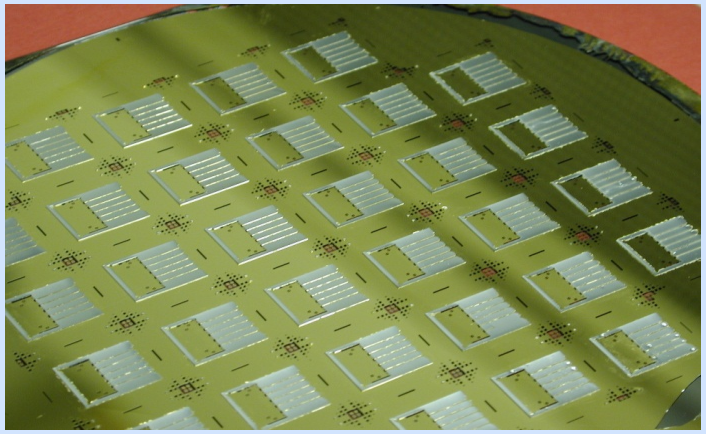




INTEGRATION OF OPTICAL FIBERS







- Thick Ni e-plated structures
- UV adhesive fixing of fiber

OUTLINE

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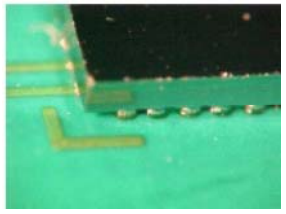
INTEGRATION OF OPTICAL SOURCES

REMEMBER: Silicon has an indirect bandgap!!

INTEGRATION OF LIGHT SOURCE IN SILICON PLATFORM

Integration of "finished" laser sources by microassembly technologies, such as "flip-chip" bonding



~ Mature technology

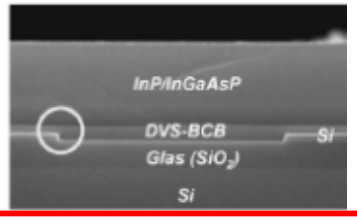
- Low integration density

Growth of direct bandgap materials directly onto silicon

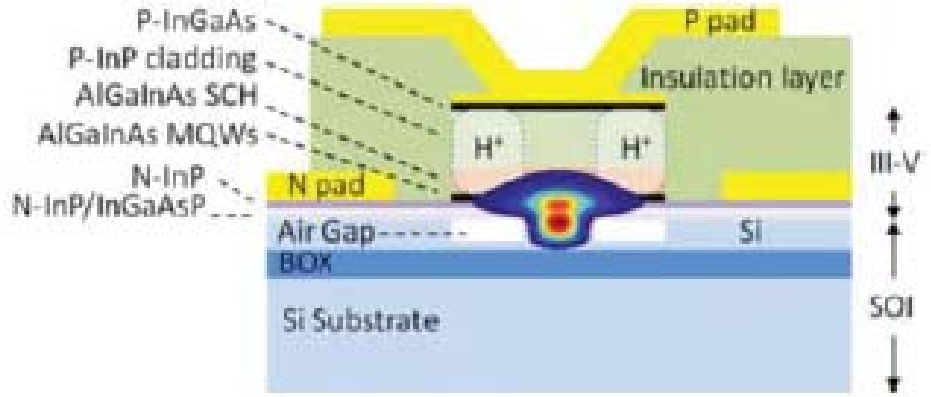
- High potential integration density

- Difficulty due to lattice mismatch -> defects

Direct bonding of direct bandgap material on silicon wafer followed by post-processing



“HYBRID SILICON” PLATFORM



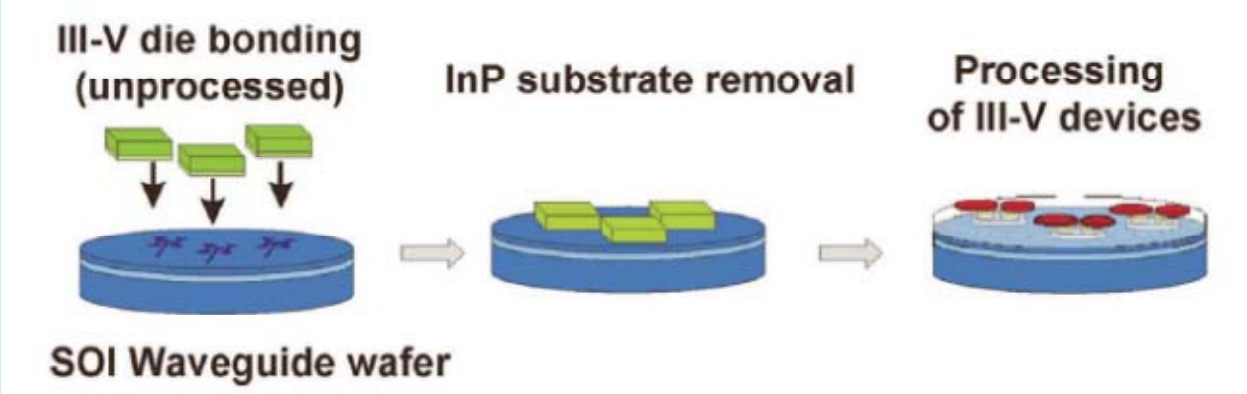
- III-V material bonded to silicon waveguide sample

- Processing of the III-V material aligning to pre-existing silicon waveguides to form the devices

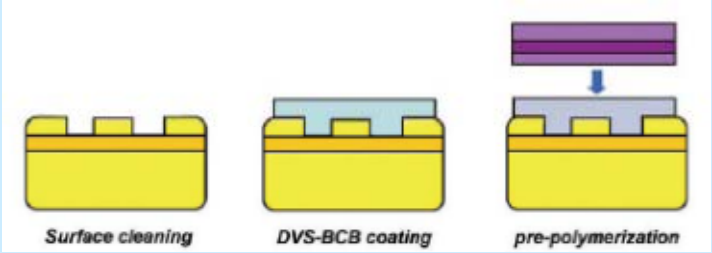
- By varying the width of the silicon waveguide, the propagating mode can be pushed towards the III-V material or towards the Si waveguide

“HYBRID SILICON”: ASSEMBLY PROCESS

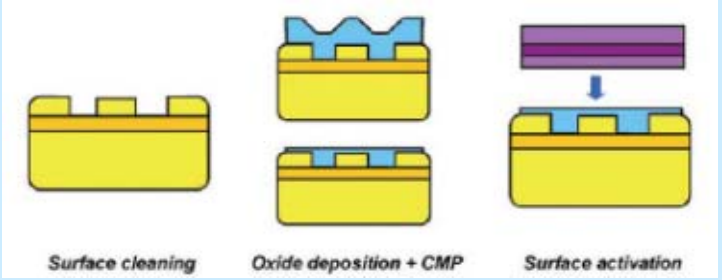
III-V to silicon nanophotonic devices wafer bonding concept:



Two main processes:



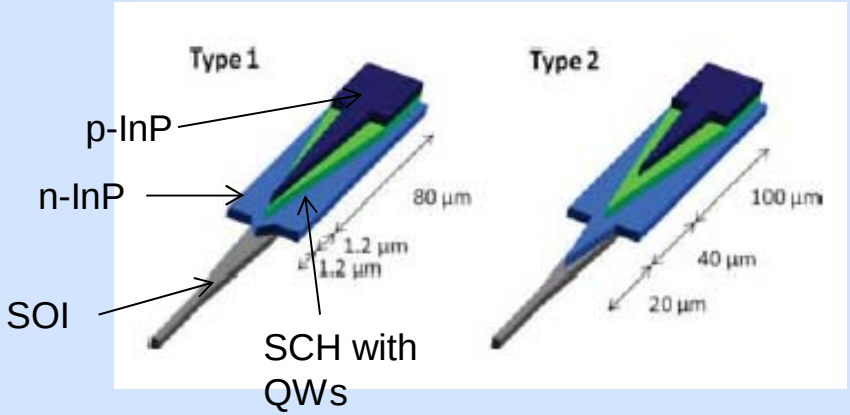
DVS-BCB adhesive bonding: Ghent University

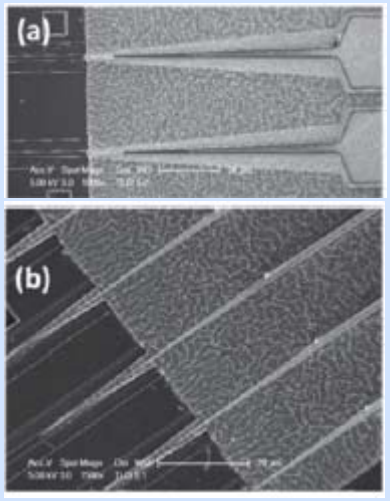


Direct bonding: UCSB (example)

“HYBRID SILICON” TECHNOLOGY PLATFORM

- Taper couplers from SOI to III-V

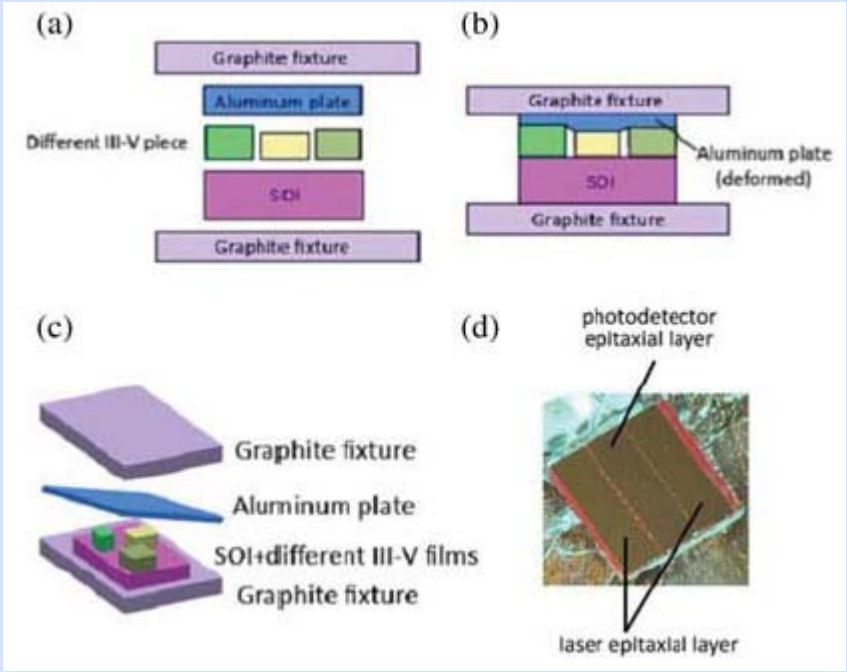




- Taper losses of 0.5 dB and 0.3 dB [M. Heck et. al., JSTQE 2013]

“HYBRID SILICON” TECHNOLOGY PLATFORM

- Simultaneous bonding of different III-V materials

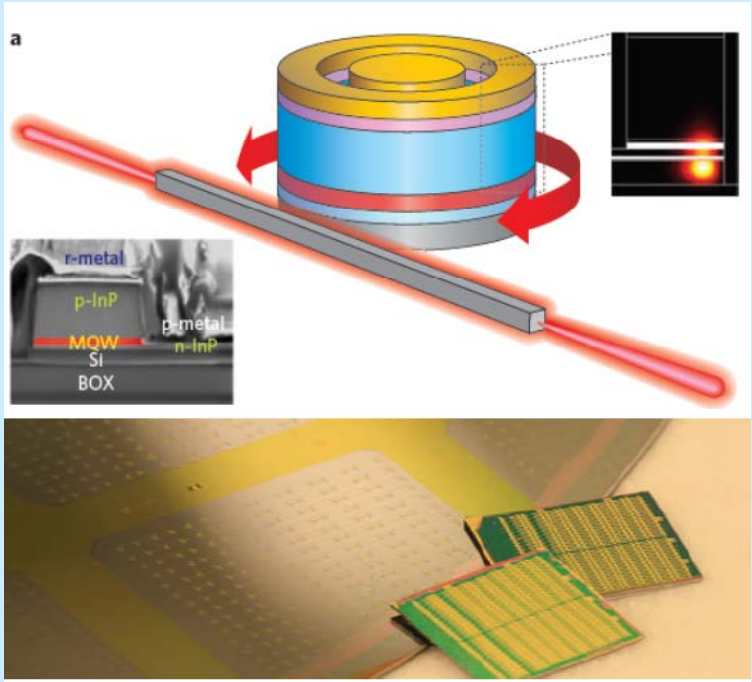


[M. Heck et. al., JSTQE 2013]

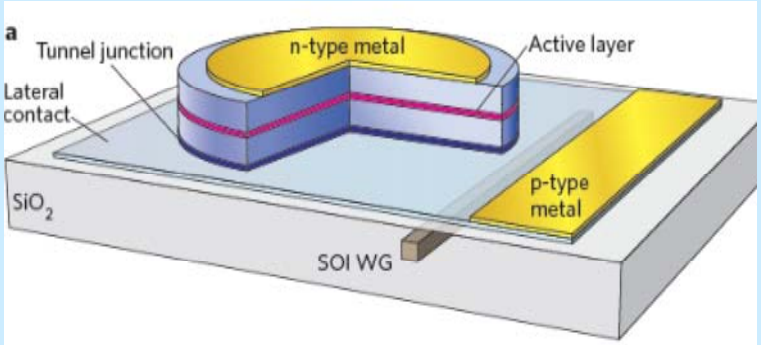
“HYBRID SILICON” BUILDING BLOCKS

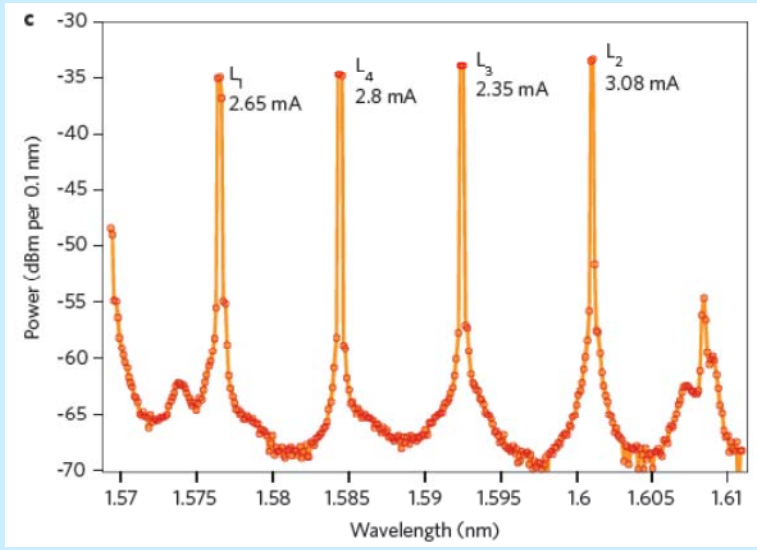
- Sources

“HYBRID SILICON” LASERS

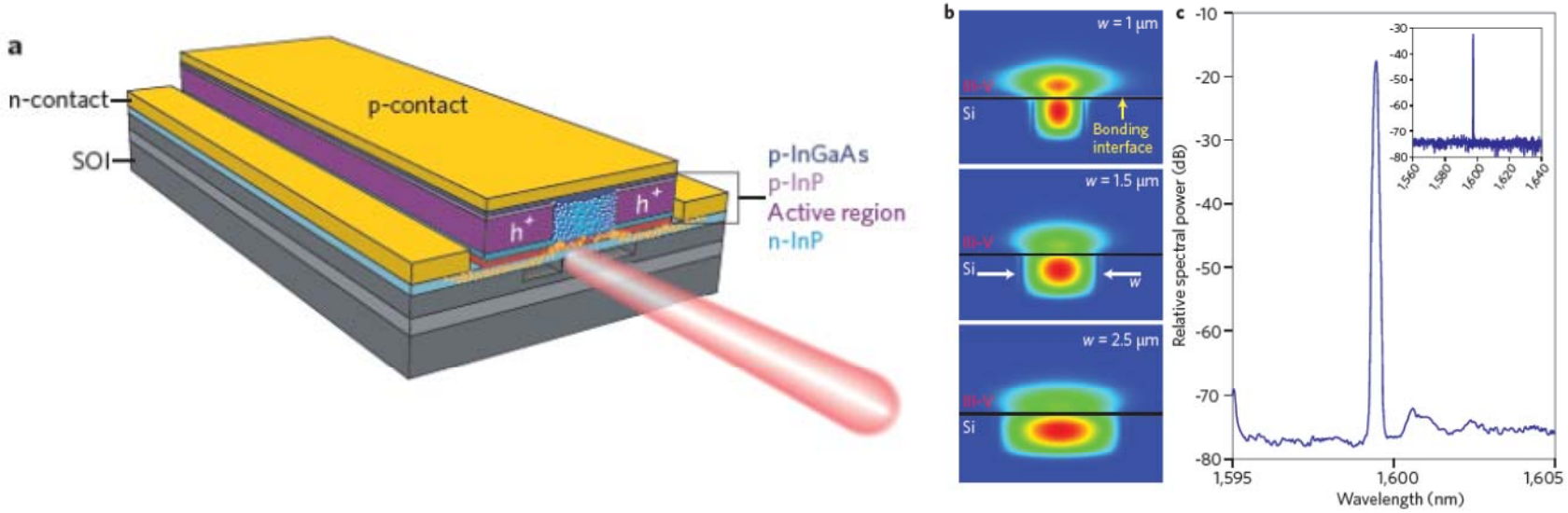


- Threshold current ~4 mA → output power ~3.5 mW
- Diameters ranging from 15-50 μm
- 400 microring lasers in a 1 cm^2 chip



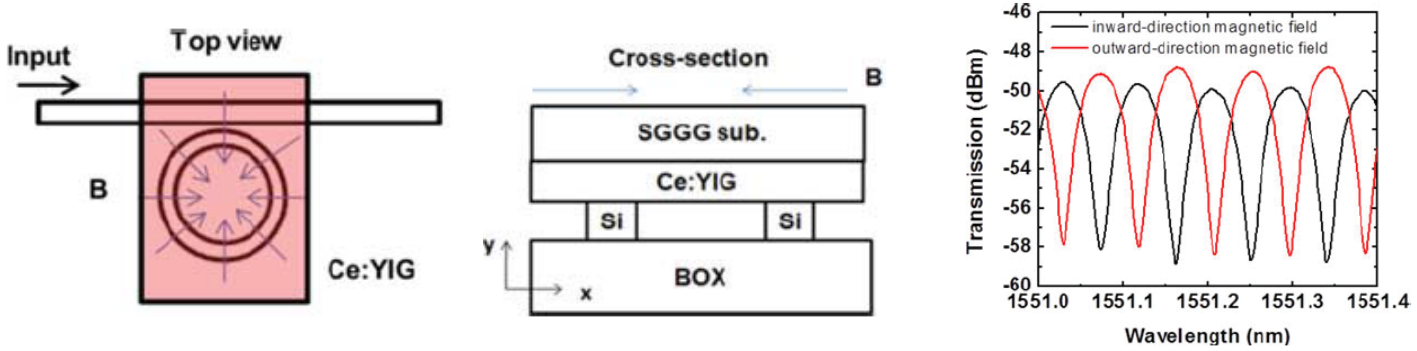


HYBRID SILICON LASERS



“HYBRID SILICON” BUILDING BLOCKS

- Sources
- Amplifiers
- Modulators → in the SOI part
- Isolators → integration of magneto-optic garnets



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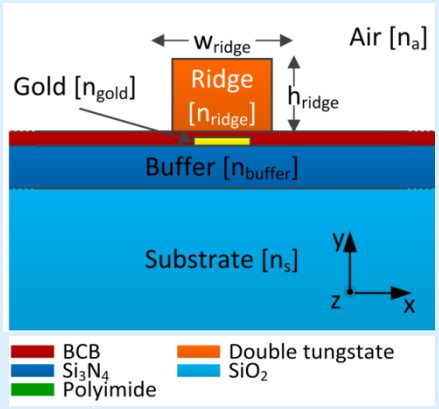
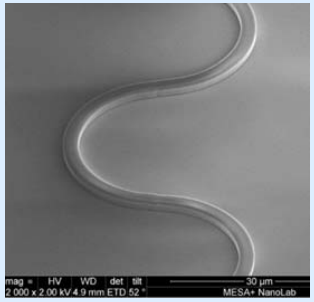
Plasmonic-based integrated optics (waveguides and nanostructures)

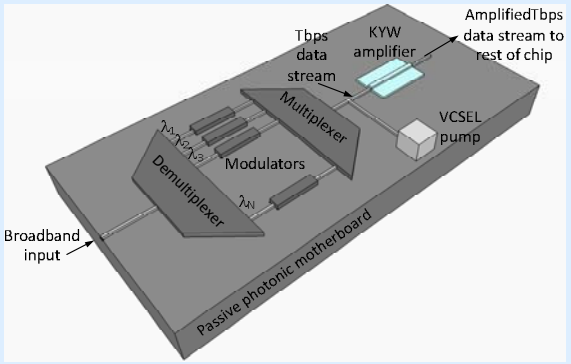


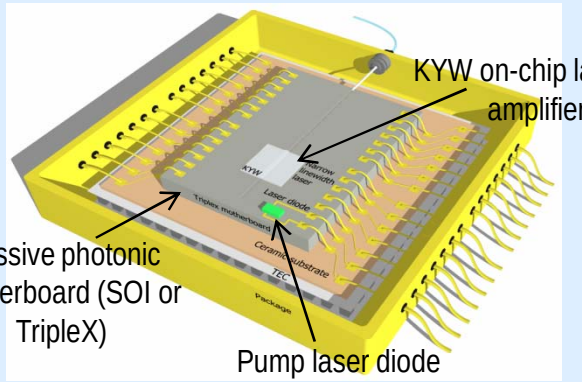
Gain compensated long-range plasmonic waveguides



Low-loss sharp bends enabled by thin metal layers

On-chip active devices





2 PhD positions are now open to work on these projects!!

[[http://os.tnw.utwente.nl/vacature.php?submenu=23]

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