High accuracy placement - passive versus active alignment, benefits and challenges

D.Lieske, 04.06.2024

Overview

- ✓ Motivation
- ✓ AEMtec at A Glance – company and technology overview
- ✓ Active and Passive alignment
- ✓ High accuracy placement
- ✓ Optical and Photonics packaging examples
- ✓ Summary

Motivation

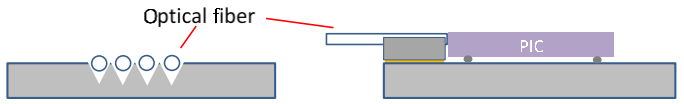
- Photonics is advanced packaging
- High accuracy placement is the key for Photonics in the next decade and beyond
- There can be seen a very good development in photonics since more than a decade, e.g. Intel and IBM (now Globalfoundries by offering PIC wafers with IBM's technology), IHP, XFAB, Ligentec and others
- At AEMtec a rising demand for high accuracy placement in Photonic applications can be seen
- High accuracy placement not only needs high accuracy placement equipment
- The understanding of materials, available interconnect technologies, wafer processing and chip handling is the key
- Smart assembly techniques will be needed, new interconnect technologies need to be developed and standardized to improve manufacturability and product reliability

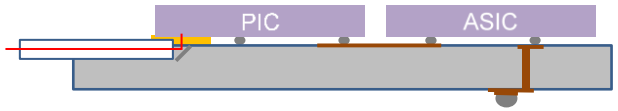
Motivation

- Photonics IC's (PIC) are on the way, but add packaging costs
- Data center drive the development of PIC's
- with PIC's the demand for Flip Chip applications for photonics packaging with higher placement accuracy than traditional Flip Chip is rising
- FC-PIC have advantages over wire bond due to high pin count and short signal length, as well as capability of integrating optical elements in photonic IC's
- But as integrated laser are still expensive VCSEL, Photodiodes and TIAs are widely used for optical applications
- For both solutions the fiber attach is adding packaging cost and complexity
- If high precision placement can be done and active alignment of fibers can be avoided it reduces cost

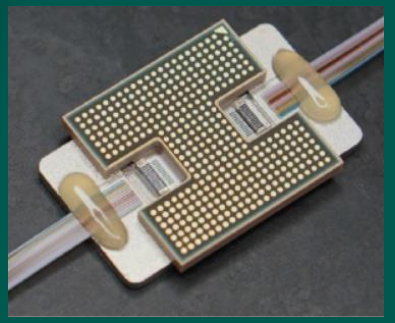
The challenge of Photonics IC packaging and fiber connection

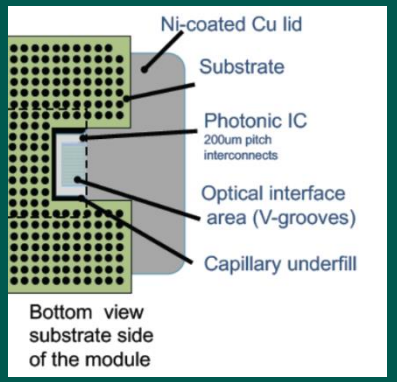
High accuracy die placement + V-groove passive fiber placement

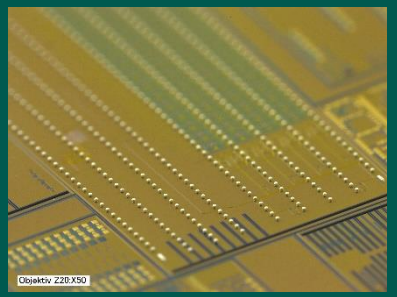




Interposer (Glass, Silicon or Organic)







1 + 2 Source: IBM
3 source: AEMtec

AEMtec at A Glance

AEMtec
Driving product Innovations

We are:

- 220⁺ employees
- 70 Mio⁺ € Revenue
- Headquarter and Production: Berlin Adlershof
- 2000 founded as Spin of from Infineon Fiber Optics
- 9000 m^2 facility including sufficient space for our employees, offices, production and test equipment (3000m^2 clean room, ISO 5, 6 and 7)
- Today the team of AEMtec is proud to count more than 60 customers worldwide and over 500 realized projects

✓ **Introduction**

What is unique about AEMtec?

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Driving product Innovations

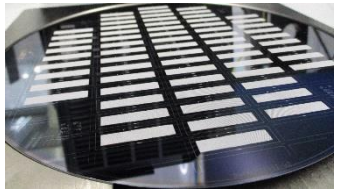
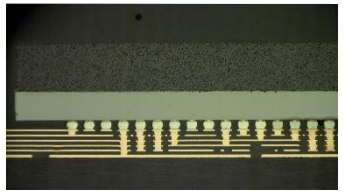
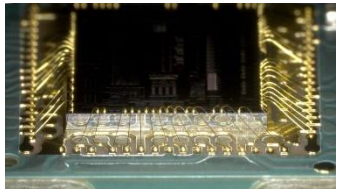
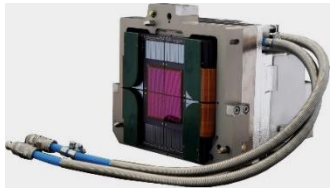
We are:

- A unique Semiconductor packaging service provider in Europe
- A full service address for Wafer backend, Advanced packaging and Test
- A strong partner with leadership in high accuracy placement under ISO5 cleanroom condition
- Very flexible and innovative in finding solutions for customized products
- Well equipped for mid volume manufacturing products in ISO 5, 6 and 7

✓ AEMtec

AEMtec - Process line up

Driving product Innovations

Wafer back-end	High-precision packaging & testing		Positioning, soldering, testing	System Integration
UBM, balling, dicing	Flip chip	Chip on board	Surface-mount technology	Complex product assembly
				
• Under bump metallization (UBM) • Solder balling • RDL or FOWLP • Au-stud bumping • Wafer Dicing	• Soldering • Gluing (ACA, ICA, NCA)[1)] • Copper pillar • Thermocompression • Underfill	• Die bonding • Wire Bonding Al and Au wedge and ball bonding • Encapsulation • Solder Cap • Heat spreader	• Pick & Place • Selective soldering • BGA Rework • Milling or Laser-cutting • AOI • X-Ray	• Product co-development • Prototyping + industrialization • Serial production including repair service • Worldwide supply

We provide Wafer Services, SMT, Chip on Board, Flip Chip and high end system integration to our customers worldwide

Examples:

- ✓ **X-ray detectors**
- ✓ **Light sources (VCSEL or LED)**
- ✓ **Multi-channel optical transceivers**
- ✓ **Optical Systems**
- ✓ **RF-chip packages on SiGe**
- ✓ **UBM and Solder bumping of PIC Wafers**
- ✓ **Photonic SiP**
- ✓ **MCM, 2.5D / 3D SiP**

Note: 1) ACA = Anisotropic conductive adhesive, NCA = Non conductive adhesive, ICA = Isotropic conductive adhesive

Active and passive alignment - a comparison

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Driving product Innovations

- **Active alignment**
  - only where needed
  - more complicated setup
  - accessibility required, DFM (Design for manufacturability) is needed in early development of the product
  - Slower than passive alignment

- **Passive alignment**
  - down to 0,5µm is the easier process
  - higher throughput, up to 500 UPH → price benefit
  - lower invest
  - use PIC's, Lenses or TIR[1)] with V-grooves
  - use ferule and alignment pin approach
  - alignment mark quality is mandatory (DFM)

Note) 1:UPH = Units per hour, 2:PIC = Photonics IC, Note: 3:TIR = Total Internal Reflection

High accuracy die bonding (Passive)

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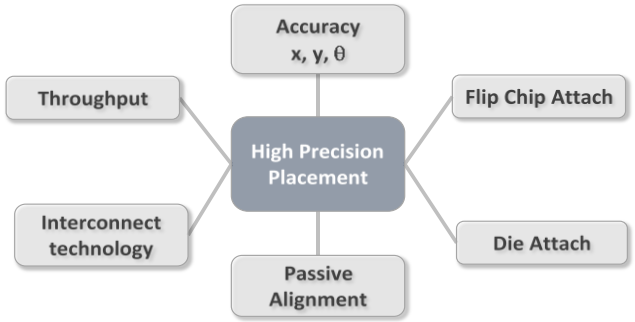
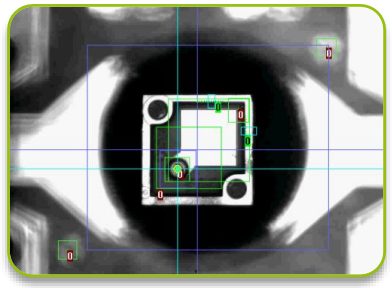
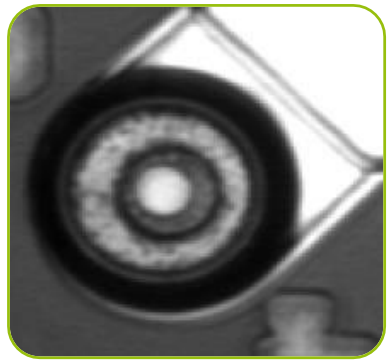
Throughput under high accuracy is key for competitiveness and price



high precision placement– What matters?

On chip structures to be used with good contrast





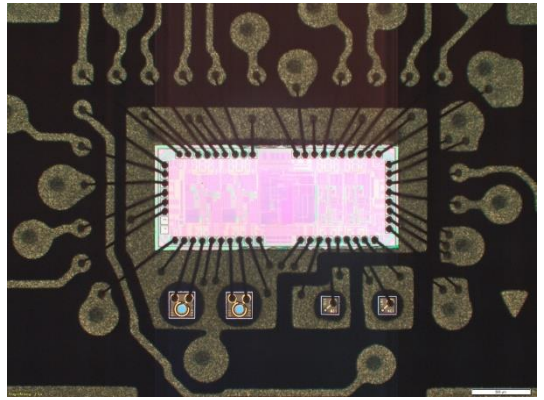
Placement accuracy depends on interconnect technology

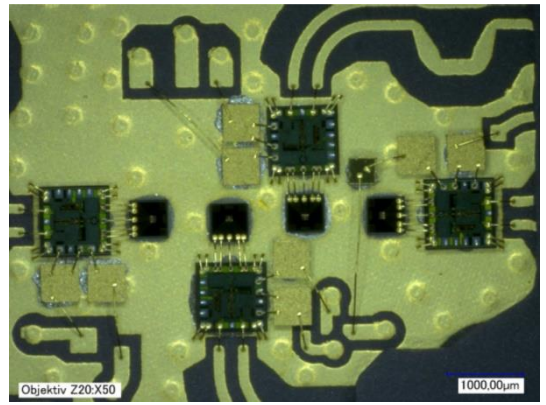
Interconnect technology	Temperature	Force	Method	Accuracy		Throughput (die bond and cure)
Adhesive	low	low	stamp, place, batch cure	high	<1,5µm	medium
Thermocompression	high	high	bond, heat	high	<3µm	medium
Pressure sintering	high	high	bond, heat, pressure anneal	medium	<10µm	medium
Soldering	high	low	place, mass reflow	low	<20µm (<5µm advanced*)	high
TLPS	high	medium high	bond, heat, anneal	medium high	<3µm	medium
Hybrid bonding (D2W)	low	medium high	clean, bond, anneal	high	<1µm	medium

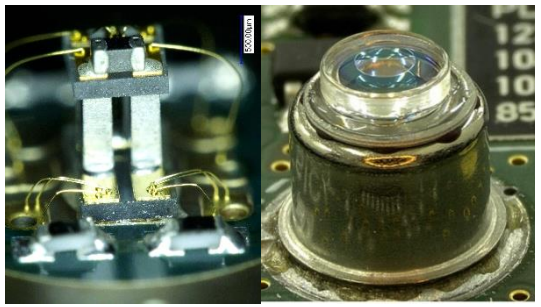
* more information on request

Examples

- Telecommunication:
  - 100Gbit Rosa (Receiver Optical Sub Assembly) x,y < 2,5µm
  - Network pluggable, long distance, 100Gbit, (SMF-ready, ferule)
  - Transceiver - fiber to chip coupling for Gbit/s link in data centers, MMF
  - Optical cable (MMF)
  - High accuracy TIR bonding
  - High accuracy Lens bonding
- Industrial:
  - Laser distance measurement Z-height <1µm (passive + active alignment)
  - Motion control sensors, VCSEL
  - Optical sensors
  - VCSEL arrays for illumination and heating
- Medical
  - Photodiode/LED integration for implantable devices
  - CT-scanners







Note: SMF: Singe Mode Fiber, MMF = Multi Mode Fiber

Telecommunication - Flip chip package for Data centers

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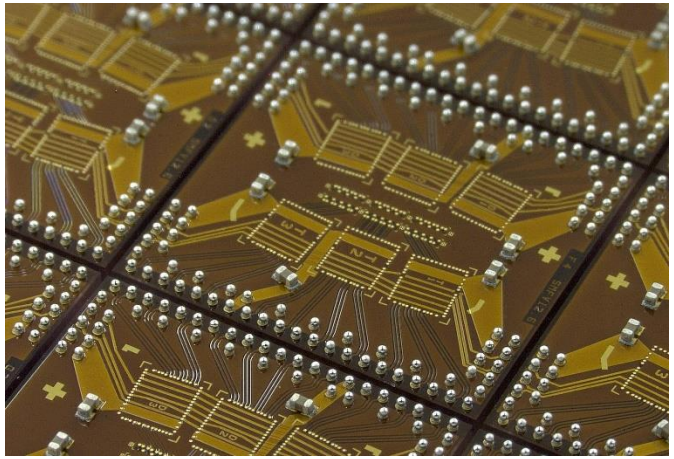
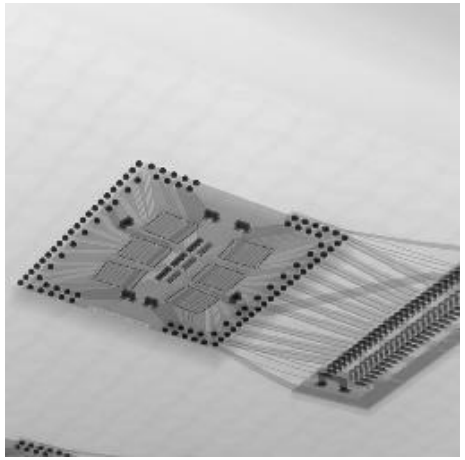
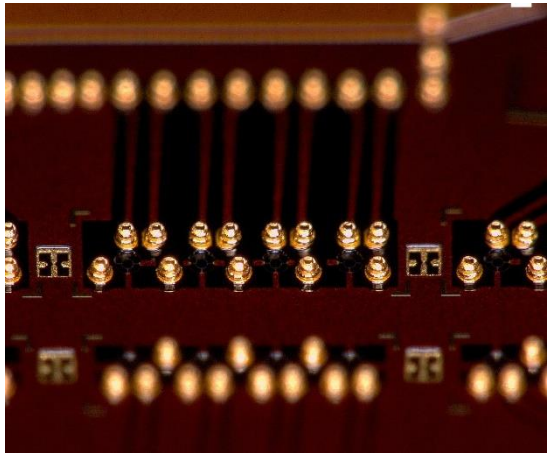
- As an example **optical Flip Chips** with an accuracy of +/-3µm are specified to be placed onto a substrate. Doing that - equipment and material, as well as temperature control does have a major influence on the final placement accuracy







- ✓ **Au- studbumping**
- ✓ **Flip Chip Thermocompression +/-2,5 µm**

Telecommunication - Flip chip package for Data centers

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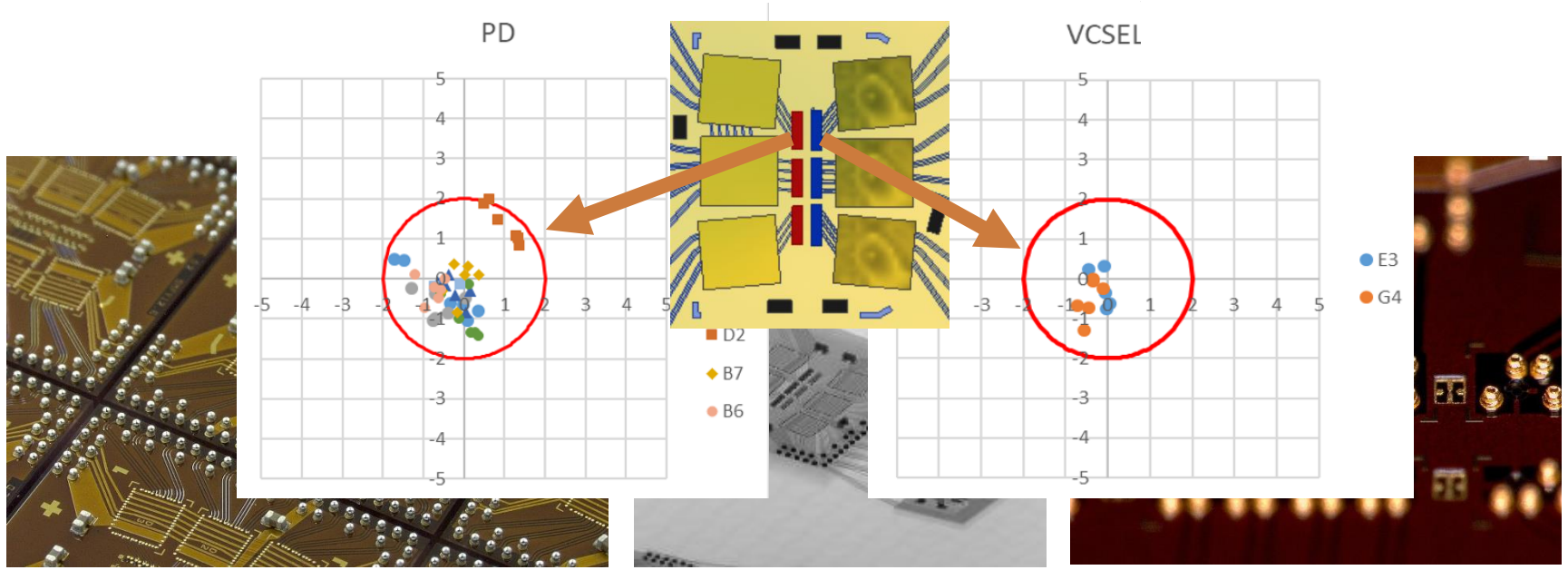
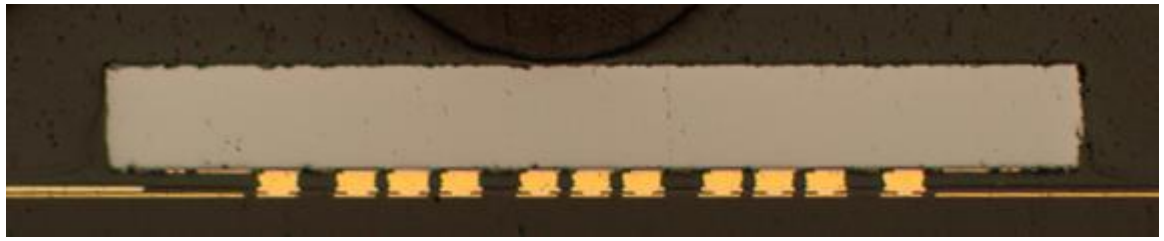
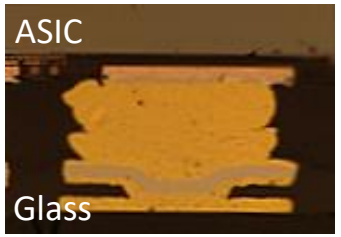
- Results: Thermocompression bonding with +/-2,5µm accuracy



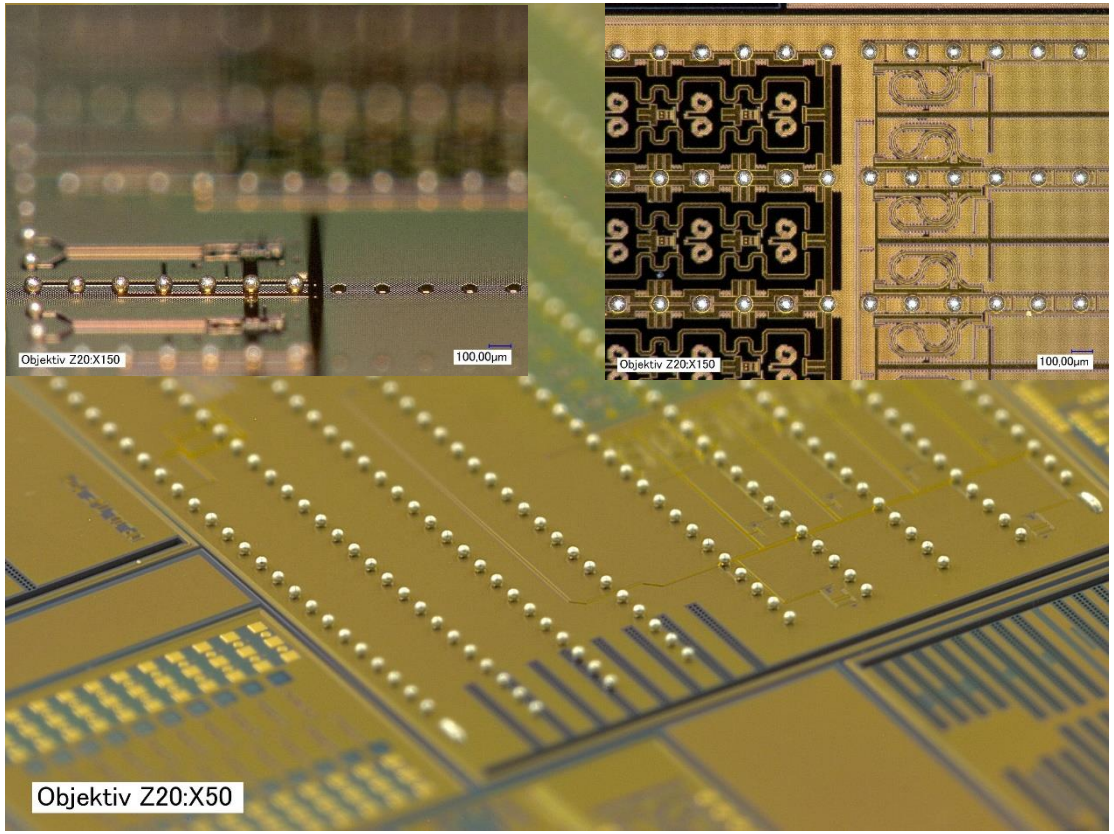


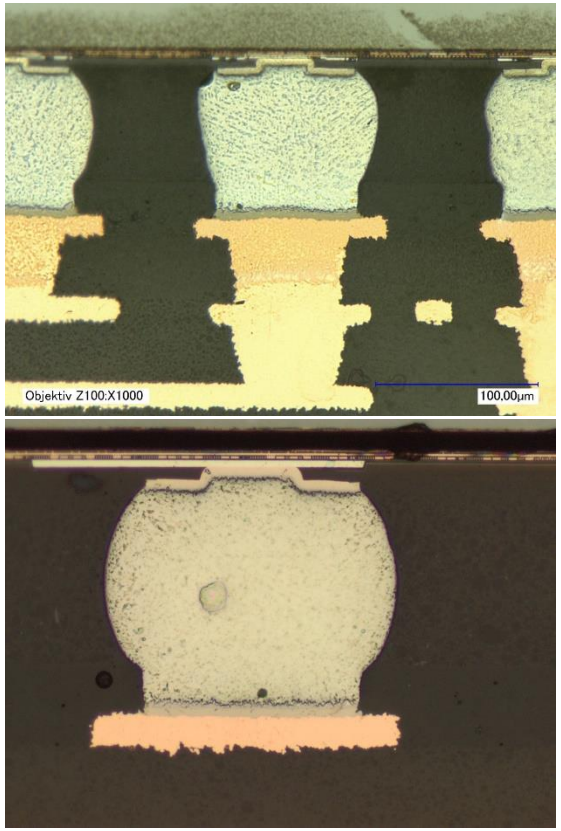


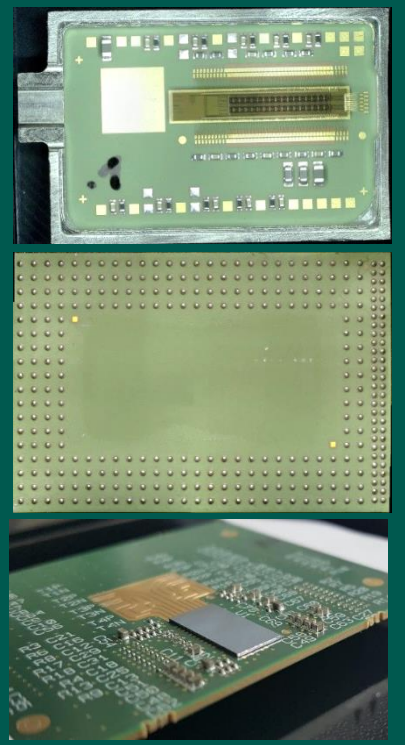
- ✓ Au- studbumping
- ✓ Flip Chip Thermocompression +/-2,5 µm

Flip Chip - Photonics Wafer

- Flip Chip photonics wafer (UBM, solder balling and packaging)
- Electroless plating ENIG, Solder balling SAC305 or low melting alloys



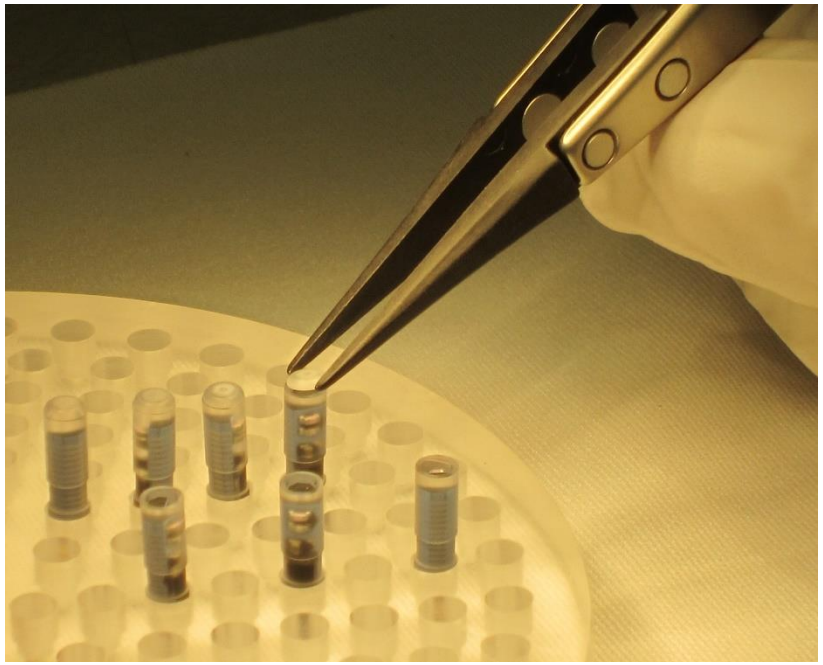


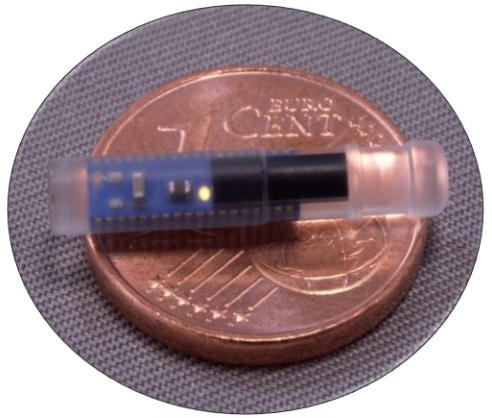


✓ Silicon Photonics Enabling Exascale Data Networks – SPEED

Medical - optical blood sugar sensor

- There is optics in!
- Wafer → UBM → Chip to wafer soldering of **Photodiodes** → system assembly
- Cleaning and biocompatible encapsulation (implantable device)





Industrial - VCSEL based high power laser module

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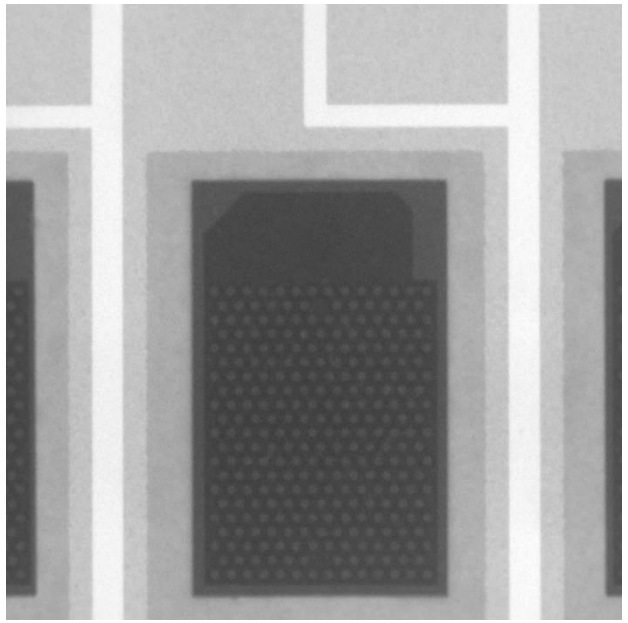
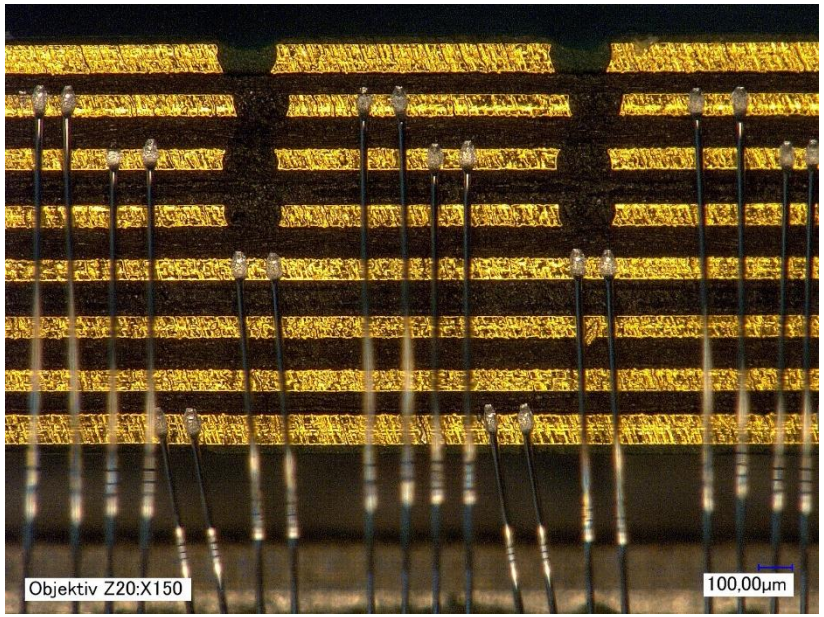
- Void free AuSn soldering of VCSEL
- Speciality: Wire Bonding onto PCB edge (vertical)



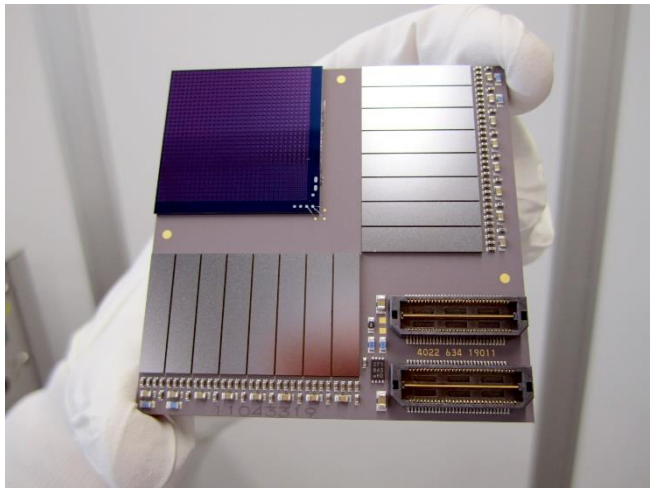
Void free AuSn soldering

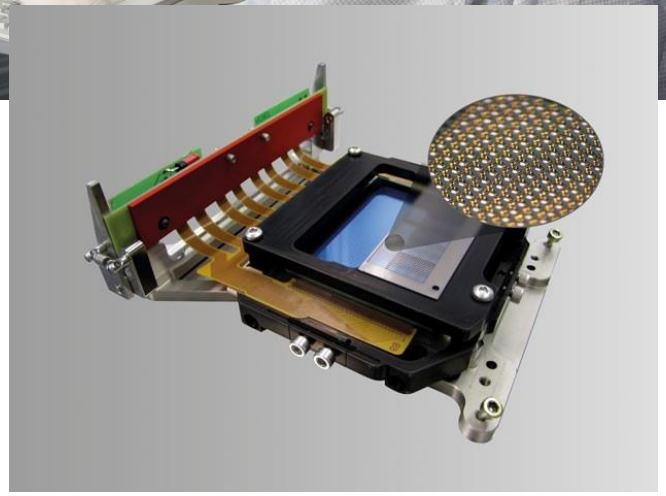


Wire Bonding onto PCB edge

✓ VCSEL Arrays

Semiconductor





- ✓ MEMS Mirror
- ✓ VCSEL light source

Summary

- Optical packaging with high accuracy placement and photonics packaging is available in Europe
- We want to convince customers, that not only development but volume manufacturing of photonics and RF packaging can be in Europe → investments are ongoing
- Next Photonics packaging will be a driver for development of new interconnect technologies
- There needs to be a strong network in Europe that combines it's capabilities
- EPIC association is doing a great job, (AEMtec is part of it)

  "EPIC drives the competitiveness of the European photonics industry"

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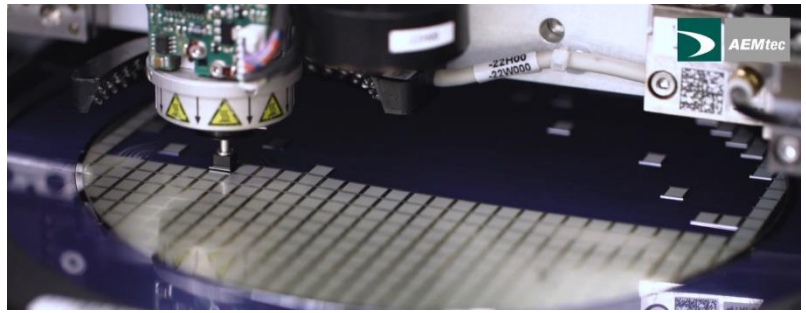
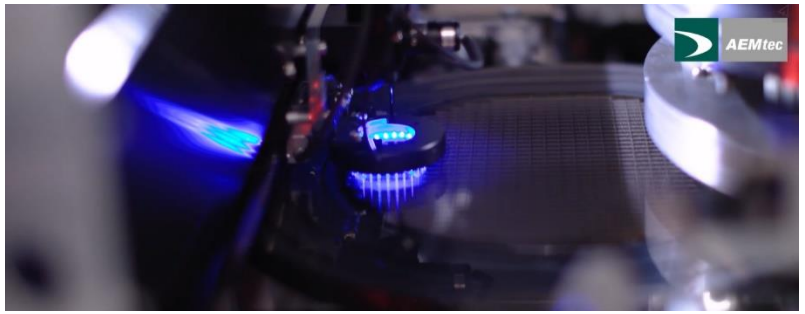
EPIC
European Photonics Industry Consortium

✓ **Photonics Packaging is a chance for Europe**

AEMtec Career





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