NEMo

Network of Excellence on Micro-Optics

Workshop on

Micro-Optics –

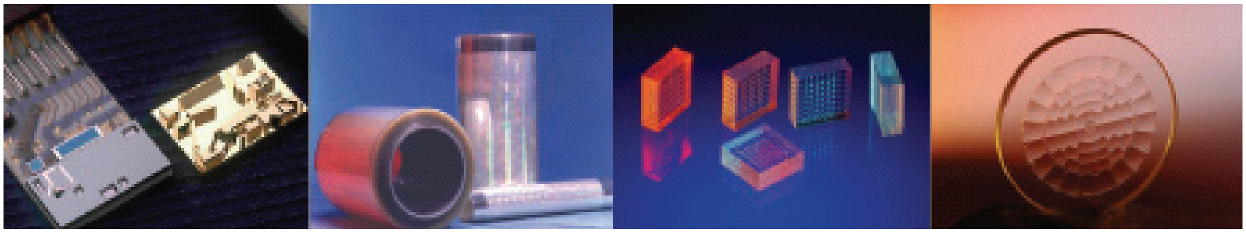
Benefits for Industry

7th April 2006

Photonics Europe

Strasbourg, France

Book of Abstracts



Sixth Framework Programme

Information Society
Technologies

Program

Time	Title	Speaker
9.00	**NEMO - a powerful tool for micro-optics in Europe**	
	NEMO - the European Network on Micro Optics, an overview	Hugo Thienpont (VUB)
	NEMO Industrial User Club (IUC)	Tomasz Nasilowski (VUB)
9.40	**NEMO's service centres 1 - capabilities and services to industry**	
	Centre for modelling of micro-optical components	Norbert Lindlein (FAU)
	Centre for fabrication of micro-optical systems	Jürgen Mohr (FZK)
11.00	**NEMO's service centres 2 - capabilities and services to industry**	
	Centre for measurement of micro optical components and new measurement tools	Malgorzata Kujawinska (MWUT)
	Centre for assembly & packaging of micro optics	Peter van Daele (UG)
	Centre for reliability & standardization issues	Oliver Kraft (FZK)
13.15	**Food Chain in Micro Optics 1: Fibre sensors**	
	Fibre sensors for strain & temperature measurement	Tomasz Nasilowski (VUB)
	Simulation, Fabrication and Characterization of new fibres for sensor applications	Waclaw Urbanczyk (WRUT)
14.10	**Food Chain in Micro Optics 2: Micro Lenses**	
	Use and advantage of micro lenses in imaging applications	Jacques Duparre (IOF)
	Simulation, fabrication and characterization of micro lenses and lens arrays	Heidi Ottevaere (VUB)
15.30	**Application fields of micro optics**	
	Optical interconnects at the PCB level	Peter van Daele (UG)
	Diffractive and sub-wavelength micro-optics for light management	Martin Salt (HEPT)
	Infrared micro optics	Peter Muys (LROE)
	Emerging applications in Micro Optics	Olivier Parriaux (CNRS-TSI)
16.50	**Summary & conclusions IUC**	Tomasz Nasilowski (VUB)

Assembly and packaging of micro optical systems

Peter Van Daele, Ghent University, INTEC Dept – TFCG-Microsystems
Technologiepark bldg 914A, B-9052 Zwijnaarde, Belgium
e-mail: peter.vandaele@intec.ugent.be

Pentti Karioja, VTT, Finland
Ulrich Gengenbach, FZK, Germany

Packaging of optical and opto-electronic components very often makes up the largest portion of the cost of the final component. This is not only caused by the fact that alignment issues are much more critical when playing with optical inputs and outputs in addition to electrical input and output, but also due to the lack of standardization. In electrical packaging, much of the packages and the processes to be used is standardized and is identical, no matter what functionality the electrical component has. This is not the case for optical or opto-electronic components, where packaging is largely determined by the functionality. As an example one can take the case of fiber-pigtailing a laserdiode: in the case of a VCSEL, the process, technology, package,… is completely different from the case for an edge-emitting laserdiode.

Just as in the case of the electronic industry, several levels are defined within the optoelectronic assembly and packaging world. The IPC identifies 4 levels in its roadmap "Optoelectronic Assembly and Packaging Technology":

- Level 0 (uncased device): Lasers, LEDs, photodiodes, fibres, micro-lenses, waveguide chips, etc. are basic devices needed for optoelectronic modules and systems.
- Level 1 (packaged device): When devices have some features added, such as, a laserdiode is encapsulated in a hermetic TO can or a fibre is equipped with a micro-lens or ferrule, we are dealing with packaged devices. At this level, issues such as alignment and sealing are envisaged. Solutions might be based on existing technologies, such as, soldering of metallised micro-optical components.
- Level 2 (modules): Module level is reached when several functional devices or components are integrated in a single package. Good examples of optoelectronic modules are fibre optic transmitters, wavelength multiplexers/ demultiplexers, splitters and couplers,…. This level of assembly requires a much more robust level of assembly (accuracy about 1 to 2 um) and a different level of sealing, as the facets of optical waveguides should be protected. New tools for handling these micro-optical sub-assemblies and mounting technologies, probably based on Flip-Chip technologies should be deployed or adapted.
- Level 3 (board-level): The final interface of the optical module towards the outer world will, in most cases, be an optical fibre.

The presentation will also present the capabilities of the NEMO NoE in these different levels of packaging and integration.

Centre for assembly & packaging of micro optics

Peter Van Daele (Univ. Gent, B)
Pentti Karioja (VTT, SF)

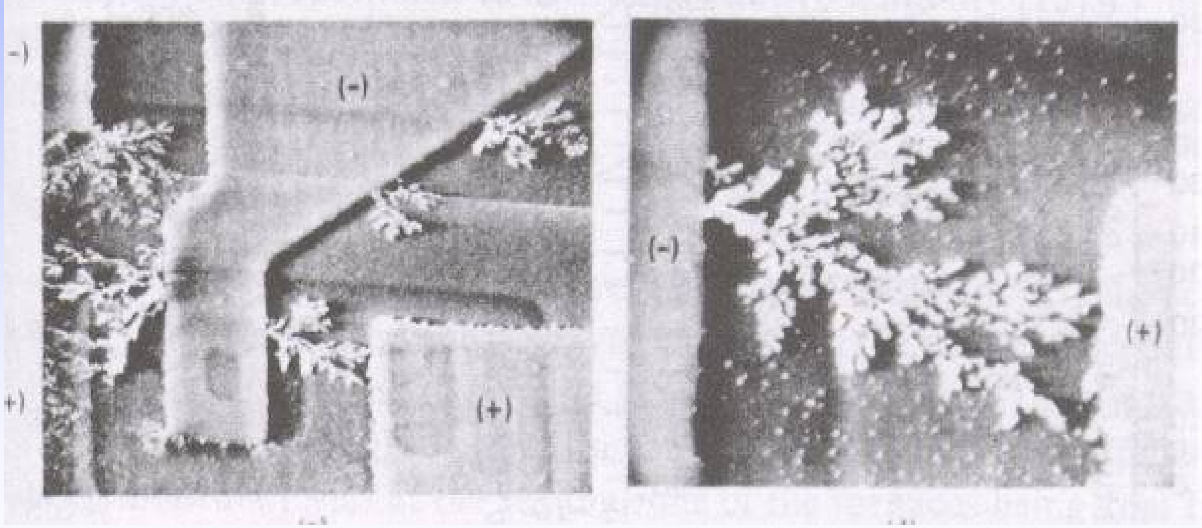
Overview

- Introduction
- Levels of Packaging
- Processes
- NEMO Capabilities
- Conclusions

Introduction

Processing yields naked chips

- difficult to characterise, handle and use
- subject to environmental influences



Packaging is the car around the engine

Introduction

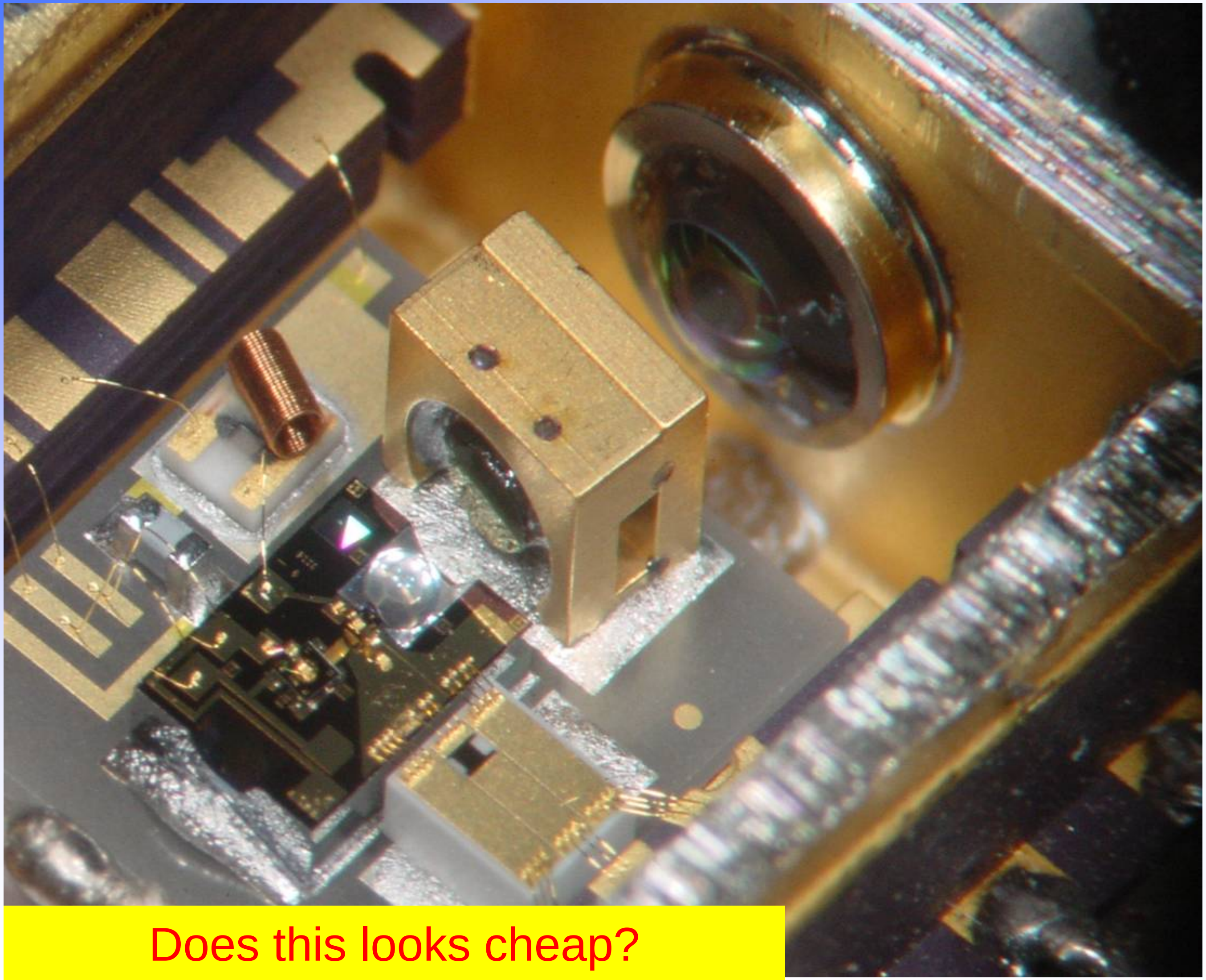
- Packaging electronic components
  - protect against environmental influences (passivation)
  - only electrical contacts
  - no accurate alignment needed
  - thermal housekeeping

- Packaging optical & optoelectronic components
  - Optical coatings
  - optical “contacts” : fibre alignment & micro-optics
  - temperature control

extreme accurate alignment needed

up to 80% or 90% of the total cost!

Introduction



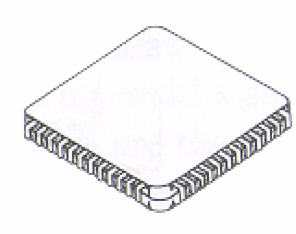
Does this looks cheap?

Introduction

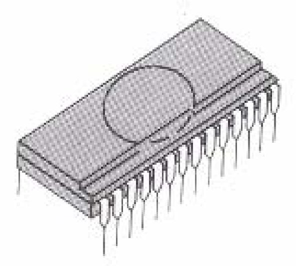
- Packaging electronic components

To cope with large I/O:

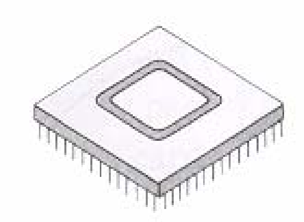
- DIP: Dual-in-Line Package
- PGA: Pin Grid Array
- SOP: Small Outline Package
- QFP: Quad Flat Package
- LCC: Leadless Chip Carrier



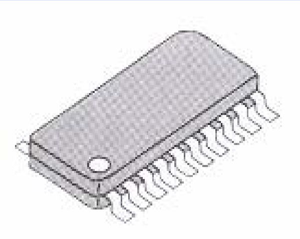
LCC



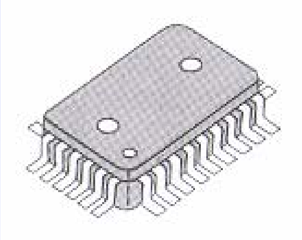
DIP



PGA



SOP



QFP

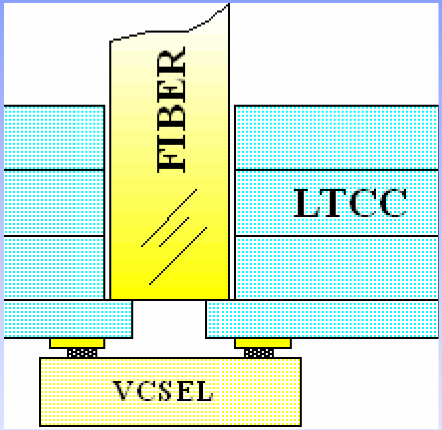
Functionality has limited influence on packaging

Introduction

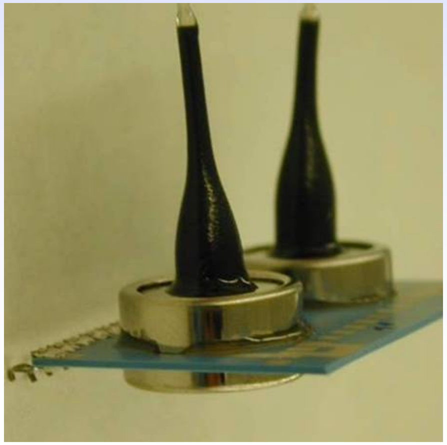
- Packaging optical & optoelectronic components

Functionality determines packaging

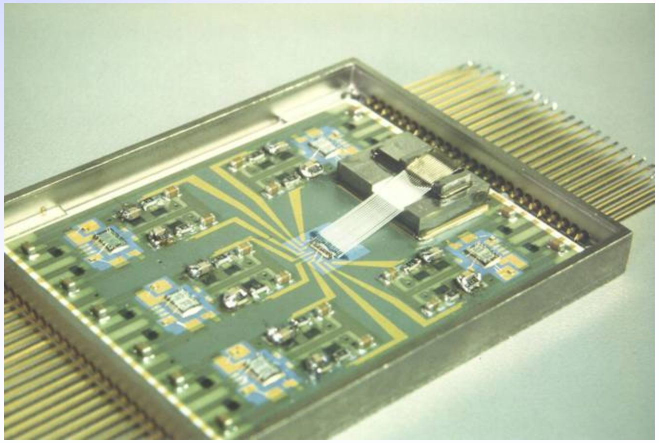
Fiber pigtailing



VCSEL



Edge emitter



Overview

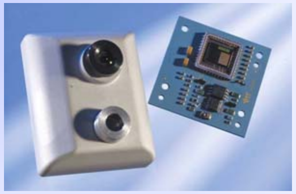
- Introduction
- Levels of Packaging
- Processes
- NEMO Capabilities
- Conclusions

Levels of packaging

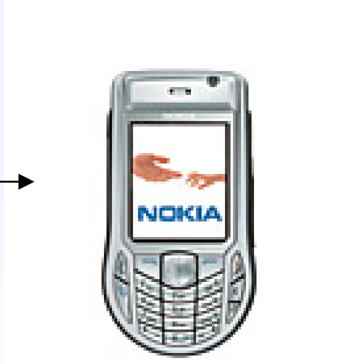
1. **Device**
   naked chip, tested or not tested

2. **Component**
   assembled chip and possibly locally encapsulated

3. **Module**
   chips, components integrated into a functional unit

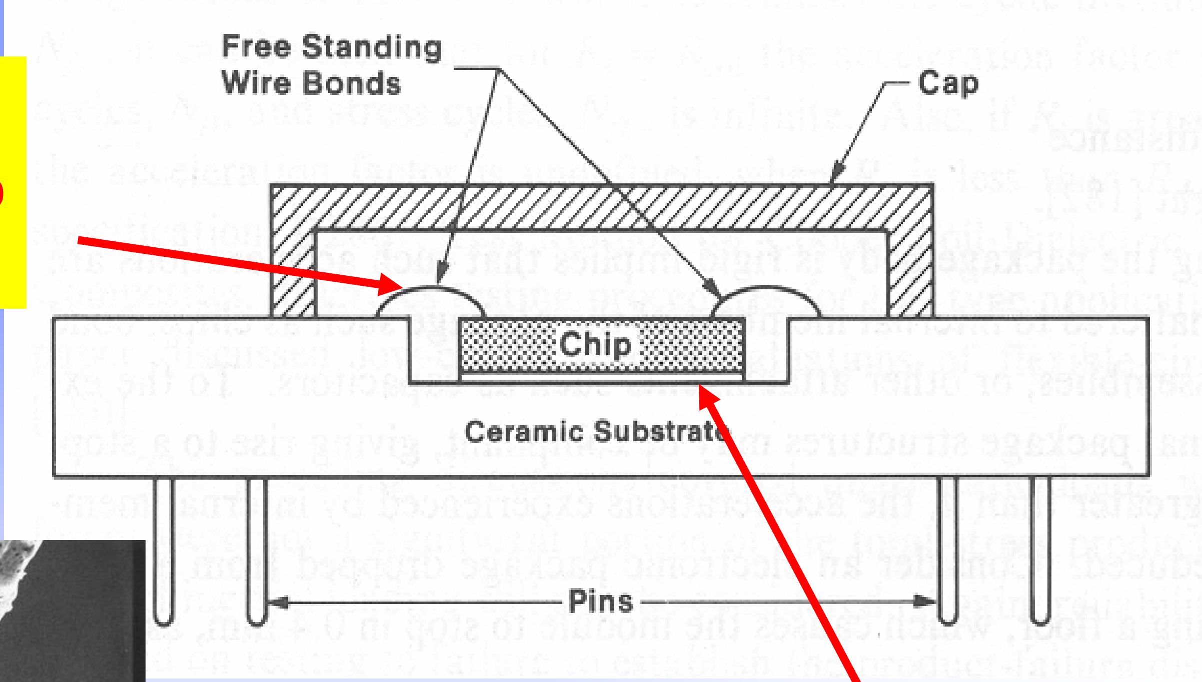


4. **System**
   modules integrated into a functional unit



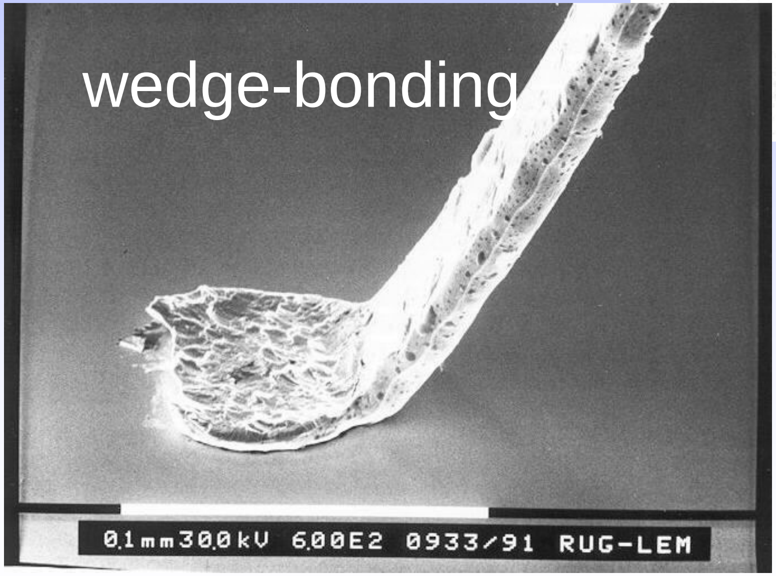
Processes

- Wire bonding:
  - electrical contacts to package pins



- Die bonding:
  - to fix Chips
  - electrical contact
  - alignment

wedge-bonding

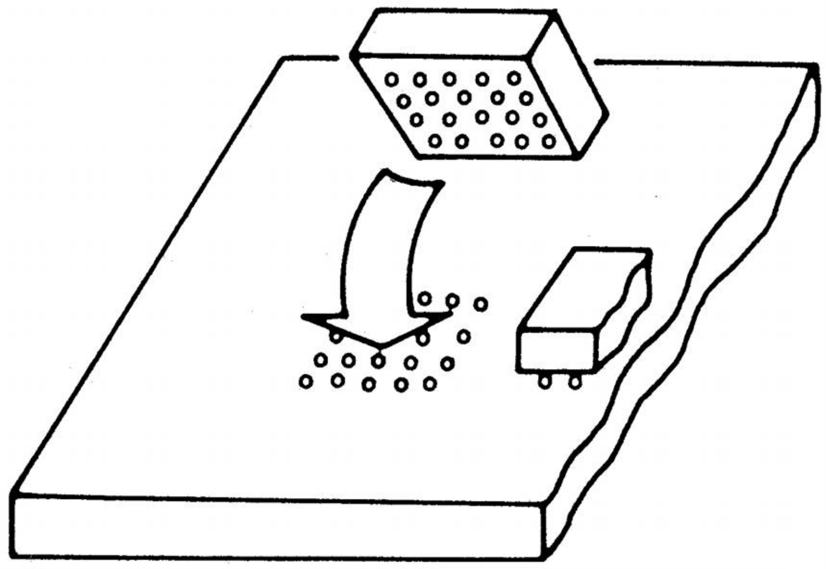


Processes

Out of requirement to cope with large I/O:

- all contacts on the outer edge
  - smaller chips ✍ smaller surface ✍ less space
- demand for increased I/O

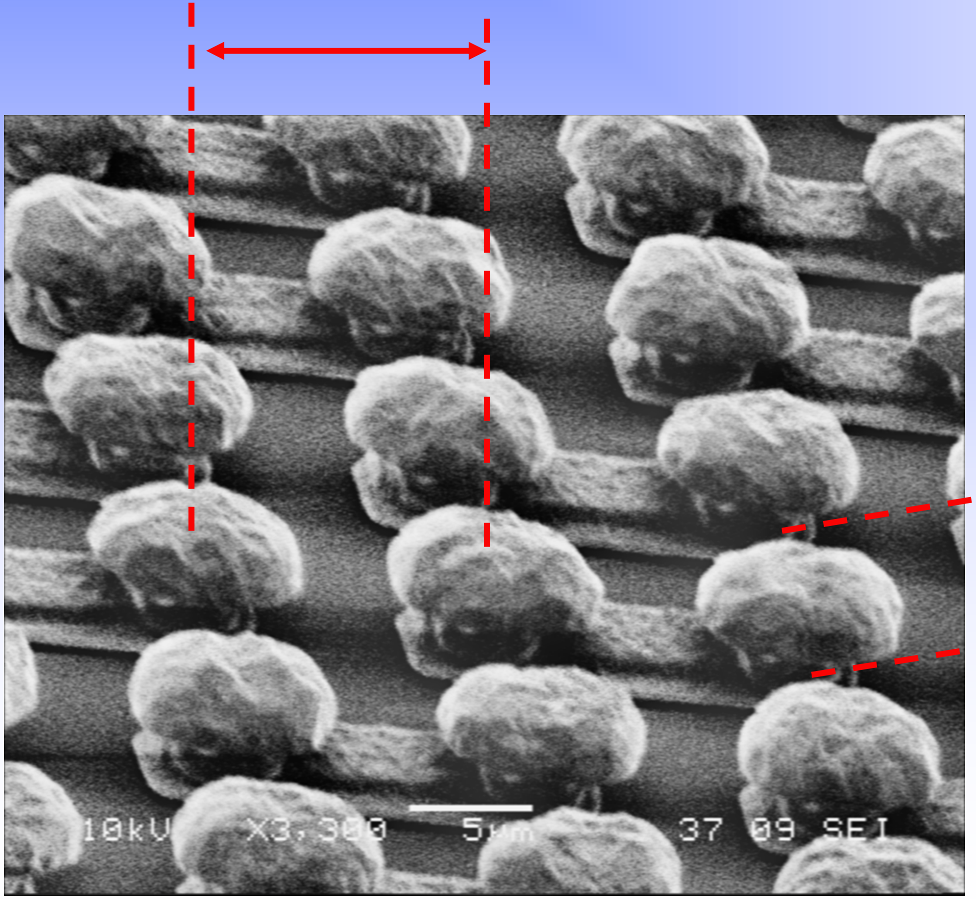
✍ Flip-Chip technology

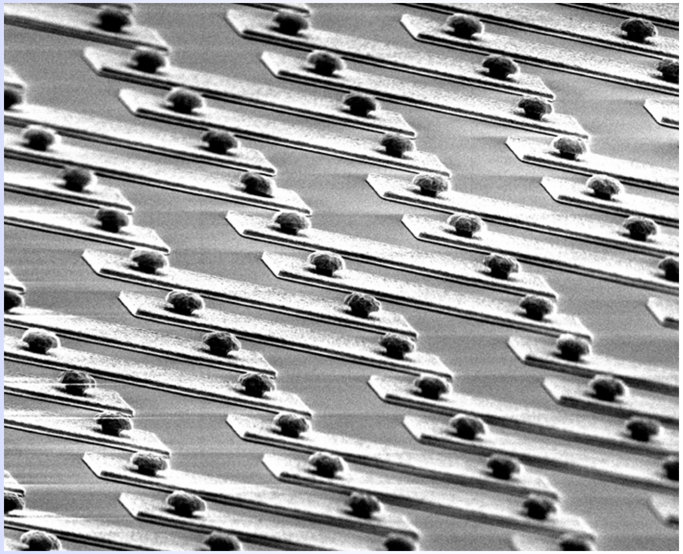


Processes

High density Au Flip-Chip

Pitch 12.5 µm

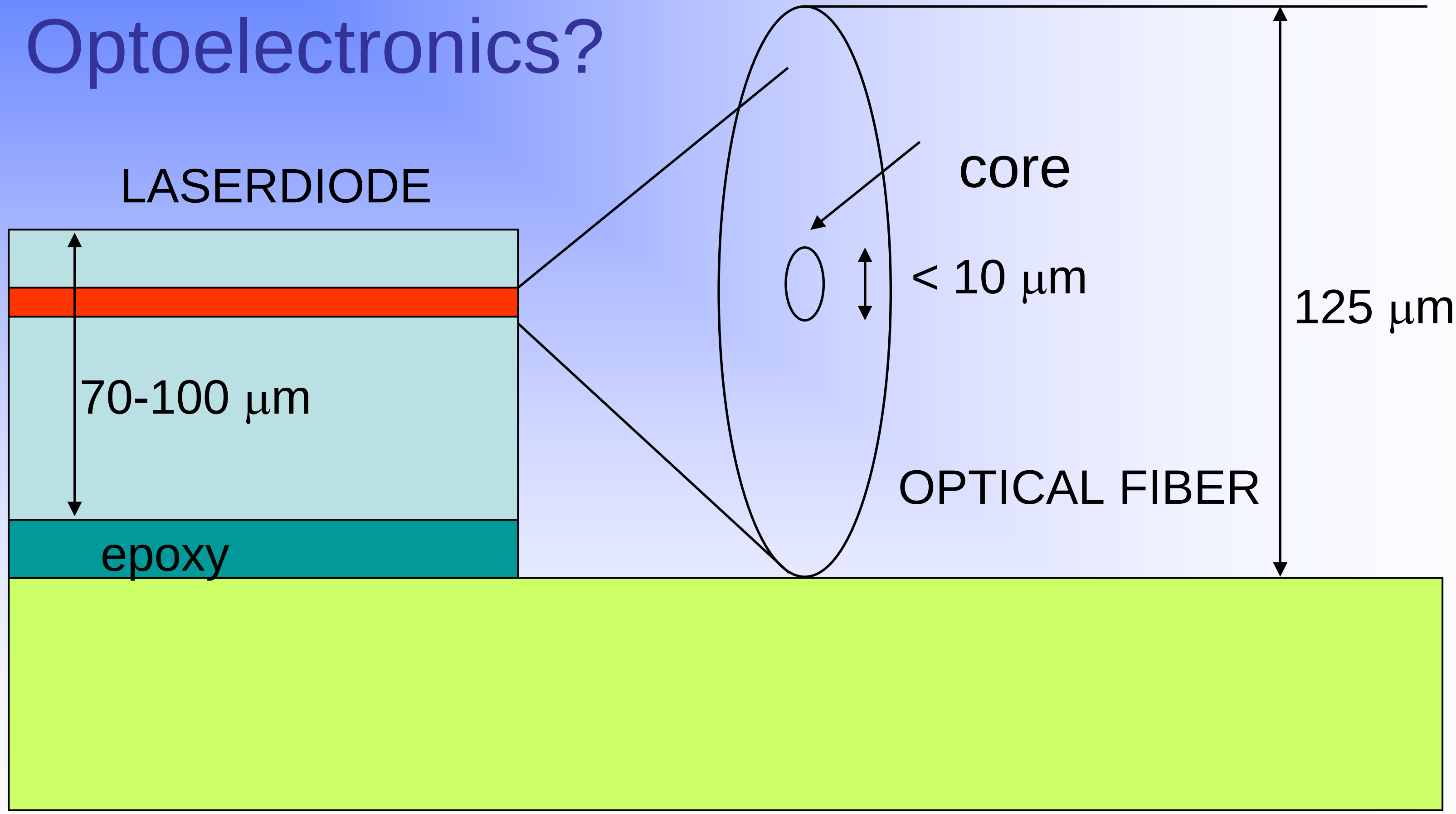




Diameter 6.25 µm

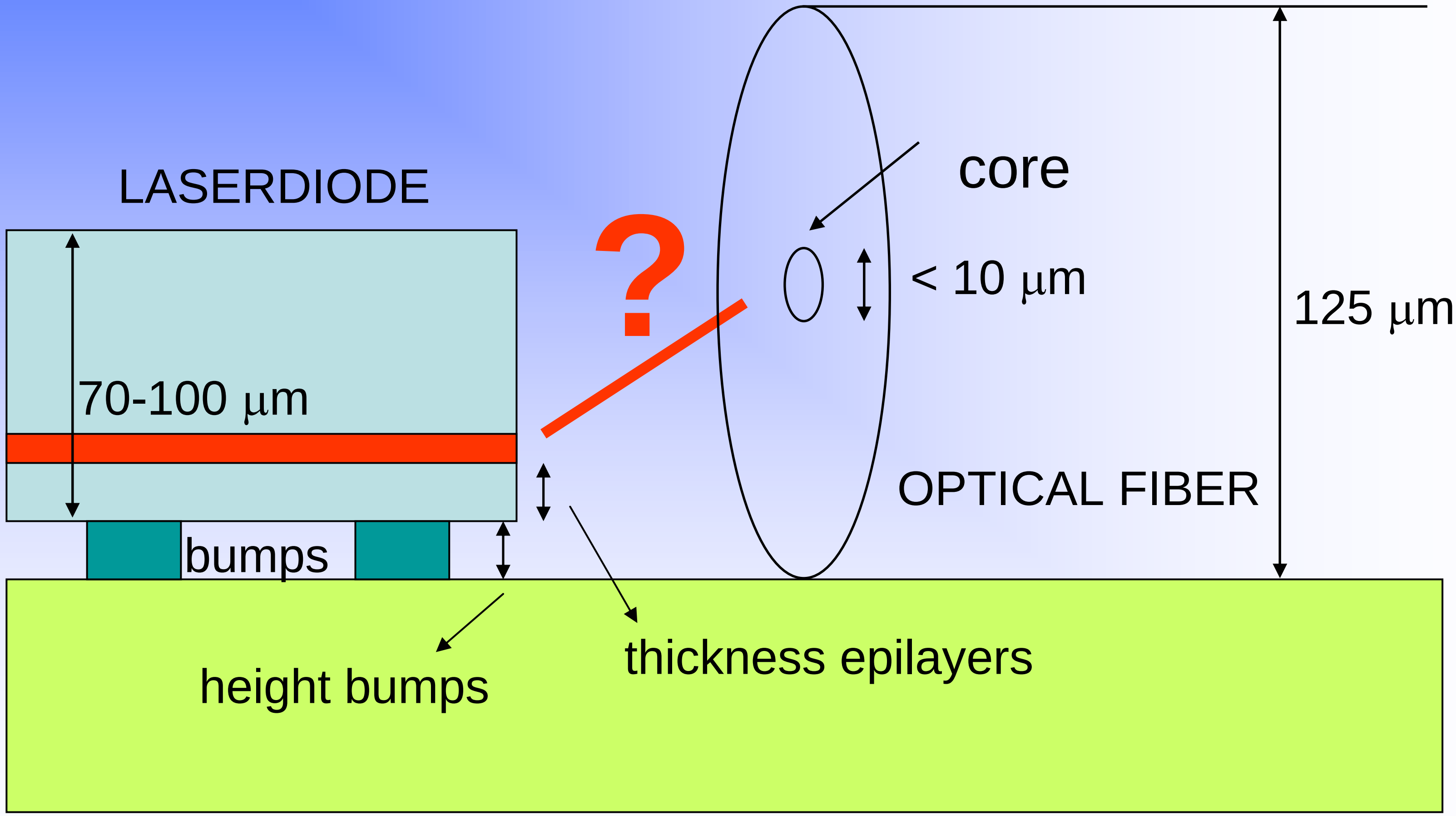
Processes

- What can Flip-Chip do for Optoelectronics?



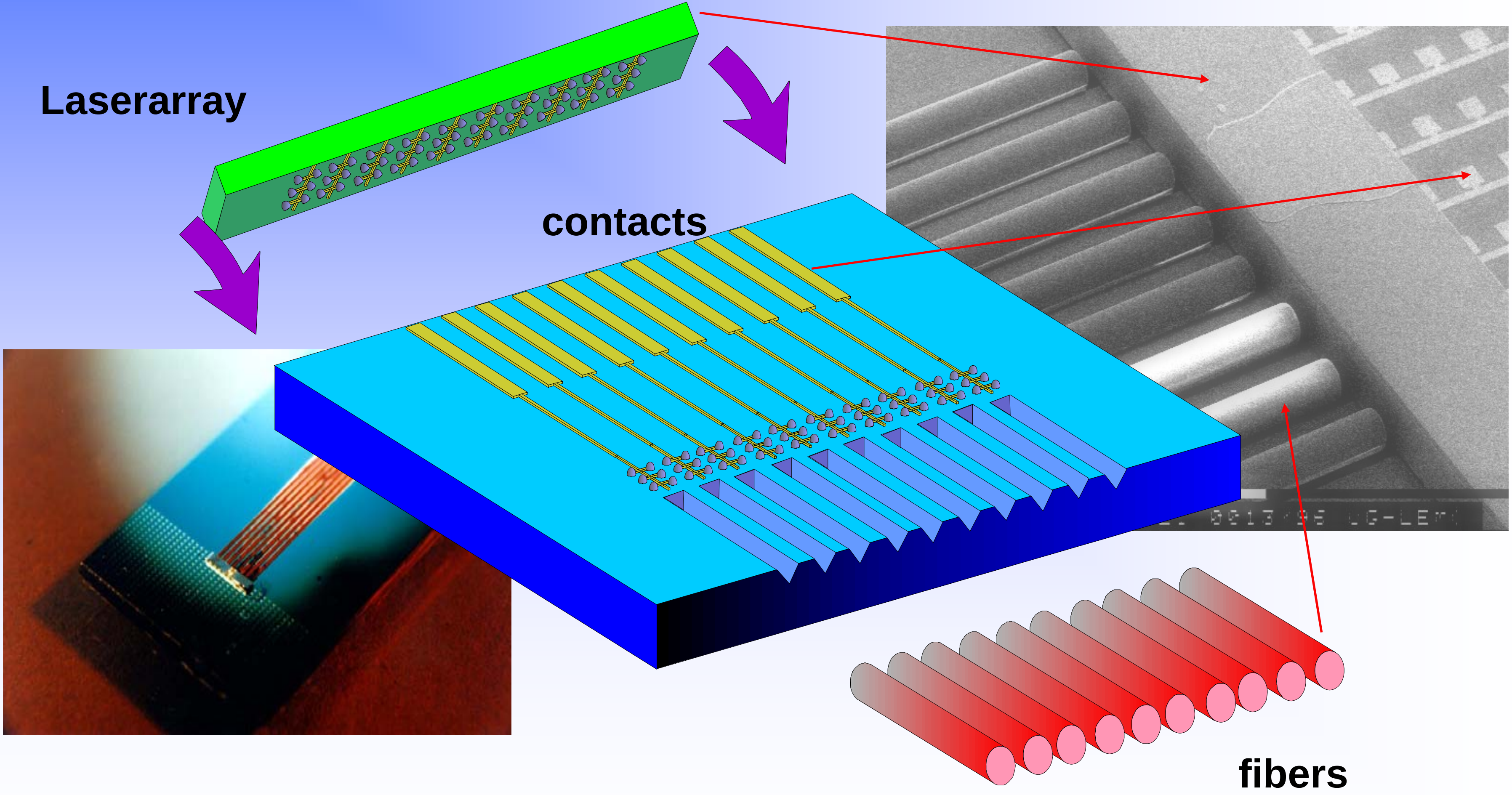
Processes

- Flip-Chip controls height of active layer



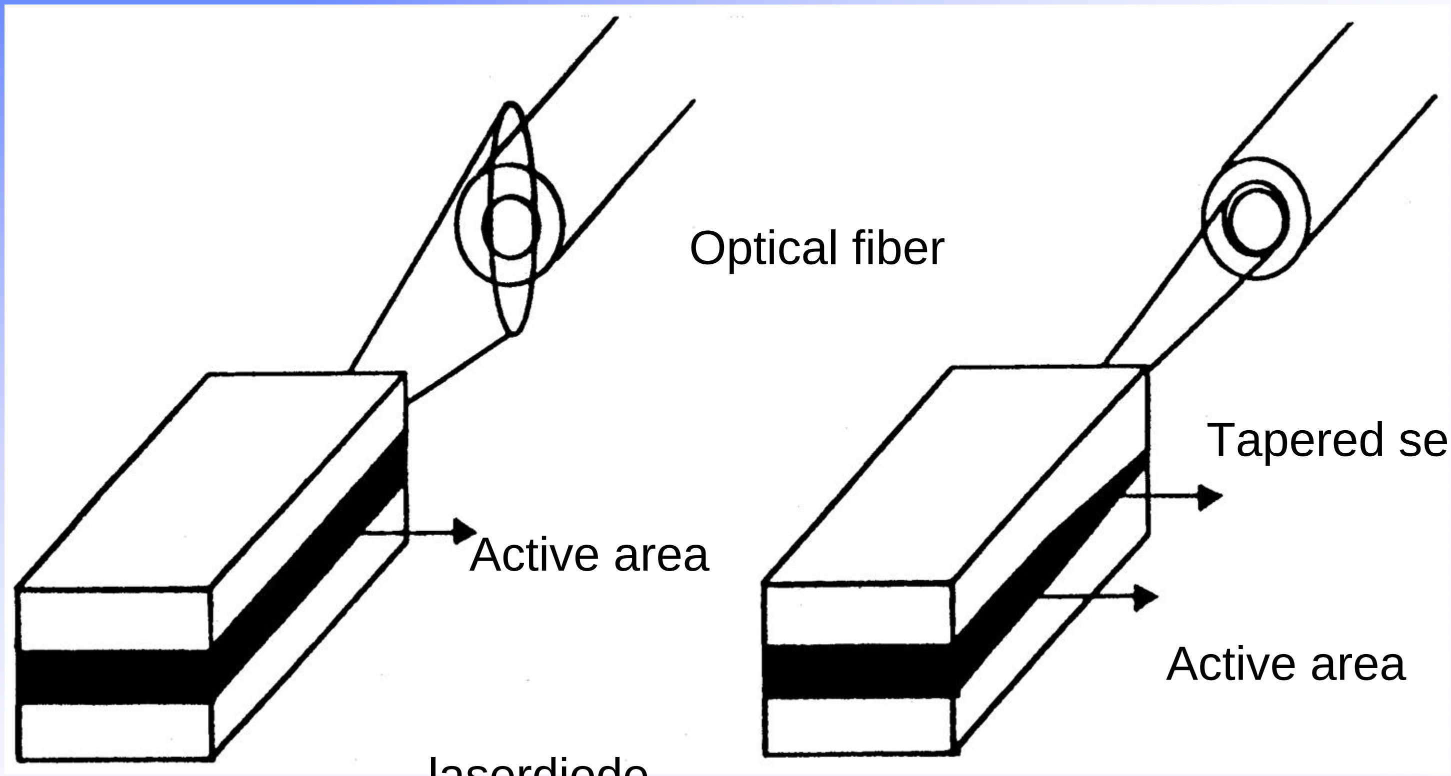
Processes

Coupling flip-chip mounted edge-emitting laser-arrays to optical fibers



Processes

Mode mismatch



Optical fiber

Active area

laserdiode

Tapered section

Active area

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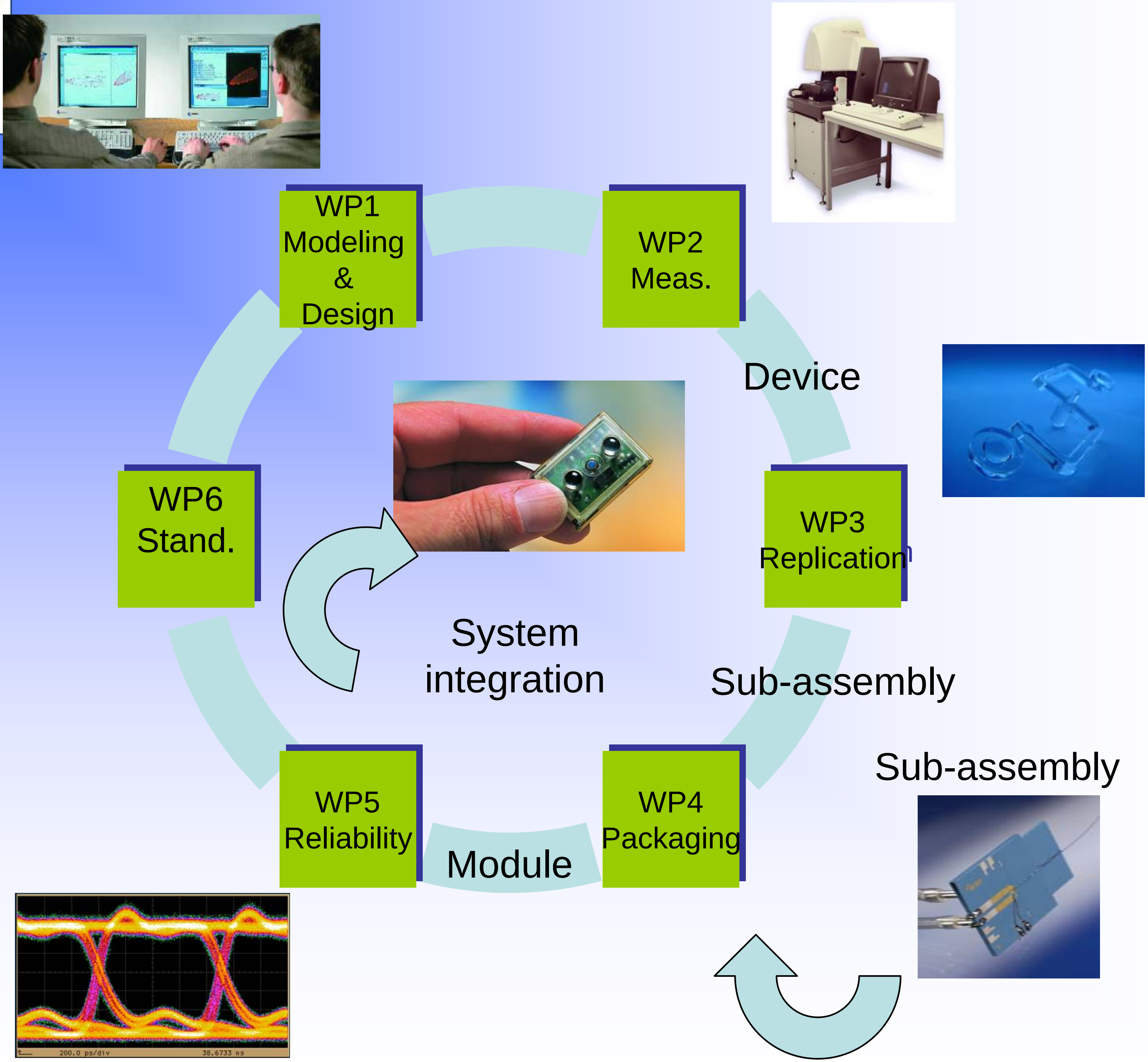

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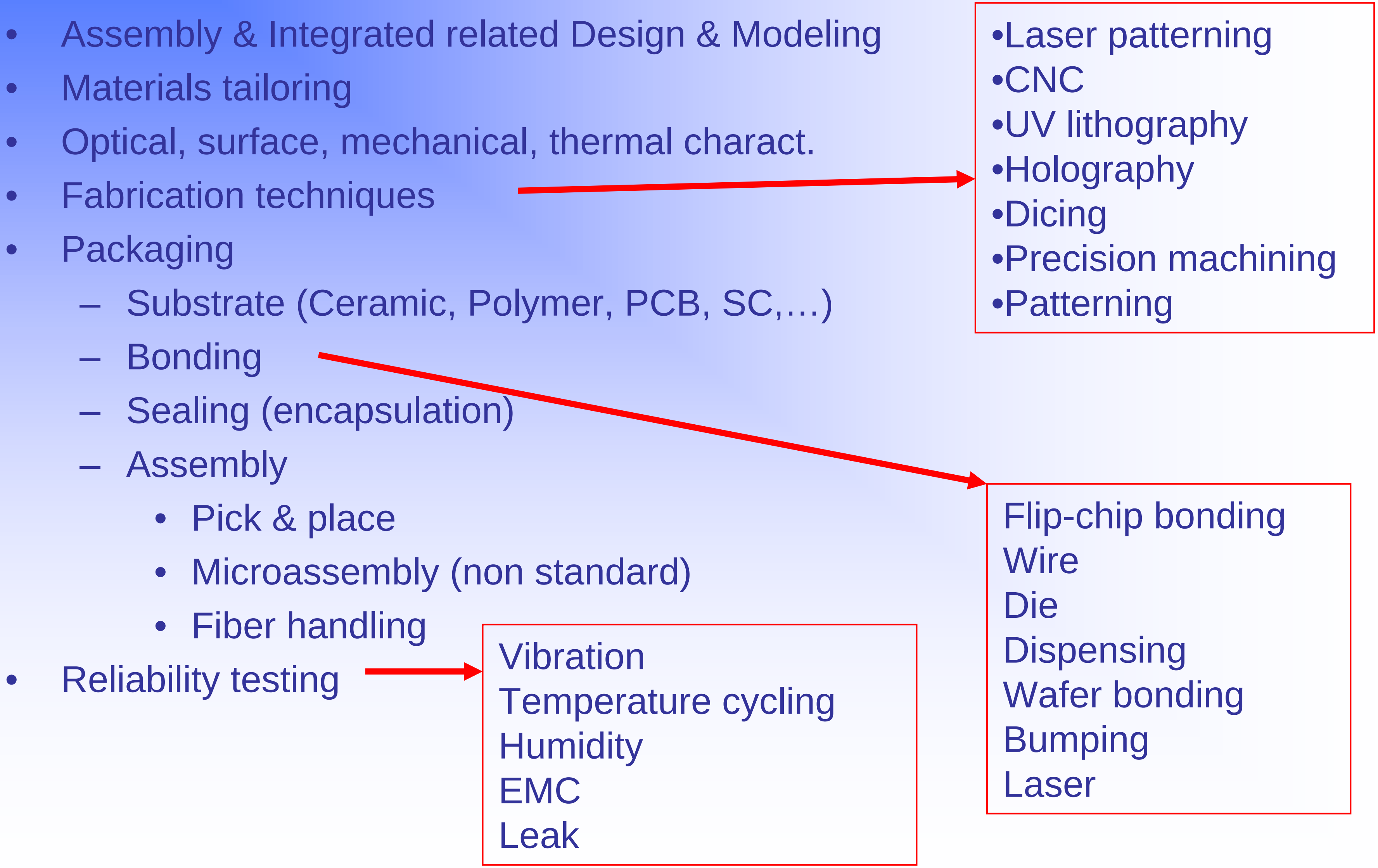
NEMO Capabilities



- Assembly & Integrated related Design & Modeling
- Materials tailoring
- Optical, surface, mechanical, thermal charact.
- Fabrication techniques
- Packaging
  - Substrate (Ceramic, Polymer, PCB, SC,…)
  - Bonding
  - Sealing (encapsulation)
  - Assembly
    - Pick & place
    - Microassembly (non standard)
    - Fiber handling
- Reliability testing

•Laser patterning
•CNC
•UV lithography
•Holography
•Dicing
•Precision machining
•Patterning

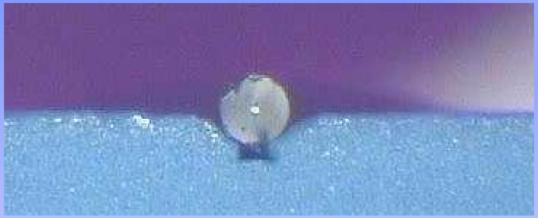
Flip-chip bonding
Wire
Die
Dispensing
Wafer bonding
Bumping
Laser

Vibration
Temperature cycling
Humidity
EMC
Leak

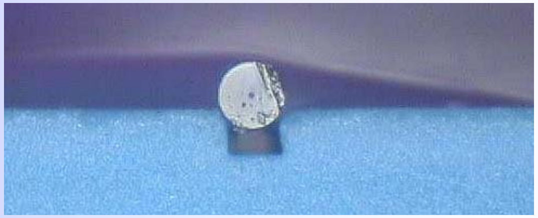
Alignment structures

- Grooves tooled by standard via punching and lamination process

  Fiber alignment accuracy ~±3 µm (vertical to substrate, horizontal to alignment marks)



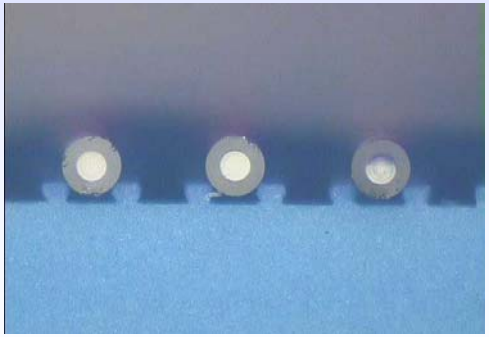
V-groove with flexible foils, (SM fiber)



Rectangular groove with steel foils, (SM fiber)

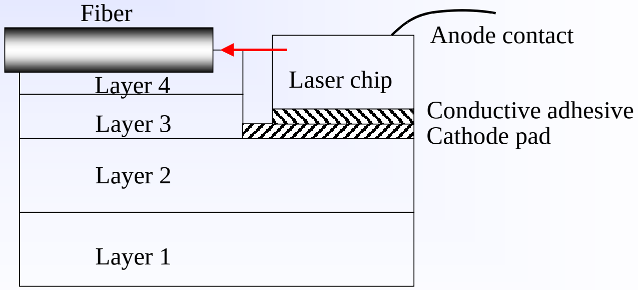
- Grooves made by photolithography using photo-definable paste materials

  Fiber alignment accuracy <±3 µm (vertical to substrate, horizontal to alignment marks)

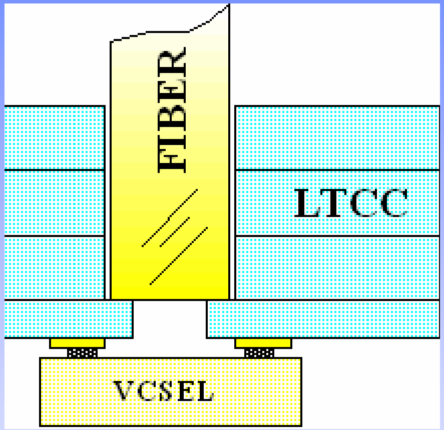


62.5/125 µm fibers, vertical tolerance ±1.6 µm

Application:



Fiber pigtailing

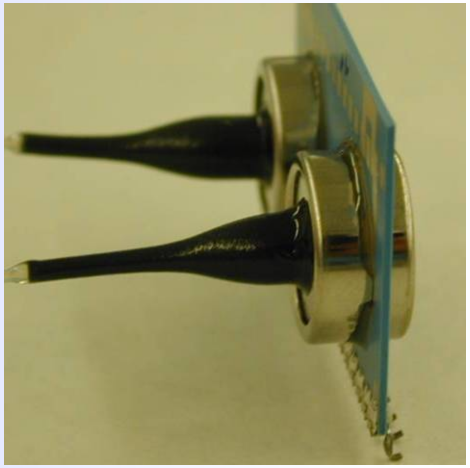


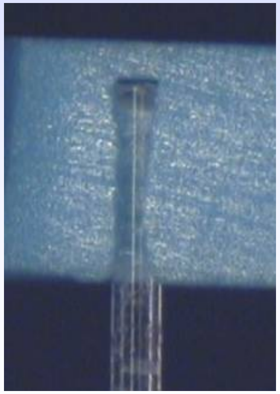
Passive optical alignment

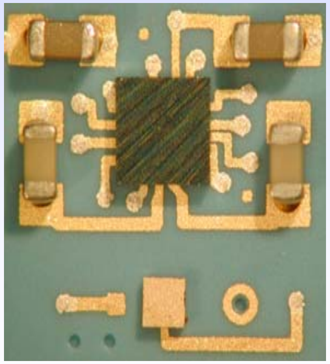
Multimode fiber

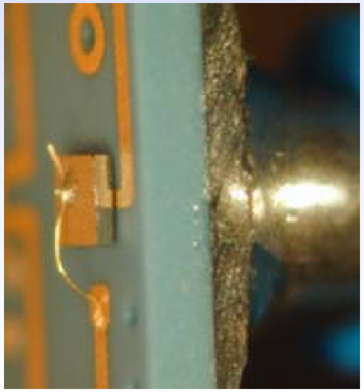
VCSEL / Photodiode

Integrated electronics







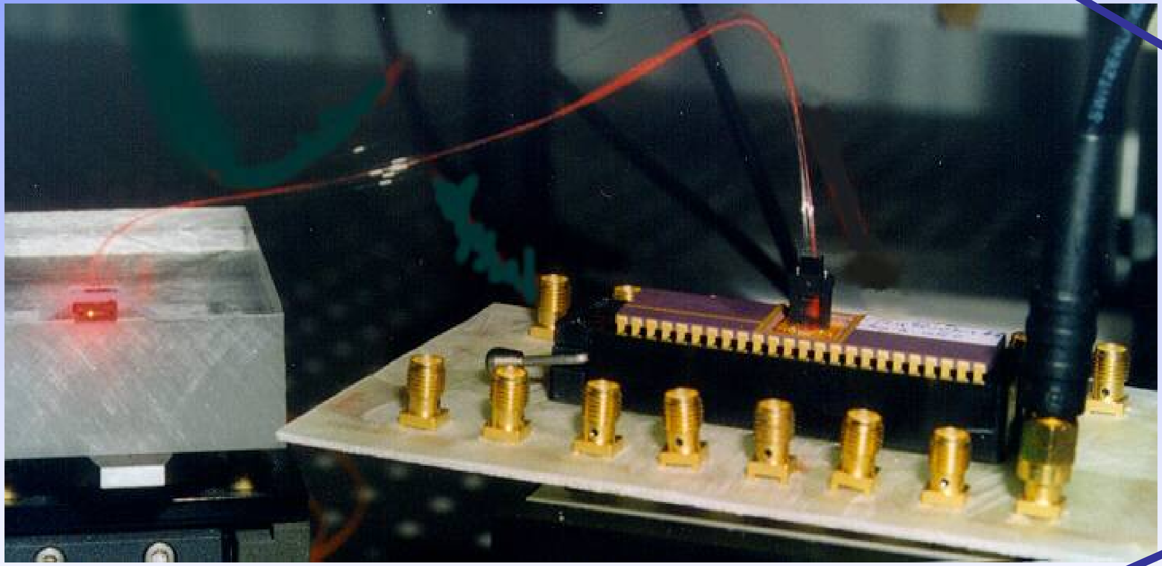


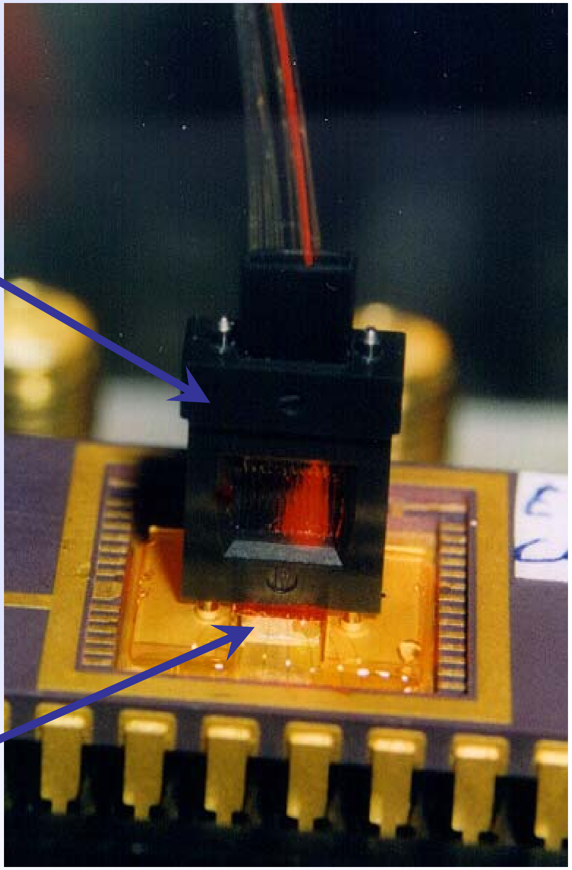
Fiber pigtailing

- *Vertical emitting laserdiodes*

Removable MT-like connector

(8 fibers, pitch 250 μm)

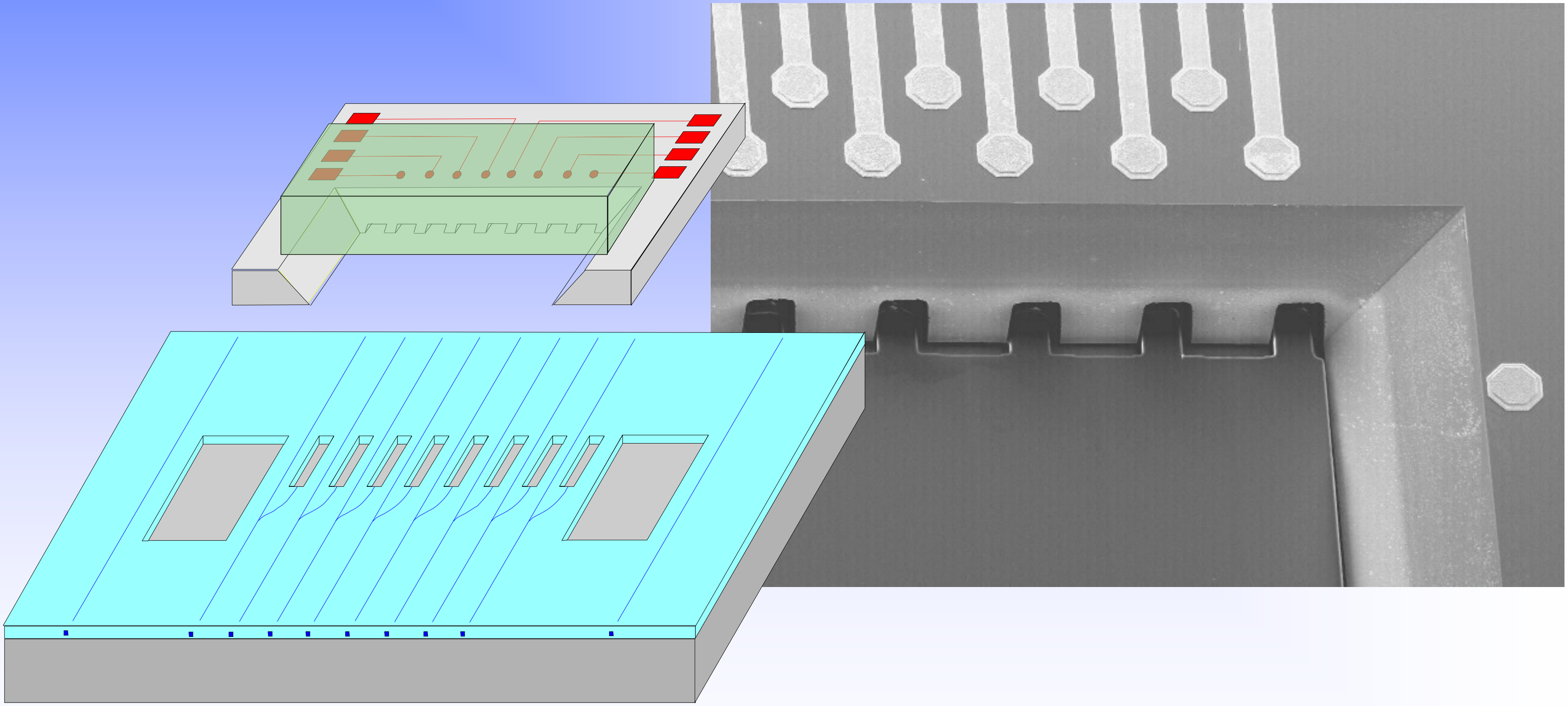




1x8 VCSEL-array (λ = 670 nm)

Assembly

- *Coupling to optical layer in PCB’s*



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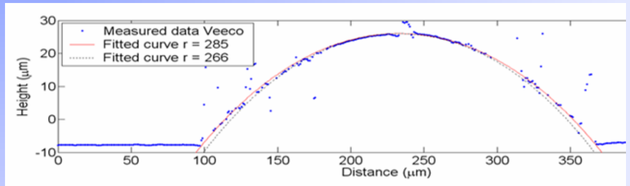
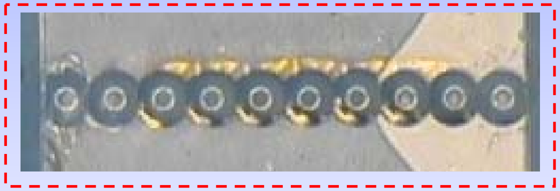
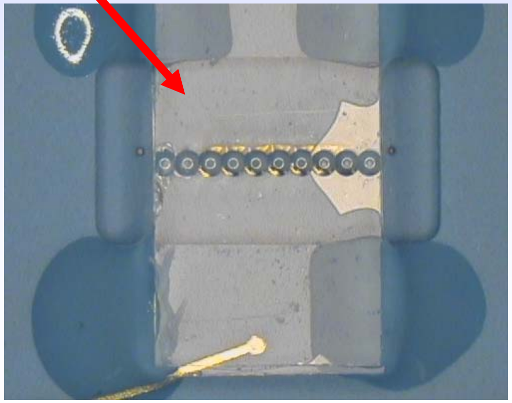
ASSEMBLY OF MICROLENS ARRAY ONTO AN LTCC-BASED VCSEL-ARRAY TRANSMITTER

1. Two microlens arrays stacked together by gluing the substrate back-sides with index-matched adhesive
   => double-sided microlens array
2. Double-sided microlens array glued to LTCC substrate

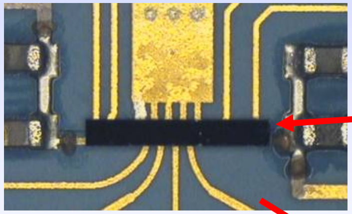


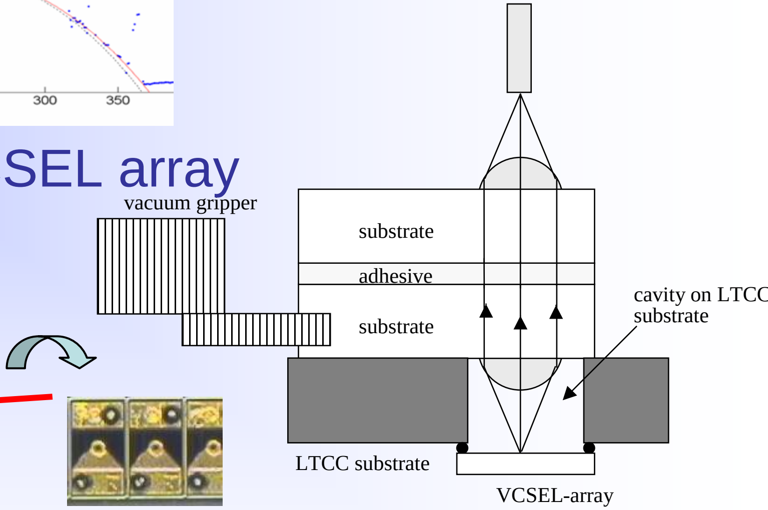
Stacked micro-lens arrays

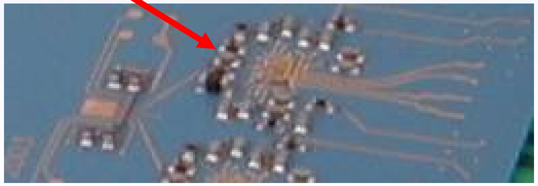




Flip-chipped VCSEL array







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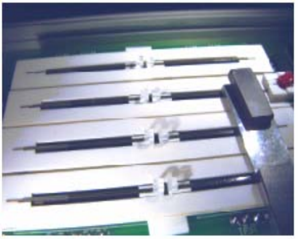
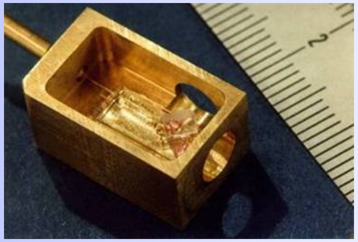
Assembly

Assembly of microoptical systems

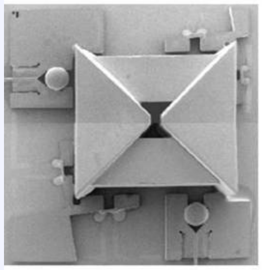
Examples of hybrid microoptical devices



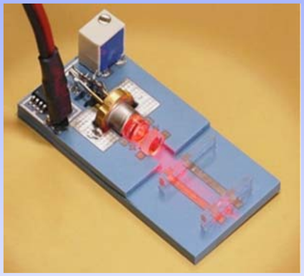
Fiber switch
piezosysteme
jena



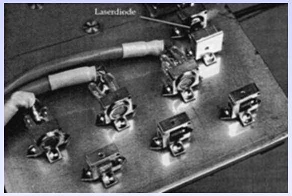
Microoptical duplexer



Heterodyn receiver

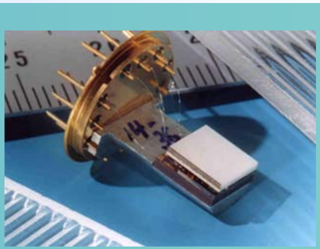


Collimator
FhG IOF, Jena



Optical-SMD
EPFL Lausanne

all by Forschungszentrum
Karlsruhe -IMT-



Proximity sensor
(first laboratory sample)

Bundesministerium
für Bildung
und Forschung

µFEMOS

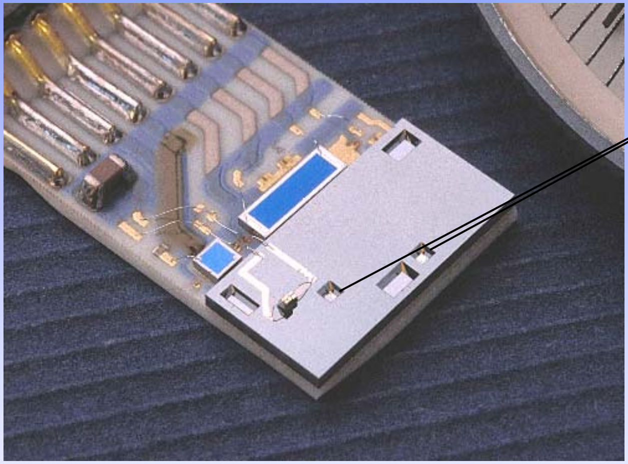
Task: Transfer of laboratory fabrication to semi- or fully automatic series fabrication

Assembly

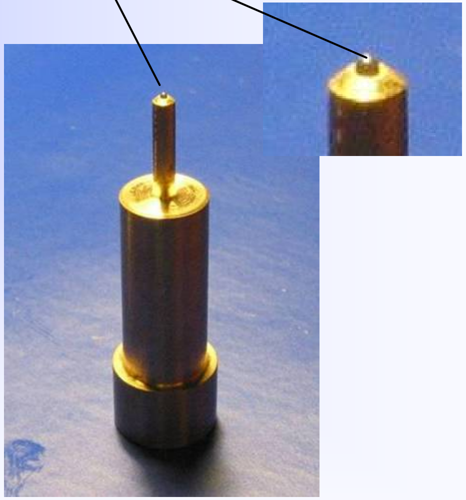
Assembly of microoptical systems

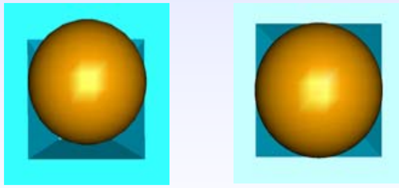
Passive assembly

Assembly of centering balls



Etch grooves for centering balls (ø 650 µm)





Passive alignment:
Selfalignment of ball in etch groove

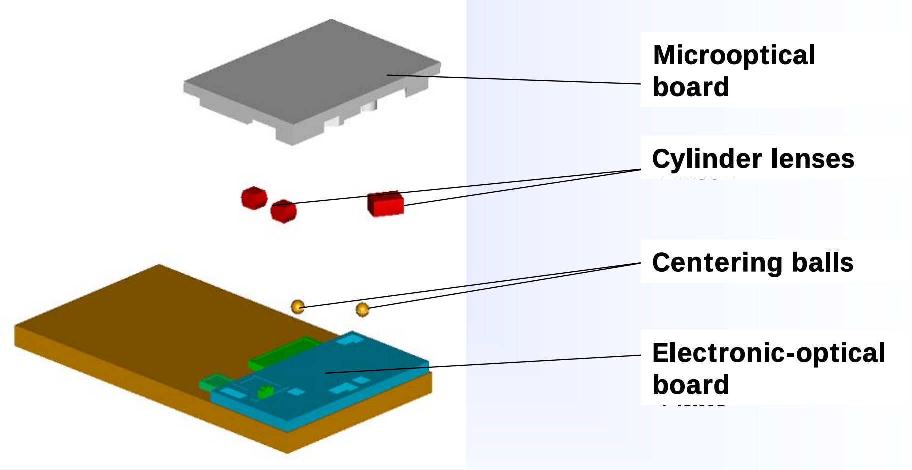
Assembly

Assembly concept

Assembly concept	**Passive alignment of components to be mounted on well defined and precisely fabricated stop faces**

Assembly tasks:

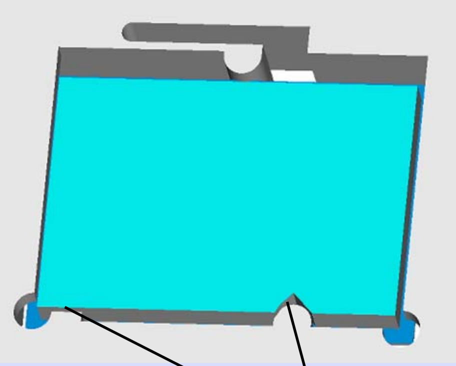
- **Insertion of cylinder lenses into a microoptical board**
- **Mounting of centering balls onto an electronic-optical board**
- **Assembly of microoptical and electronic-optical board**

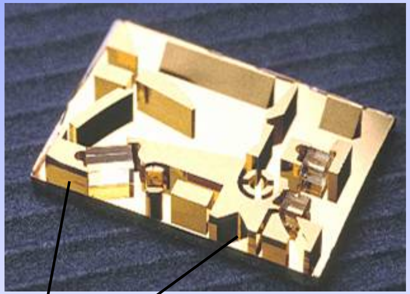


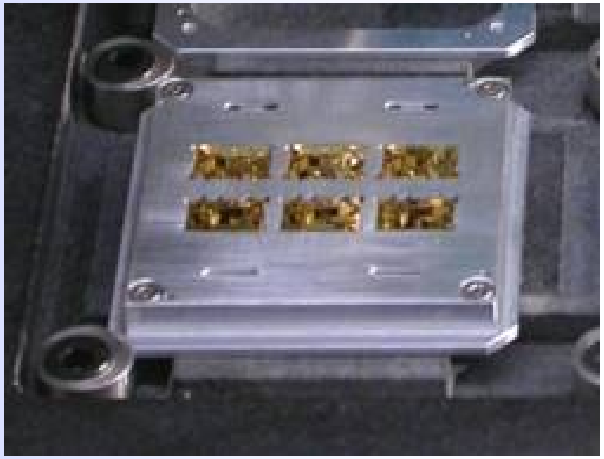
Assembly

Feeding of components

Example: Tray for micro optical board

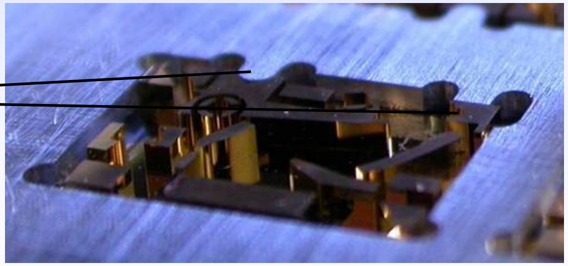






Tray with six
microoptical boards

Integration of alignment features
into design of microoptical board



Design for assembly!

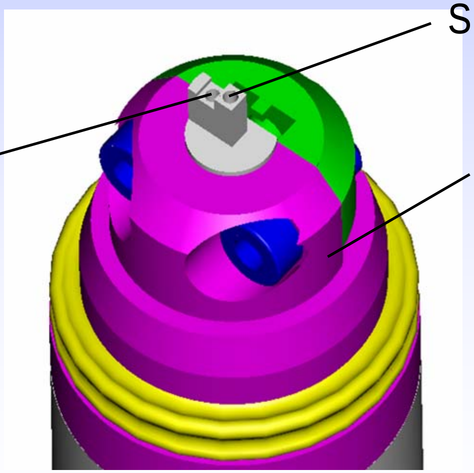
Equipment

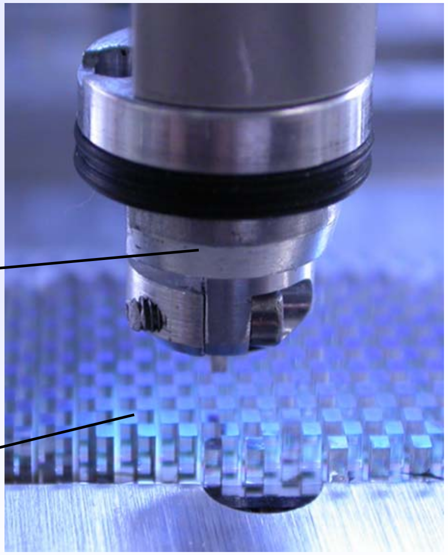
- **Modular, high precision assembly machine MIMOSE**
  - Cartesian system (x,y,z,∅)
  - workspace 200 x 200 x 70 mm³, 360°
  - repetitive accuracy < 5 µm (resolution 1 µm)
  - payload 5 N
- Feeding of components with standardised 2” - 8” trays (DIN 32561)
- Depending on configuration proprietary or standard tool change system (DIN 32561)
- Various suction grippers and miniaturised adhesive dispensers
- Optional image processing system (DIPLOM)
- Minienvironment (up to class 1000)

Equipment

Multifunction gripper with multiple suction orifices

- **Suction orifices on common vacuum supply**
- **Suction orifice 1: Gripping for shearing of lenses from wafer**
- **Suction orifice 2: - Gripping of lenses after reversal**
  - Gripping of centering balls





Suction orifice 2

Suction orifice 1

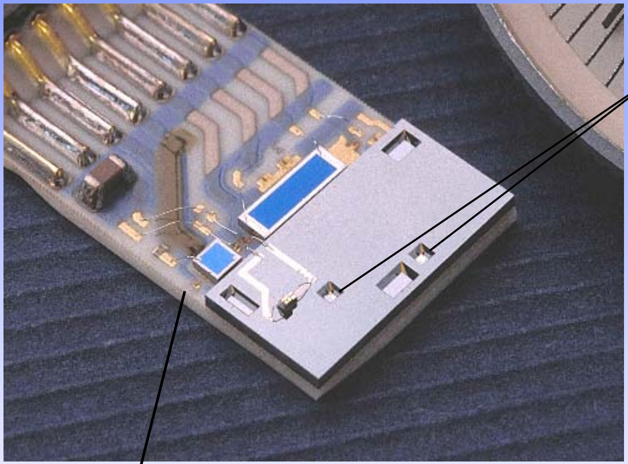
Multifunction gripper

Lens substrate on tray

Equipment

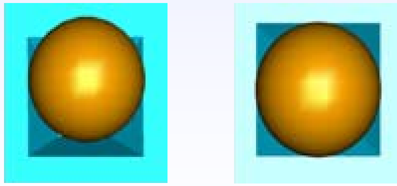
Multifunction gripper with multiple suction orifices

Example: Mounting of centering balls onto electro-optical board



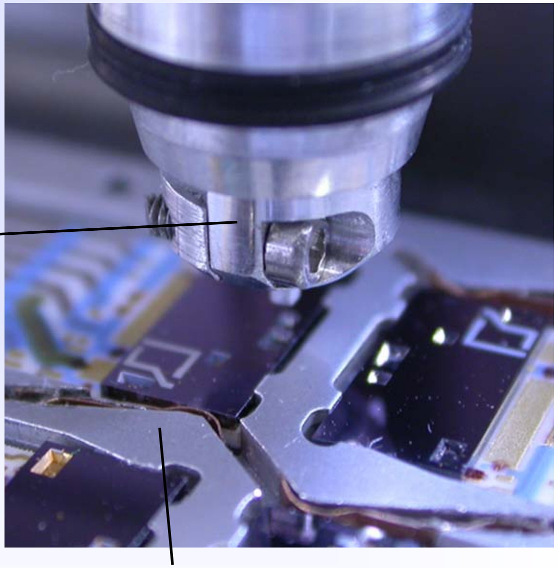
Etch grooves for centering balls (ø 650 µm)

Electronic-optical board



Passive alignment:
Self centering of ball
in etch groove

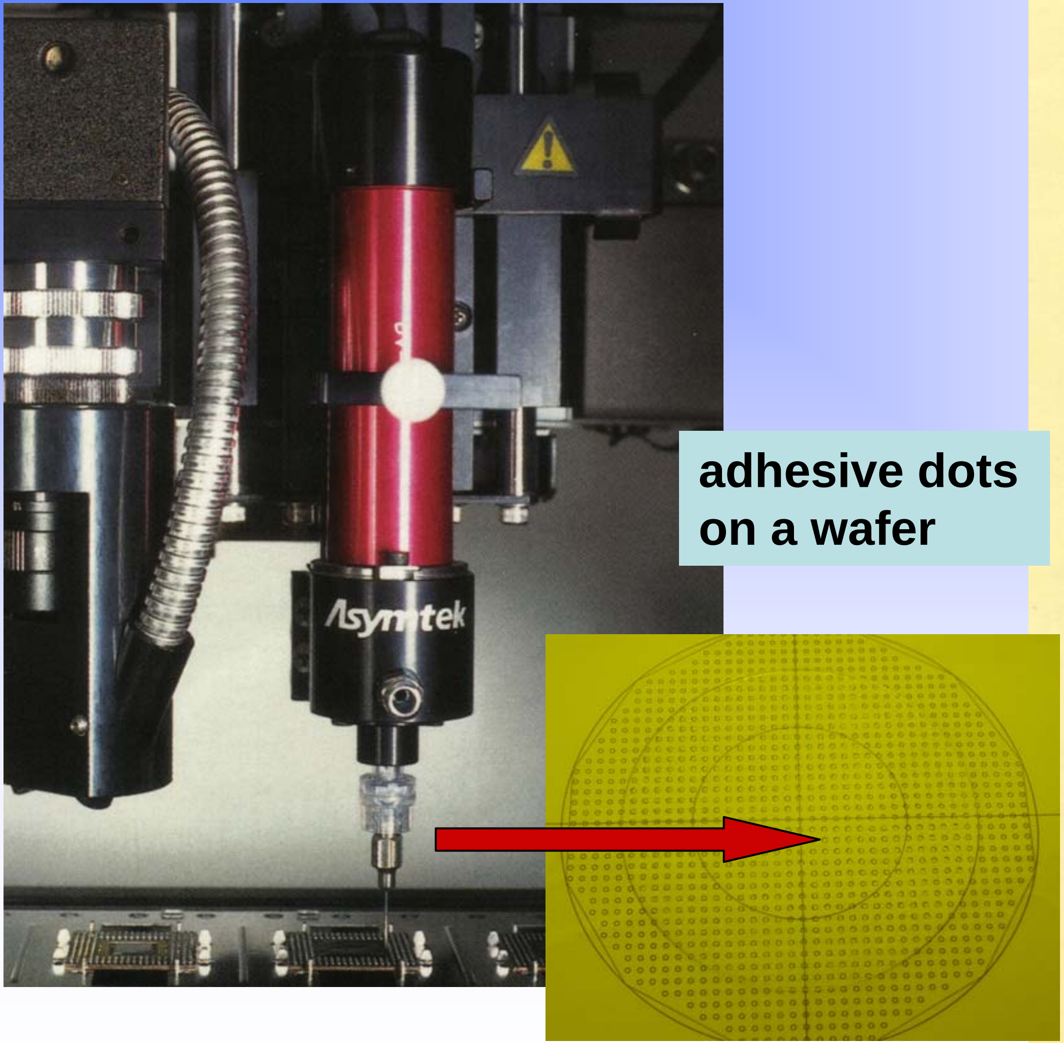
Gripper



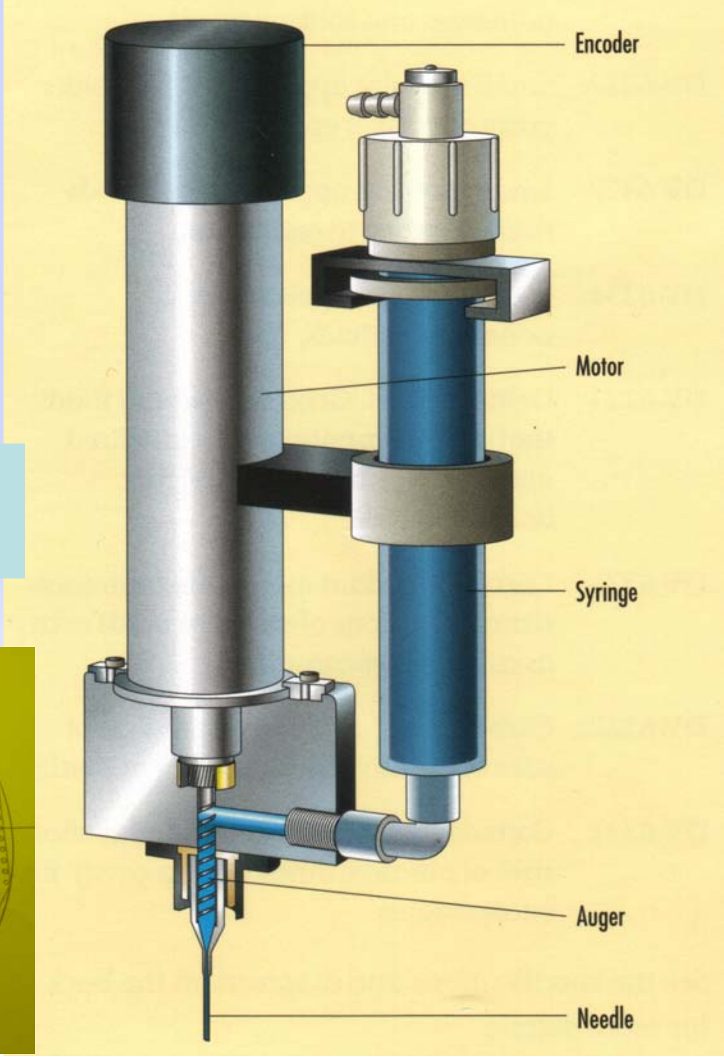
Tray with electronic optical boards

Equipment

Adhesive Dispenser

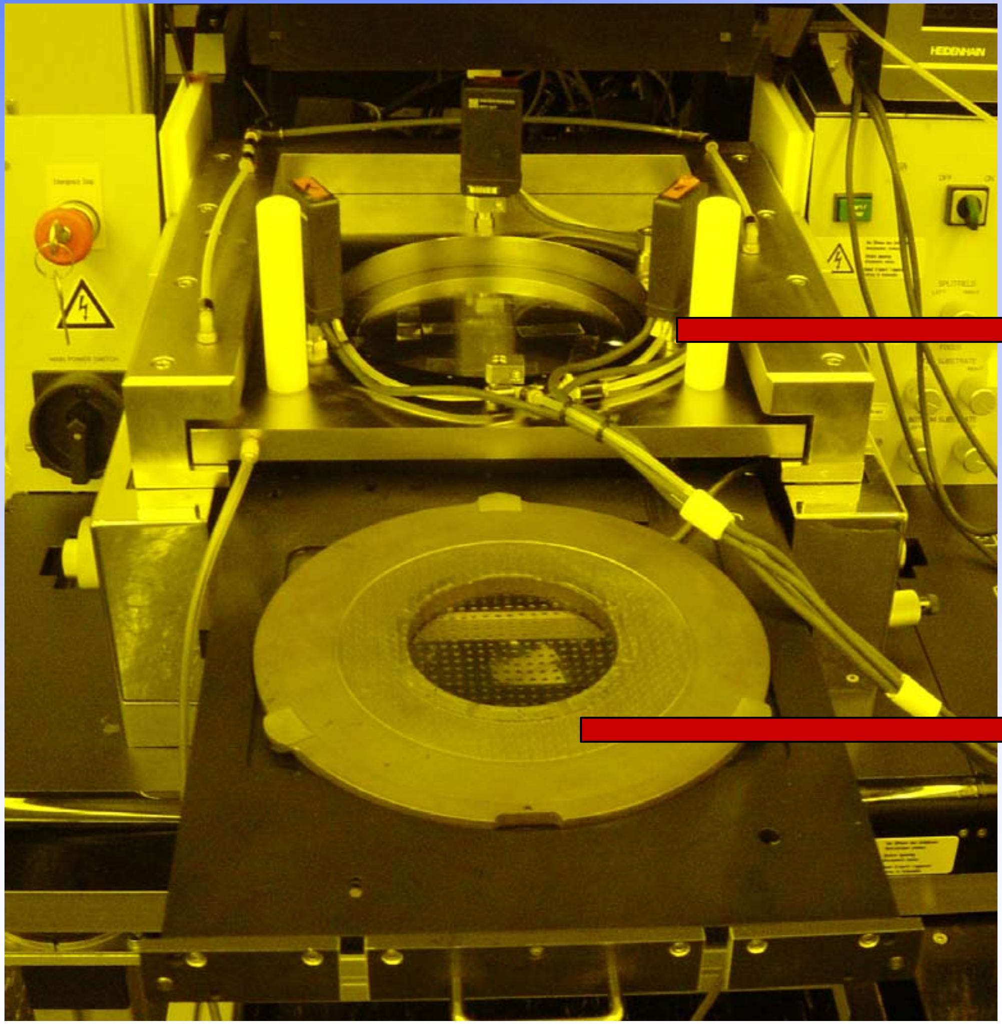


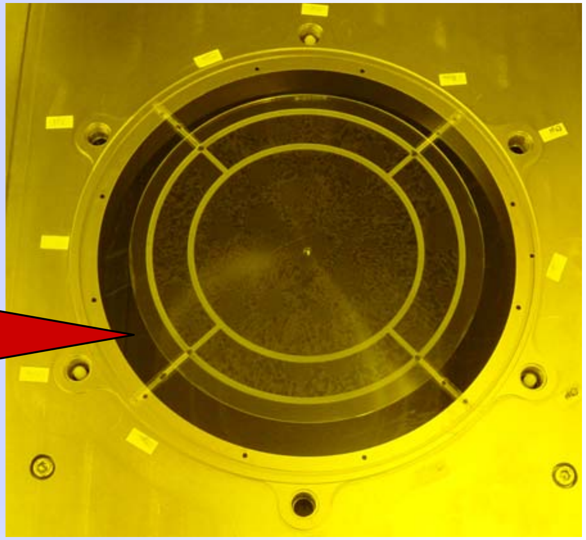
adhesive dots on a wafer



Equipment

Wafer bonding : SUSS MA6





1st wafer

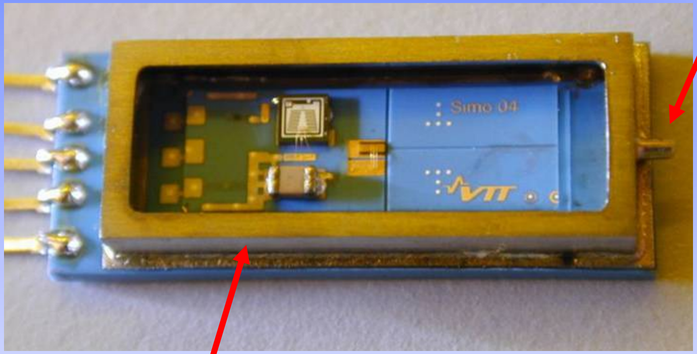
2nd wafer with adhesive dots

after alignment UV curing of the adhesive

Hermetic encapsulation

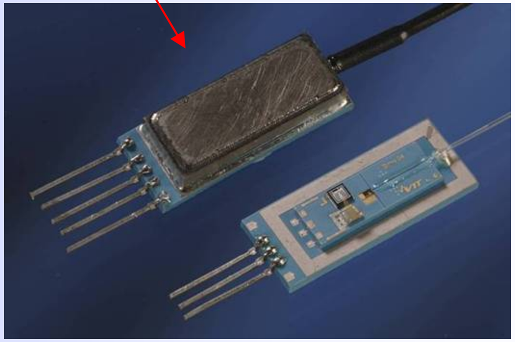
Photonics sub-assembly
based on LTCC board

Hermetic fiber feedthrough by
the use of solder glass preform

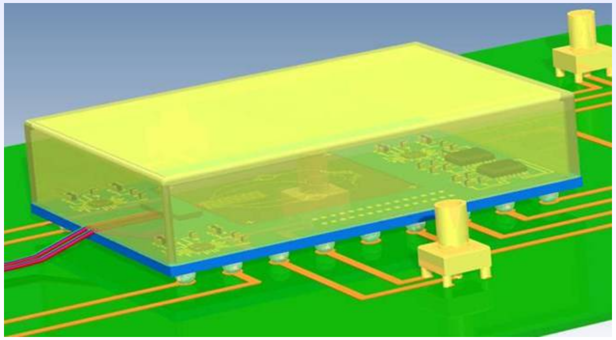


Kovar frame, solder reflow
sealing to LTCC using
integrated resistance heating
element or reflow oven

Kovar lid, sealing with laser



Encapsulated & pigtailed LTCC module
BGA-assembled on PCB



Conclusions

Packages allow components to be used

- Wide range of possible packages & techniques
- Optimise technologies for optical packaging
- Costs are extremely high

Much research still to be done
Look around and be creative !!