Optical and RF transparent long-term biocompatible micro-packages

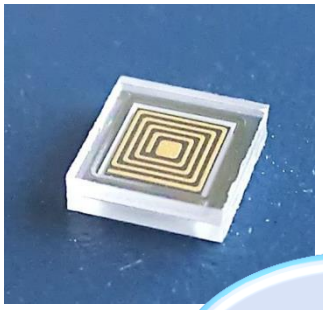
Rony Jose James, Guido Spinola Durante, Mark Fretz, Ch. Bosshard, Stefan Mohrdiek

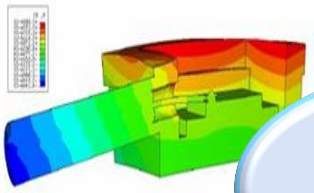
Alpnach, 08.06.2015

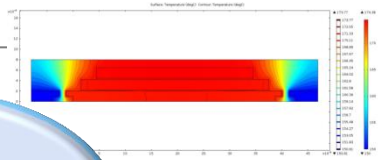
Agenda

- General overview (photonics) packaging at CSEM: Packaging Examples
- Challenges in packaging of long-term Active Implantable Medical Devices (AIMDs)
- CSEM development : Implantable micro-packages
- Applications
  - Optical cochlear implant: Optically transparent implant
  - Implantable Pressure sensor: RF transparent implant
  - Overview of long-term implantable sensors
- Conclusion

General overview (photonics) packaging at CSEM

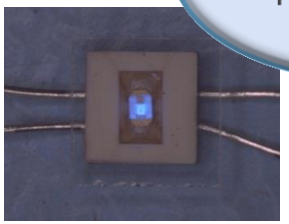






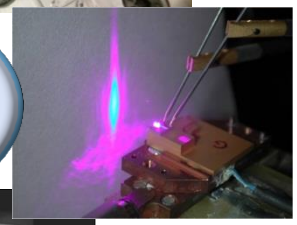
Modelling

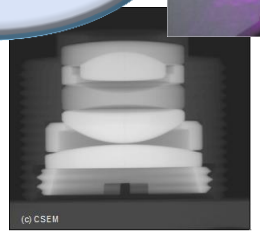
Biomedical Packaging



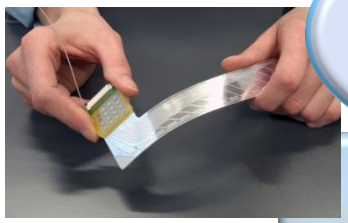
Microsystems Packaging & Integration

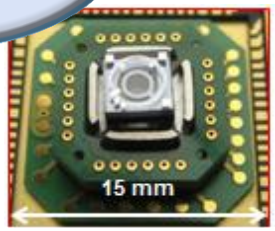
Optical Assemblies



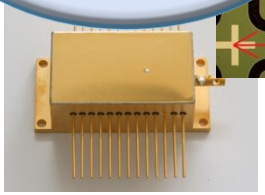


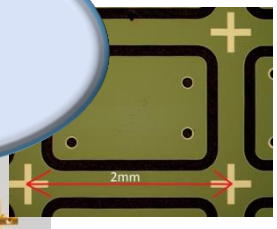
Hybrid Integration





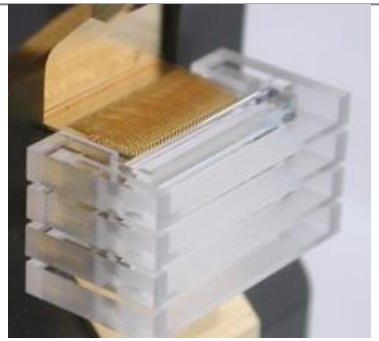
Hermetic Sealing



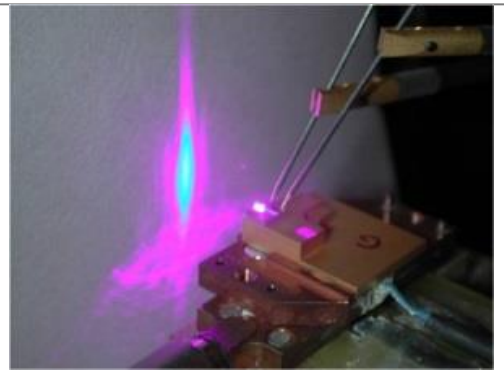


Examples: Miniaturized light sources

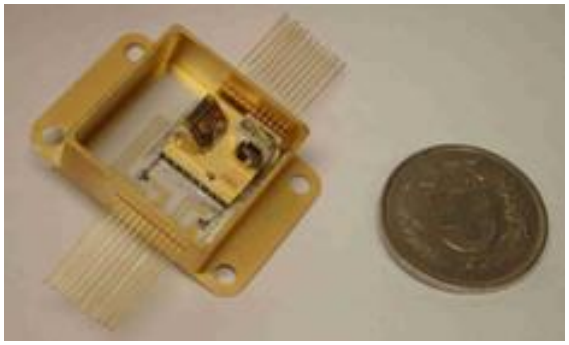
Small series production capability



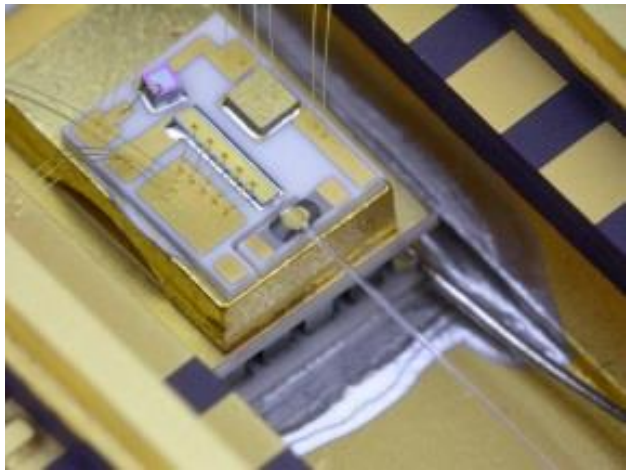
Stacked laser bars with lens coupling



GaN laser die assembly



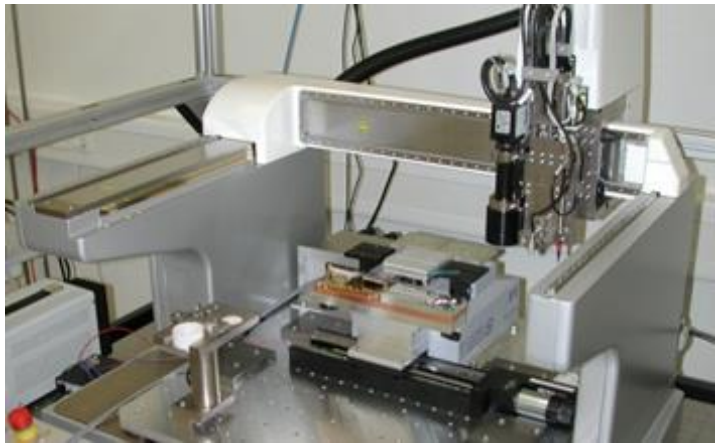
Mid-infrared laser module development

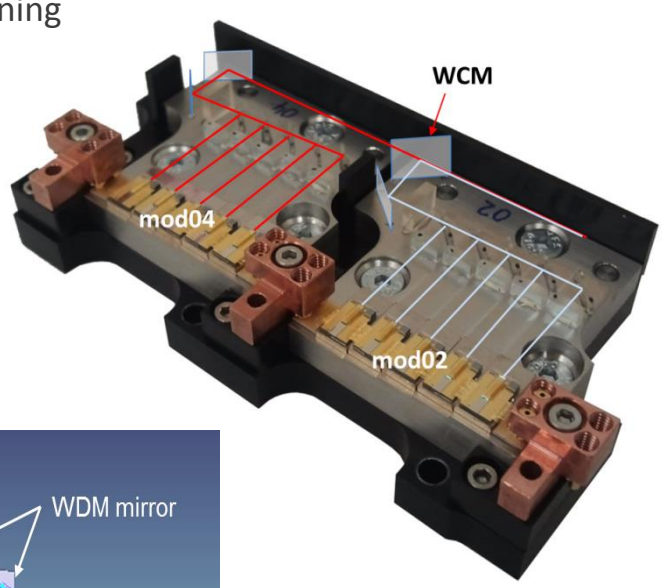


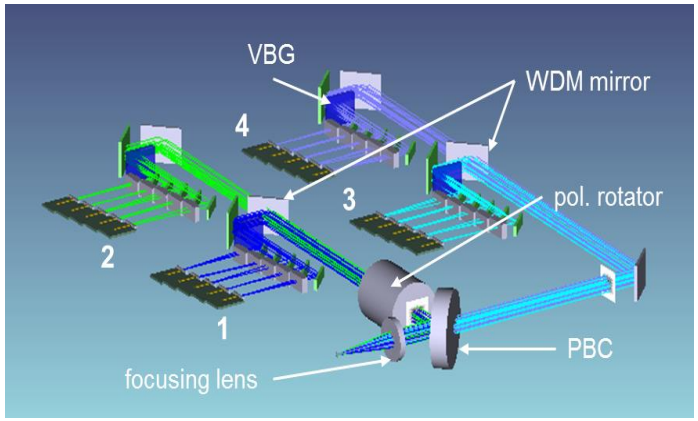
Fiber coupled laser modules

Examples: Packaging with automated assembly solutions

- Positioning and fixing of components by various bonding methods (Solder & adhesives)
- i.e. microchips, semiconductor lasers, optical fibers, lenses, mirrors and gratings
- High precision assembly with accuracy down to 200 nm for active positioning

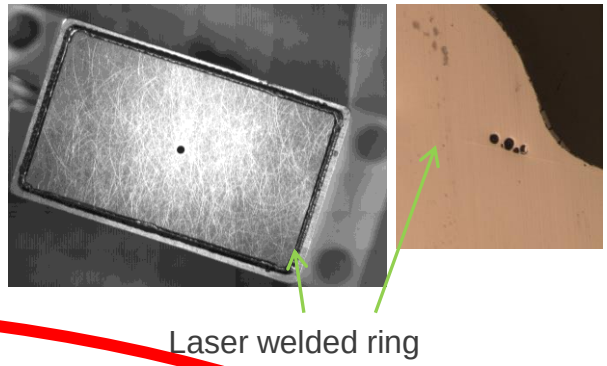




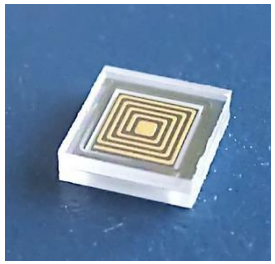


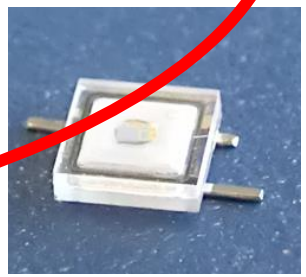
Examples: Hermetic sealing

- **Hermetic sealing of e.g. Kovar (Fe-Ni-Co) Packages**
  - Temperature of components during process < 100 °C
  - Crackless, strong hermetic sealing < 10^{-10} mbar l / s



- **Long term biocompatible chip scale packages**
  - Low temperature bonding < 220°C
  - Miniaturization < 1 mm^2
  - Feedthrough technologies with pitch down to 300 µm
  - Hermetic with only long term biocompatible materials

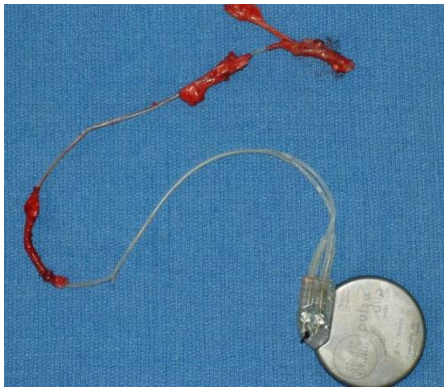


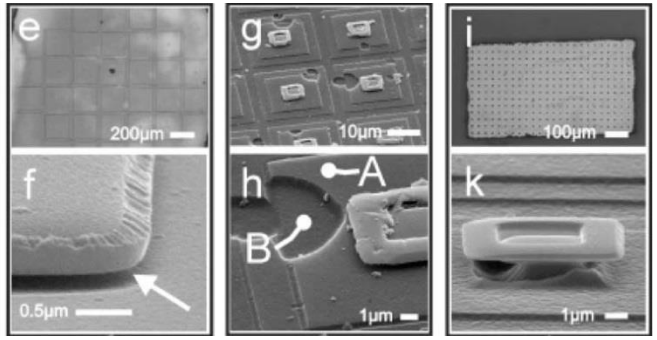


this presentation

Why is packaging of medical implants so Important? Environment is very harsh

- **A very corrosive environment**:
  - A highly oxygenated saline electrolyte at a pH of around 7.4 and a temperature of 37°C
  - ionic composition and protein concentration
- **Bio-Security**
  - It will not inflict any damage on the biological environment
  - No Toxicity, allergic reactions and Tumorigenesis
- **Bio-Functionality**
  - The active device is functional for an extended period of time
  - No bio-fouling (the attachment of an organisms, fibrinogen/ protein growth)





Courtesy: Natural and Medical Sciences Institute, Markwiesenstraße 55, D-72770 Reutlingen, Germany

Challenges in packaging of Active Implantable Medical devices

Biocompatible → Limited materials
Pt, Ti, Al_2O_3, Zirconia &
few more Au?,Si?

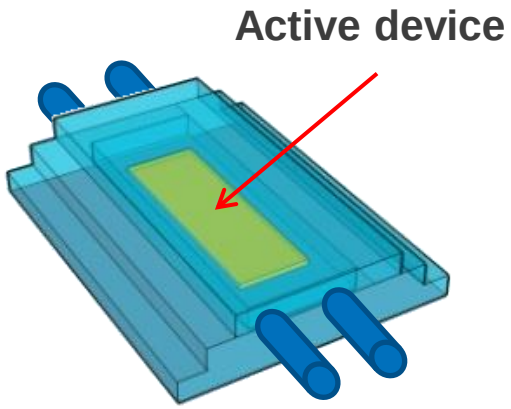
Temperature → Sealing maximum temperature
compatible with CMOS i.e. <250°C

Hermetic → Seal must be liquid and gas-
tight for a long term

Feedthroughs → ≥2 contacts are required to drive
active electrical components

Miniaturization → Micropackage sealing ring lateral
dimension: 500μm – 3500μm

Testable → Seal must be testable on
each device. Non destructive
testing is required.



Optics & Radio Frequency in active implants

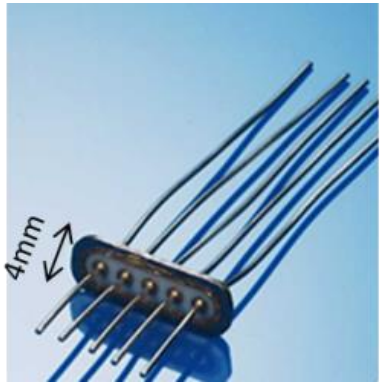
- More and more implantable applications using Optics
  - Optogenetics — activation or deactivation of brain cells by illumination with different colors of light to treat brain disorders.
  - Optical nerve stimulation: Specific wavelengths used to stimulate
  - Optical cochlear implant

- Miniaturization has to go with wireless (RF transparency necessary)
  - Wireless Data communication
  - Remote Charging

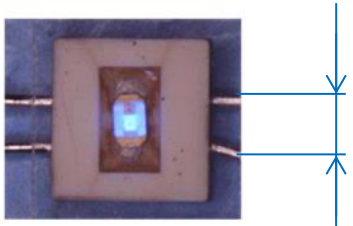
Miniaturization & Optical and RF transparency

Hermetic sealing

Feedthroughs



Images source: internet



1.5mm

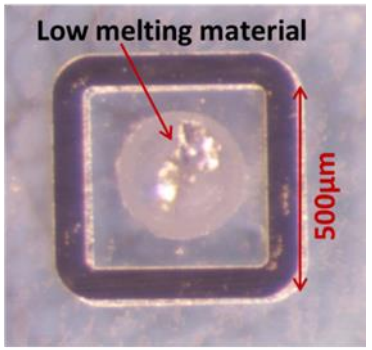
Optical and RF transparent
Micropackage
with miniaturized feedthroughs

Development at CSEM

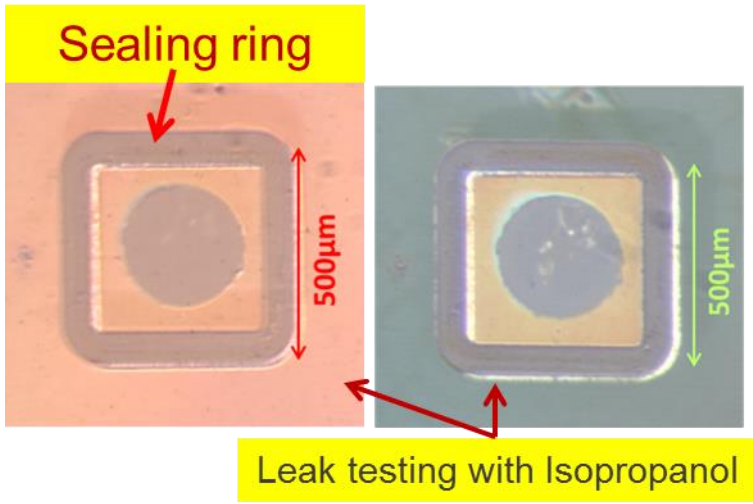
Miniaturized package development

Hermetic sealing technology

- **CSEM proprietary sealing technology**
- **Can be used for different material combinations**
- **Laser based bonding**
- **Miniaturization**
  - 500 µm sealing ring
- **Temperature < 150 °C**
- **Hermetic Seal**
  - Helium leak tightness < 10^{-12}mbar.l/s
  - Stable operation for 10`s of years targeted
  - Bond Strength: 110 Mpa
- **Only Biocompatible materials used**
  - Sapphire & Biocompatible metals

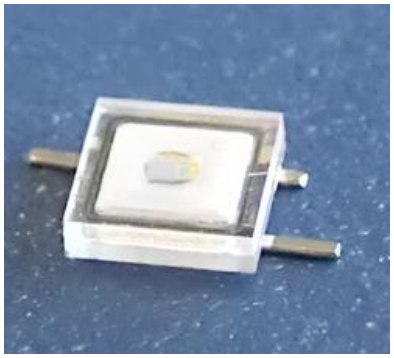


CSEM proprietary technology



Hermetic feedthroughs

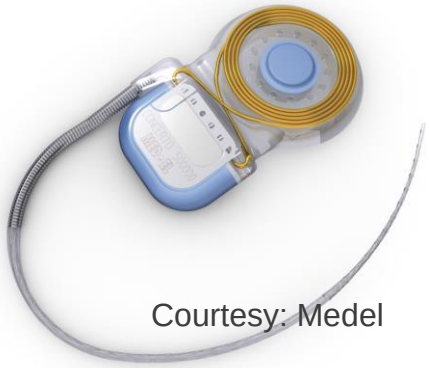
- Via of diameter down to 70 um
- Pt/Pt-Ir/Ta/Nb leads
- Via filling technology
- Laser/spot weldable Pt contact pads
- **Hermetic sealing**
  - $<10^{-12}$mbar.l/sec
- **Shear strength : <100Mpa**
- **Pitch: 300µm**
- **Only Biocompatible materials used**
  - Sapphire & Biocompatible metals



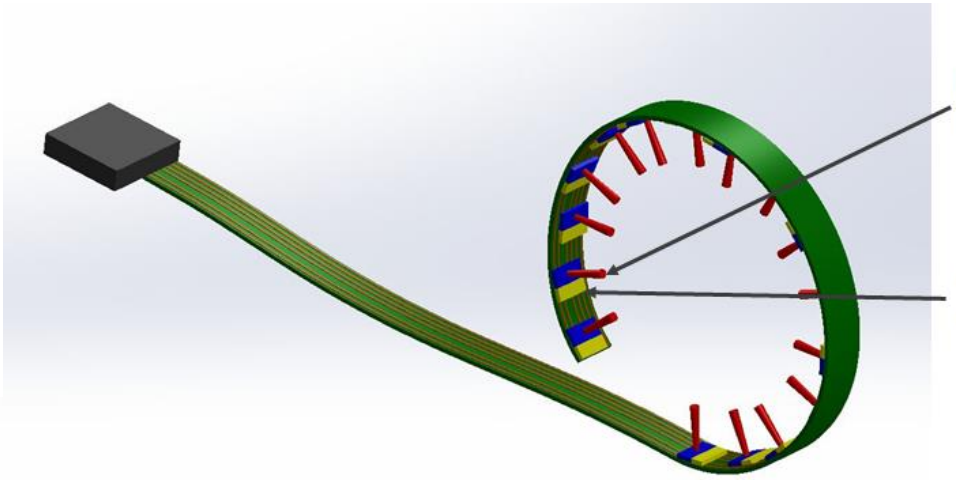
CSEM proprietary technology

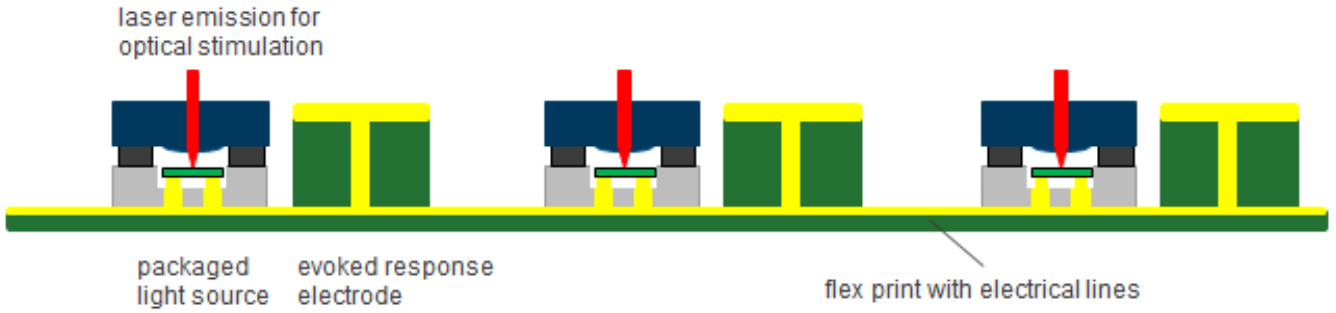
Cochlear implant for opto-acoustic stimulation of hearing nerves: Optical transparent implant

- Poor spatial resolution with electric stimulation due to cross talk
- Optoacoustics based hearing recovery



Courtesy: Medel

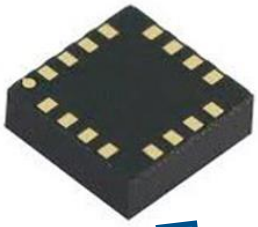


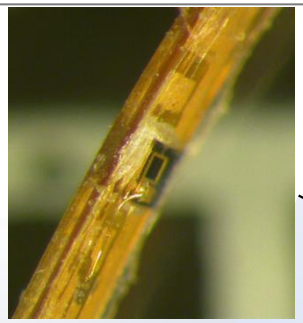


Cochlear implant for opto-acoustic stimulation of hearing nerves: components

External wireless power & comm. interface

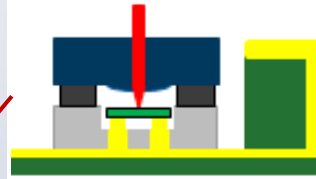
Power and Signal I/O





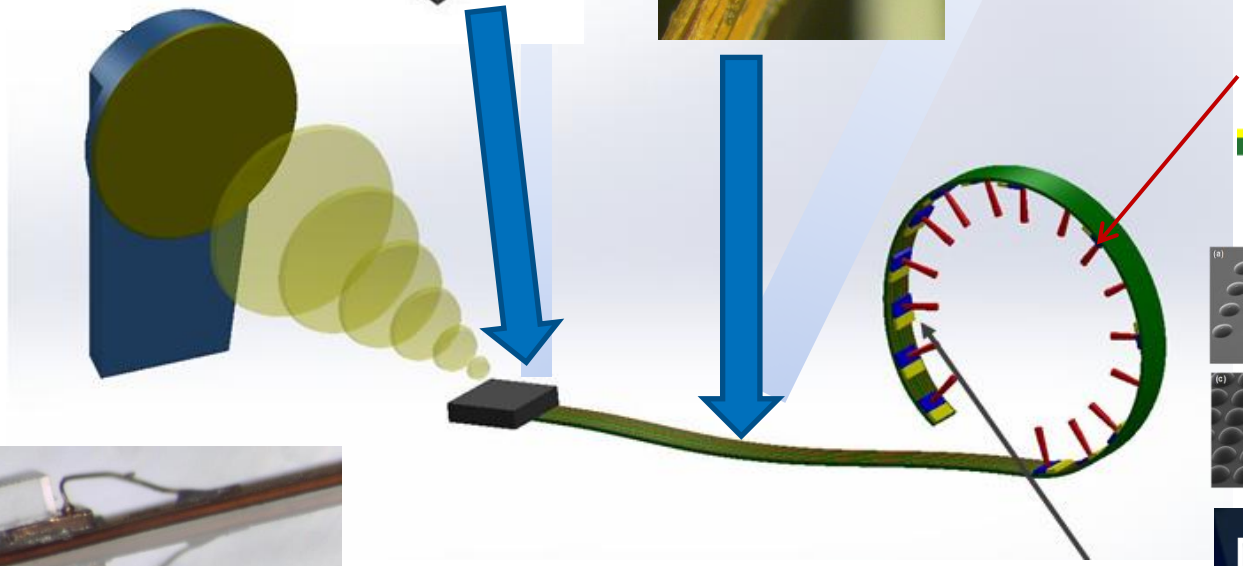
Biocompatibility of flexprint electrodes

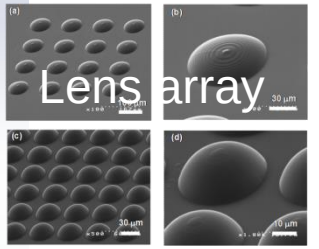
laser emission for optical stimulation

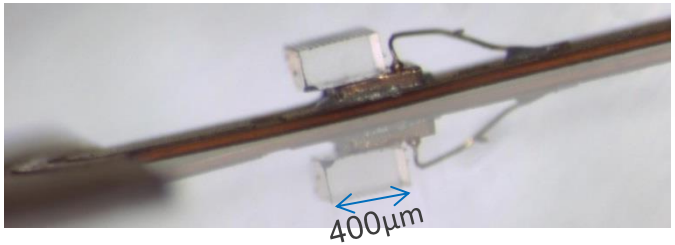


packaged light source

evoke electr

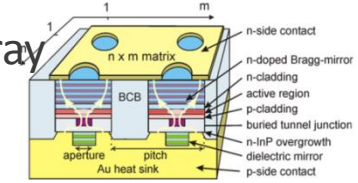


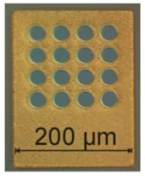


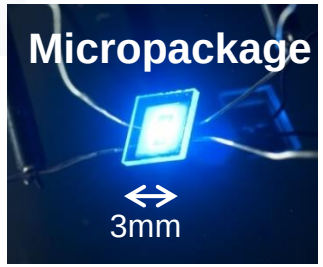


Miniaturization

VCSEL Array IR light sources

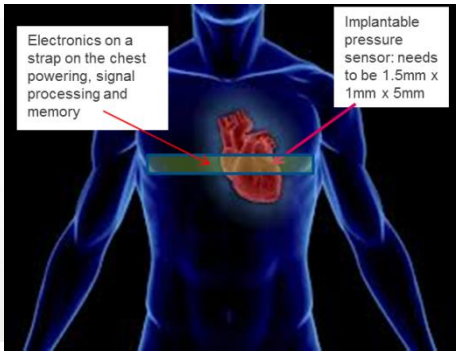


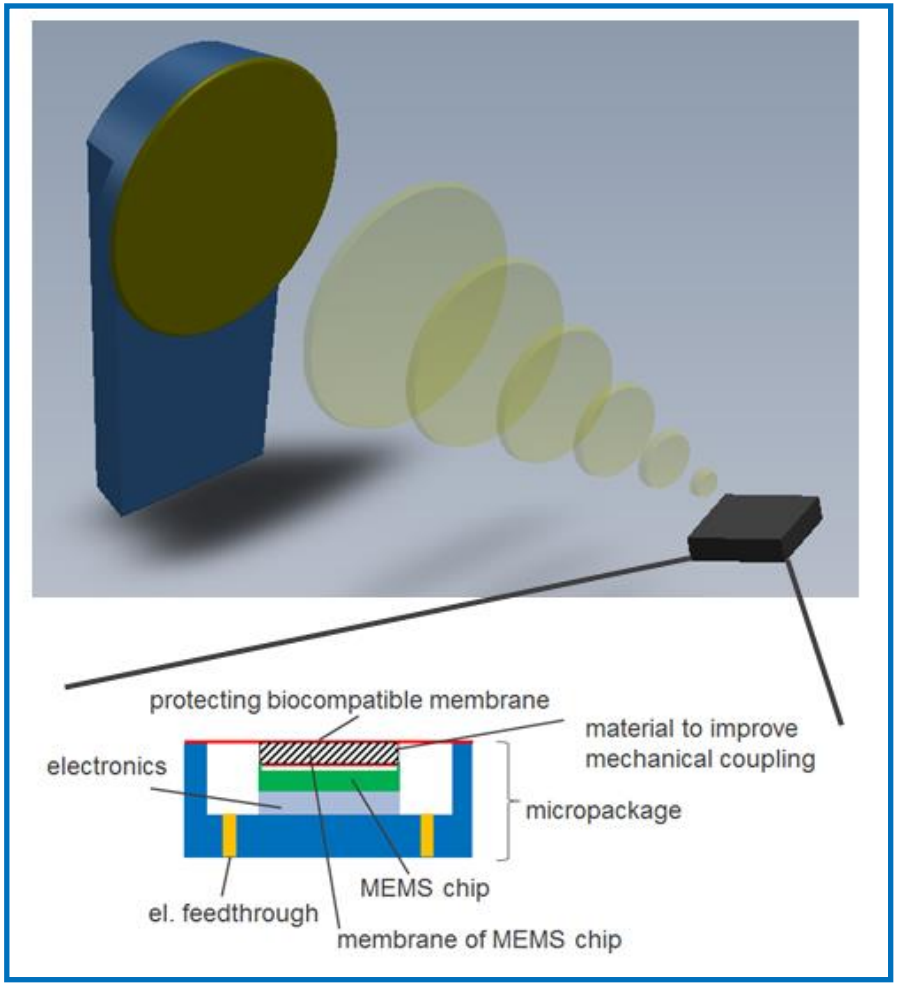




Implantable Pressure sensor : RF transparent implant

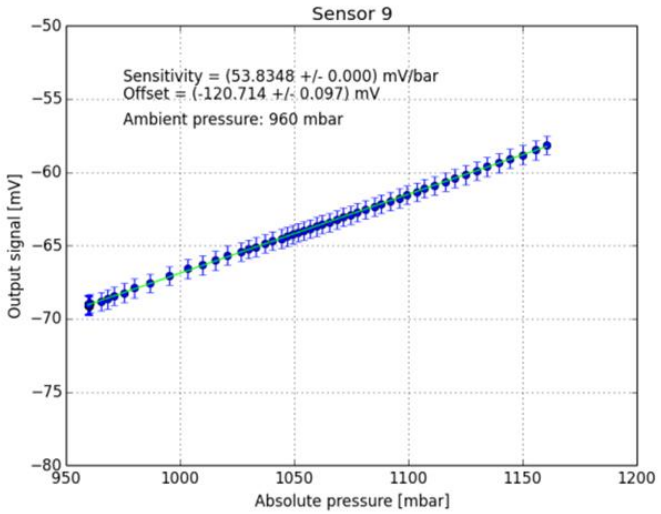
1) **Miniature** (a few mm, e.g. 1.5 X 2mm)
2) **Highly HERMETIC** and long term Biocompatible
3) Thin biocompatible membrane
4) Electronics: Pressure sensor
5) Patented Pressure sensing concept



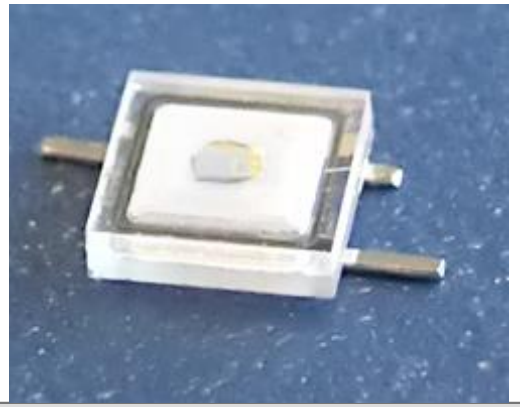


Miniaturized MEMS pressure sensor implant realised

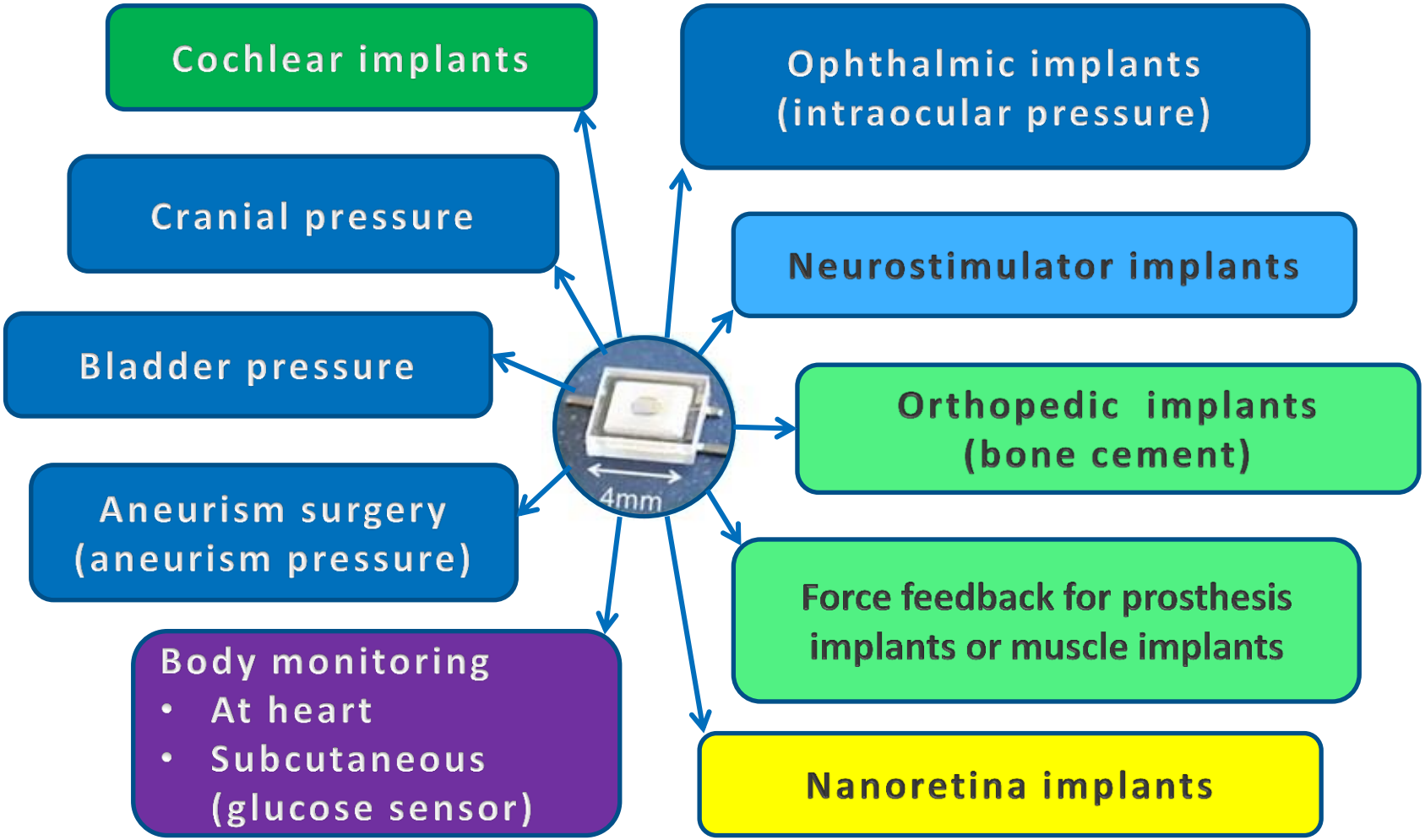
- **Active device with RF window**
  - RF device like RFID integration possible
- **Active device with mechanical coupling**
  - MEMS integration possible
- **Active device with feedthrough array**
- **Coupling concept**
  - **Yielded** acceptable **pressure sensitivity**



Hermetically sealed
Long-term implantable pressure sensor



Potential markets the implant packaging



Automated and semiautomated infrastructure used

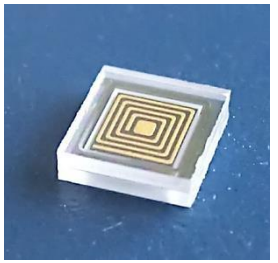
Pick & Place Machine
Reflow Oven
Wirebonding
10 μm positioning accuracy

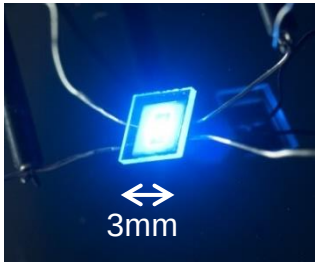
Laser microsoldering and welding
Hermetic sealing at low temperatures

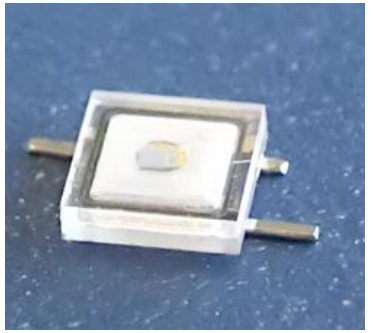
Flip-Chip-Bonding
1 μm positioning accuracy

Conclusion

- **Long term biocompatible chip scale packages**
  - Highly Biocompatible materials only
  - Low temperature bonding
    - <220°C for 0.8x0.8mm^2 package
    - <140°C for 4x4mm^2 package
  - Miniaturization
    - From 0.5x0.5mm2 up to 3.5x3.5mm2 µpackages
  - Hermetic Long term implantable
  - Optical and RF transparent
- **Feedthrough Technologies**
  - Size reduction to ≥2 feedthough with pitch down to 300µm
  - Hermetic with only long term biocompatible materials
- **Implantable flex circuit**







csem

from research ….
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