Heterogeneous Technology Alliance

The photonic sensing and integration platform of the HTA

Christian Bosshard & the HTA Photonics Platform Team

Noordwijk, October 15, 2012

csem

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VTT

Fraunhofer MIKROELEKTRONIK

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Photonics – benefits for Europe

- Photonics accepted as a EU key enabling technology
- Photonics components and systems
  - Development and integration
  - Automation whenever needed
  - (Small) series production
  - Testing of components
- Benefit for Europe:
  - Today assembly of optical systems is moving to Extreme East
  - Miniaturization and integration means automation:
    - Less dependence on human assembly
    - Possibility of relocating/regrowing industry back to Europe

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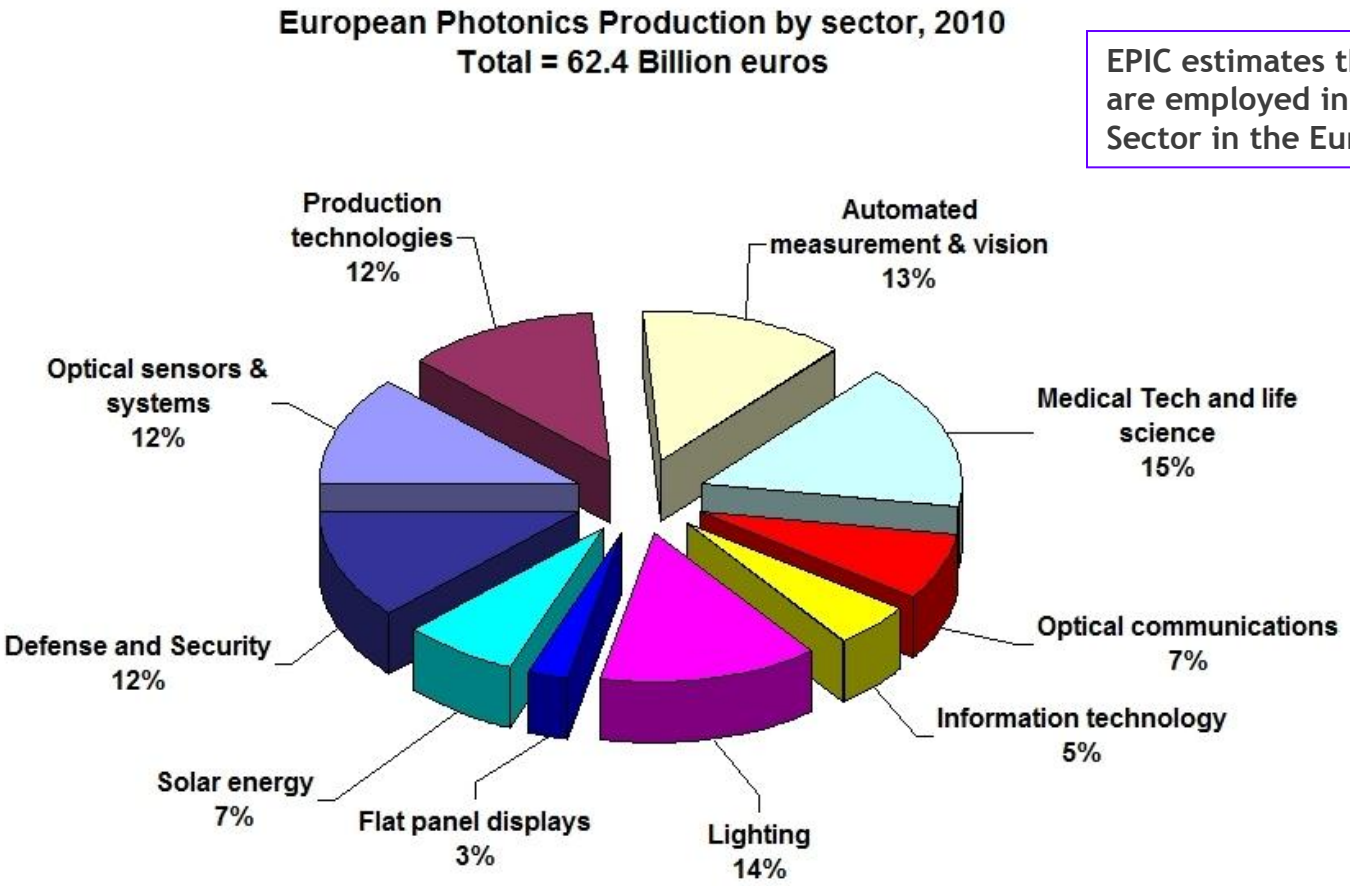
Photonics: a 62 billion EURO business in 2010 & 2011



EPIC estimates that 350 000 are employed in the Photonics Sector in the Europe zone.

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Why HTA ?

Because Photonics comprises many aspects

- From the device to the architecture
- Design for assembly
- Several types of devices involved:
  - Lasers, detectors, modulators, multiplexing components, etc
- Several type of materials involved:
  - Si (CMOS), III-V (lasers), $LiNbO_3$ (modulators), Glass, etc…
  - With different levels of trade-offs in terms of cost, complexity and performances
- Optical SiP (O-SiP) versus Optical SoC (O-SoC)

The targeted Photonics platform will be available for Space applications

HTA strategy

Combine a variety of HTA technologies to address the above challenges

- Light sources
- Light processing (fiber, waveguides, micro-(opto)-electromechanical systems (MOEMS),…)
- Light filtering
- Light detection
- Assembly and integration
- The next layer

➢ Enable photonics to deliver more functionality without adding complexity for the user

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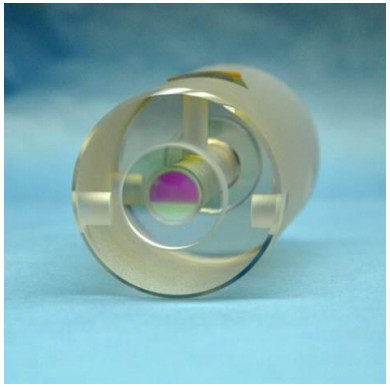
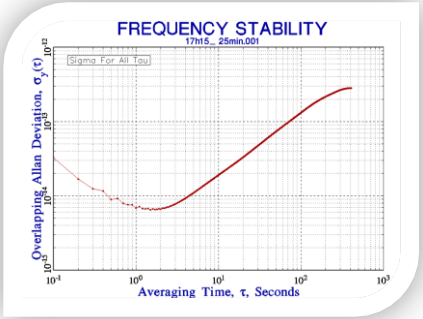
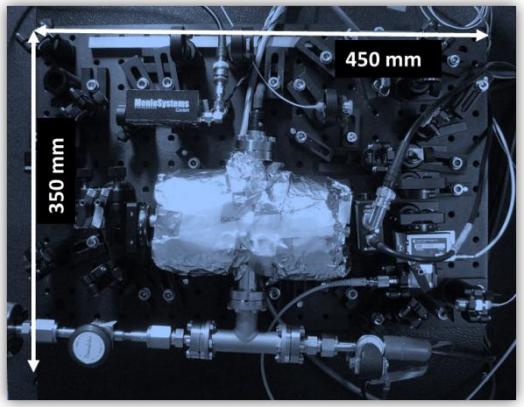
Stabilized cw-lasers: Industry-fit high performance & miniaturization

High Performance: Pound-Drever-Hall stabilization in optical cavity.



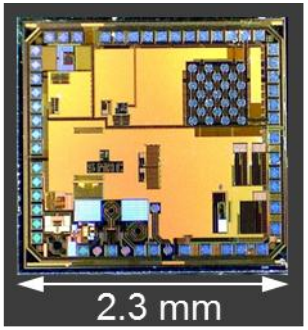


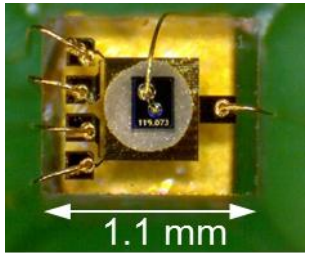
Achieved @ CSEM:
Robust 1 Hz linewidth @ 1s



Going towards:
Smaller, lighter, more robust, space compatible

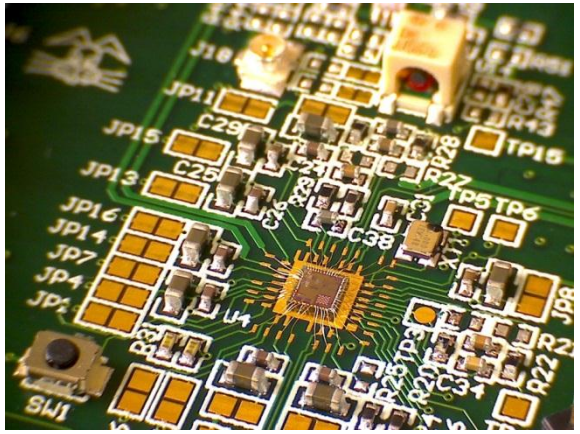
Miniaturization: Frequency lock through synchronized detection





Achieved @ CSEM:
ASIC-controlled VCSEL wavelength stabilization on Rb absorption line.

Going towards:
Lower power, higher integration, other laser types (DFB) and molecular absorption lines



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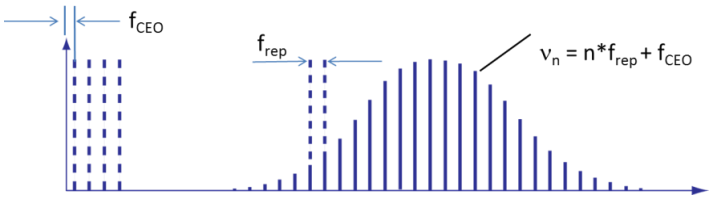
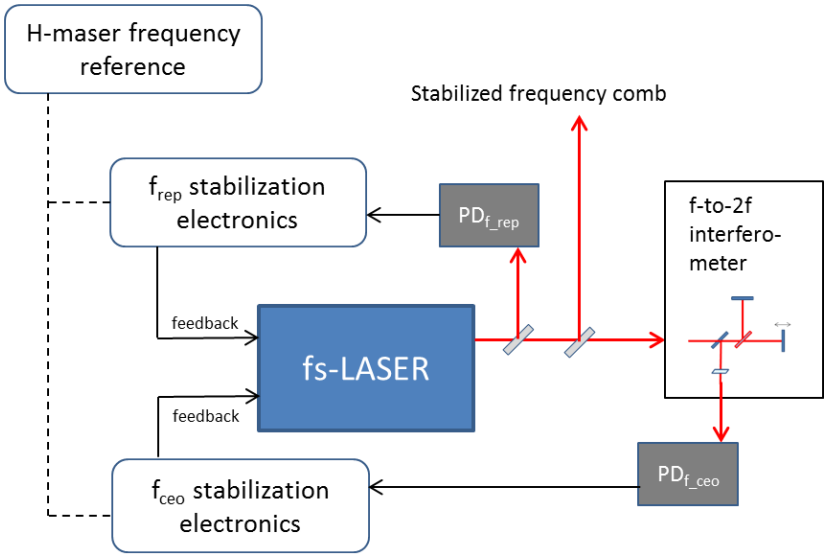
Stabilized optical frequency comb (fs laser)

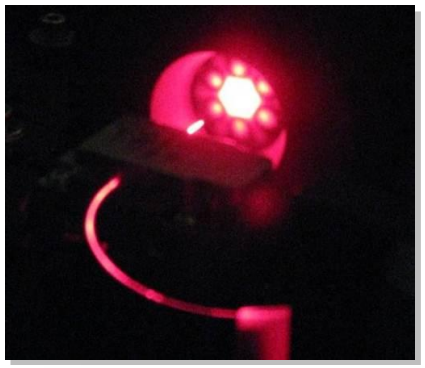
Applications:

- Fast high resolution optical spectroscopy
- Distance measurement
- Time and frequency transfer
- Low phase-noise microwave generation

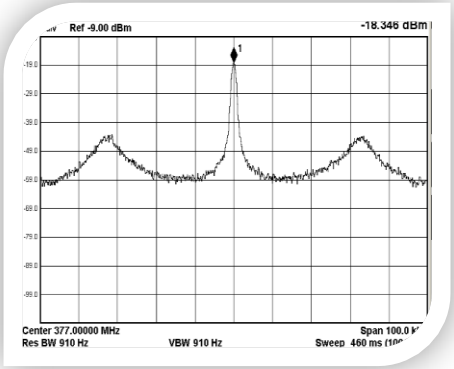


Stabilization setup





supercontinuum generation



state-of-the-art stabilized carrier-envelope offset frequency

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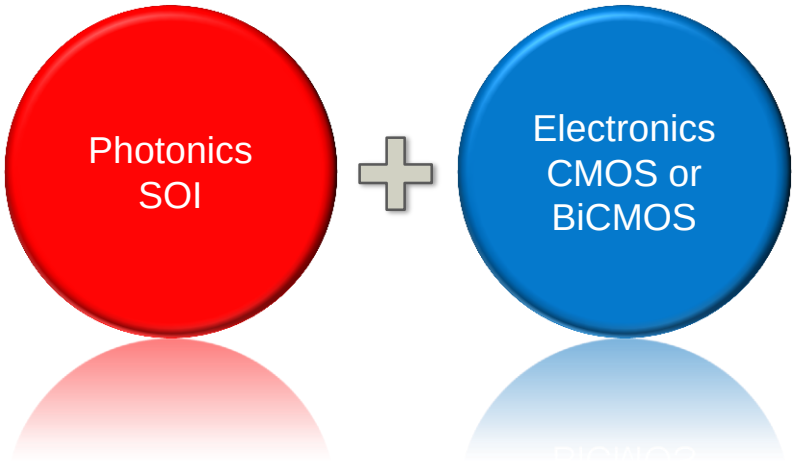
Silicon photonics

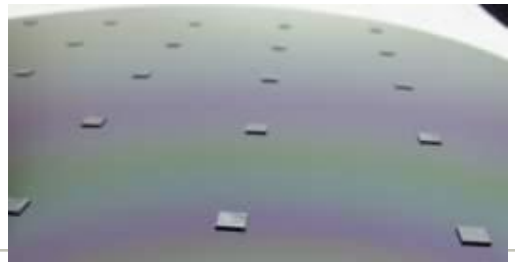
- Our objectives:
  - Build a complete technology platform (design, process, test, packaging) for photonics /electronics integration
- Our approach
  - Photonics/electronics 3D integration

  → yield, performance, cost



  - Heterogeneous integration III-V on silicon

  → wafer-scale laser integration



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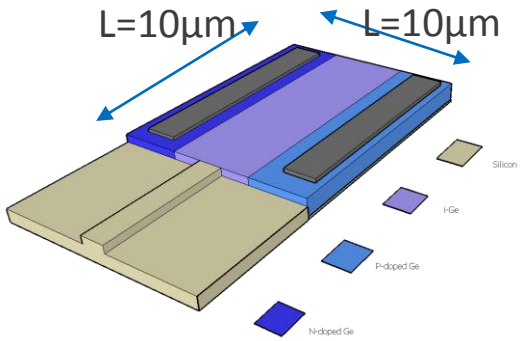
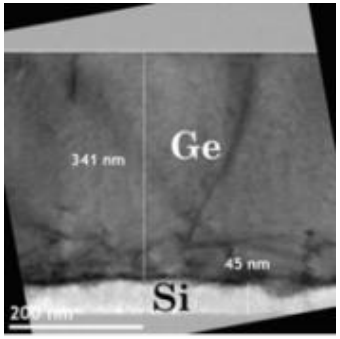
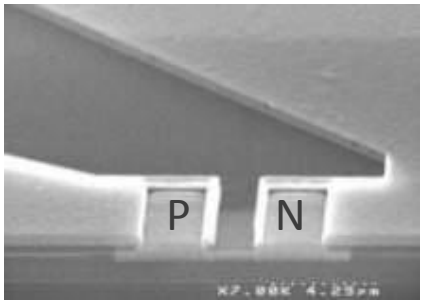
Germanium photo-detectors on silicon



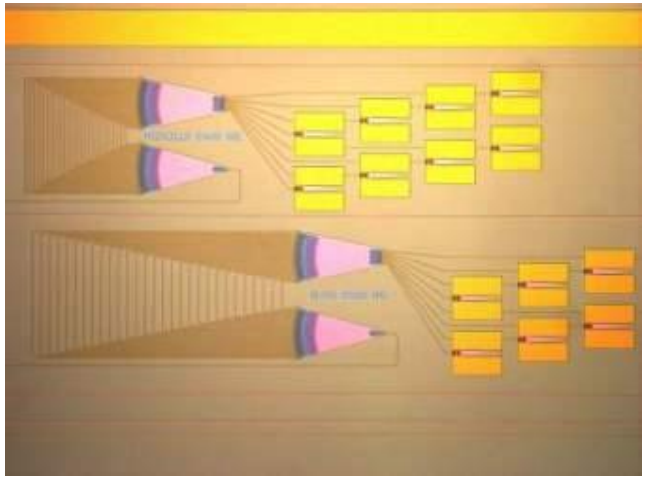




Median dark current:
- < 180nA @-2V
- < 25nA @-0.5V

Responsivity @1550nm 0.8 A/W

40GHz BW @0V bias



Integration with SOI waveguides

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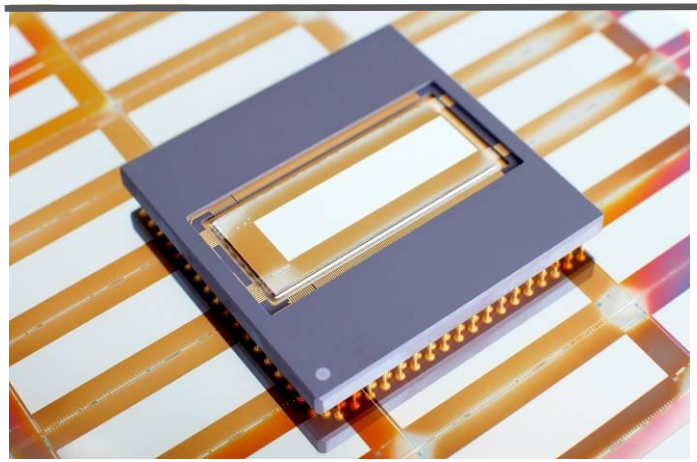
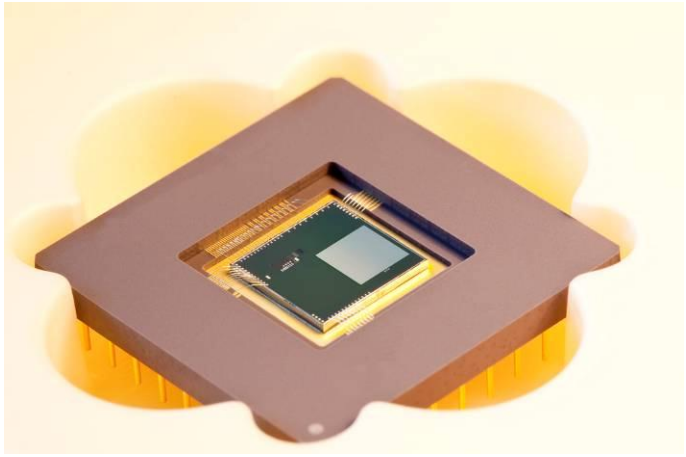
Micro mirror arrays

Programmable masks

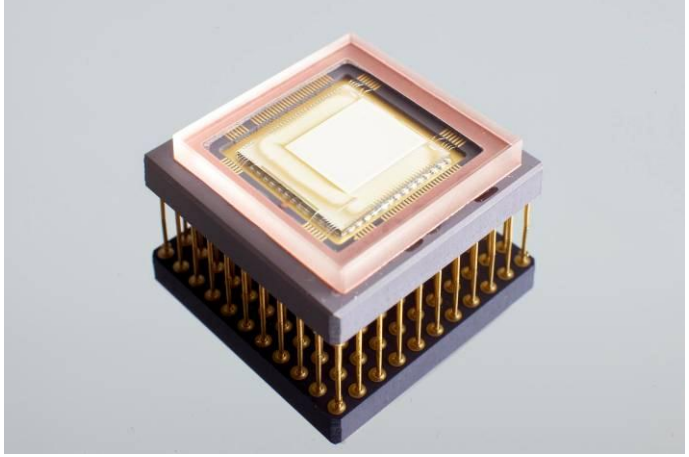


Direct Imaging

Microscopy



Adaptive Optics



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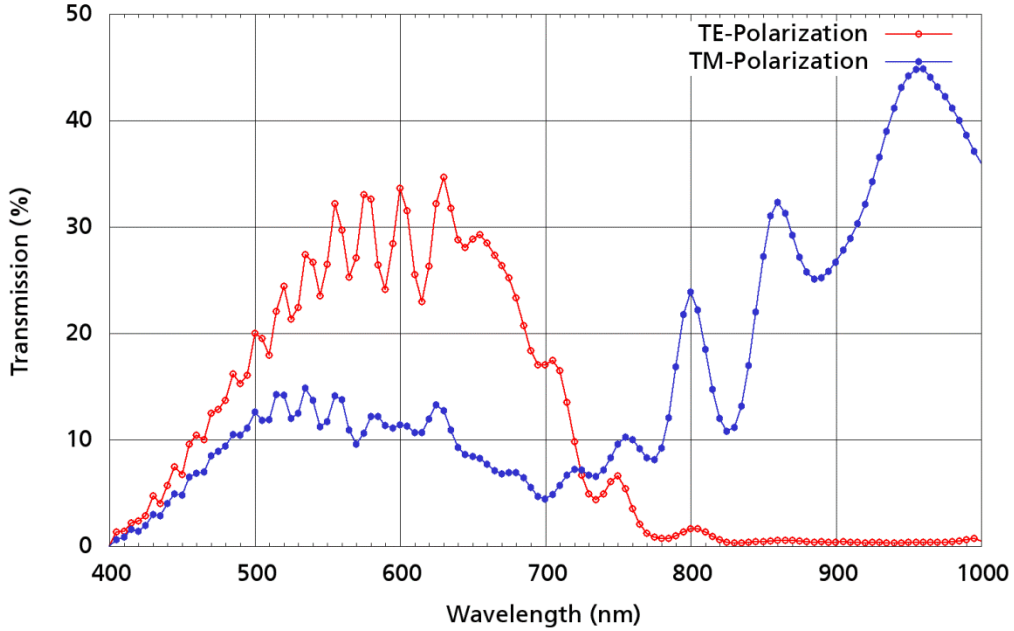
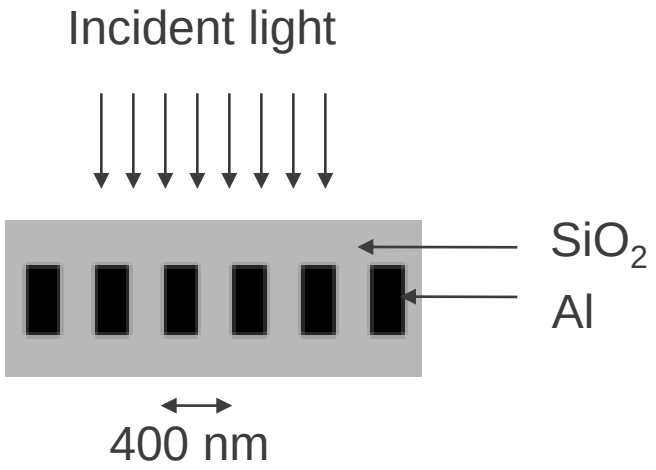
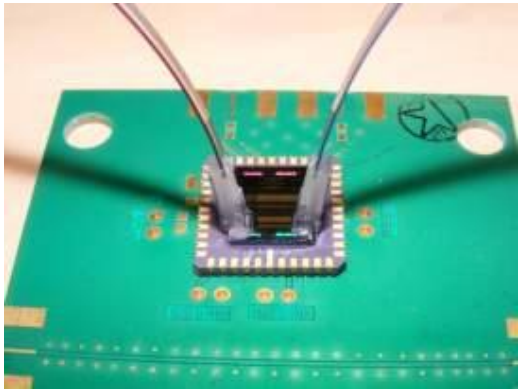
Nanostructured optical filters in CMOS: Polarization filters

- Wire gratings fabricated in CMOS technology
  - Good polarization sensitivity
  - Contrast ratio > 50:1 at 850 nm
  - Low attenuation of filters

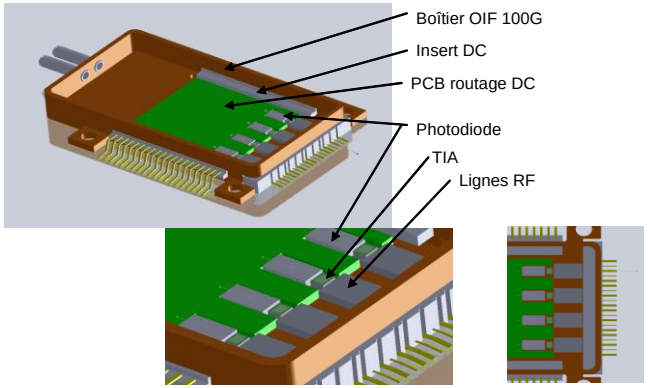




Packaging and module integration

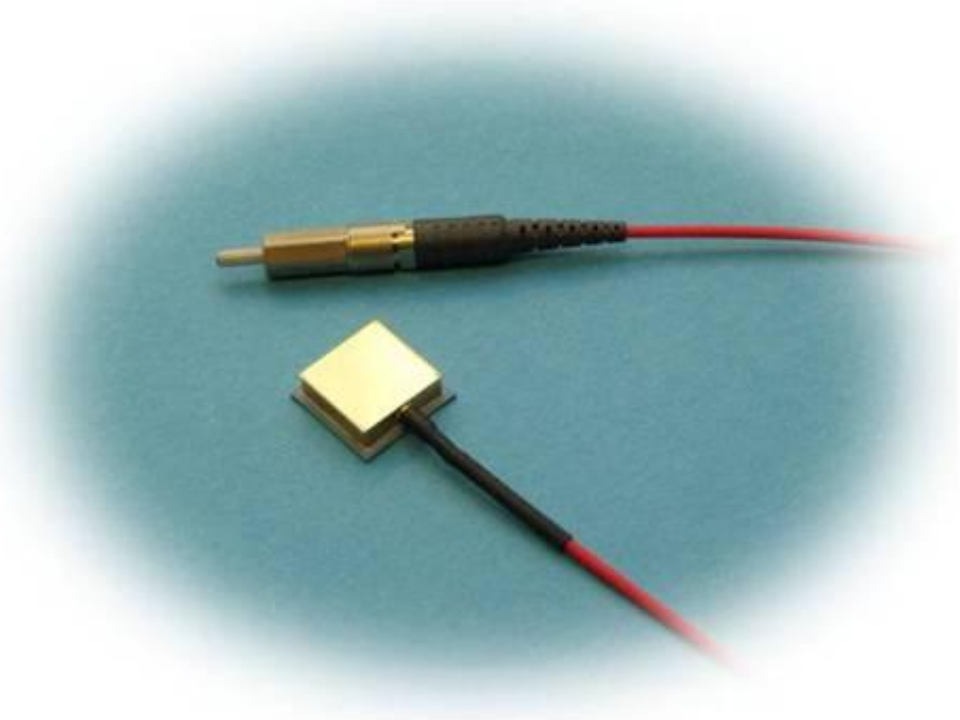


- Fiber Pigtailing
  - Active alignment (multichannel)
  - Vision assisted alignment
  - Passive alignment
- Electronics Hybrid Integration
  - Multi Chip Module (wire bonding)
  - System In Package (flip-chip)
    - Copper Pillar
    - Other
- Optical 2D/3D Interconnects (Interposers)



Developed and tested for extreme environment

- Shock 3000 g
- Random vibration 25 grms
- Vacuum
- Radiation 1000 Gy (gamma, protons, ions)
- Temp: operation -40…+85 °C, storage -55…+125°C
- Hermeticity verified: 500 cycles -55…+125°C
- Space-grade fibre cable and connector



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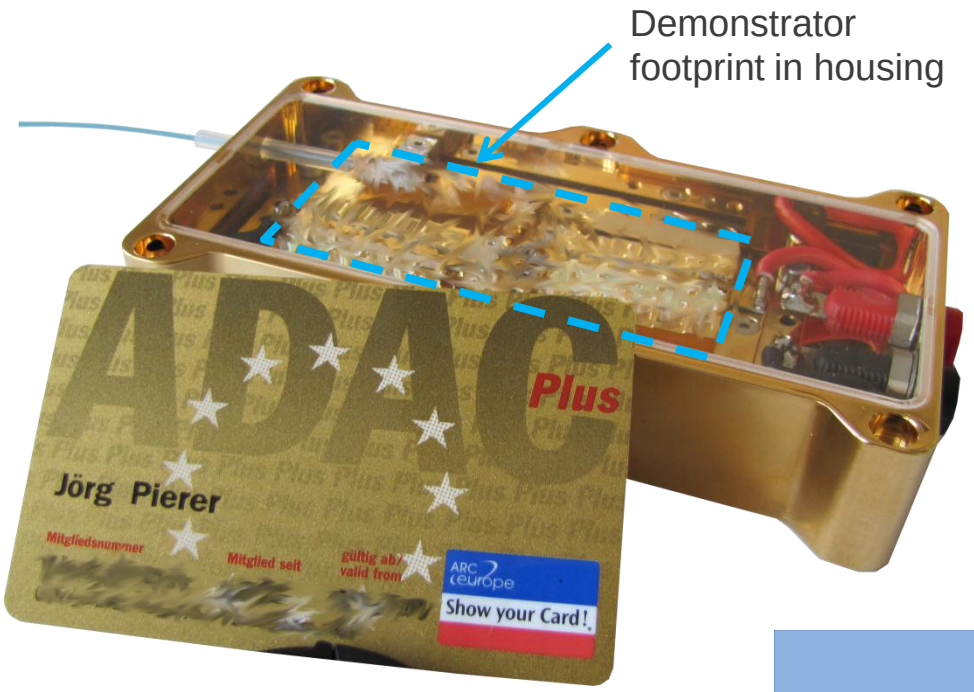
High power single emitter laser diode modules

- optical powers > 100 W
- highly repeatable processes
- very fast assembly (more than 40 optical components in less than 2 hours)
- easy process adaptation to
  - different product lines
  - miniaturized modules



- high yield rates
- reliable products

DDP 100

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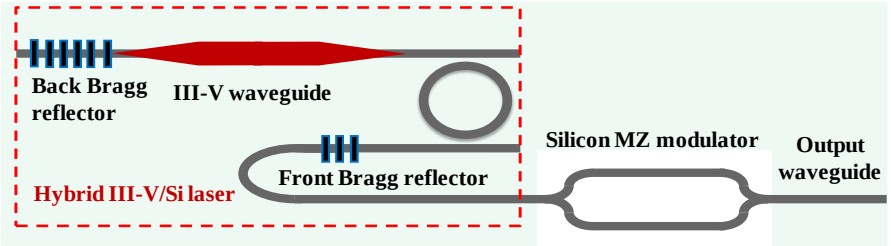
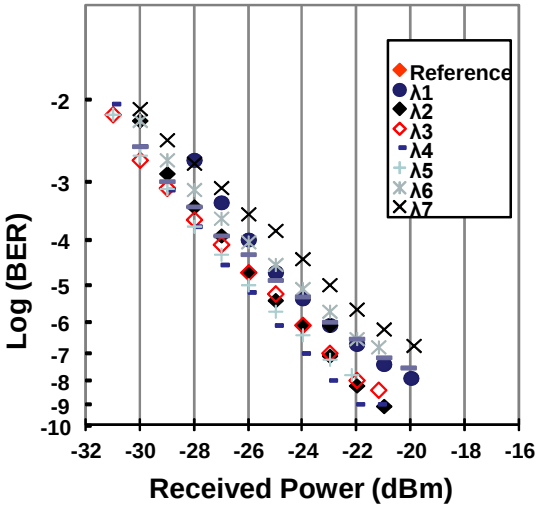
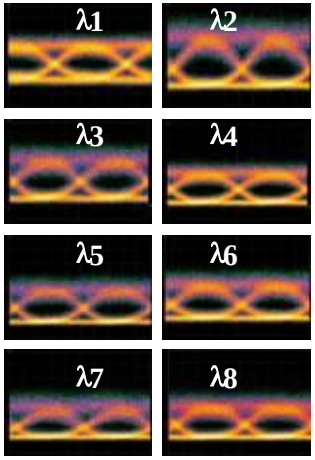
From components to circuits: Integrated tunable transmitter

- hybrid III-V/Si laser + silicon Mach-Zehnder modulator
- 8 nm tunability







Excellent BER performance at 10Gb/s

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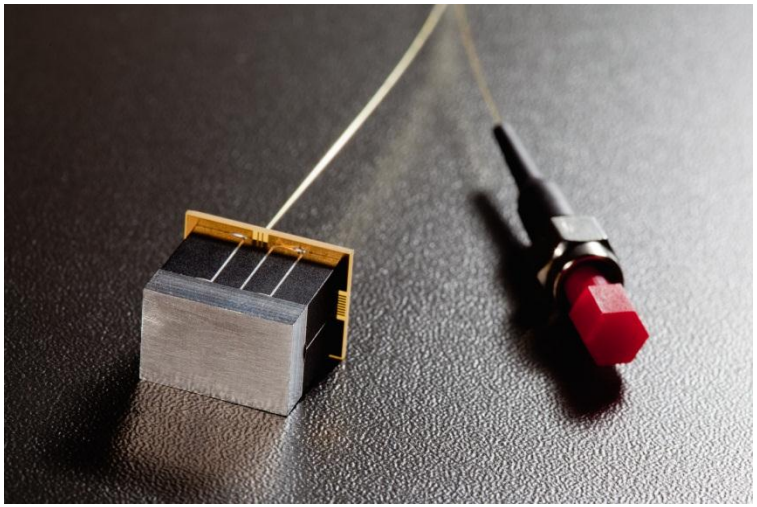
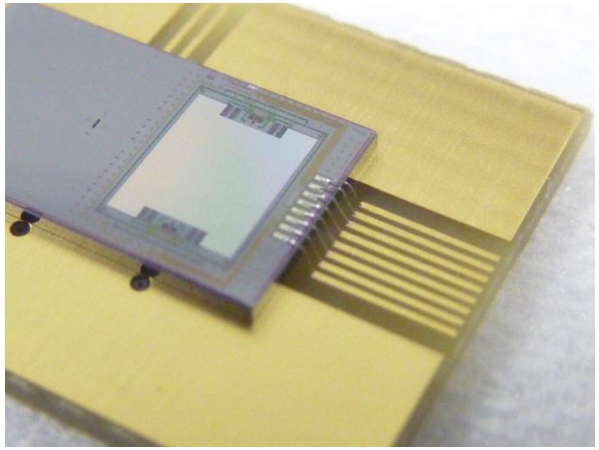
Miniaturized NIR Spectrometer



Micro spectrometer Size: 2cm³



Scanning grating chip

Application example: food quality

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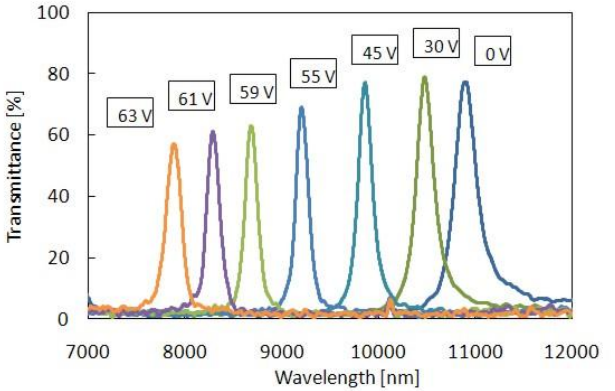
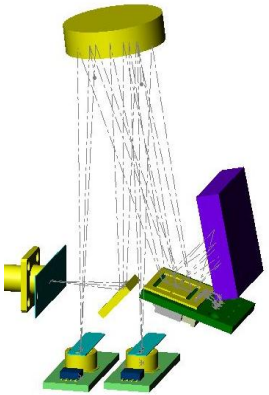
Interferometer and spectrometers



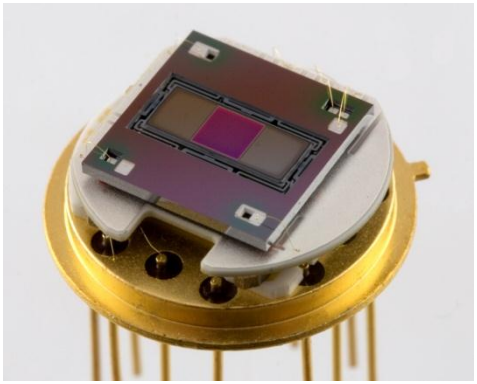
Transmittance vs. drive voltage

Fabry-Pérot-
Inteferometer

Micro-Mirror
Spectrometer



Optical scheme of the spectrometer



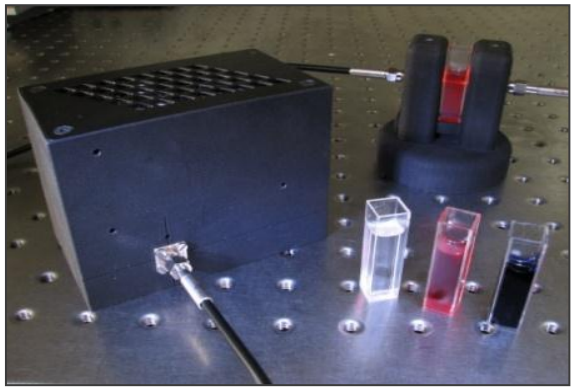
FPI and pyroelectric detector (courtesy of InfraTec GmbH Dresden)

Benefits:

-Spectral range 0.6 – 11 µm

Applications:

- Gas analysis
- Safety systems
- Analysis of fluids



MOEMS spectrometer

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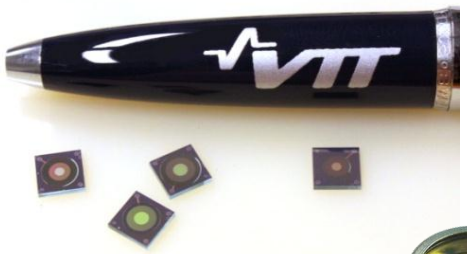
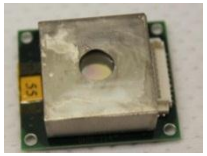
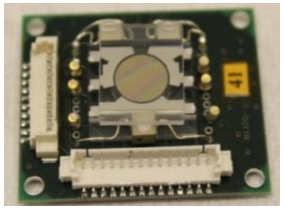
Fabry-Perot technologies

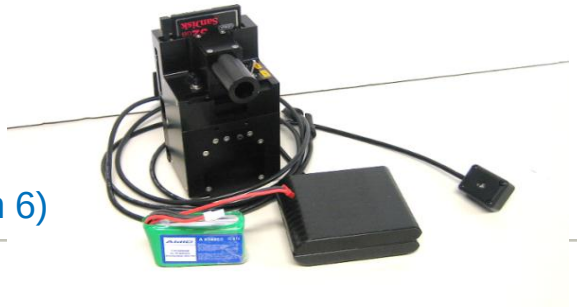
- **MEMS Fabry-Perot Interferometer**
  - For high volumes (>10’000/a)
  - Small, robust, inexpensive, batch-producible



- **PIEZO-actuated Fabry Perot Interferometer**
  - Especially for imaging and multipoint applications
  - Assembled ’one-by-one’
  - For small to medium volumes (10 – 1’000 /a)





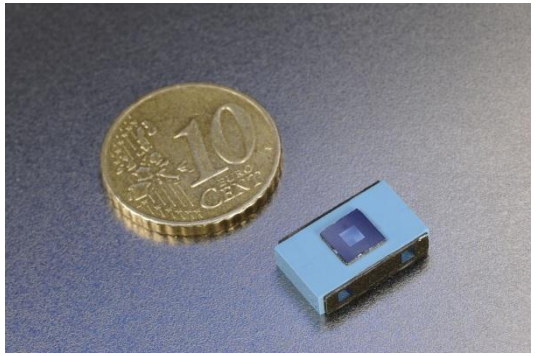


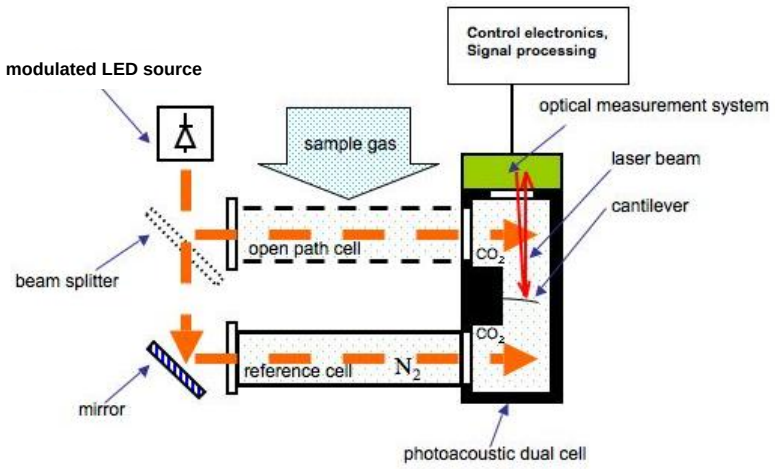
More details: October 16, 2012 at 17:10 (Session 6)

The next layer

Miniaturized photoacoustic gas sensor based on patented interferometric readout and novel photonic integration technologies

- Photoacoustic gas sensor with a volume of less than 5 cm^3
- Two or three orders of magnitude better sensitivity than other methods
- Based on the use of a MEMS cantilever microphone.
- VTT (coordin.), QinetiQ (UK), Ioffe (RUS), University of Turku (FI), Gasera (FI), Doble (NO), Selex (IT)





MINIGAS

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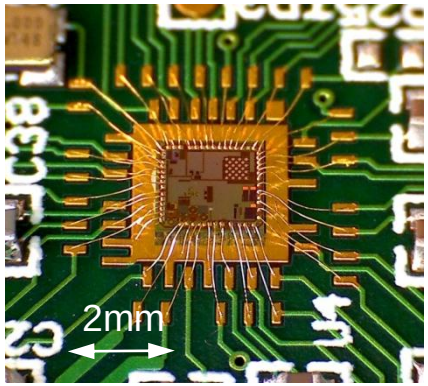
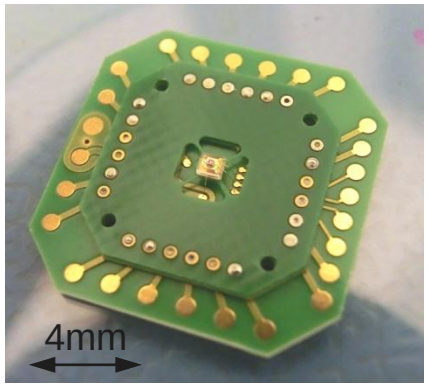
SMAC – Swiss Miniature Atomic Clock

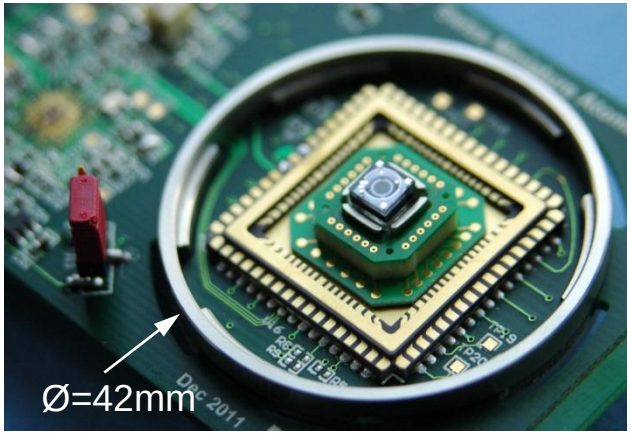
ASIC

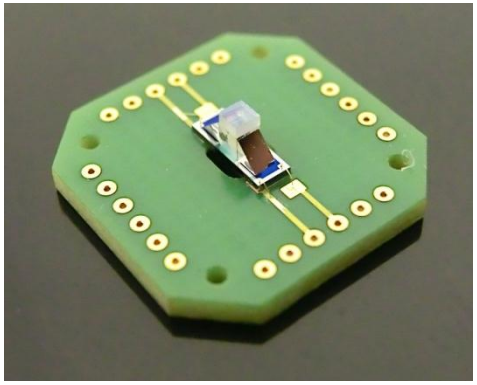


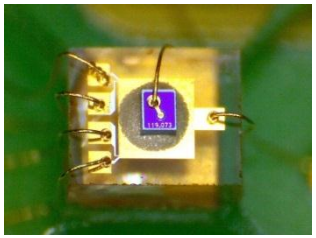


csem

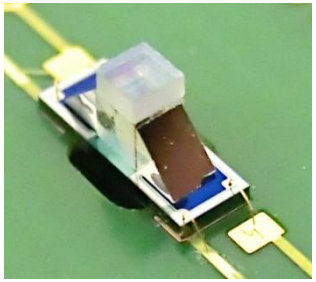
SMAC



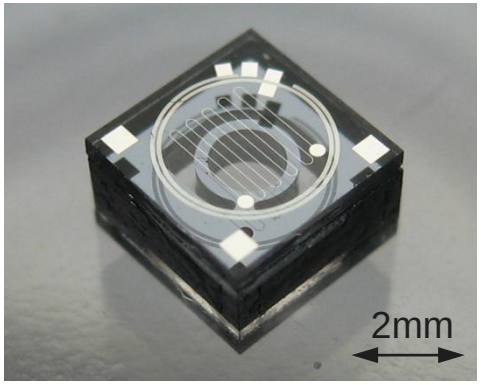




Laser



Optics



Cell

More details: Wednesday, October 17, 2012 at 16:20 (Session 10)

The HTA Photonic Sensing and Integration Platform

Applications are manifold including

- Image sensing
- Biosensing
- 3D measurements of components and objects
- Fiber-optic sensors for harsh environment and medical applications
- Medical diagnostics
- High-power lasers for marking, cutting and welding
- Industrial process control
- **Space (shock, vibration, vacuum, radiation, temperature, hermeticity)**

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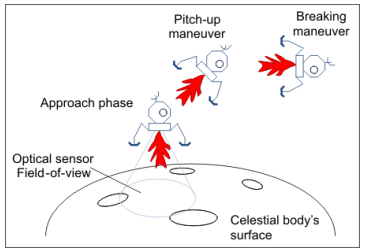
The HTA Photonic Sensing and Integration Platform for Space

Applications including

- Optical communication: Intersatellite laser communication, (mobile) optical ground stations, optical receivers, pointing, acquisition, tracking, …
- 3D time-of-flight for space (e.g. Mars Sample Return Mission):
  - Precise entry, descent and (soft-) landing
  - Rendezvous/docking in orbit (sample canister with orbiter)
  - Structure deployment monitoring (e.g. PV panels)
  - Rover navigation.
- Spectroscopy: ChemCam (NASA) measures chemical rock content on MARS optically
- …



The HTA Photonic Sensing and Integration Platform

The platform will provide many opportunities and solutions for the European photonics market including

- the development of robust, reliable and low cost processes designed for devices/sensors and complete photonic systems
- precision robot systems for automation,
- manufacturing capabilities through the build up an extension of an infrastructure for process development and pilot and small series.

Key devices such as Silicon MEMS and high-brightness light sources will be combined with 3D integration technologies to allow flexible manufacturing.

The Heterogeneous Technology Alliance HTA

Made in Europe

Summary and Conclusions