IPCEI on Microelectronics

Webinar:

The IPCEI Microelectronics: Tech solutions for the digital transformation, IoT, smart sensors and Industry 4.0

November, 11th, 2020, 11.30-13.15

Organized by:

Airi ASSOCIAZIONE ITALIANA PER LA RICERCA INDUSTRIALE

Italian Association for Industrial Research
www.airi.it

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Organizing Committee:

- **Lorenza Ferrario**, Bruno Kessler Foundation
- **Cosimo Musca**, STMicroelectronics
- **Claudia Pinna,** Airi
- **Andrea Porcari**, Airi
- **Pasquale Sanfilippo**, STMicroelectronics
- **Sesto Viticoli**, Airi

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- Technologies, processes, applications
- spillover on multiple innovation eco-systems and sectors
- RtoR and RtoB opportunities

Information, questions and follow-up on the webinar: info@airi.it

Important Projects of Common European Interest (IPCEIs) are about

- Disruptive and ambitious research & innovation **beyond the state of the art.** From Research Development Innovation to **First Industrial Deployment**
- Aim to generate positive **spillover** effects, exploiting knowledge & results, beyond «business as usual of partners»
- Participation is open to EU players

On going discussion on future IPCEIs

- **Connected, clean and autonomous vehicles**
- **Smart health**
- **Low carbon industries**
- **Hydrogen technologies and systems**
- **Industrial Internet of Things**
- **Cybersecurity**
- **Batteries**

Note: IPCEI Microelectronics 2: design of a potential new initiatives still in progress, and open to new companies/RTOs
(Italian organizations: see MISE website)

More info:
Forum for IPCEIs and Strategic Value Chains https://ec.europa.eu/commission/presscorner/detail/en/ip_19_6204

MISE: https://www.mise.gov.it/index.php/it/213-normativa/notifiche-e-avvisi/2041387-invito-a-manifestare-interesse-per-un-secondo-importante-progetto-di-interesse-comune-europeo-ipcei-sulla-microelettronica-scadenza-11-09-2020

IPCEI on Microelectronics

IPCEI Microelectronics in a nutshell (2020-2024)

Investments:

- 4 Member States: Germany (coordinator), France, Italy, UK
- 29 direct participants
- Aggregate State aid: > EUR 1.75 billion
- Total investments: EUR 7.9 billion

Goals:

- Structure the sector of microelectronic in Europe
- Unlock the technological and economic potential of key technologies (KET)
- Favor the dissemination of microelectronic technologies in the industry

Connecting Europe's Microelectronic Industry to foster Digitization in Europe

IPCEI Structure and partners

www.ipcei-me.eu

Technologies Fields & Spillover & Target markets

5 Technology Fields

Energy efficient chips (TF1)

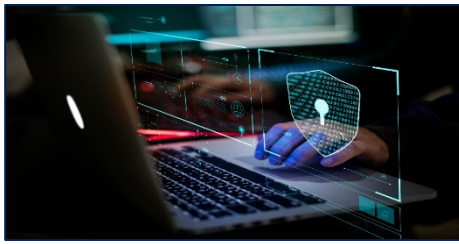
Power semiconductors (TF2)

Smart sensors (TF3)

Optical equipment (TF4)

Compound materials (TF5)

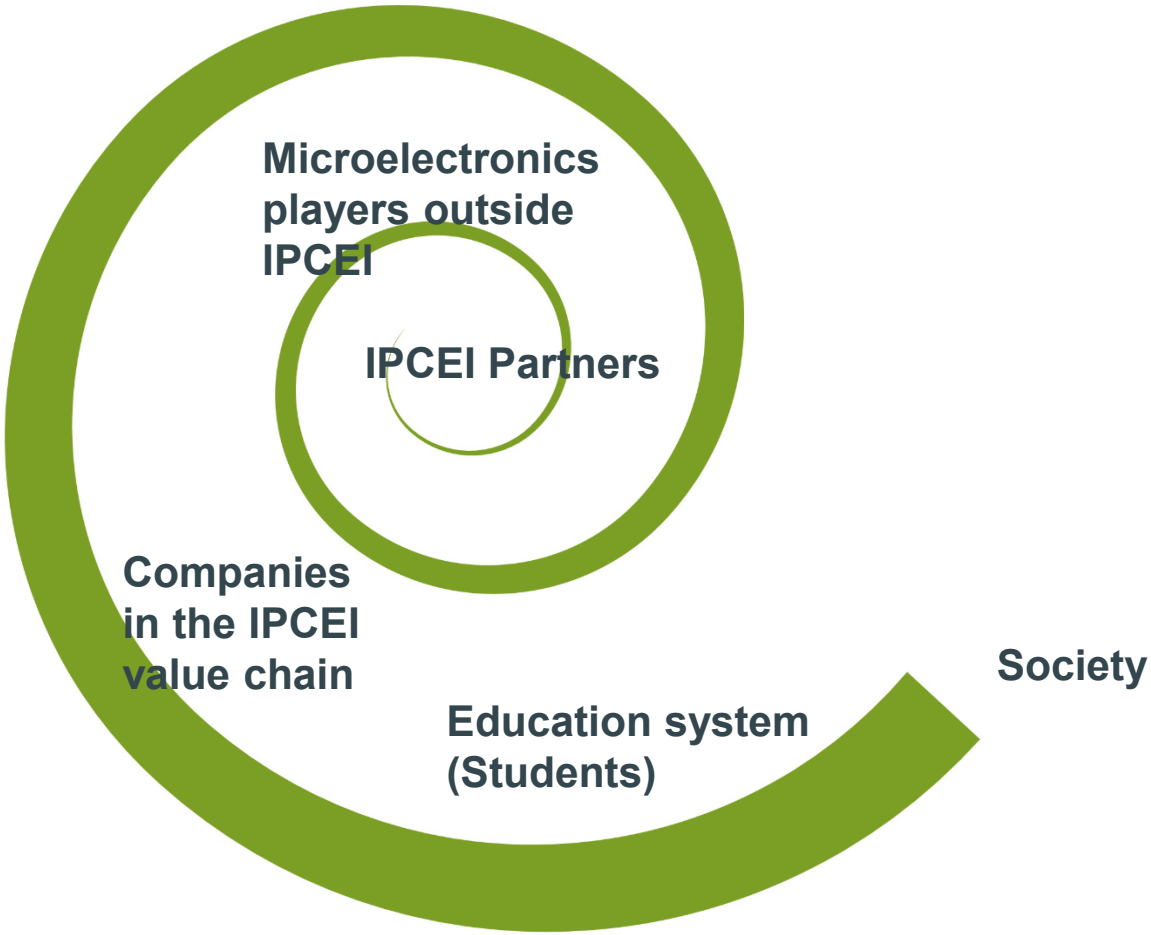
Automotive	IoT	Space & Avionics	Security



Power Smart Grid	Smart Home Smart Cities	Industry 4.0	Artificial Intelligence	Health

This webinar will focus on TF3, with inputs from the other TFs , to develop IoT solutions for the **industrial, medical, environment, and transport sectors**

Spillover targets



Dissemination and Spillover actions
for the benefit of European economy

Knowledge creation & sharing

Education & Training

Access to IPCEI technology

Tech customization

Prototyping

Proof of concept networks

and more to discuss…

Panel discussion will focus on spillover models and practices

Spillover IPCEI-microelectronics – events at national level

1. **June 11th, 2019 (NanoInnovation):** Introduction to the IPCEI - microelectronics
2. **June 30, 2020 (Airi webinar):** progress, and partnership opportunities
3. **September 16,17, 2020 (NanoInnovation):** school on microelectronics
4. **November 11, 2020 (Airi webinar):** technology developments, national and international networking
5. **Beginning of 2021 :** applications and markets, spillover practices, etc

Follow next initiatives on www.airi.it, www.st.com, www.fbk.eu

Airi Webinar:
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WELCOME AND INTRO

- **Andrea Porcari**, Italian Association for Industrial Research (Airi)

TECHNOLOGIES AND APPLICATIONS (11.30-12.30)

- *Silicon photomultipliers (SiPM) 3Dintegration: applications in Light Detection And Ranging (LiDAR) and subnuclear physics experiments*
  Alberto Mazzi, Bruno Kessler Foundation, Italy

- *LiDAR dedicated Single Photon Avalanche Diode (SPAD) Developments and Laser Driver in Automotive CMOS Technology*
  Thomas Rotter, Elmos Semiconductor SE, Germany

Q&A

- *Innovative Nanoelectronics: Neuromorphic computing, Power electronics, Si photonics*
  Christophe Wyon, CEA-LETI, France

- *The last generation of MEMS technologies and the new opportunities for products and applications*
  Sara Loi, STMicroelectronics, Italy

Q&A

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SPILL OVER TO INDUSTRY AND TERRITORIES: MODELS AND EXPERIENCES
(12.30-13.10)

Experiences from:

- *NanoRegion, A network of Italian and Slovenian nano-laboratories open to the small-medium enterprises*
  Marco Lazzarino, National Research Council (CNR), Italy

- *Education and open innovation approaches, the APTE experience*
  Paul Svasta, Association for Promoting Electronics Technology (APTE), Romania

Panel discussion with speakers, chairs and delegates: models and practices to favour exploitation of IPCEI technologies

CLOSING REMARKS

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THANKS FOR YOUR PARTICIPATION!

SiPM 3Dintegration: Applications in LiDAR and subnuclear physics experiments

Alberto Mazzi
Fondazione Bruno Kessler

mazzi@fbk.eu
www.fbk.eu

content review

IRIS
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FUTURE BUILT
ON KNOWLEDGE

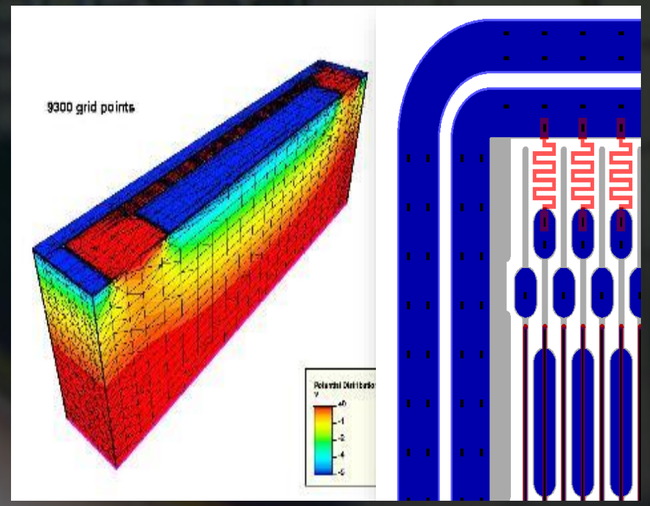
7 RESEARCH CENTRES

+400 RESEARCHERS

+100 INTERNATIONAL PHD STUDENTS

FBK Expertise

Simulation and Design



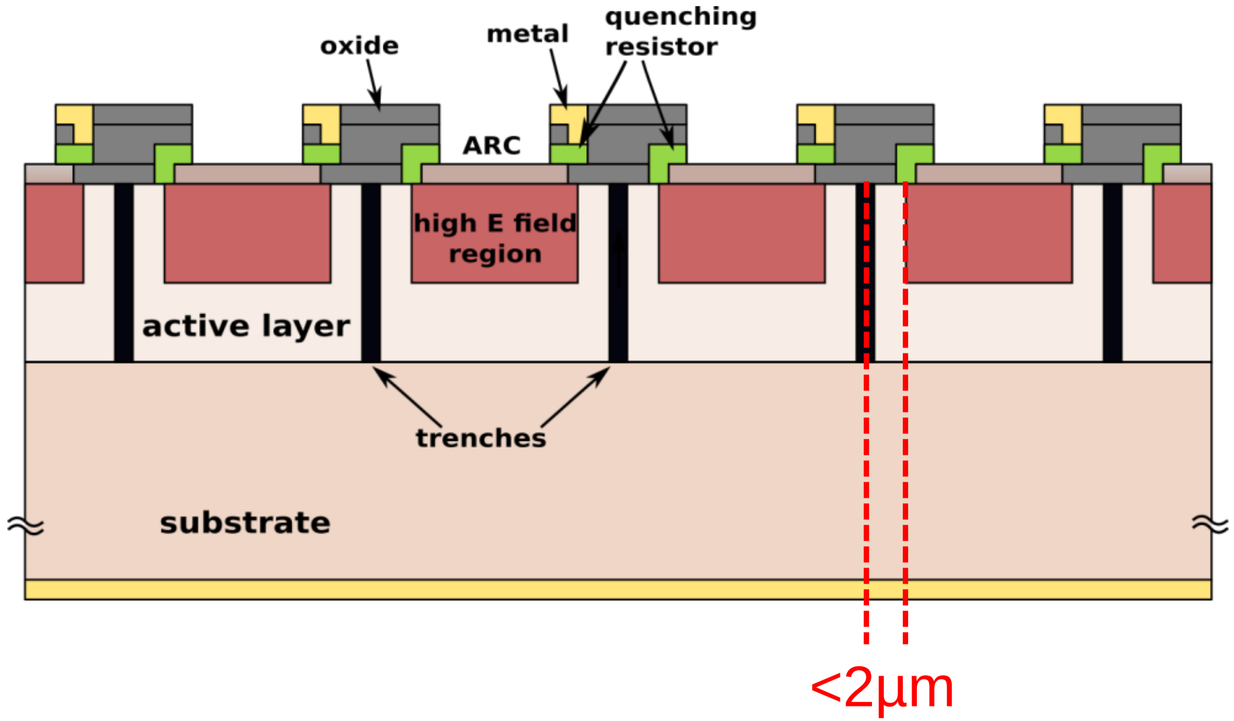
Fabrication

Device Testing

Conventional SiPM technology

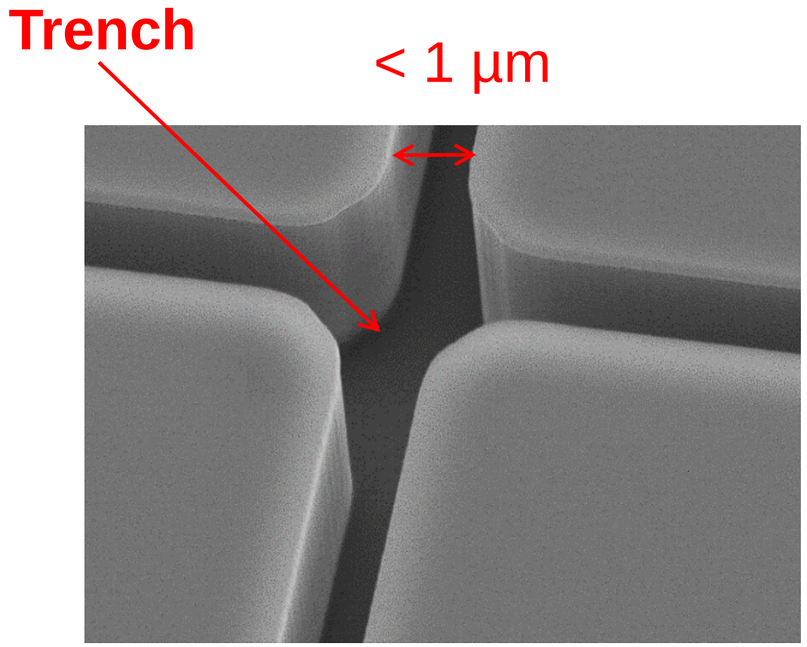
Conventional SiPM process

- Single junction in the epitaxial layer
- Trench insulation to reduce optical crosstalk
- Built-in quenching resistor for each cell
- Antireflective coating

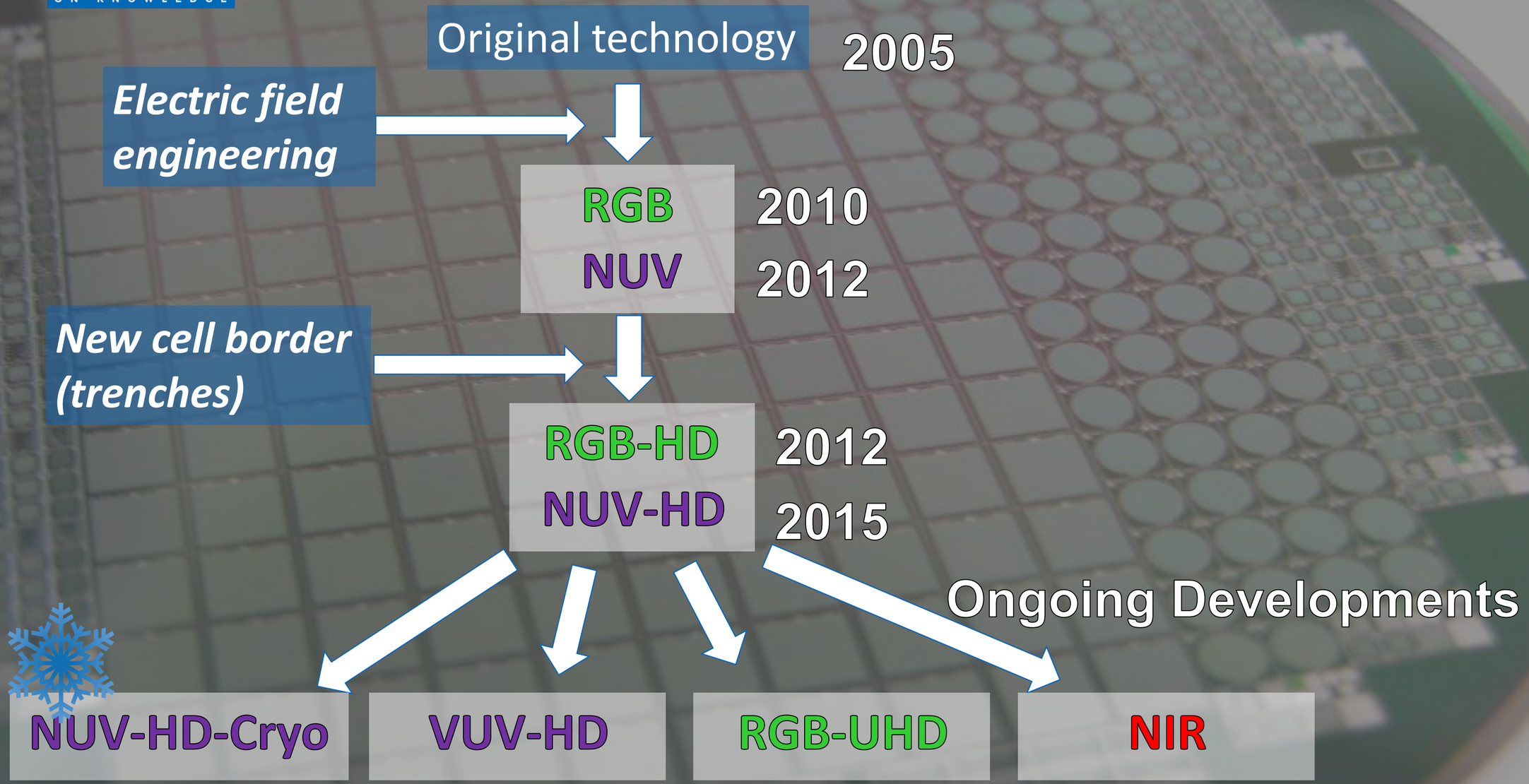


SiPM connections

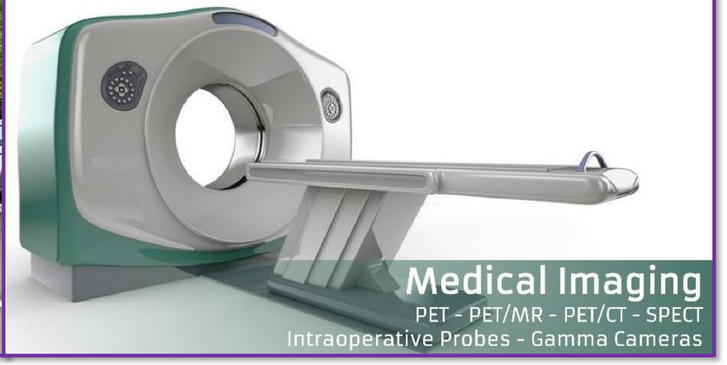
1. Conductive backside + front side wire bonding
2. Bulk contact from front side (anode/cathode wire bonding)
3. Through silicon vias (TSVs)



FBK SiPM Technology Roadmap



FBK SiPMs and applications

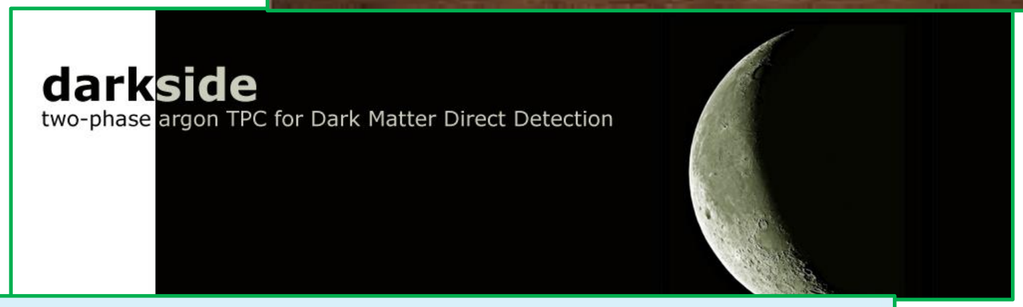


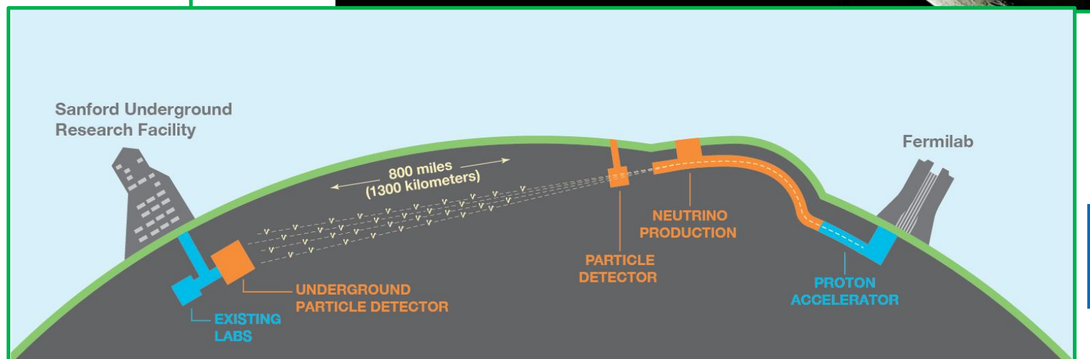
Industrial applications

- Time-of-flight Positron Emission Tomography
- X-ray spectroscopy
- Automotive and industrial LiDAR

Scientific experiments

- Astrophysics experiments
- Dark-matter research
- High-energy physics
  (precision timing and calorimetry)
- Subnuclear physics
  (neutrinos and rare events)





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IPCEI program
FBK cleanroom upgrade

2021: FBK Cleanroom upgrade

- 3D integration technologies
- New device interconnection capabilities
- Backside illumination

↓

Next-generation SiPM technology

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SiPM 3Dintegration for LiDAR

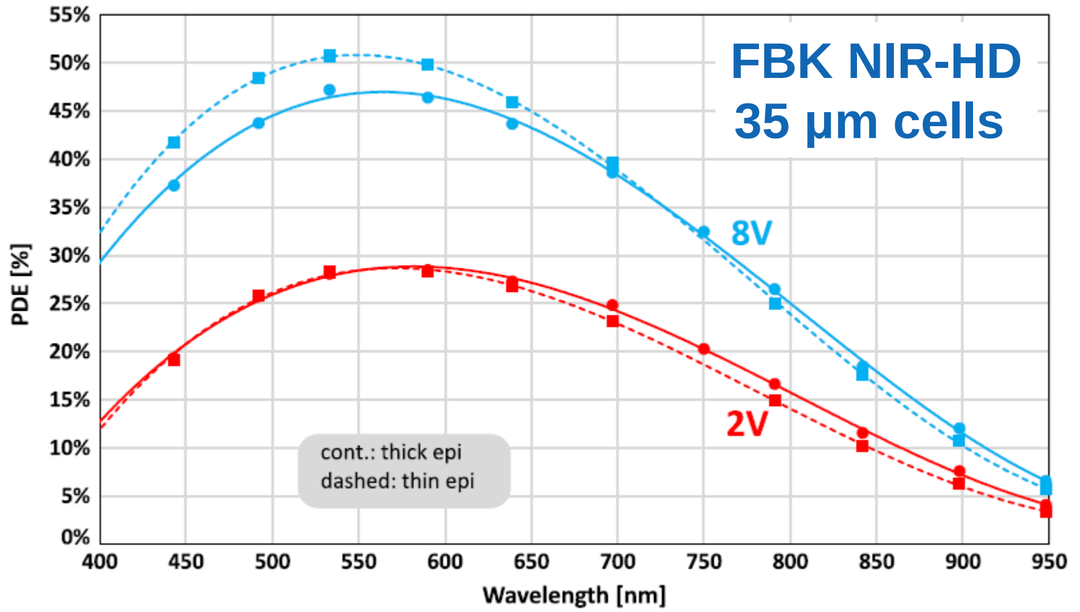
Automotive LiDAR Challenges and goals

Goals

- High efficiency @ 900 nm
- High dynamic range (small cells)
- Fast timing to achieve good spatial resolution

Challenges

- Absorption depth in silicon ~30 um
- Fast timing with small cells



Current status

PDE of current technologies

- FBK NIR-HD
  35 µm cells – PDE 12%
- Hamamatsu S13720 series
  25 µm cells – PDE 7%
- ON Semiconductor RB series
  40 µm cells – PDE 10%

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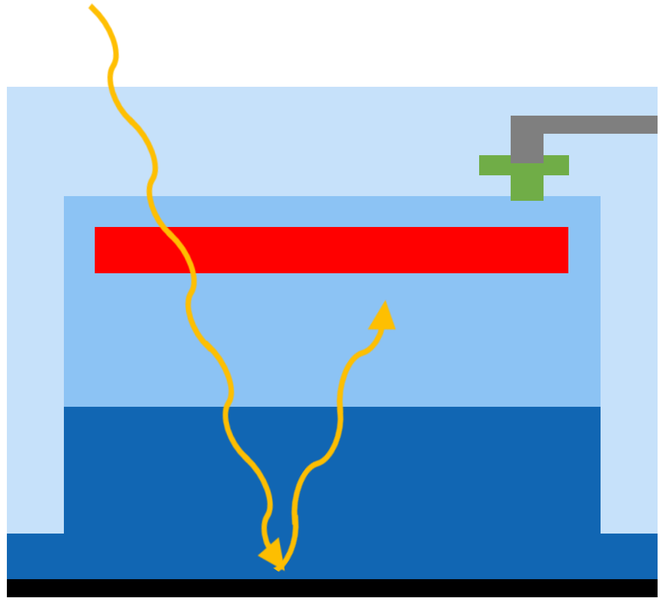
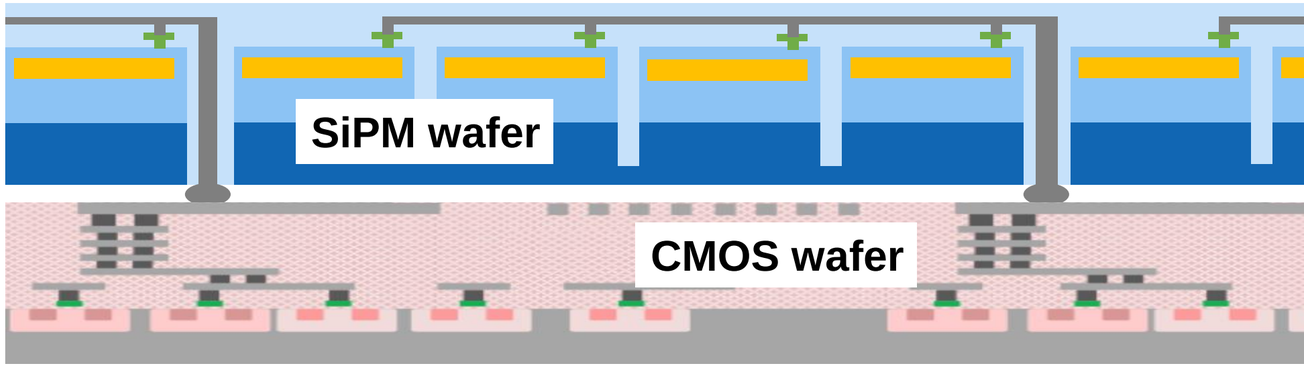
Automotive LiDAR
3D integration opportunities

Fast readout

- SiPM segmentation with µ-vias
  - From segments to single-cell access
  - Reduction of transient time spread





Increase of light path through reflections

- Reflective surfaces / interfaces to confine NIR light
- Higher efficiency with same device thickness

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3D-SiPMs in subnuclear physics experiments

Subnuclear physics
Next-generation experiments

SiPM: goals

- High efficiency in detection of liquid noble elements scintillation
- Cryogenic SiPM technology
- Radio-purity constraints

Challenges

- Scintillation of liquid Ar
  λ 128 nm / T 87 K
- Scintillation of liquid Xe
  λ 175 nm / T 165 K

Current status

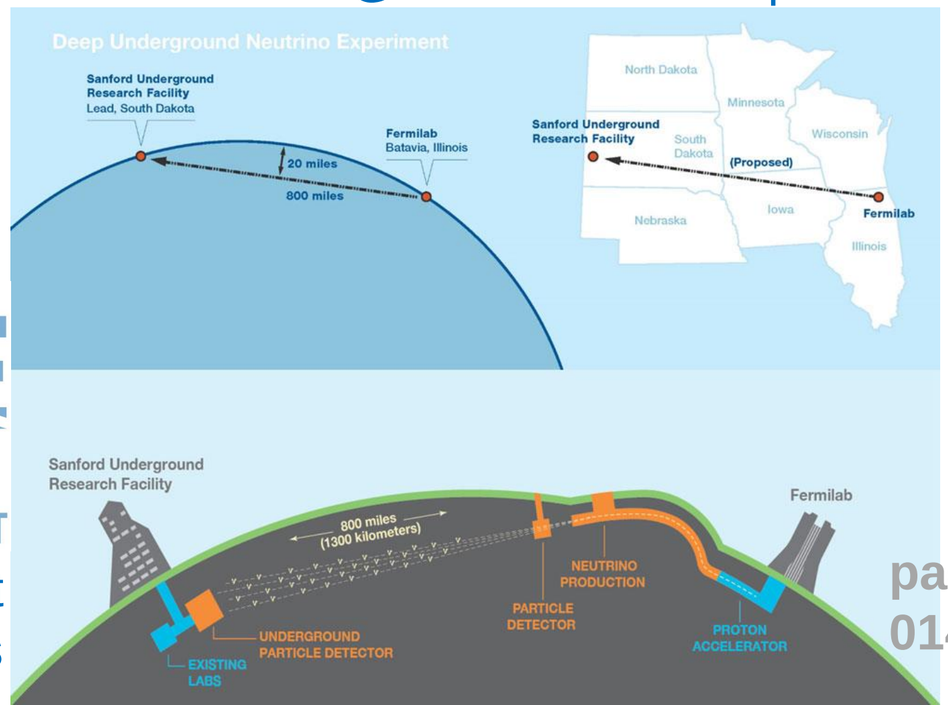
- Cryogenic SiPM technology already available
  (FBK NUV-HD-Cryo)
  with extremely low dark noise
- VUV sensitive technologies are being optimized
  Efficiency of FBK VUV-HD
  22% @ 200 nm with 35 μm cells

Next **E**nriched **X**enon **O**bservatory
Neutrinoless double-beta decay

nEXO

DUNE
DEEP UNDERGROUND NEUTRINO EXPERIMENT

Deep **U**nderground **N**eutrino **E**xperiment
Neutrino oscillations, mass, flavors



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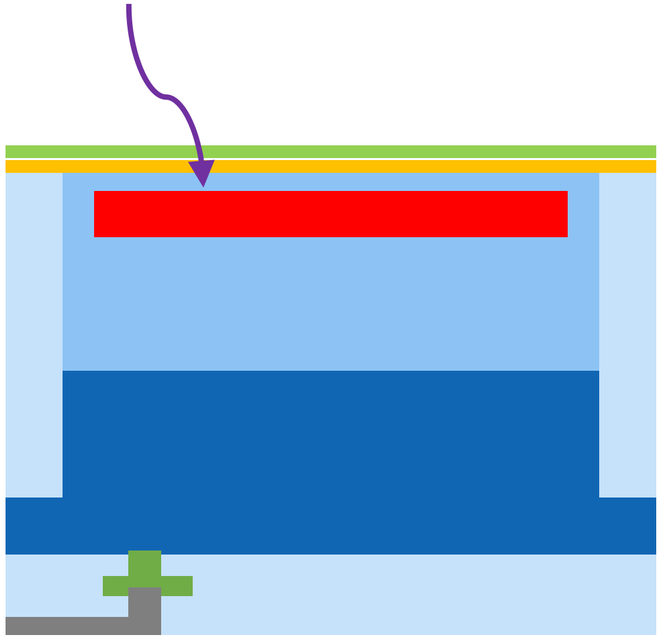
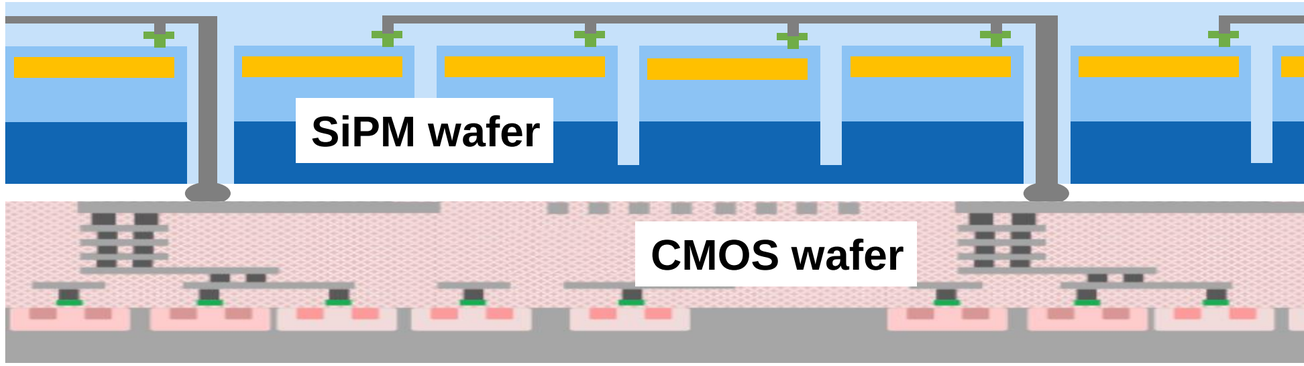
Subnuclear physics experiments
3D integration opportunities

High spatial resolution

- SiPM segmentation with µ-vias
  - Spatial sensitivity within a SiPM device
- SiPM imagers for next generation experiments
  - Single cell access, very challenging!





Optimization of entrance window

- New solutions to improve transmission of VUV
- Sensitivity with ultra-short absorption depth
- Backside illumination (BSI)

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Conclusions

A reference for SiPM R&D in Europe

- Collaborations with industry
- Collaborations with research partners CERN, INFN,…

Next-generation SiPM technology

- Thanks to IPCEI program FBK will develop 3D integration and advanced SiPM processing capabilities
- Applications in high efficiency devices for automotive LiDAR
- Technology developments for next-generation physics experiments

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Thank you!

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Fondazione Bruno Kessler: fbk.eu
Center for Materials and Microsystems: cmm.fbk.eu
Integrated Radiation and Image Sensors: iris.fbk.eu
FBK and FBK-IRIS are on LinkedIn!

Contact us: gola@fbk.eu mazzi@fbk.eu

All the members of the team working on custom SiPM technology at FBK:

- **Fabio Acerbi**
- **Anna Rita Altamura**
- **Giacomo Borghi**
- **Andrea Ficorella**
- **Alberto Franzoi**
- **Alberto Gola**
- **Alberto Mazzi**
- **Stefano Merzi**
- **Vladimir Mozharov**
- **Laura Parellada Monreal**
- **Giovanni Paternoster**
- **Maria Ruzzarin**
- **Nicola Zorzi**

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IPCEI on Microelectronics

elmos

Innovation Matters

LiDAR dedicated SPAD Developments and Laser Driver in Automotive CMOS Technology

11th November 2020 Thomas Rotter

Expert in analog mixed signal solutions focused on automotive market

35 years experience

- Development, production & marketing of **Integrated Circuits (ICs)**
- Sales: ~85% **automotive** ~15% **non-automotive**
- **Main strength:** design of innovative products and specialized application know how

Worldwide leading products

- Elmos serves the **megatrends** (ADAS, EV…) & **attractive niches** with benchmark innovations
- **#1 positions:**
  - Ultrasonic Parking Assistance
  - Ambient LED Light
  - Motor Control Applications
  - Gesture Control
  - **Soon** Rear Light LED & more…

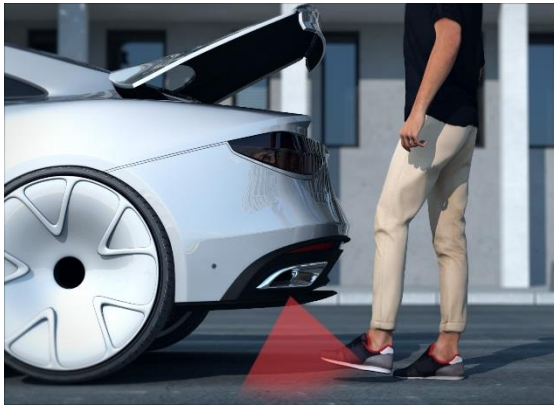
Ready for further growth

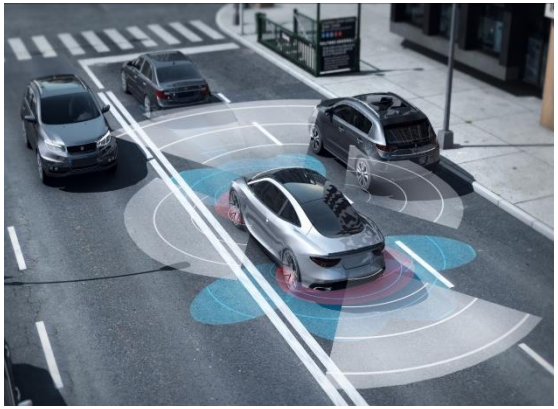
- **Global player for automotive** ASSPs and ASICs
- Significant addition to **design/application resources**
- **Fablite:** Flexible production strategy for Frontend and soon for Backend (Test)

From a statistical point of view: >**4 Elmos ICs** in every new car *…soon >5!*

IC = Integrated Circuit / ASSP = Application Specific Standard Product / ASIC = Application Specific Integrated Circuit

Optical Sensors Portfolio





HALIOS® IR Sensor IC

- Pioneering in gesture control with **>50 million ICs in the field**
  - Applications e.g. proximity, swipes, object detection and touchless door access
- **2012: Market launch** (VW Golf 7)
- Today: available in almost **all VW group** models – started in **BMW models**
  … more OEMs to come

3D ToF - Imager

Exterior gesture recognition
Interior gesture control

2019: Market launch

Next Gen 2020

SPADs & SiPM for LIDAR

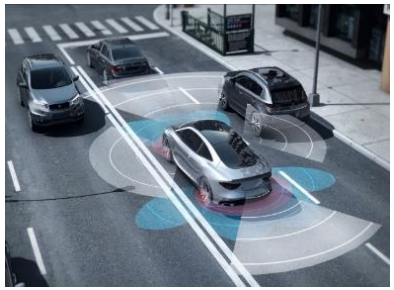
Emergency breaking
Pedestrian detection
Environment mapping
Collision warning

Product definition, Customer Sampling

HALIOS®= High Ambient Light independent Optical System /
SPAD=Single Photon Avalanche Diode/SiPM=Silicon Photomultiplier

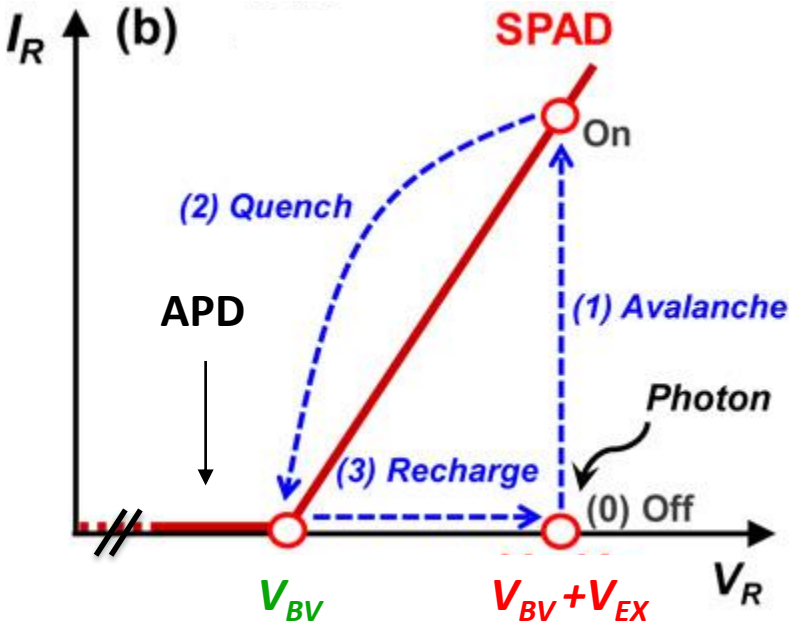
ToF= Time of Flight
LIDAR= Light Detection and Ranging

The Role of LiDAR in Advanced Driver Assistant Systems



Outline

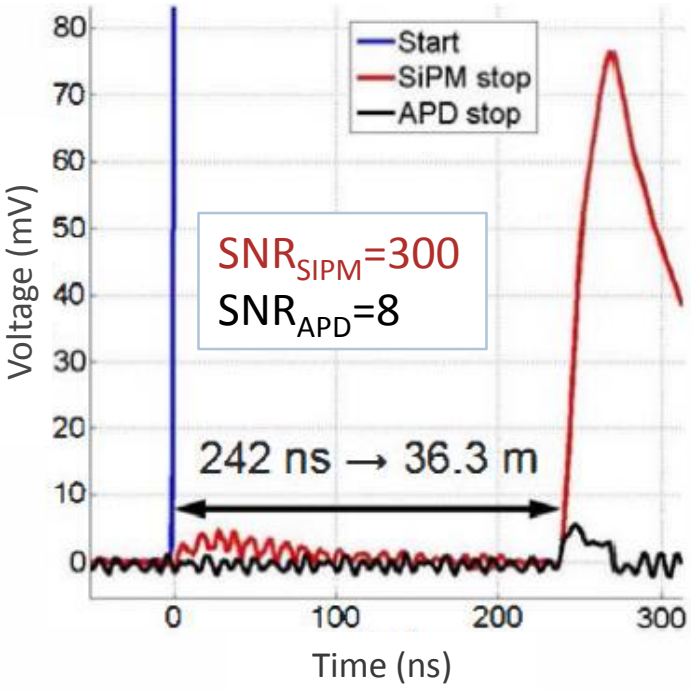
- Short Introduction to CMOS based SPADs
- 256 x 16 SPAD Array and Readout IC
  - Architecture and Features
  - Benefit of multi-event detection
- 16 Channel Laser Driver
- Solid State LiDAR Demonstrator



- **APD**
  - Bias: slightly below V_{BV}
  - Linear-mode (amplifier-mode)
  - Gain: limited (<1000) and noisy

- **SPAD/SiPM**
  (SPAD array with passive quenching)
  - Bias: well above V_{BV}
  - Geiger-mode (working as trigger)
  - Gain: large ($10^5..10^6$)

- **ToF of APD vs SiPM**

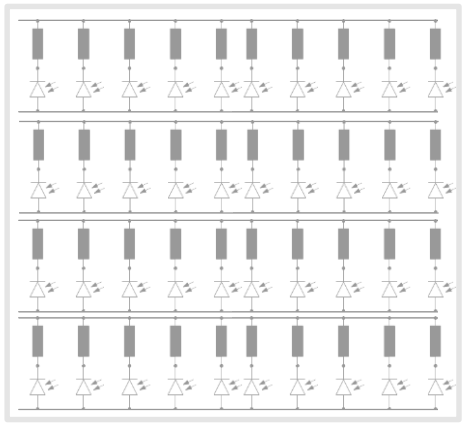


Source: G. Adamo, *"Time Of Flight measurements via two LiDAR systems with SiPM and APD"*, AEIT, 2016

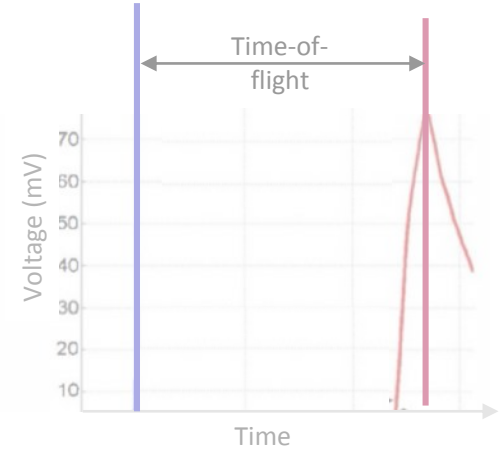
SPAD Structure – Two Different Device Operations

Silicon Photomultiplier (SiPM)

n photons

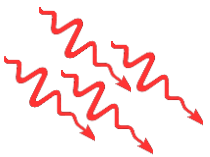


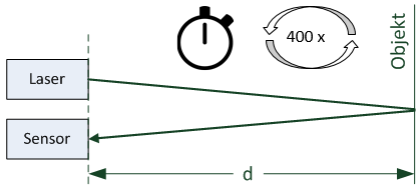
single measurement

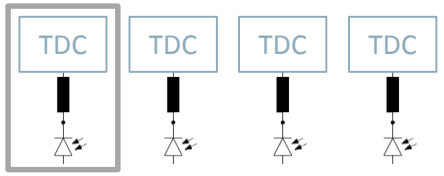


dToF SPAD imager array

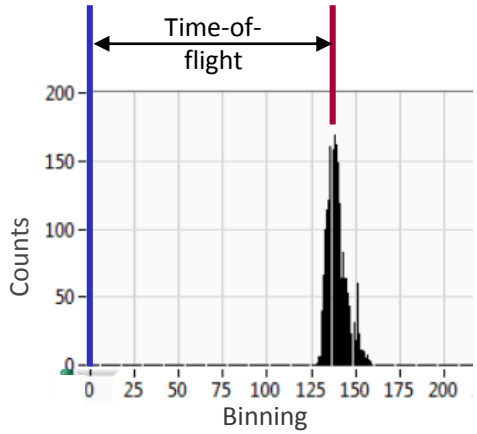
n times a
single photon





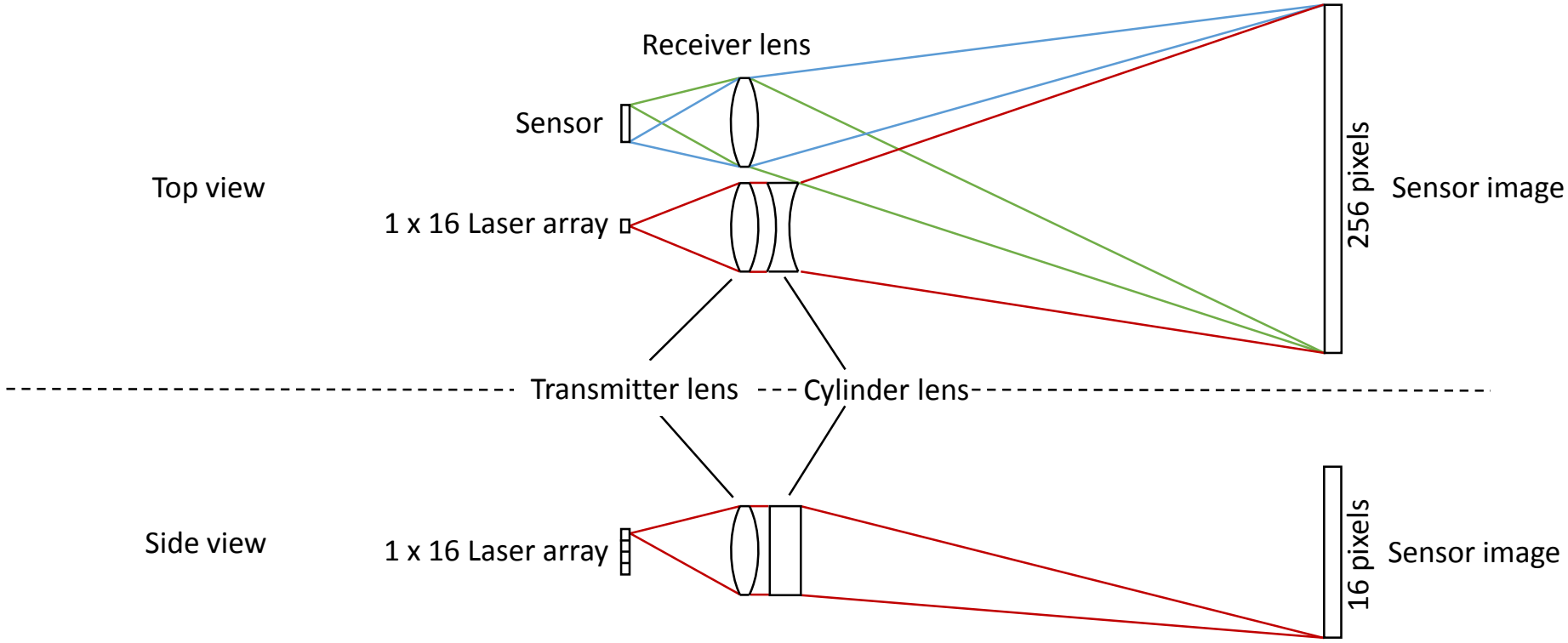


n measurements

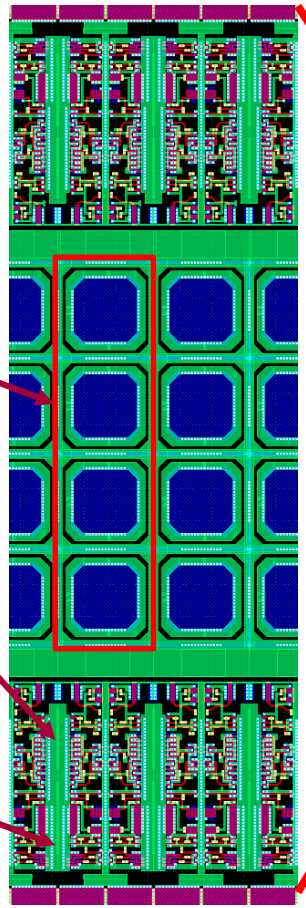


Elmos – Rolling Shutter + Solid State Laser Scanner

- No moving parts on either the macro or the micro scale
- Highly efficient and scalable
- Energy is only emitted into the observed field of view (1 x 16 laser array)
- Observed field of view is only extending over illuminated area (rolling shutter)



2nd Gen 16 x 256 Pixel SPAD CMOS Array

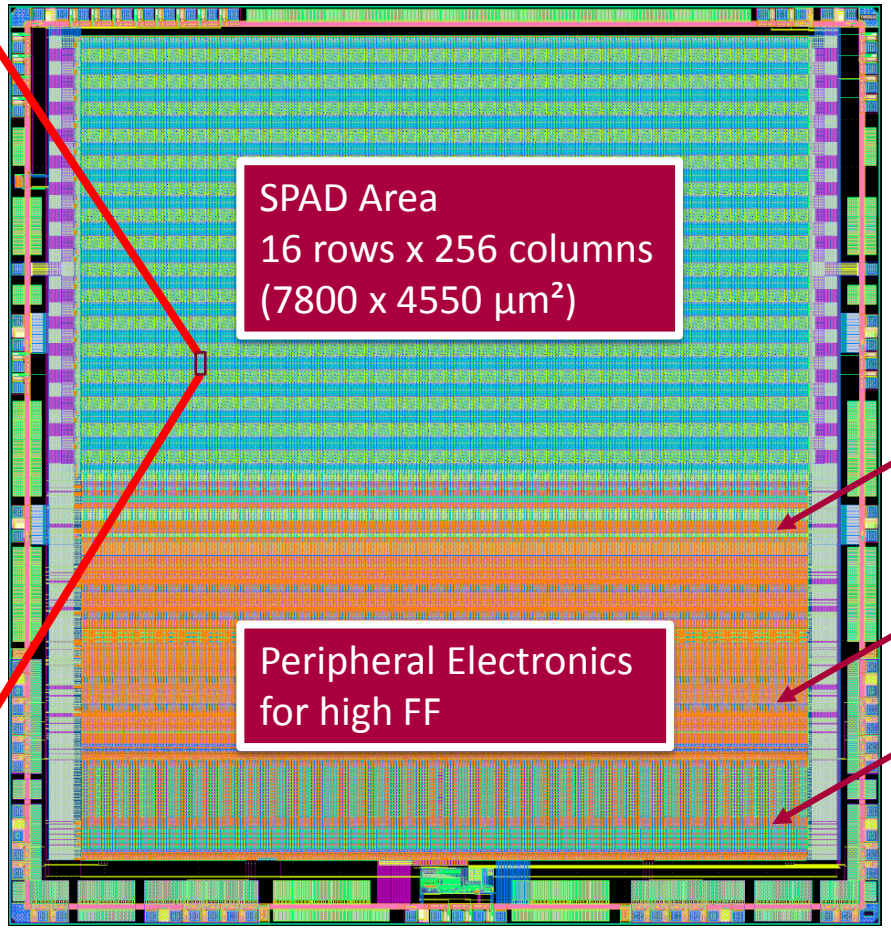


1x4 SPADs per Pixel

Active Quenching

Pulse Shaping

Total Chip Size: 9200 x 9700 µm²



120µm SPADs
160µm Electronic

280µm Line Pitch

SPAD
Active: 20µm
pitch: 30µm
FF: 42%

Coincidence Circuits

Time-to-Digital Converters

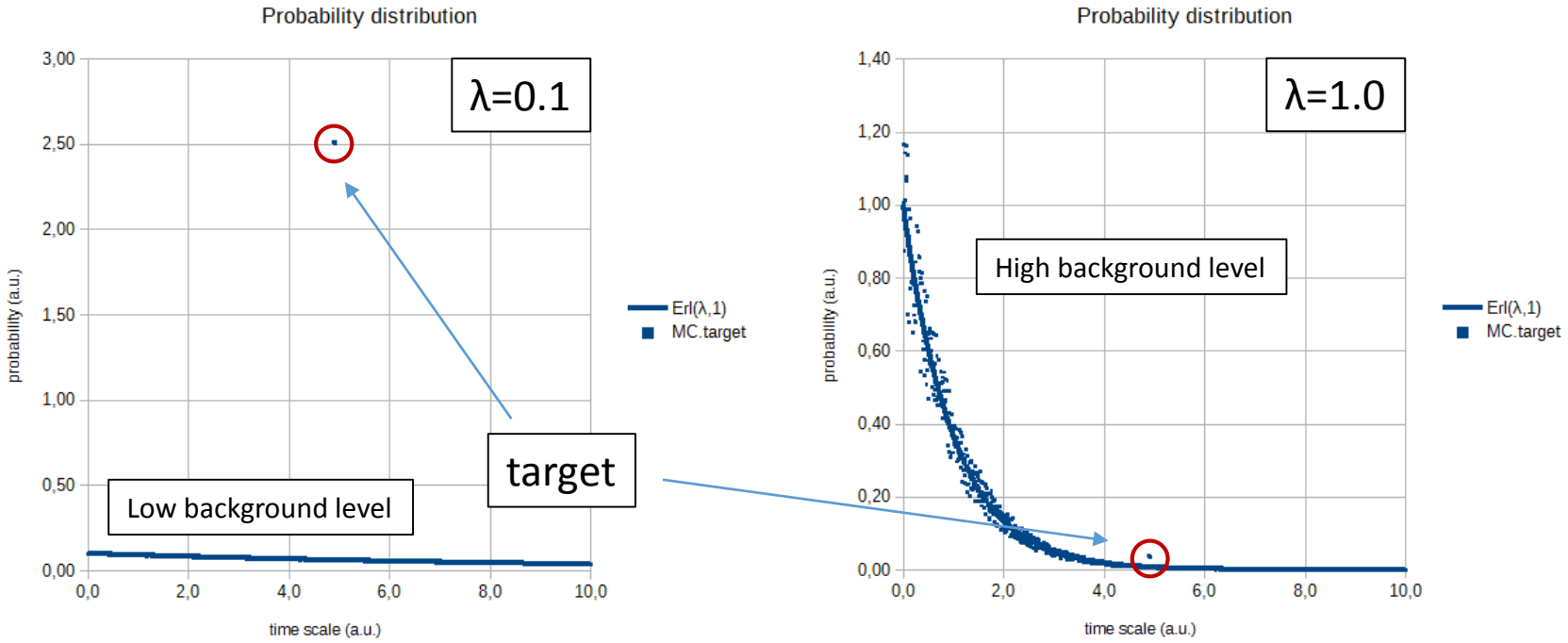
Output:
2 x 12 bit digital

in cooperation with:

Fraunhofer IMS

Effect of background illumination - conventional

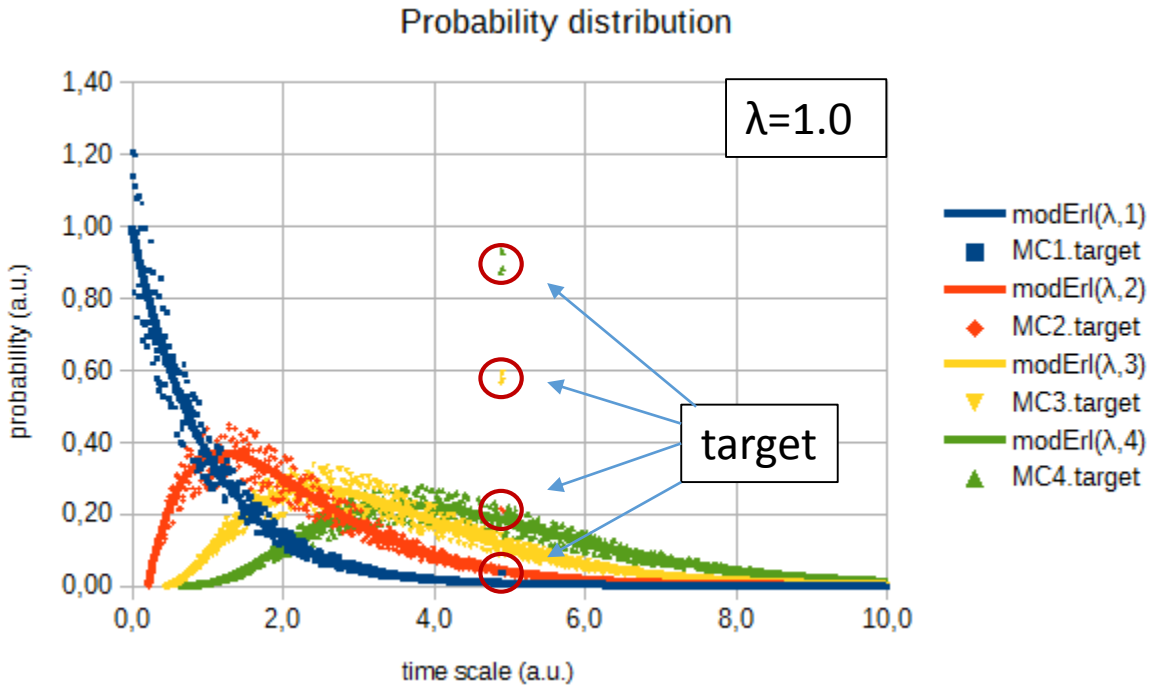
- SPAD Detector cannot distinguish between a background/ambient and target signal photon; target signal damped at high background illumination due to reduced population of unfired cells to a few percent (which are triggered by first-photon arrival)
- Background illumination is described by λ (event rate per time unit), typically in the range of kHz to many MHz



Erl=Erlang-Distribution
MC=Monte-Carlo Simulation

Benefit of Multievent Detection (simulation)

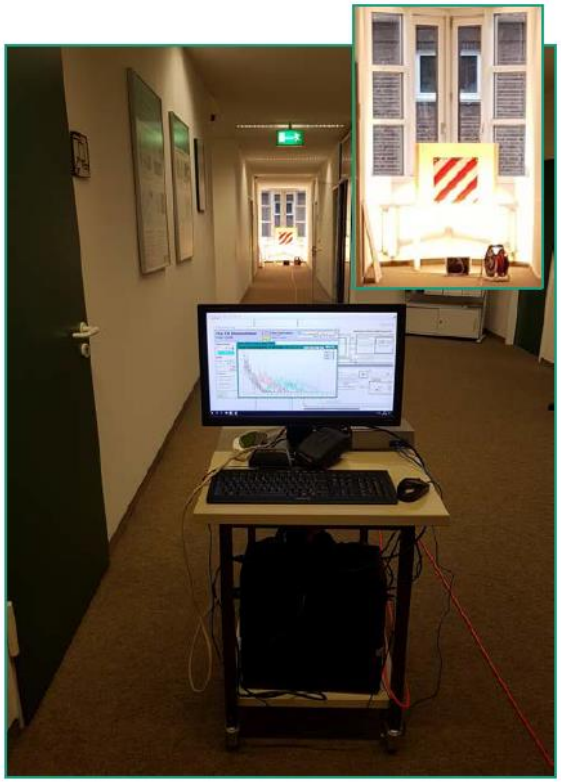
- By introduction of multievent (within same laser shot) the population of unfired detector cells is recovered and therefore the effective range is prolonged
- Signal quality improves for far target
- Beneficial also for difficult situations (e.g. fog, rain) and targets of higher order (glass, fence)

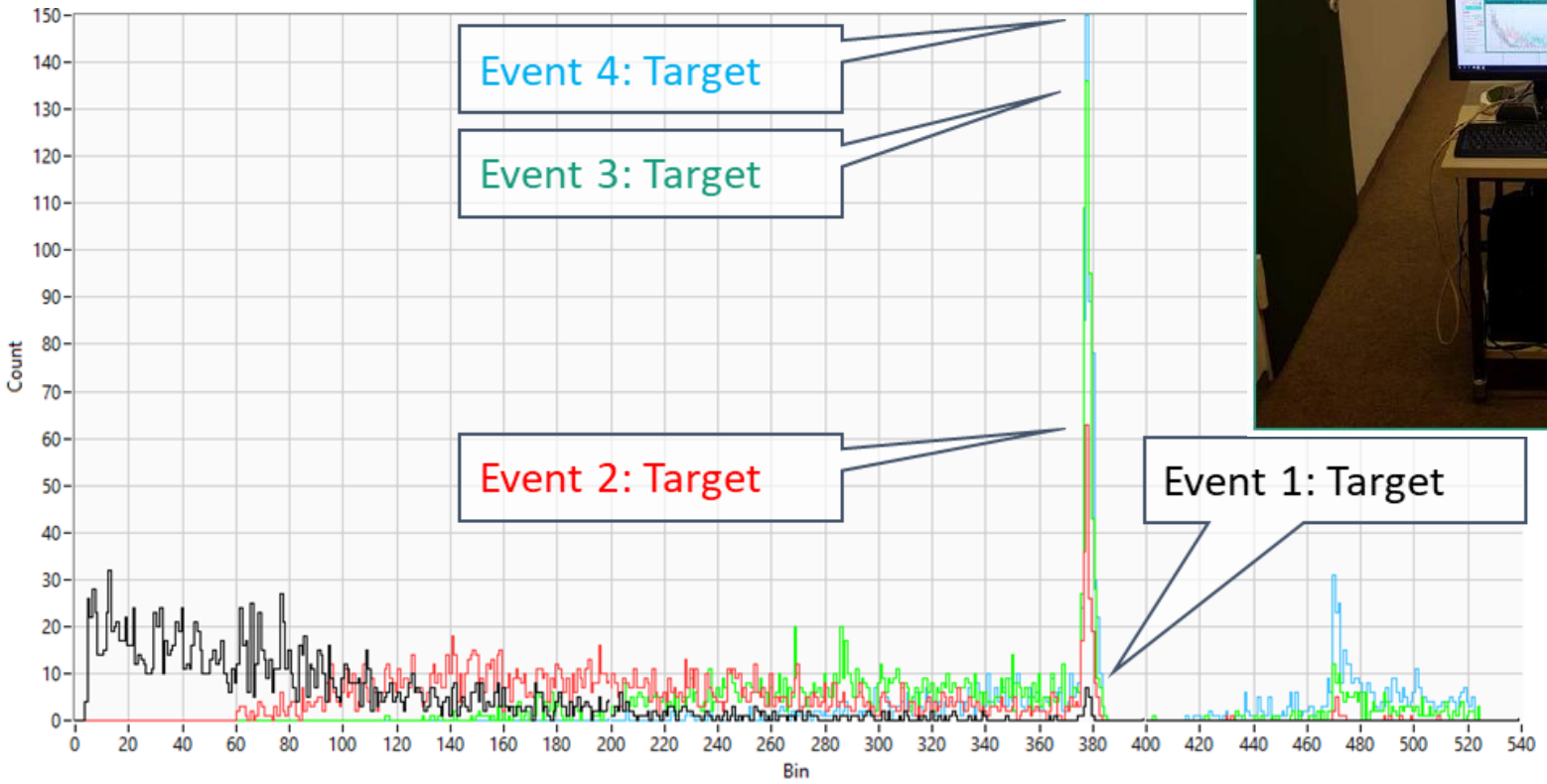


modErl=modified Erlang-Distribution (including delay effects)

Benefit of Multievent Detection (experiment)

- Target: Retro reflector in 21m distance
- High ambient light due to mobile spotlight
  (no LED spotlight, with strong IR spectrum)
- 2000 laser pulses in conventional flash (full FOV, 1TX)

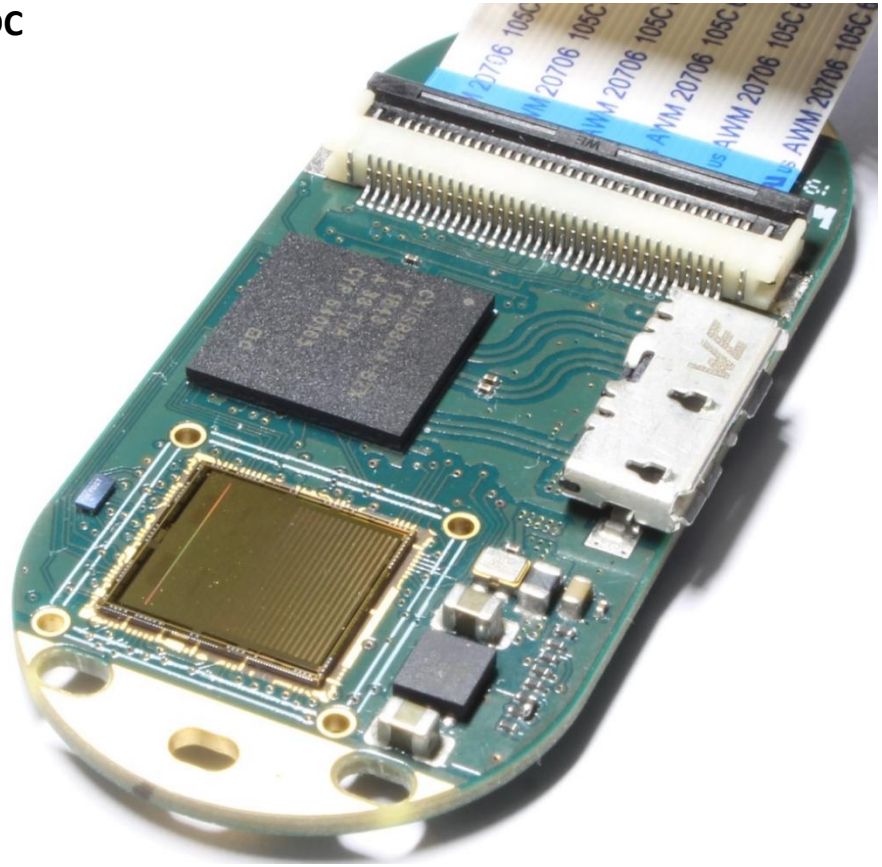




Solid State Scanning LIDAR Camera – Detector

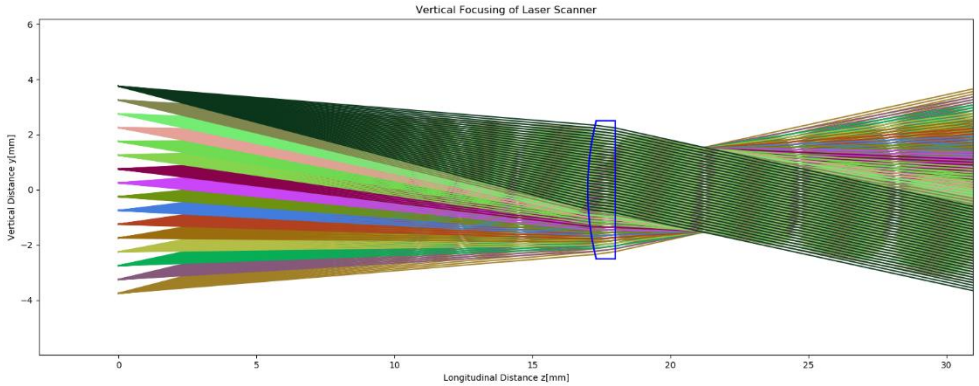
2nd Generation SPAD Array

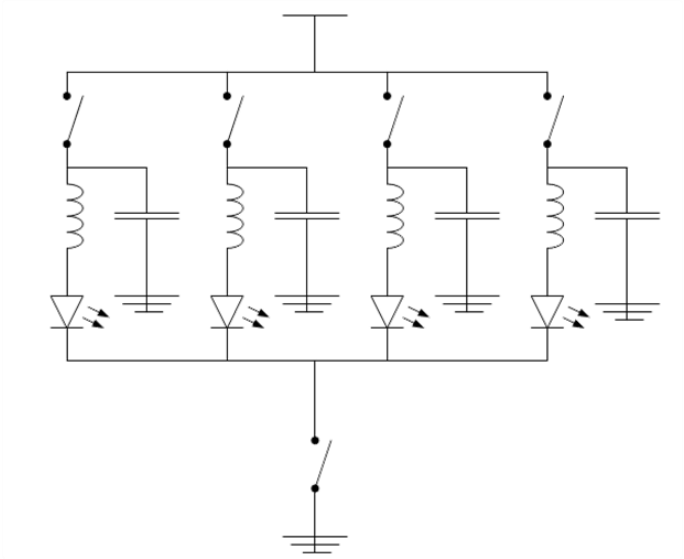
- **256 x 16 CMOS SPAD Array**
- Massive parallel data processing with **multi-channel TDC**
- **3mm distance resolution** by interpolation
- 192m full range
- **Rolling shutter operation**
- Build on robust & automotive qualified process
- Active quenching circuit for SPAD dead-time variation
- 4x vertically arranged single SPADs
- **Multi-event detection mode**
  - **Up to 4x event/pixel & pulse**
  - **Increased Range & Noise Immunity**
- Ready for auto-coincidence
  for high ambient light rejection
- Statistical evaluation offers rich analysis of raw data
  - Distance
  - Brightness / ambient light
  - Visualization of multiple reflections
  - Rain and fog detection

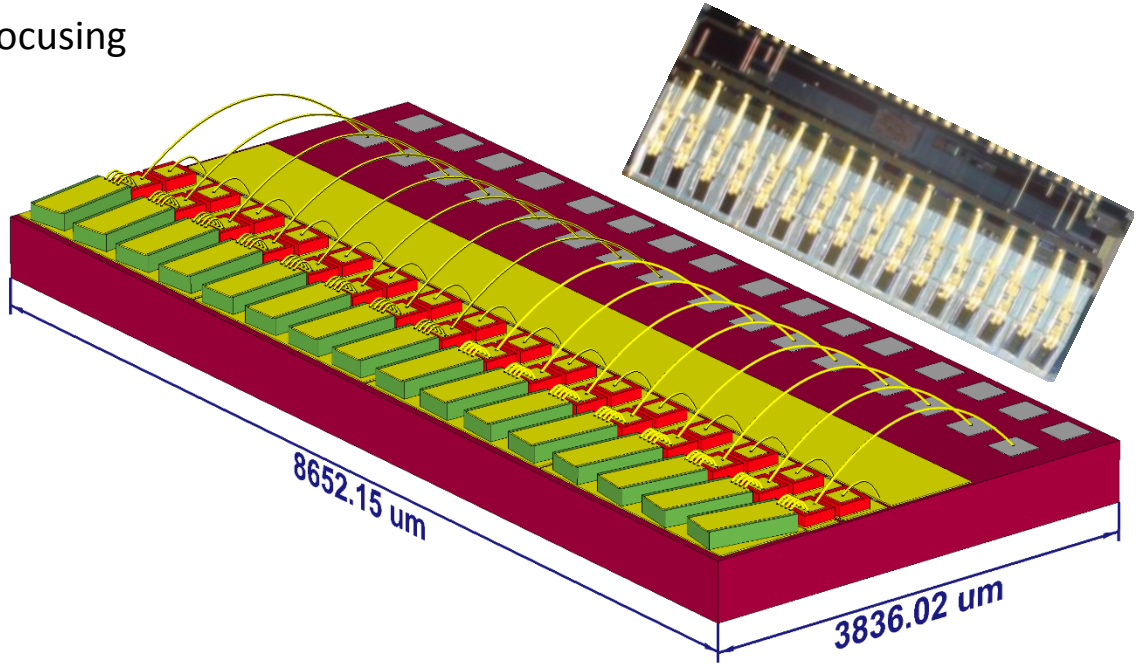


ALIS16 – Automotive LIDAR Illumination System

- 16 channel module, 4 common cathode
- Full integration of pre-driver, output FET HV switches and digital control
- Each single-channel edge emitting laser bar gradually rotated up to ±10° for massive simplification of optics
- Compact single lens design for vertical focusing and horizontal de-focusing



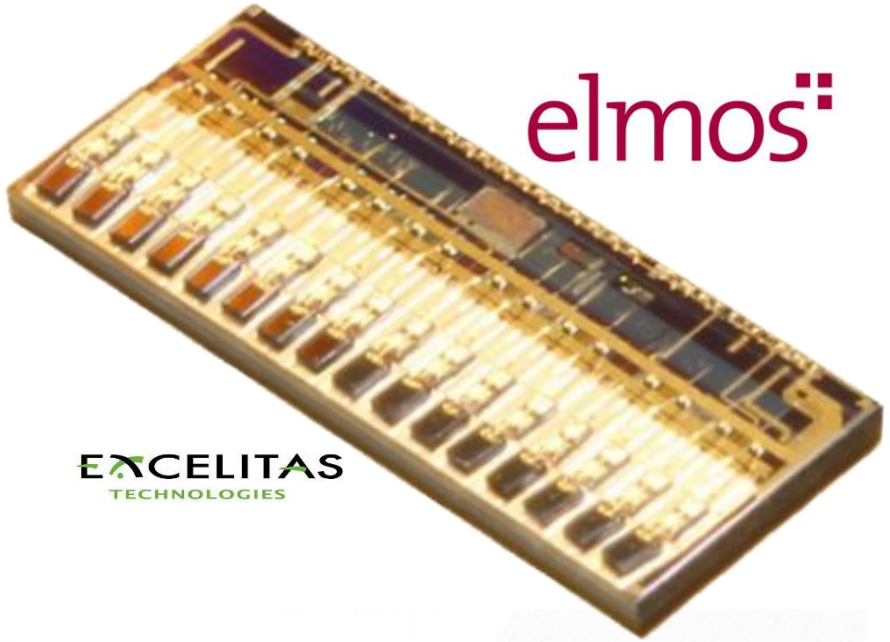




Solid State Scanning LIDAR Camera – Laser Scanner

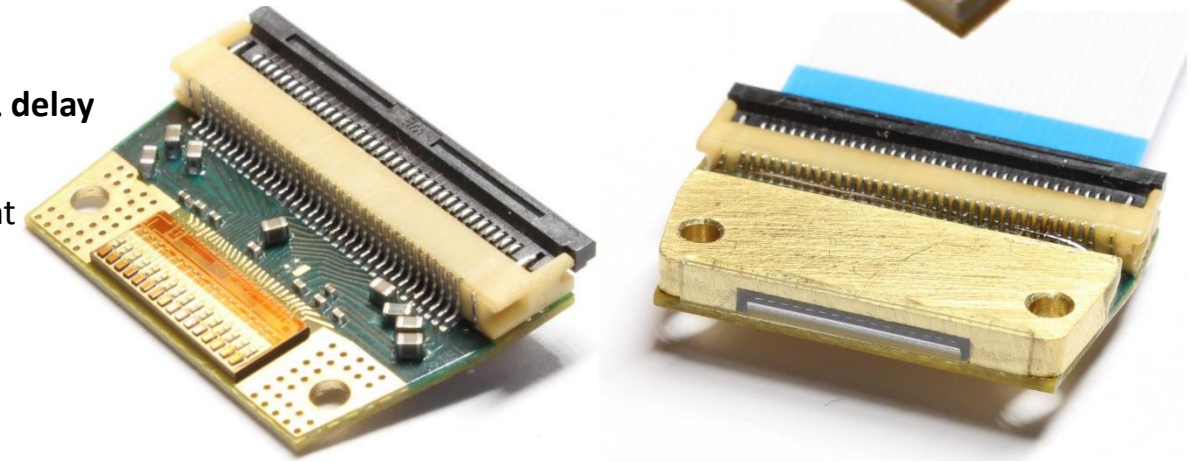
1st Generation Multi-Channel Laser Driver Module

- **16-channel configurable laser driver IC**
- 16x Excelitas edge emitting 905nm pulsed laser diodes
- 32x Murata 1nF UWSC caps
- **1ns pulse width @ 50A peak current**
- **HV charge & discharge function for each channel**
- **Lowest inductance stack-up multi-channel driver**
- Scalable building block approach for high channel count
- Build on robust & automotive qualified process



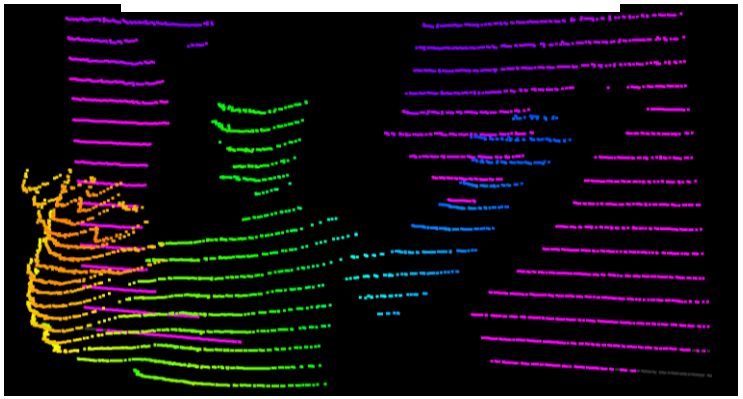
Special Features

- **Configurable pulse width (<1-15ns) & delay**
- **10ps resolution**
- Integrated diagnostics & measurement
- **Control average laser power**
- **Monitoring of eye safety**
- 10x temp sensors w/digital readout
- 100MHz SPI interface
- On-chip channel sequencer

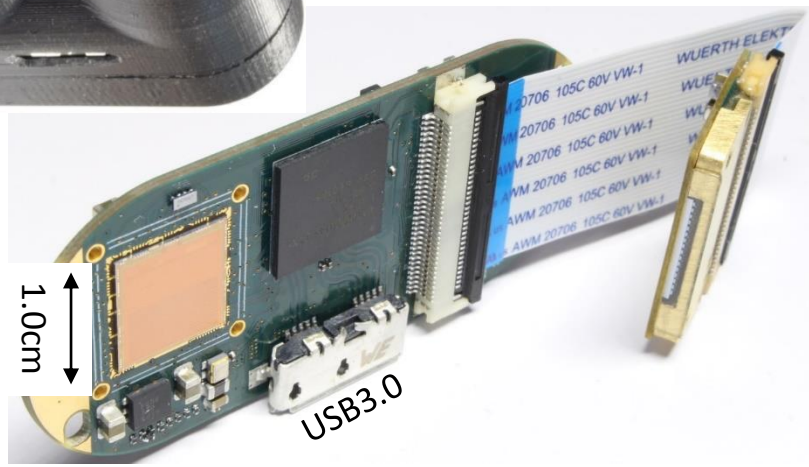


True Solid State Scanning LIDAR System

short range 3D Point Cloud(40° x 20° FOV)



- System features
  - **USB3.0 microcontroller and fully bus powered**
  - **GUI with 40 fps framerate**
  - **Ultra-compact form-factor**
  - **Proof of concept and CAD tailored laser optics for optimal projection of 16 EE laser beams**
- **16 channel pulsed laser module**
  - **1ns pulse width @ 50A peak current**
  - Integrated diagnostics & measurement
  - Control of average laser power
  - Monitoring of eye safety
- **256 x 16 pixel CMOS SPAD array**
  - **Rolling shutter**
  - Auto-coincidence circuit
  - **Multi-event detection**



GUI=Graphical User Interface
EE=Edge-Emitter
CAD=Computer Aided Design

Acknowledgments

IPCEI on MICROELECTRONICS

Technology Field 3
„Smart Sensors“

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and Energy

on the basis of a decision
by the German Bundestag

Contact:
Dr. Thomas Rotter
R&D Engineer
Email: thomas.rotter@elmos.com

Thank you for your attention!

Elmos Semiconductor AG

Heinrich-Hertz-Str. 1 | 44227 Dortmund | Germany
Telephone: + 49 231 75 49 0 | Telefax: + 49 231 75 49 149
info@elmos.com | www.elmos.com

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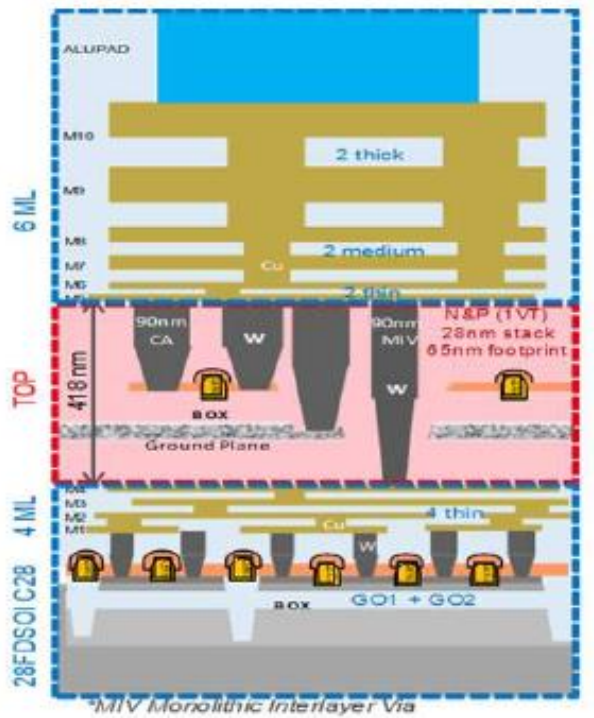


INNOVATIVE NANOELECTRONICS: NEUROMORPHIC COMPUTING, POWER ELECTRONICS, SI PHOTONICS

Nom événement | Nom Prénom | Date

IPCEI
on Microelectronics

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE
Le Gouvernement
and the local public authorities

Leti: a CEA Technology research institute

CEA,

#1 Innovative Public Research Organization in Europe

Clarivate Analytics

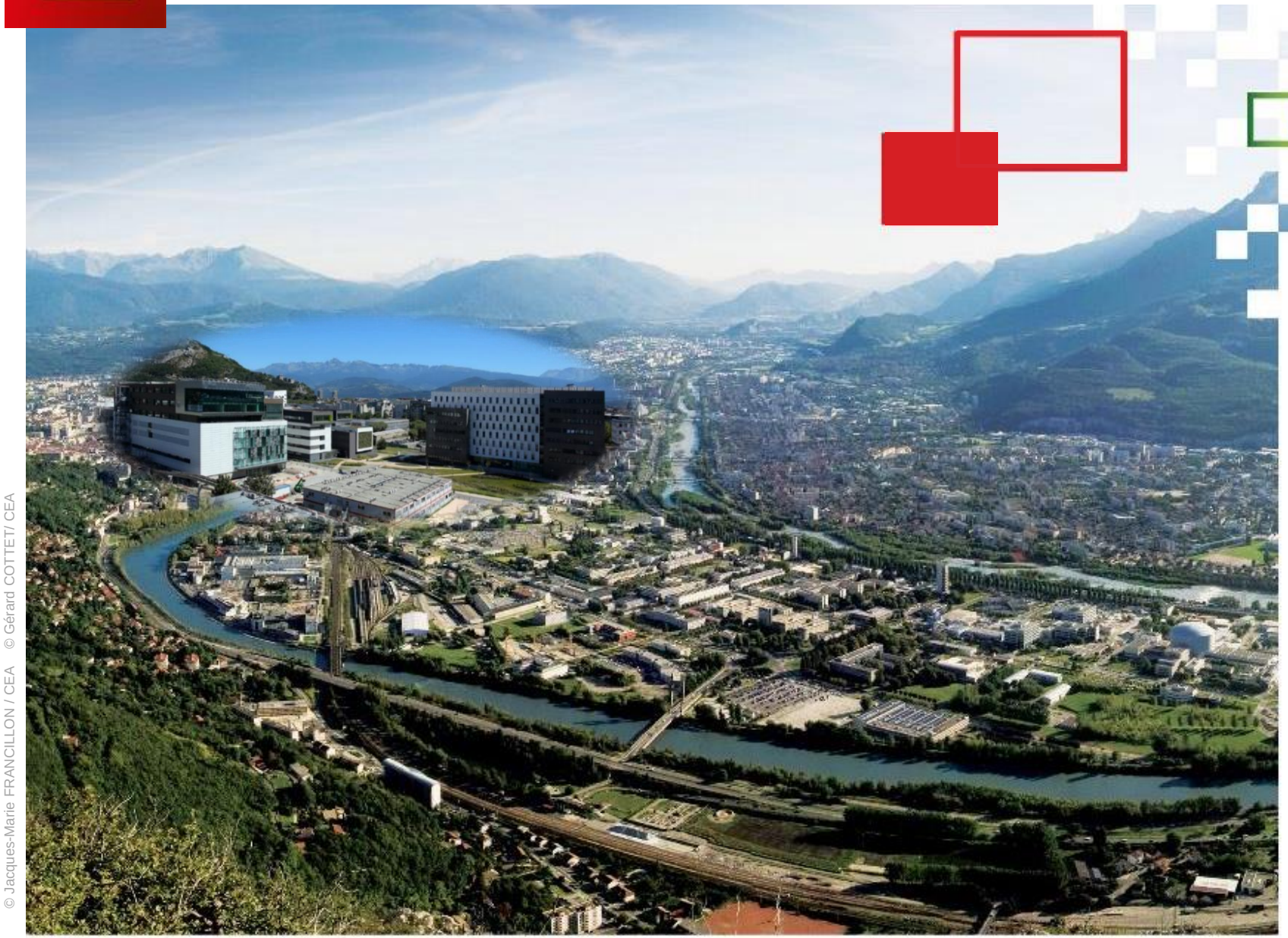
TOP 100 GLOBAL INNOVATORS SINCE 2011

“CEA is a key player in research, development and innovation in four main areas:

defense and security,
nuclear and renewable energies,
technological research for industry,
fundamental research in the physical sciences and life sciences.

Drawing on its widely acknowledged expertise, the CEA actively participates in collaborative projects with a large number of academic and industrial partners”

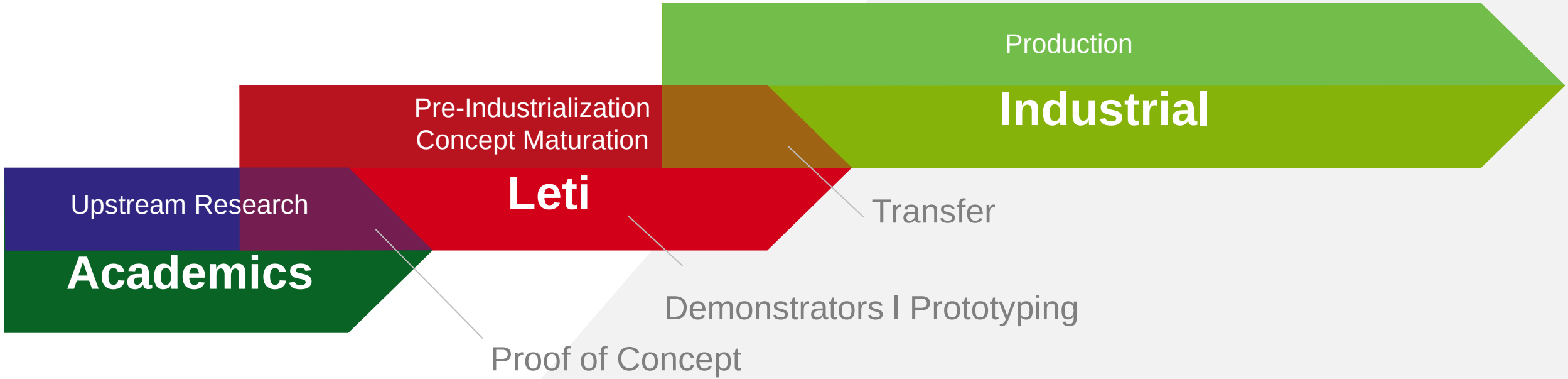
Key R&D partner to build your next best tech innovations



Grenoble (FR)

- Since **1967**
- France, USA, Japan
- **2,000** People
- **> 2,760** Patents in Portfolio
- **350** Industrial Partners
- **> 65** Startups Created
- **10,000 m²** Cleanroom 200-300mm
- **315 M€** Budget
  (**85%** from R&D contracts)

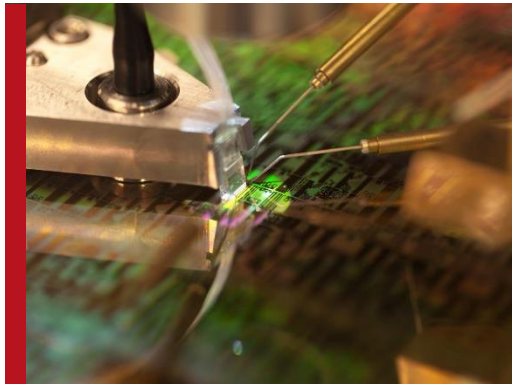
Bridging the gap between academia & the semicon Industry



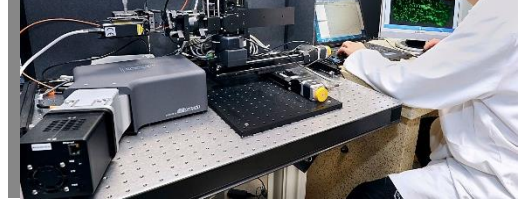
- **Long-term partnerships**
- **Milestones-oriented** projects
- Highly available and flexible teams

World-class infrastructures & platforms

Nanoelectronics Micro & Nanosystems



Photonics



Nano-biotechnology

Clinatec

IC & Embedded System Design

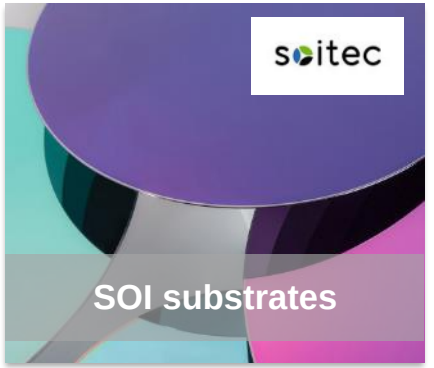
Nano-characterization

EXAMPLES OF LETI'S INNOVATIONS AVAILABLE ON THE MARKET

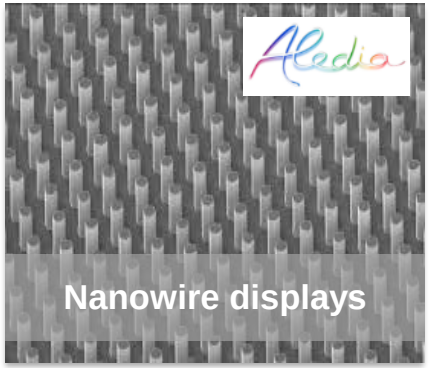
IR image sensors

Thermal image sensors


CMOS image sensors



SOI substrates



Nanowire displays

Gas analyzers

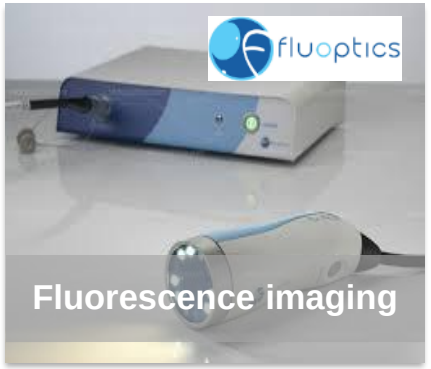
OLED displays

PACS camera

Gas sensors

X-Ray Imaging

LiFi



Fluorescence imaging

Leti's silicon platform

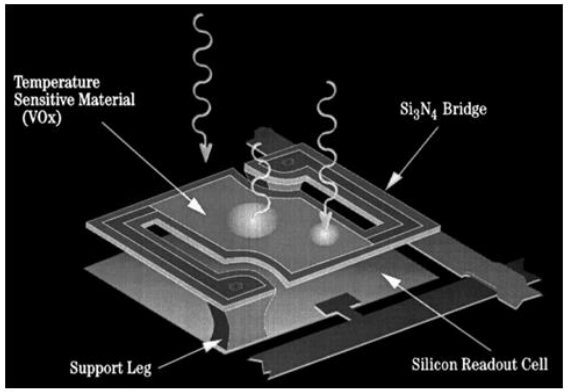
World-class facilities supporting your innovation needs

Pierre JAYET/CEA

1	CMOS / FDSOI
2	BEYOND CMOS
3	POWER
4	MEMS
5	EMBEDDED MEMORIES
6	MEMORIES
7	IMAGERS
8	DISPLAY/LED
9	Si PHOTONICS
10	3D
11	SOI SUBSTRATE

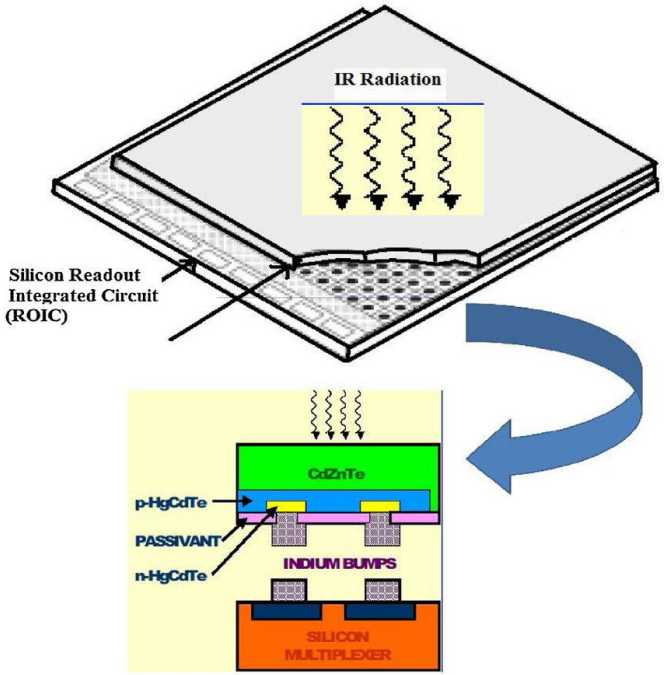
300 mm 200 mm

DEVELOPMENT OF IMAGE SENSORS



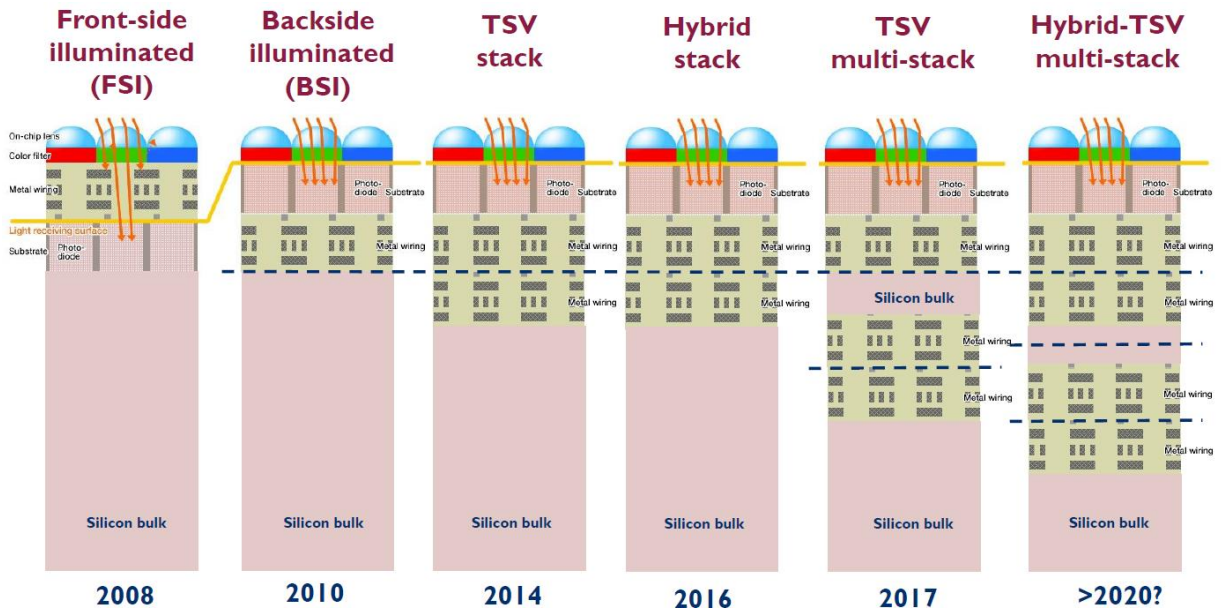
Microbolometer Unit Cell Depiction

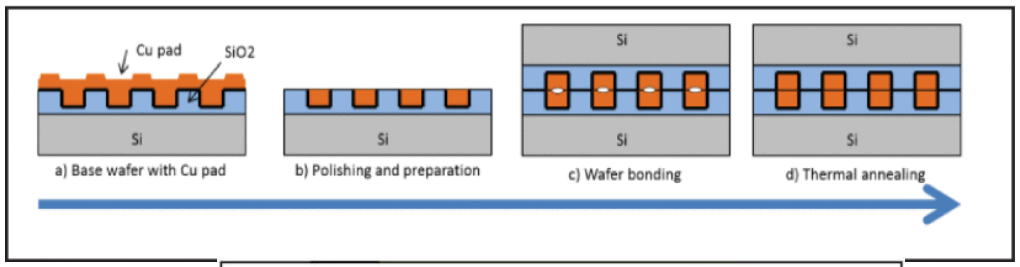
- **Development of thermal IR sensors**
  - **With Lynred (ULIS + SOFRADIR)**
  - **Uncooled IR sensors: microbolometers**
  - Applications: ADAS, LIDAR, Industry, Health monitoring, security…
  - **Cooled IR sensors**
  - Based on II-VI or III-V materials
  - Applications: Defence, Astrophysics, Space…
- **Development of visible CMOS imagers**
  - **With ST-France**
- **Improvement of** (power consumption and cost!!)
  - Sensitivity => new photo-detector materials, micro-lenses…
  - Pixel pitch => more pixels per surface
  - Integration of the detector and the CMOS Read-out IC (for IR sensors)
  - Wafer-level Packaging (for IR sensors)

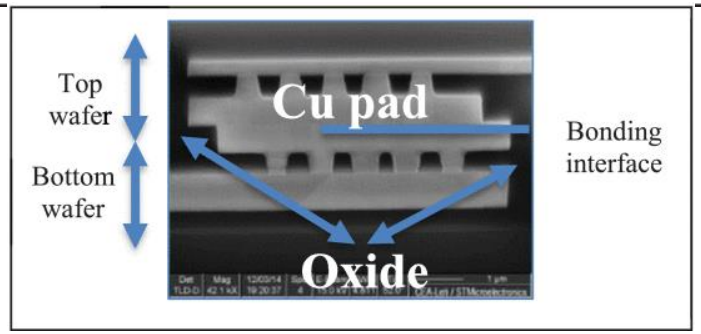


DEVELOPMENT OF SMART IMAGE SENSORS (1)

- **Provide Intelligence to sensors**
  - Coupling sensors, memories and Computing
- **Applications:**
  - Fusion of data from several sensors
    - Examples: ADAS, health monitoring…
  - Transforming data into valuable Information
- **Heterogeneous integration**
  - Through Si vias Interconnect pitch: 10-100µm
  - Hybrid bonding Interconnect pitch: 1-10µm





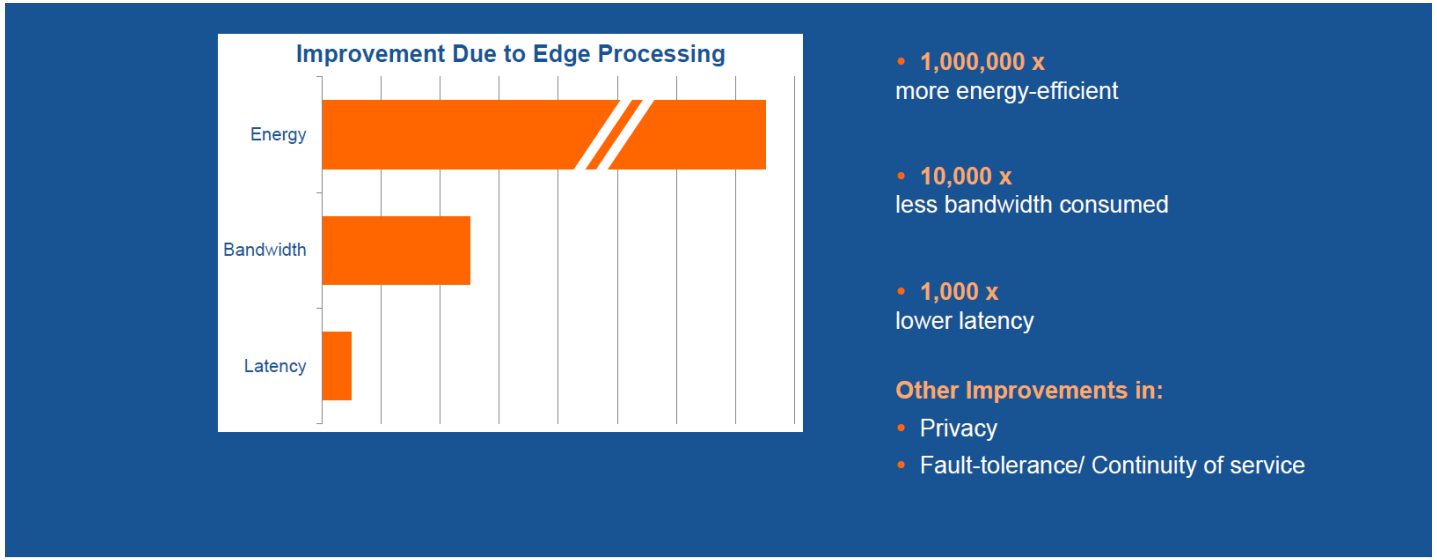


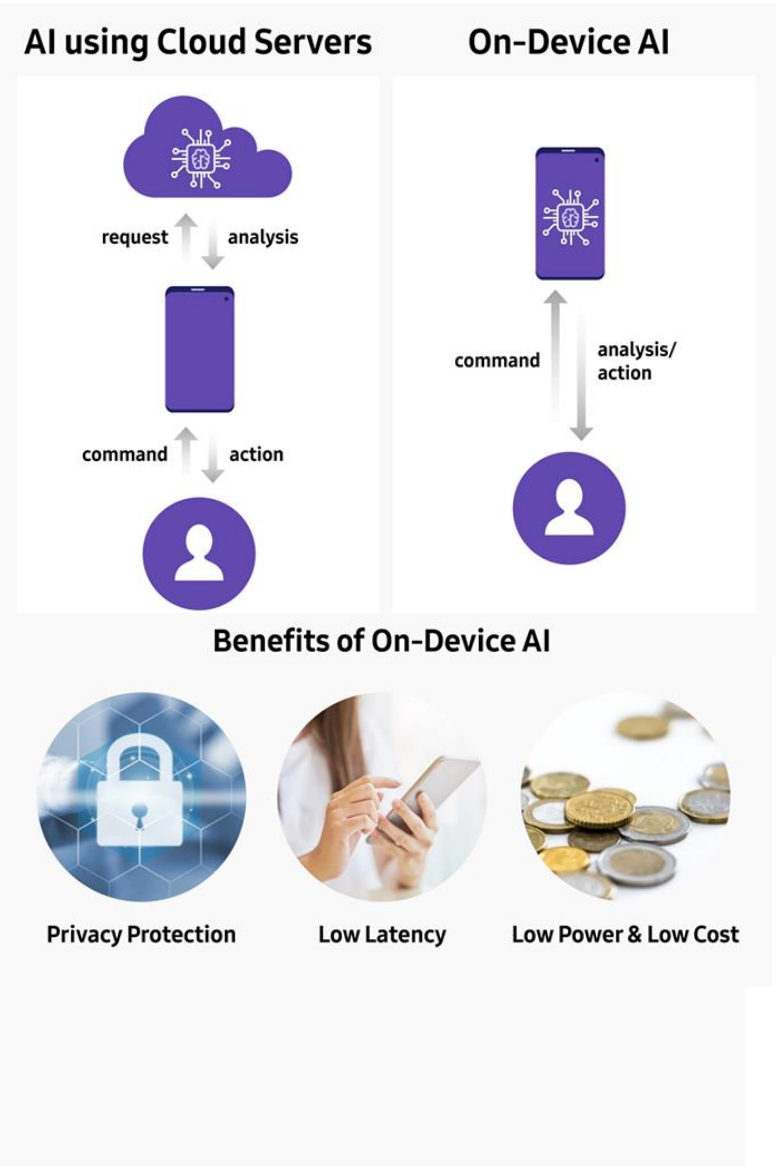
DEVELOPMENT OF SMART IMAGE SENSORS (2)

- **Data processing close to the sensors**
- **Provide Artificial Intelligence for defining actions**

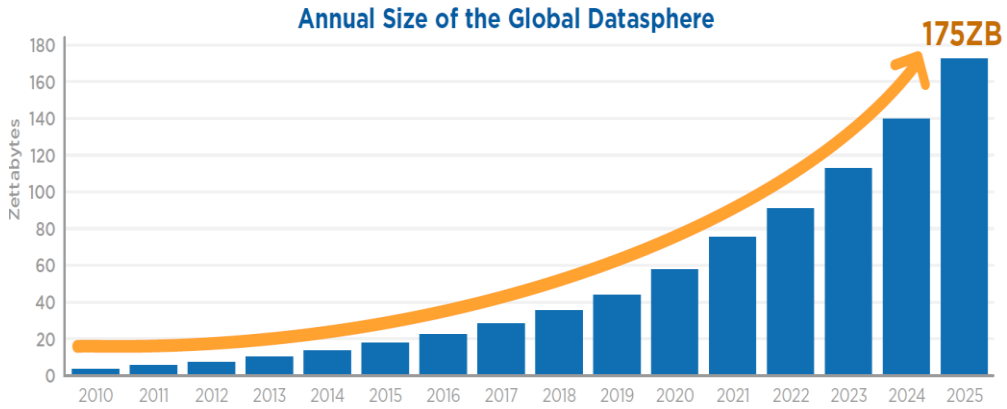
as soon as valuable information is available => **edge computing** (on-device AI, AIoT…)

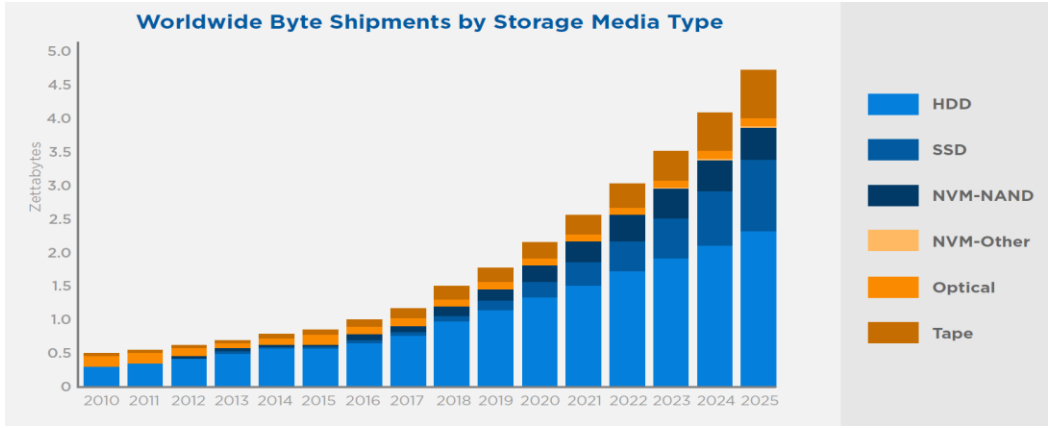
- Applications: ADAS, health monitoring…





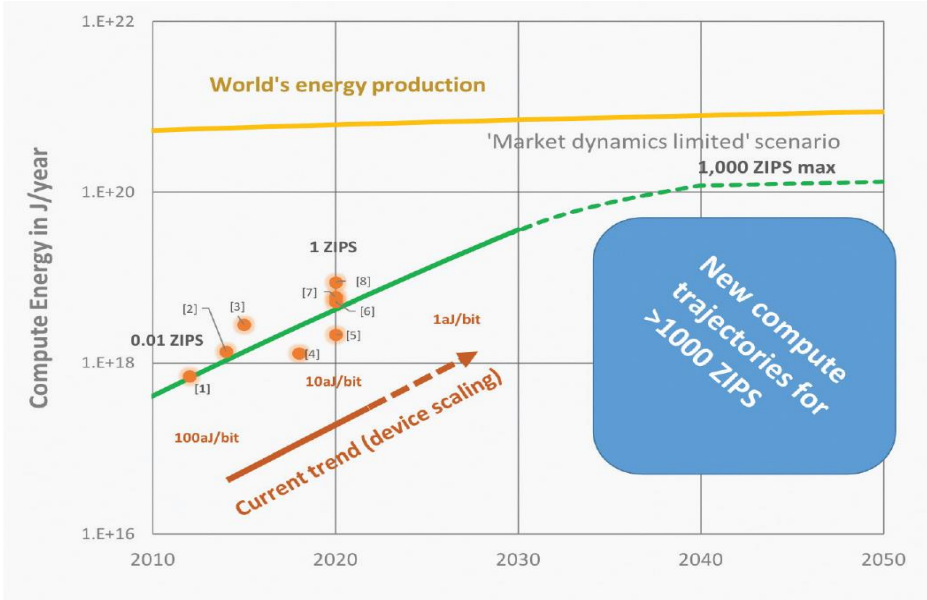
ICT SECTOR WILL FACE SEVERAL ISSUES IN A NEAR-FUTURE



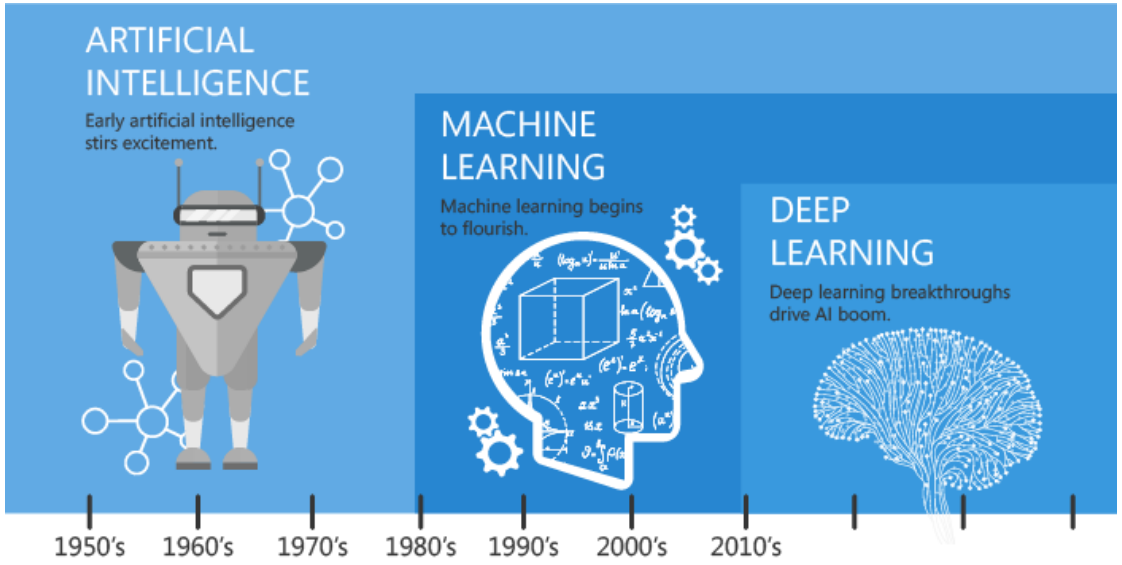


- **Only 2% of the data is currently exploited**
- **Rise of IoT devices (+ our usual data)**
- **Data storage has to be drastically increased**
  - Lack of Si substrates in 2040
- **WW power production will not be sufficient for the ICT sector in 2040**

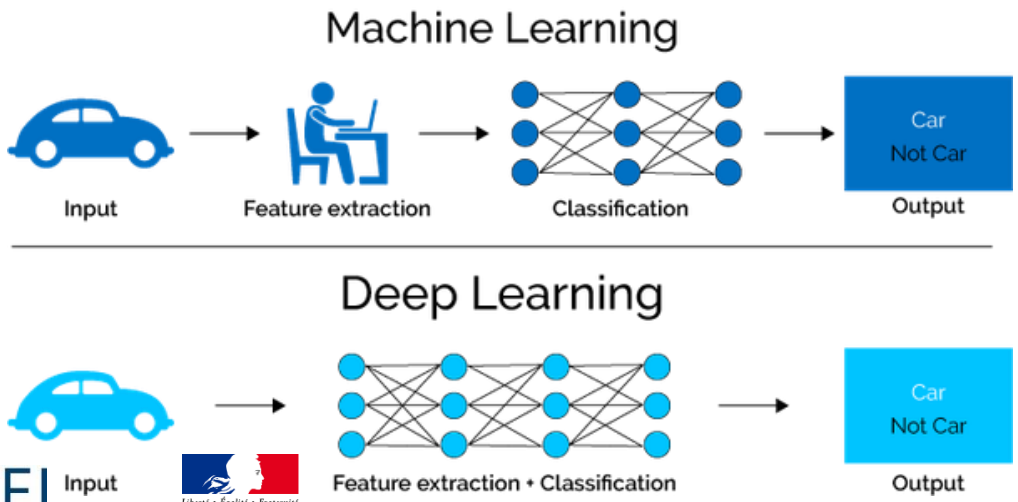
=> Reduction of data transfer and power consumption

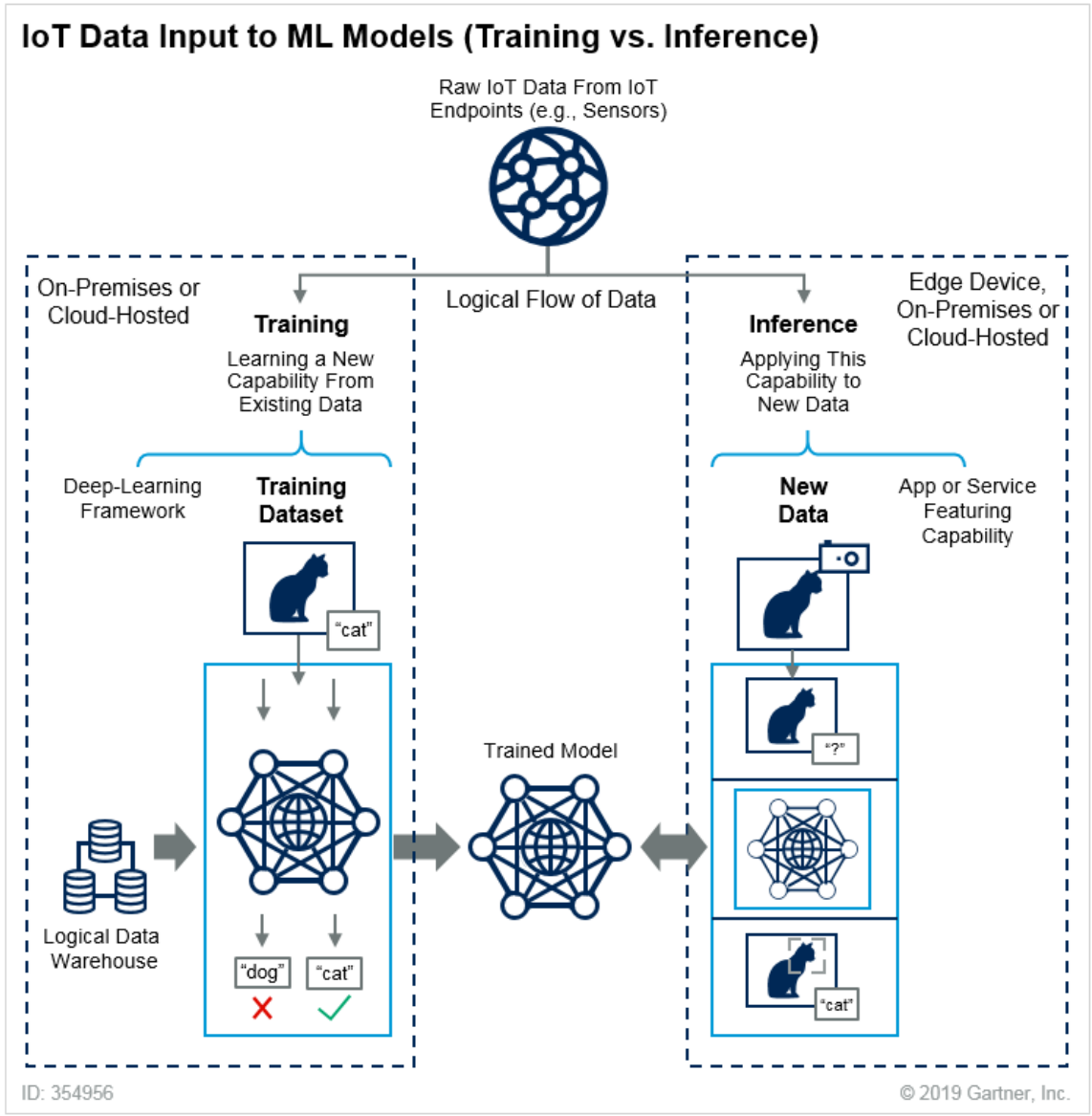


MACHINE AND DEEP LEARNING

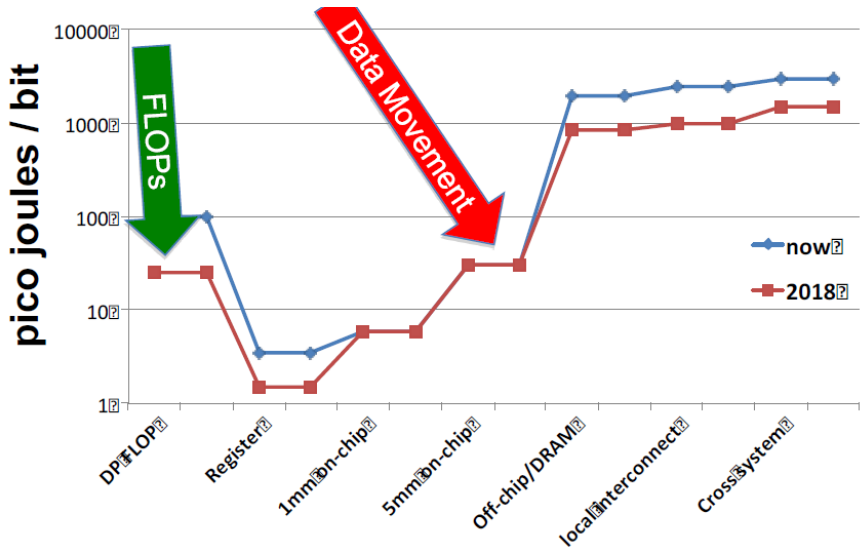


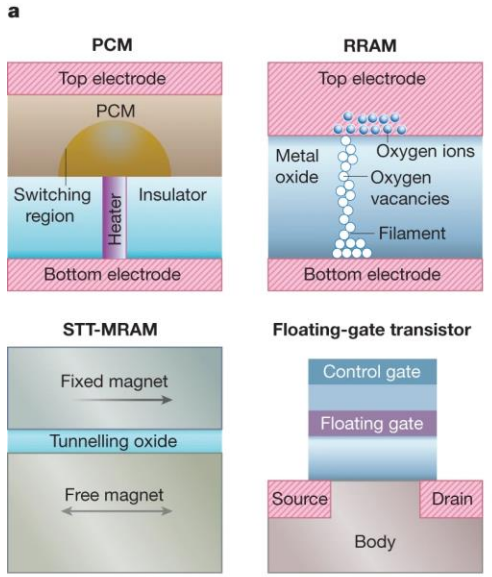
Since an early flush of optimism in the 1950's, smaller subsets of artificial intelligence - first machine learning, then deep learning, a subset of machine learning - have created ever larger disruptions.

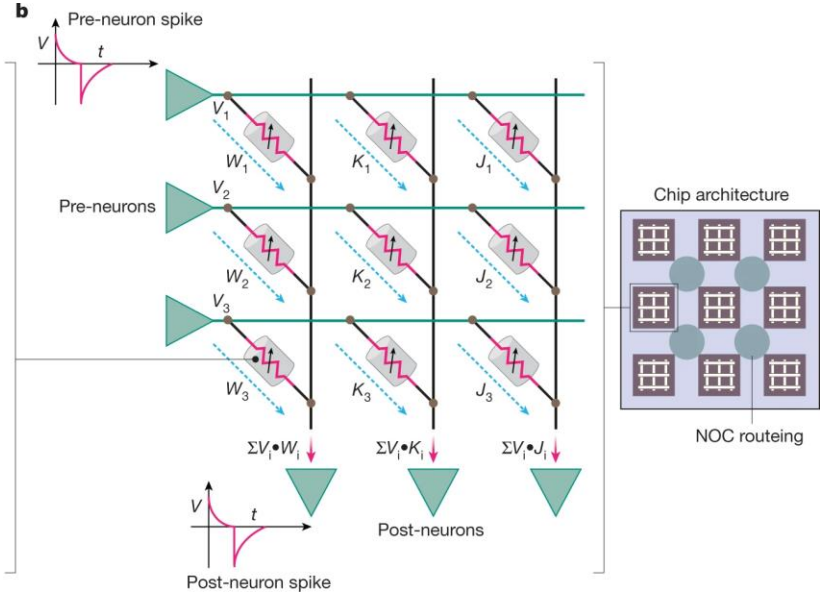


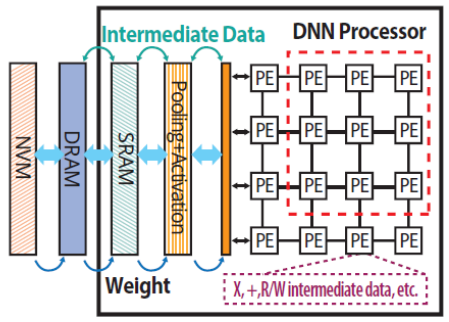


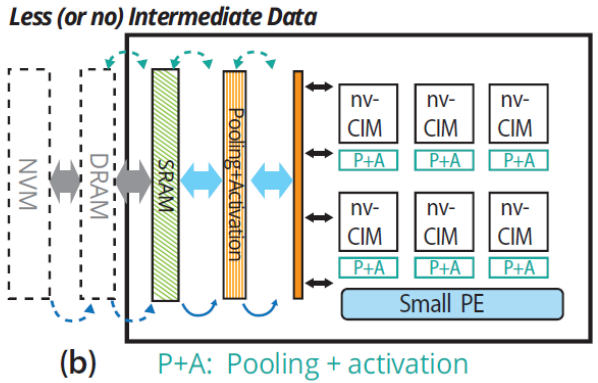
NEUROMORPHIC COMPUTING

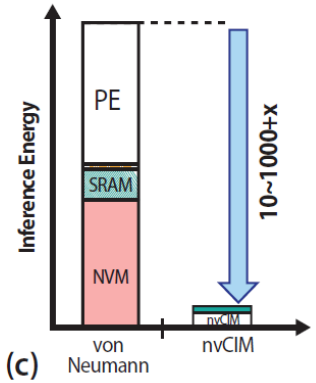


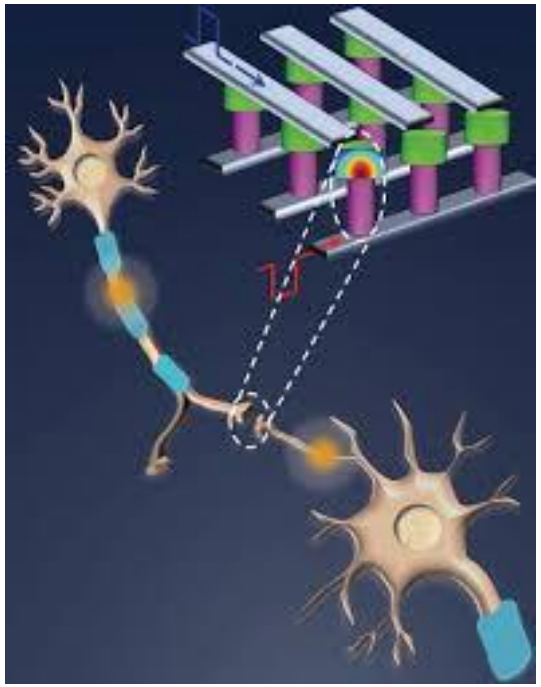






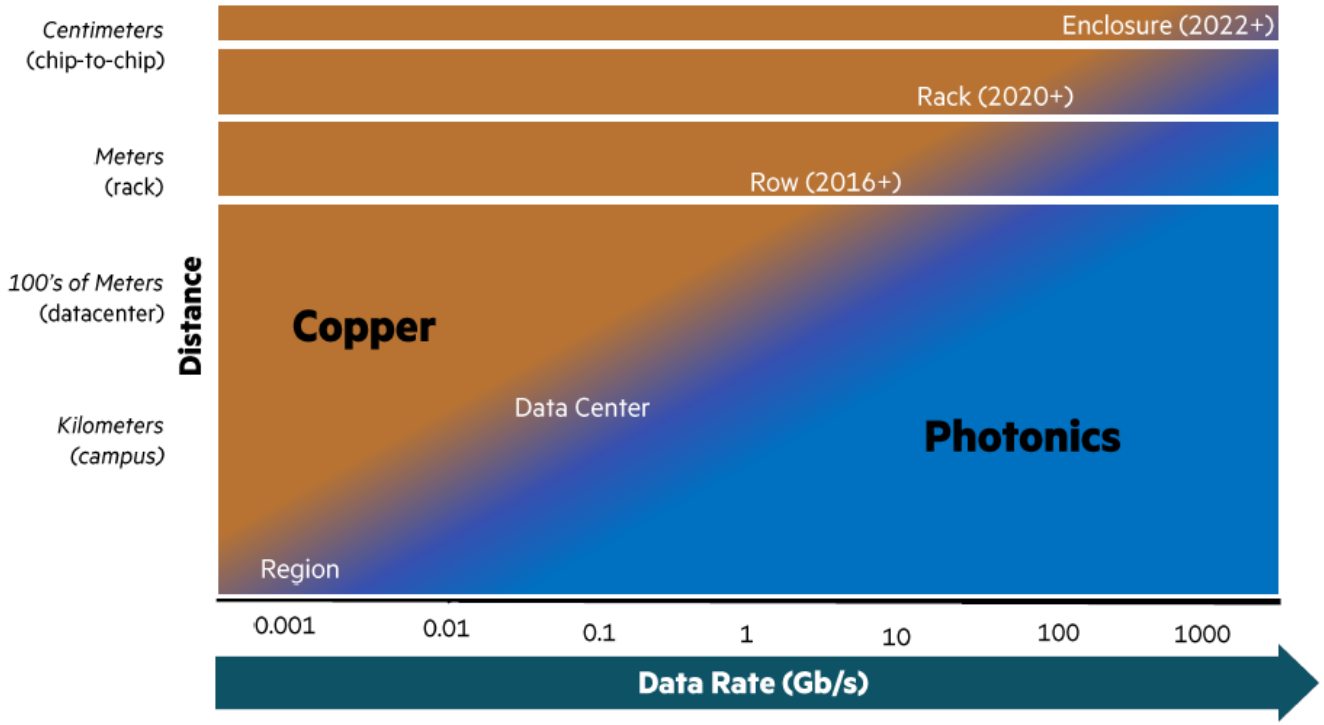


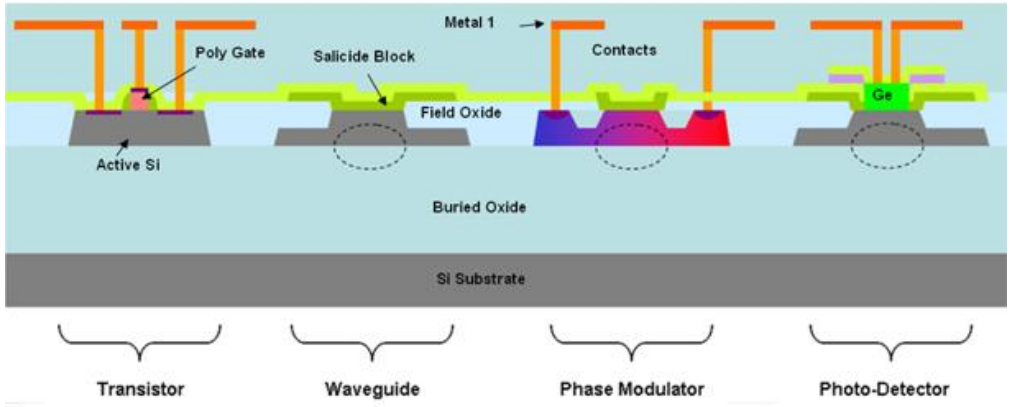


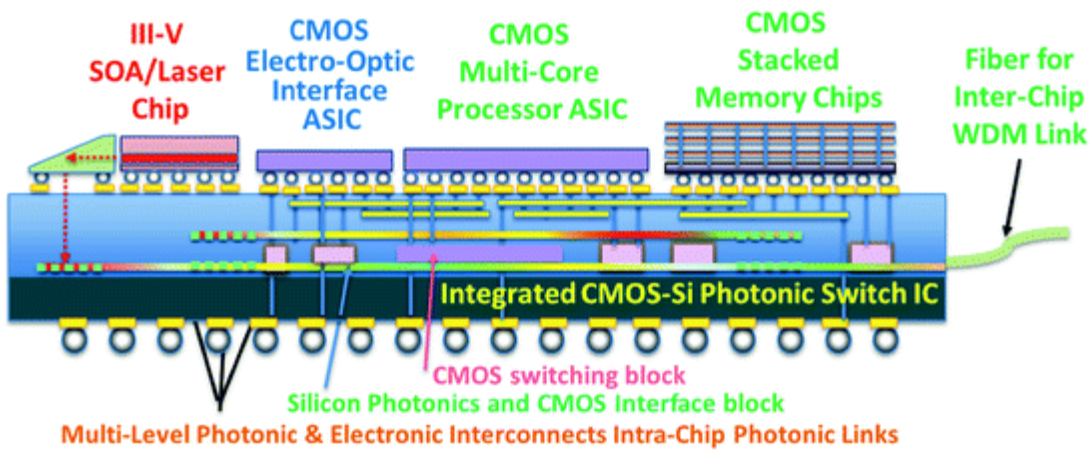


SI PHOTONICS

Power required to move a bit in a conductor: Data rate*L/cross-section



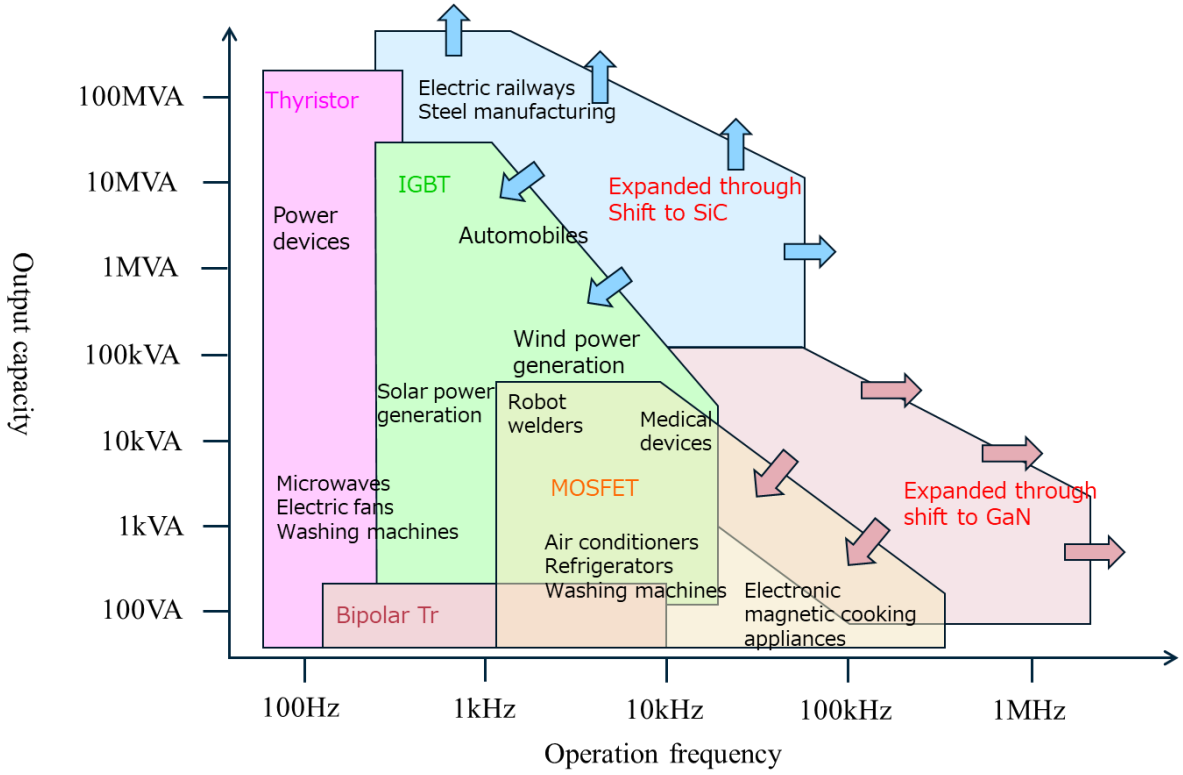


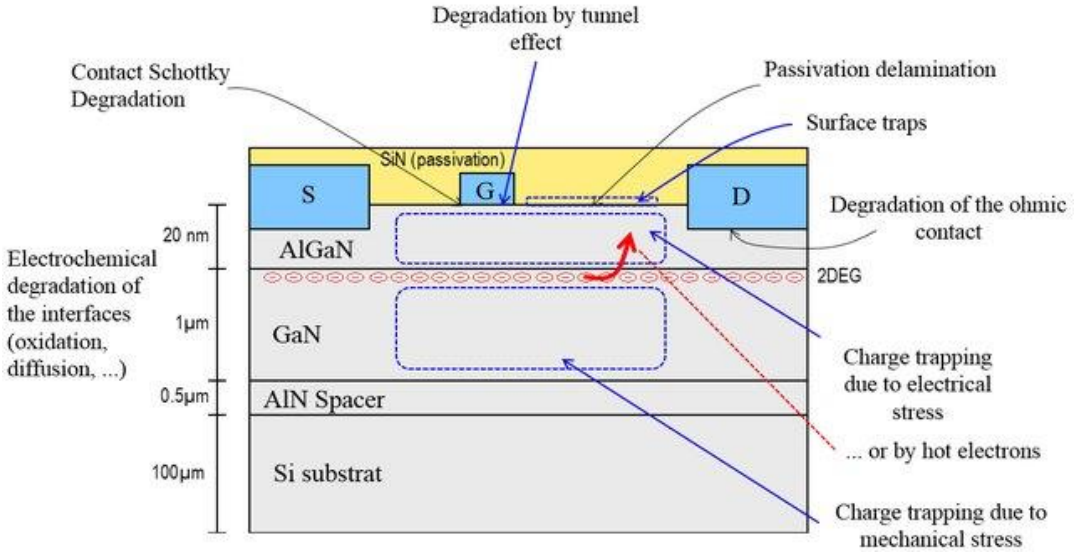


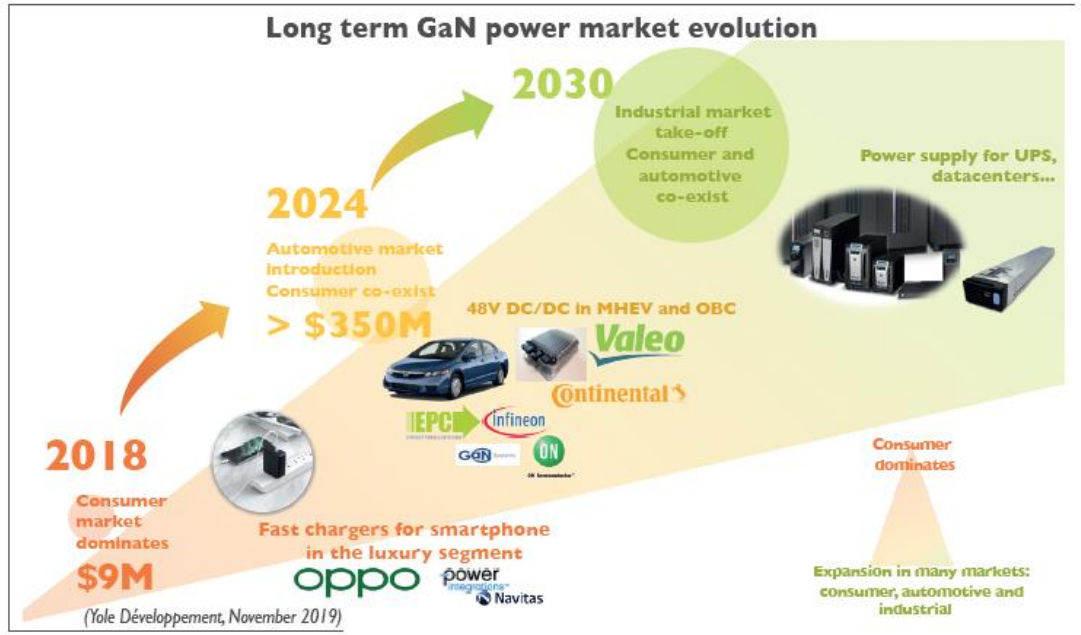
GAN POWER DEVICES

Power electronics dominated by Si devices (MOS, IGBT…)
SiC and GaN are outsiders pulled by automotive

GaN HEMT/Si: new concept => horizontal transistors

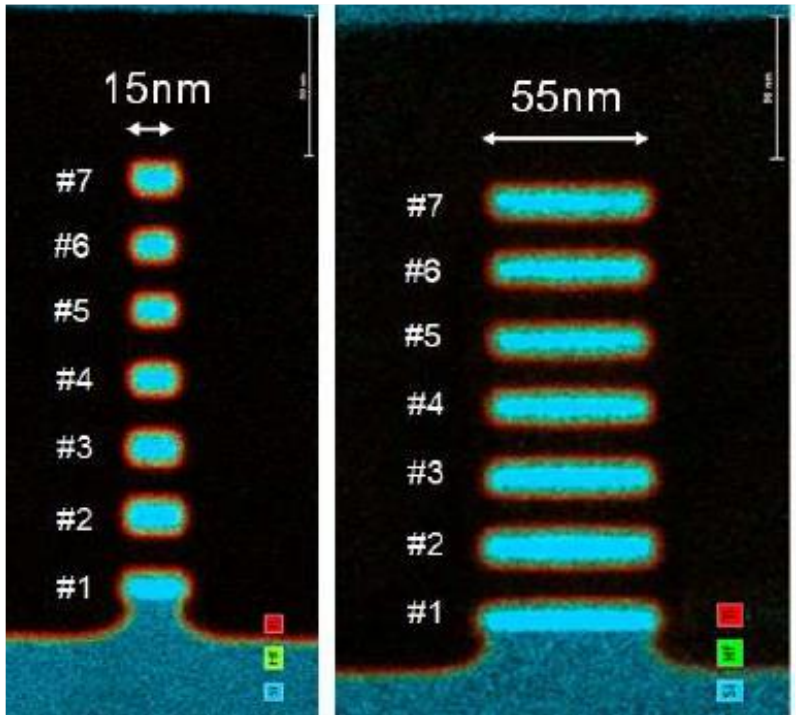


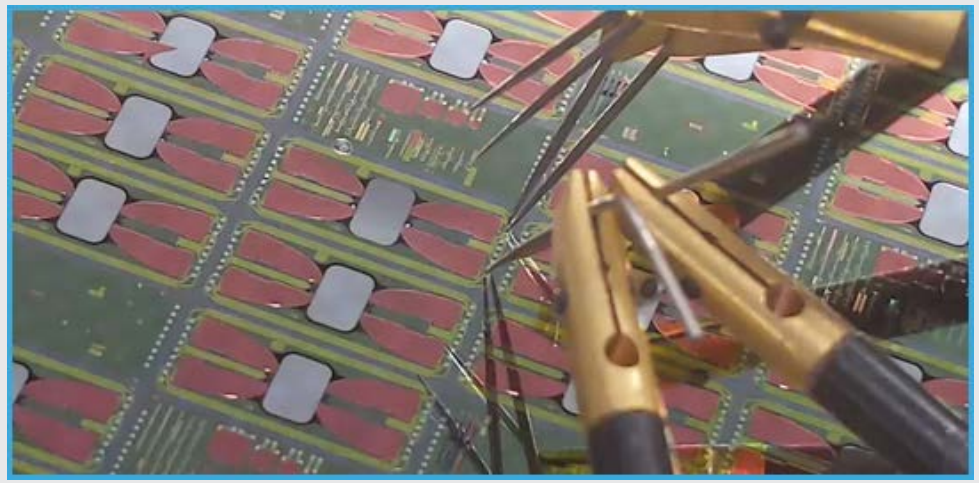




TAKE AWAY

- **CEA-LETI is deeply involved in the IPCEI on microelectronics**
  - In close collaboration with industrials
- **Development of smart sensors, power devices and Si photonics**
- **But also in**
  - Advanced microelectronic modules: Nanosheet, Monollithic integration…
  - SOI substrates: RFSOI, substrates for RF filters…
  - Passive components





The last generation of MEMS technologies and the new opportunities for products and applications

Sara Loi, PhD

STMicroelectronics

We are creators and makers of technology

- One of the world’s largest semiconductor companies
- 2019 revenues of **$9.56B**
- **46,000** employees of which **7,800** in R&D
- Over **80** Sales & marketing offices serving over **100,000** customers across the globe
- **11** Manufacturing sites

As of December 31, 2019

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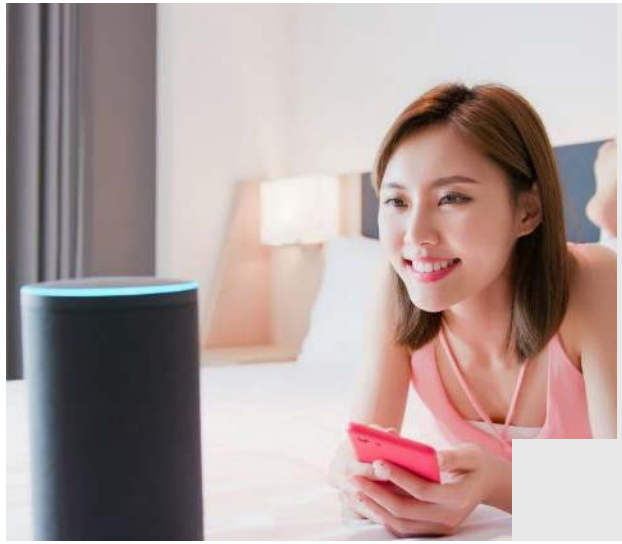
Where you find us

Making **driving** safer, greener and more connected

Enabling the evolution of **industry** towards smarter, safer and more efficient factories and workplaces

Making **homes & cities** smarter, for better living, higher security, and to get more from available resources



Making everyday **things** smarter, connected and more aware of their surroundings

Agenda

1. PETRA technology, products and applications
2. ThELMA 2 technology platform
3. New product for IoT

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PETRA *(Piezoelectric Transducers & Actuators)*

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Key applications for micromirros

> 10M MEMS Mirrors shipped addressing different applications

Augmented Reality

- Visible Projection
- Small volume occupation
- Low Power Consumption

Projection

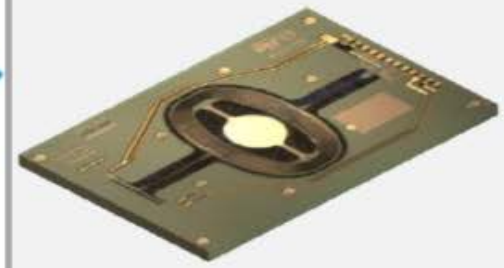
- Visible Projection
- High Brightness
- High Resolution

Gesture & Face Recognition

- Infrared Projection
- Small volume occupation
- Large Scan Angle

MML10300
VIS range, Linear Slow Scanner
Monoaxial, 60Hz, Electrostatic

MMR10300
VIS range, Resonant Fast Scanner
Monoaxial, 21kHz, Electrostatic



MMM10100
VIS range, Raster Scanner
Biaxial, 27kHz x 60Hz,
Electromagnetic

MMR10700
IR range, Resonant Fast Scanner
Monoaxial, 5kHz, Electrostatic

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AR/MR glasses: display requirements

- **Field of View** (FoV): today < 50°. Target 80°
- **Resolution**: 720p→1080p→1440p
- Reduced **power consumption**: impacting weight and size
- **Size and weight**: all day wearable (<80g)
- Short persistency/latency
- Brightness (outdoor application/transparent lenses

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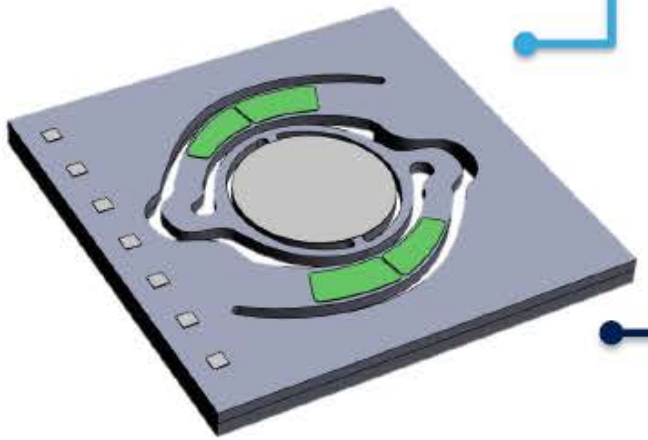
Thin film PZT technology for MEMS mirrors

Enabling performance required for **high resolution** display solutions (1080p → 1440p)

Expanding FoV: to enable AR/MR display requirements (50deg → 80deg)



Smaller Real Estate than other actuation technologies:

- Smaller die size than Electrostatic actuation thanks to higher force coming from PZT
- No additional volume occupation from external components (NO MAGNETS / NO BULK PIEZO)

Reduced Power Consumption thanks to capacitive load drive and energy recovery driver from ST

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Laser Beam Scanning systems (LBS)

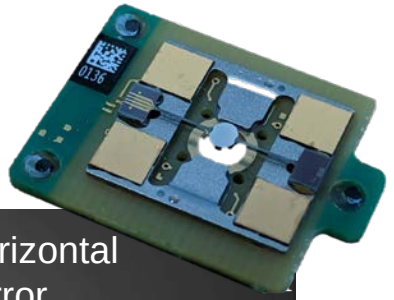
- Resolution and FoV vs power consumption:
  - Patented mirror driver design in ST BCD technology

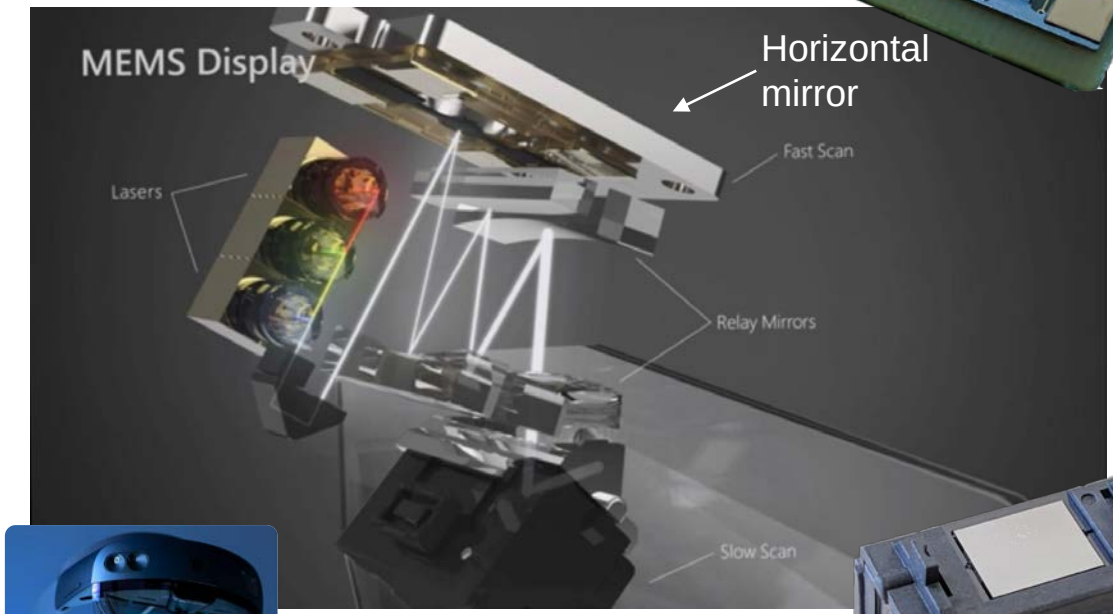
$$\text{Power Consumption}: CV^2f \rightarrow \left(\frac{1}{6}\right)CV^2f$$

  - increase of resolution and FoV at acceptable power consumption

Hololens Gen 2 (high end/industrial):

- High resolution: 2K
- High FOV: 52°
- Immersive → Big





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ThELMA 2 *(Thick Epitaxial Layer for Microactuators and Accelerometers)*

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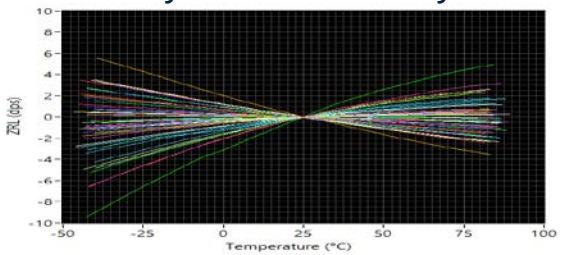
ThELMA

Gyro ZRL accuracy

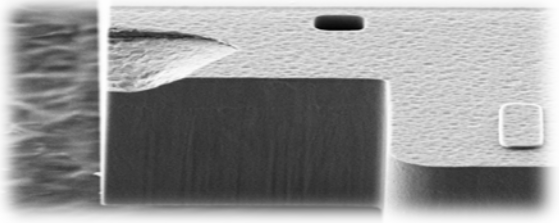


CD-loss σ

Gyro Q-factor σ

Wall-Angle

Mechanical robustness



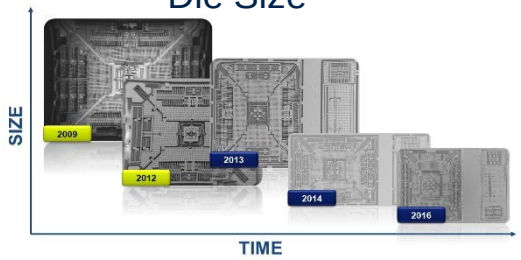
DRIE profile

XL Performance

XL Q-factor σ

CD-loss σ

Die Size



CD-loss σ

- Evolutionary process spread reduction

Parameter	Units	Current Value	Target Value
CDloss spread, 3σ	µm	0.2	0.15
Robustness 200 tumble failures	%	~4	~2
Wall Angle spread, 3σ	°	0.2	0.15 *
XL Q factor spread, 3σ	-	8	3
Gyro Q factorspread, 3σ	%	± 30	± 10

** Achieved with AMEC etch*

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ST roadmap on inertial sensors

1st Generation

LSM6DS3

LOW CURRENT
LOW NOISE

2nd Generation

LSM6DSM

LOW CURRENT

ThELMA

3rd Generation

LSM6DSO

LOW CURRENT
ROBUSTNESS

LSM6DSO32

+ 32g FS

LSM6DSR

HIGH STABILITY
HIGH CURRENT

4th Generation

LSM6DST

LOW CURRENT
ROBUSTNESS

ThELMA+

5th Generation

LSM6DSV

LOW CURRENT
HIGH STABILITY

...

ThELMA 2.0 step

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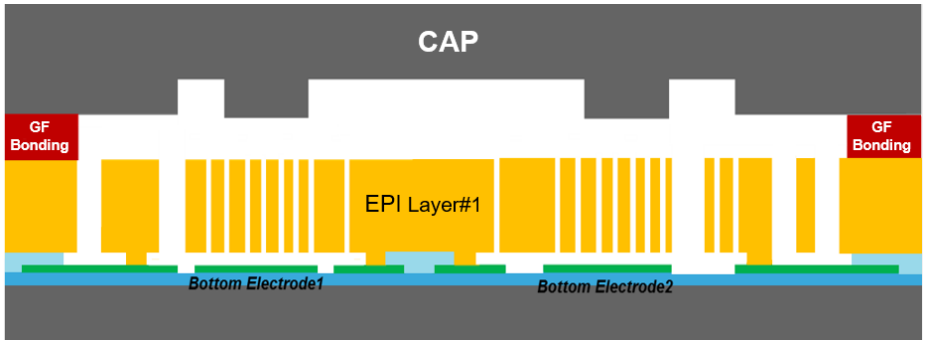
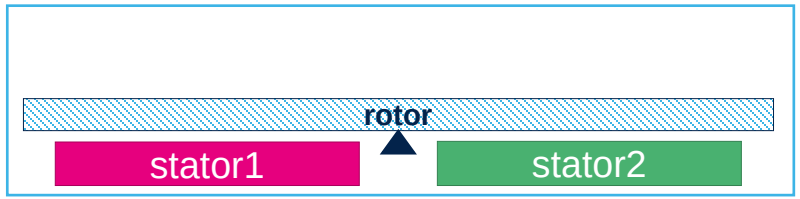
ThELMA 2.0 for Inertial Modules

- ThELMA 2.0 to enhance the performance of Inertial Modules (e.g. sensitivity and area shrinkage)
- Two independent silicon layers instead of one to form more complex “3D-like" structures



- Out of plane double differential architecture
  - Electrode area reduction
  - Intrinsically stable Architecture (i.e. sensitivity stability)



NEW PRODUCTS for IoT

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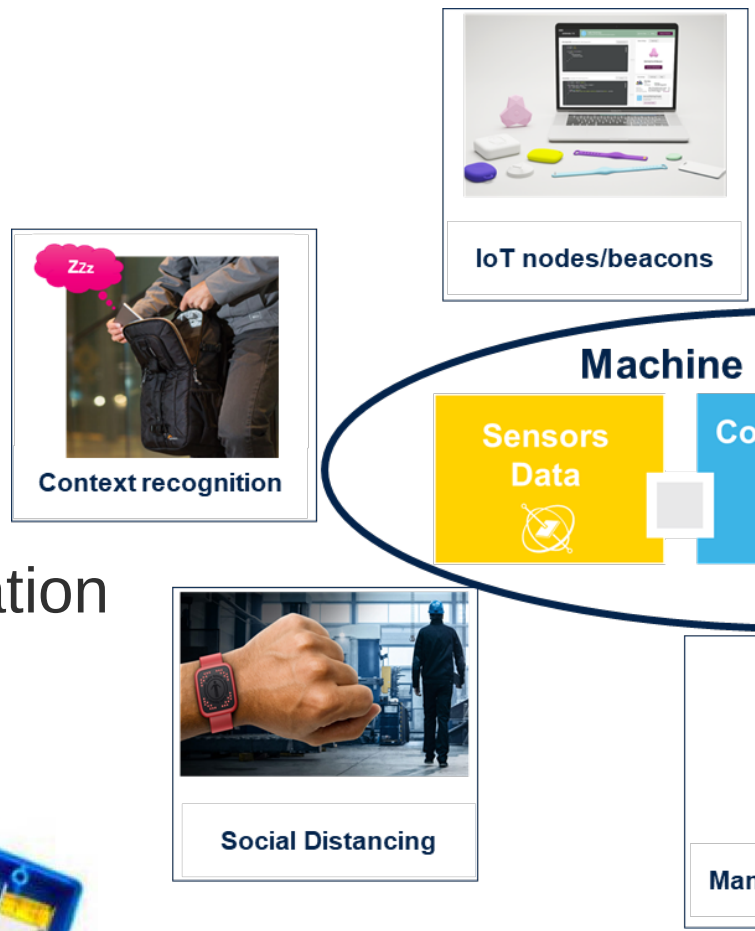
AI at the edge for the IoT

- Edge computing for processing data on the IoT node and generate information locally
- Motion-detecting Machine-Learning Core (MLC)
- IMU modules with improved accuracy and lower power consumption
- Extend to industrial (e.g. vibration monitoring) and consumer applications



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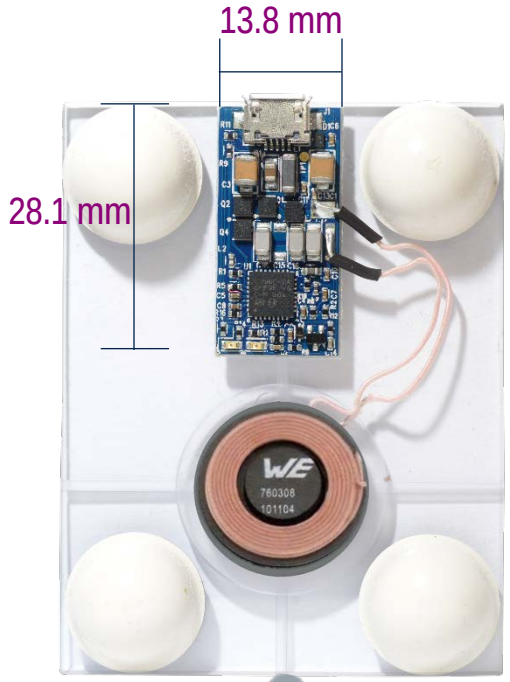
Wireless charging for the IoT: wearable solution

Full Bridge 2.5W Transmitter based on STWBC-WA

5V 1A USB input power

Smart standby
Automatic receiver recognition
Open FOD for increased safety
Patented demodulation



2.5W Receiver based on STWLC30

- 5V output voltage

- Space saving solution: 6x10mm
  1mm total thickness (PCB + BOM)

- Additional dedicated solutions for consumer and industrial application (e. g. smart phones, smart watches)

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Thank you

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NanoRegion

Small we can

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Engage business processes to contribute to the competitiveness

JOIN THE GAME

Access cutting edge research to get head of the game

Ring the bell

Are you looking for a solution in your productive process? Do you have a problem you can't solve? Are you looking for new ideas? Enter NanoRegion and sign up on our portal: we have got a nanotechnological answer to your needs.

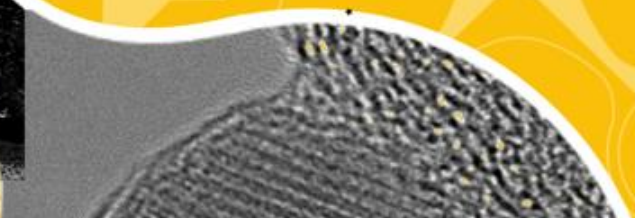
NANOREGION

Disseminate awareness of nanotechnologies potential

Share state-of-the art instrumentation

Develop beyond-state-of-the-art knowledge

Project small and medium-sized innovative enterprises into the future.



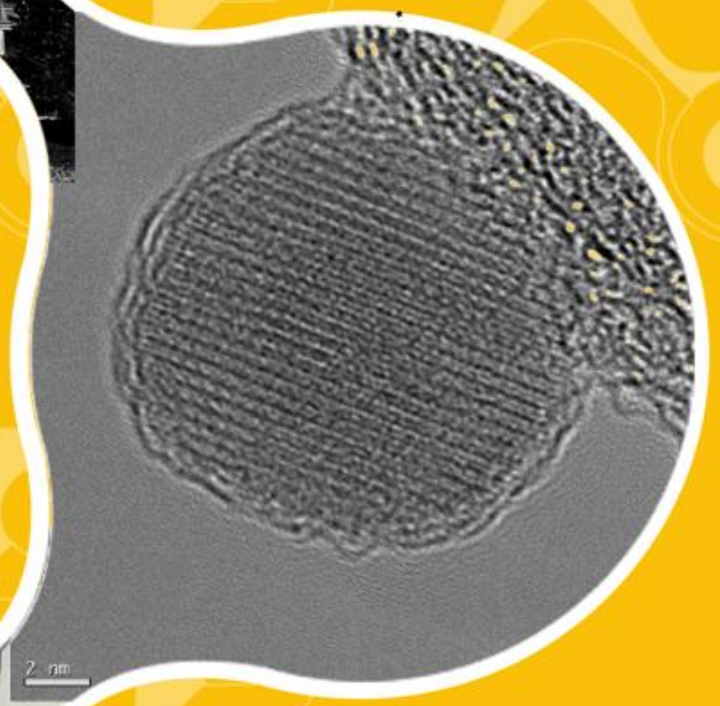
Stronger Together

We create a **network** of well established centers of excellence for nanotechnologies. We offer our **expertise** to local companies as a single entity.

»There's plenty of room at the Bottom« (R. Feynman)

»There's plenty of room at the Bottom« (R. Feynman)

We want to promote new opportunities to boost **businesses** in the region through innovations, strengthening processes and products. New business models can be outlined as nanotechnology **potential** is yet to be fully discovered.



Overcoming mistrust, seeding awareness, thinking small to grow up

NanoRegion encourage local manufacturing community to take advantage of the **opportunities** offered by nanotechnology. We help by organizing dedicated events and **training** activities.

.

All for one...

.... and one for all

All for one...

Our user friendly portal is the **starting** point to learn about technological offer of *NanoRegion* network.

Standardized processes, methods and activities provide companies an homogeneous catalog of our **expertise**.

.... and one for all

Through the execution of test experiments, **Proof of Concept action**, we help you identify your **challenge**, indicate a specific need and develop a verified and customized technological **strategy.**

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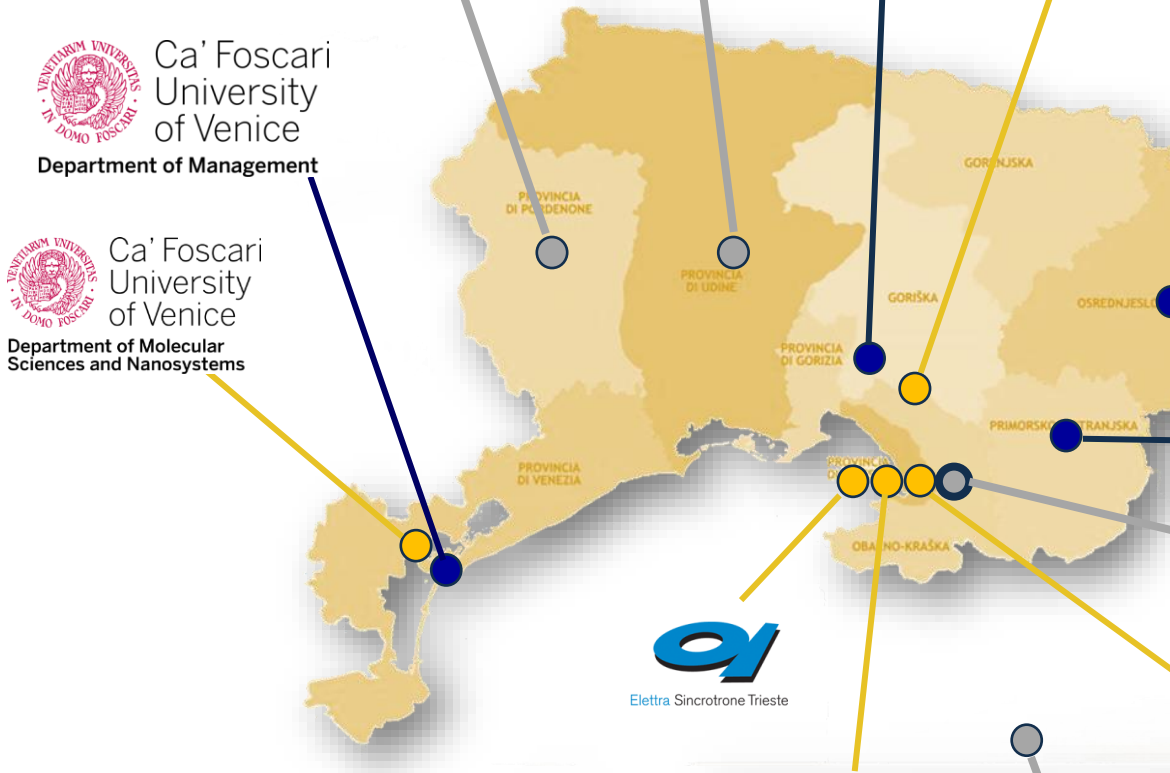
UNIVERSITÀ DEGLI STUDI DI UDINE
PRIMORSKI TEHNOLOŠKI PARK
UNIVERZA V NOVI GORICI
TEHNOLOŠKI PARK LJUBLJANA 01
TU Graz
Ca' Foscari University of Venice
Department of Management
REPUBLIC OF SLOVENIA
GOVERNMENT OFFICE FOR DEVELOPMENT AND EUROPEAN COHESION POLICY
Ca' Foscari University of Venice
Department of Molecular Sciences and Nanosystems
Nanocenter
RRA Zeleni kras
AREA SCIENCE PARK
Elettra Sincrotrone Trieste
iom Istituto Officina dei Materiali
UNIVERSITÀ DEGLI STUDI DI TRIESTE
SVEUČILIŠTE U RIJECI



- Technological transfer
- Laboratory network
- Associated partners

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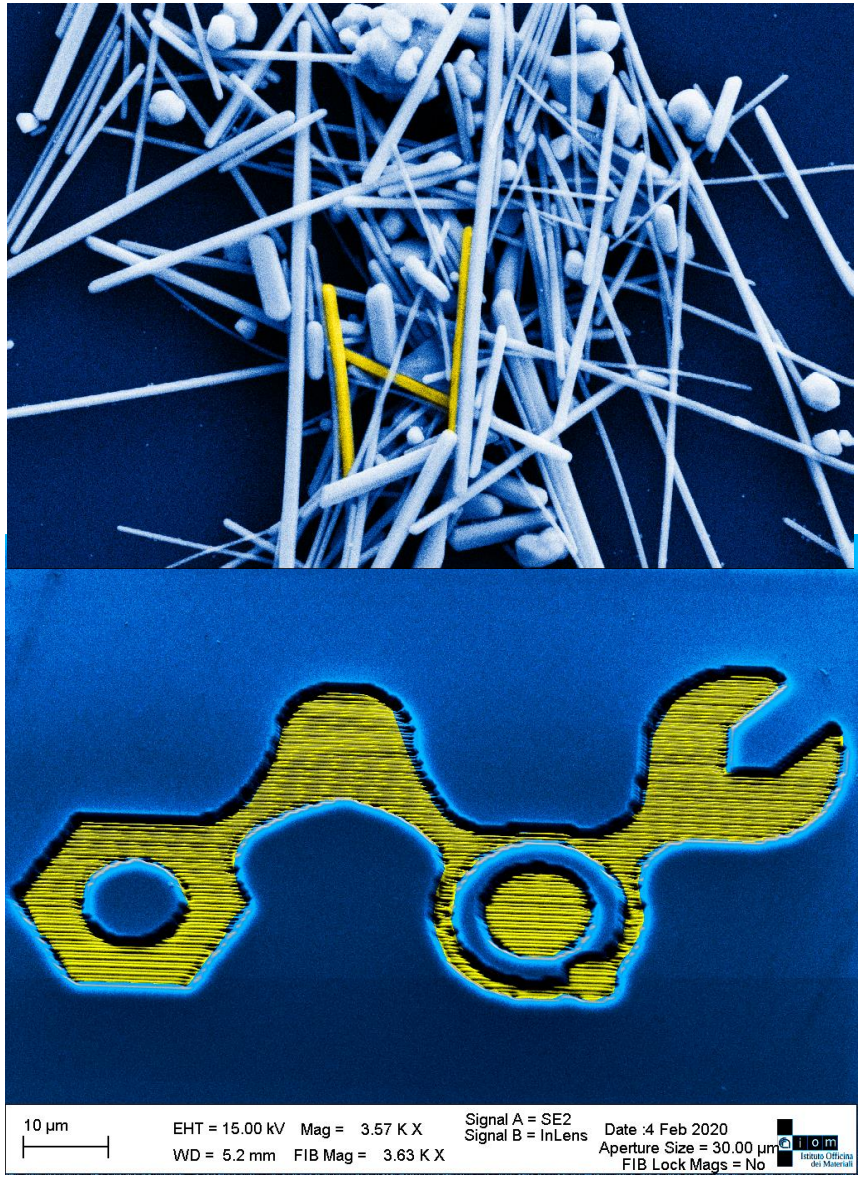
Laboratories

- 4 TEM
- 2 Cross beam (SEM+FIB)
- 6 SEM (EDX, STEM, Catholuminescence)
- 2 Direct laser writing lithography
- 2 EBL systems
- 4 AFM
- 2 Raman microscopes
- UV lithography, Imprint Lithography, etching, deposition
- 1 Synchrotron (X-ray imaging, small angle X-ray scattering, X-ray lithography)
- *1 Free Electron laser*



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Looking for companies

- Word of mouth
- Previous projects
- Website and events
- databases
- Scientific and technological parks

After less than 9 months of PoC activity opening and in spite of the COVID-19 issue we already have 18 PoC proposal!
6 of which are dealing with sensing or detecting

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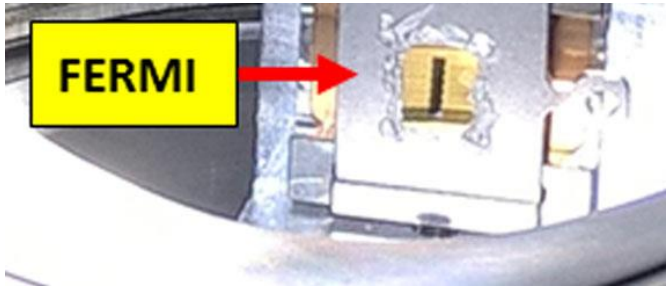
And we develop sensors also in-house

PHYSICAL REVIEW ACCELERATORS AND BEAMS **23,** 042802 (2020)

Nanofabricated free-standing wire scanners for beam diagnostics with submicrometer resolution

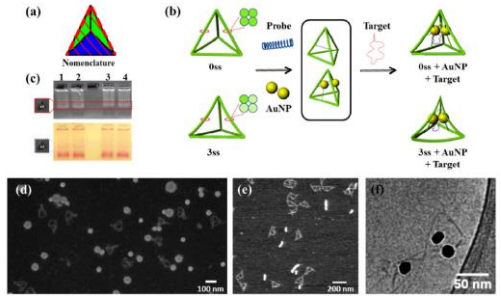


Nano Research

ISSN 1998-0124 CN 11-5974/O4
https://doi.org/10.1007/s12274-019-2535-0

A DNA origami plasmonic sensor with environment-independent read-out

Valentina Masciotti[1,2] (✉), Luca Piantanida[1,†], Denys Naumenko[1,2], Heinz Amenitsch[4], Mattia Fanetti[5], Matjaž Valant[5,6], Dongsheng Lei[7,8], Gang Ren[7], and Marco Lazzarino[1] (✉)



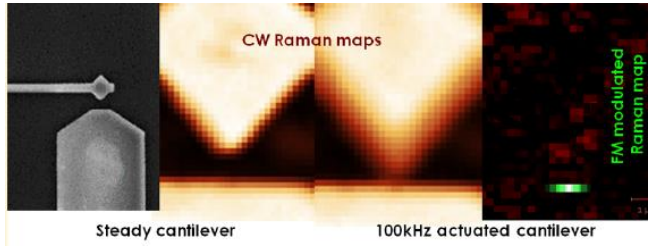
ACS Photonics

Letter

Cite This: *ACS Photonics* 2018, 5, 312−317

Frequency Modulated Raman Spectroscopy

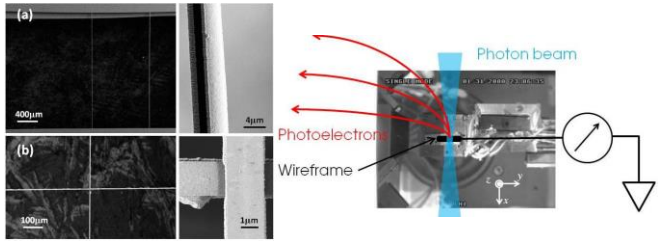
Silvio Greco,[†,‡] Simone Dal Zilio,[†] Alpan Bek,[§] Marco Lazzarino,[*,†] and Denys Naumenko[†]



JINST

Microfabricated wire scanner for photon beam characterization

S. Greco,[a,b] A. Giglia,[a] M. Malvezzi,[a] S. Nannarone,[a] S. DalZilio[a] and M. Lazzarino[a,1]

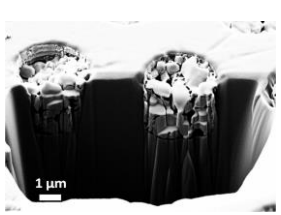


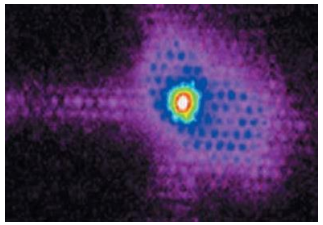
JSR JOURNAL OF SYNCHROTRON RADIATION

ISSN 1600-5775

A novel approach in the free-electron laser diagnosis based on a pixelated phosphor detector

Alessia Matruglio,[a,b] Simone Dal Zilio,[a,*] Rudi Sergo,[c] Riccardo Mincigrucci,[d,e] Cristian Svetina,[b,f] Emiliano Principi,[d] Nicola Mahne,[f] Lorenzo Raimondi,[f] Alessio Turchet,[g] Claudio Masciovecchio,[d] Marco Lazzarino,[a] Giuseppe Cautero[c] and Marco Zangrando[a,f]



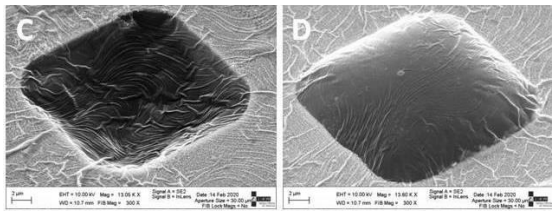


Public deliverable for the ATTRACT Final Conference

ATTRACT

GRaphene Golay micro-cell Arrays for a color-seNsitive TeraHertz imaging sensor (GRANT)

Erik Betz-Güttner[1*], Davide Truccolo [1], Nicola Cefarin[1], Alessandro Pitanti[2], Leonardo Vicarelli[2], Alessandro Tredicucci[2], Andrea Perucchi,[3] Giuseppe Cautero [3], Ralf Menk[3], Simone Dal Zilio [1], Marco Lazzarino [1*]



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CONCLUSIONS

- NanoRegion explores the needs of SME enterprises in the region and the neighbor regions
- More and more SME base their business on the development and/or the implementation of *smart* sensors.
- These companies may be either end users or can stimulate new needs, propose new applications , introduce improvements.
- Our goal is first to help, but, more important, to stimulate new business models based on nanotechnology….
- …and why not, on smart sensors

APTE

Association for Promoting Electronics Technology

TÜV PROFI CERT ISO 9001 + 14001 73 100 / 104 4916

SILVER Cluster Management Excellence DEDICATED TO CLUSTER EXCELLENCE

E L I N C L U S

ELectronics INnovation CLUSter

Education and open innovation approaches, the APTE experience

Prof. DHC. Paul SVASTA Ph.D., University Politehnica of Bucharest

APTE President

ELINCLUS President

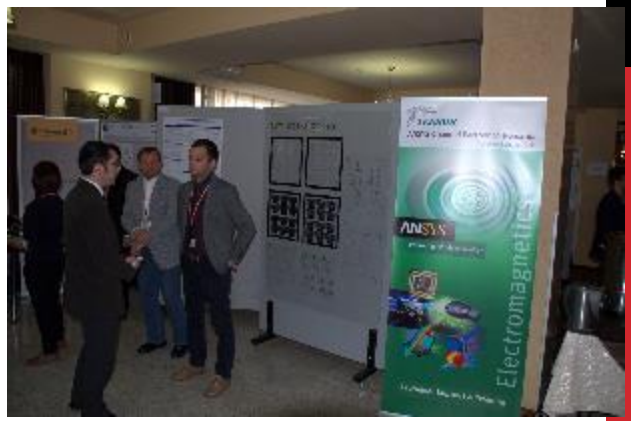
APTE- ASSOCIATION FOR PROMOTING ELECTRONICS TECHNOLOGY

Outlook

- *Introduction to APTE*
- *APTE –Cluster management entity*
- *Infrastructure for product development*
- *APTE- catalyst for the Electronic Packaging Community*
- *Conclusion*

APTE,

bridge between the academia and the industry



Main objective:

To establish a proper environment in order to promoting the

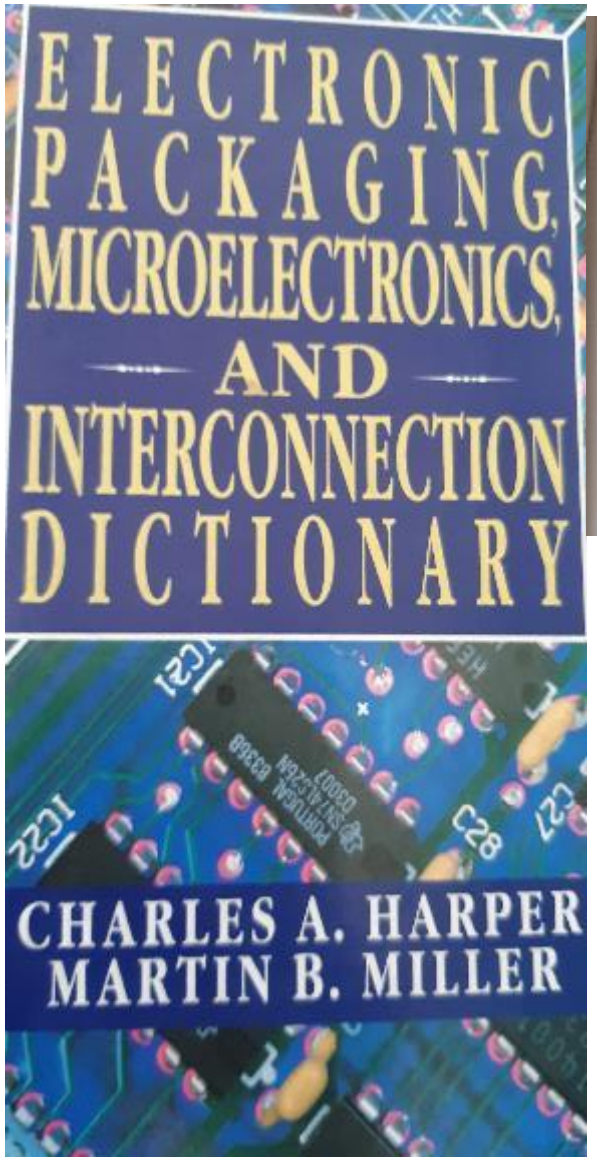
electronic packaging* issues

in the research, education and innovation activities.

_____

Electronic packaging* : *the engineering discipline that combines the engineering and manufacturing technologies required to* ***convert an electrical circuit into manufactured assembly.***

***Charles Harper & Martin Miller, "Packaging, Microelectronics and Interconnection Dictionary", McGraw-Hill, Inc. New York & all, 1993, ISBN 0-07-026688-3**



Electronic Packaging, Microelectronics, and Interconnection Dictionary

Charles A. Harper
Martin B. Miller

McGraw-Hill, Inc.

New York San Francisco Washington, D.C. Auckland Bogotá
Caracas Lisbon London Madrid Mexico City Milan
Montreal New Delhi San Juan Singapore

Electronic Packaging The engineering discipline that combines the engineering and manufacturing technologies required to convert an electrical circuit into a manufactured assembly. These include at least electrical, mechanical, and material design and many functions such as engineering, manufacturing, and quality control.

electronic package

Electronic Package The electromechanical assembly resulting from electronic packaging design and manufacture. The level of an electronic package may range from the integrated circuit package assembly to a printed wiring board assembly to a subsystem or system package assembly. *See also Electronic Packaging.*

SPECIFIC OBJECTIVES:

- RESEARCH AND MANUFACTURE OF INNOVATIVE ELECTRONIC MODULES AND SYSTEMS

- SUPPORTING THE EDUCATION/ TRAINING ACTIVITIES TO BUILD UP HIGH QUALITY HUMAN RESOURCES FOR THE ELECTRONICS INDUSTRY

.

- NATIONAL AND INTERNATIONAL COLLABORATION

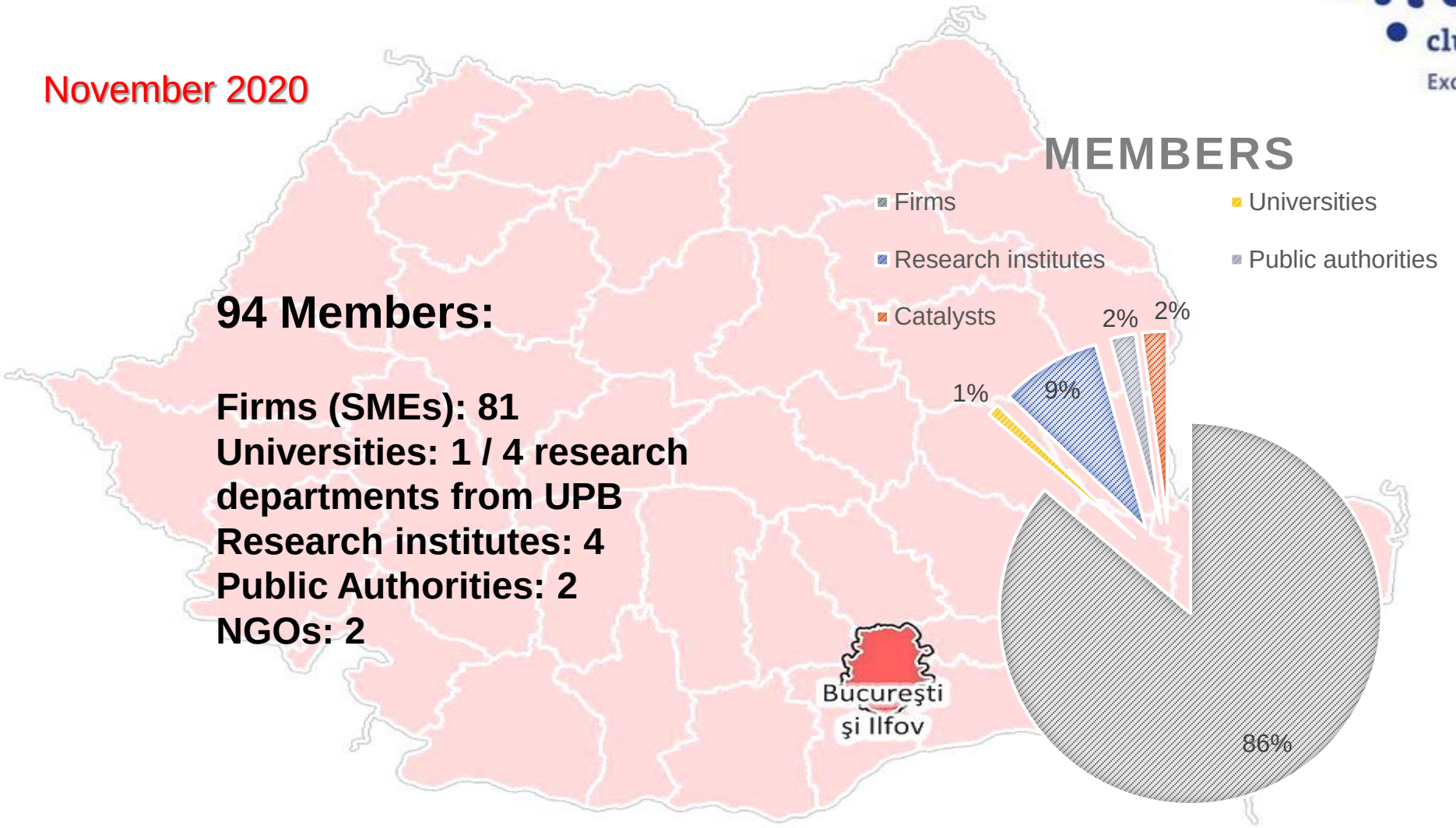
APTE is the Cluster Management Entity

ELINCLUS: ELectronic INovation CLUSter

November 2020

94 Members:

Firms (SMEs): 81
Universities: 1 / 4 research departments from UPB
Research institutes: 4
Public Authorities: 2
NGOs: 2



ELINCLUS indicators 2019

No. of employees (aggregate)	> 720
Turnover (aggregate)	45.8 M€
Value of exports	~20%
R&D value	~17%
Over 45 national and international patents obtained by cluster's members (since 2005).	
National and international organizations partnerships	• founding member of the Romanian Cluster Association (www.clustero.eu) • Bucharest-Ilfov Cluster Consortium founding member • Bucharest-Ilfov & Sud-Muntenia - Digital Innovation Hub (Smart eHUB) founding partner

Smart eHub
Step into the digital

MAIN DOMAINS OF ELINCLUS' MEMBERS

- ✓ **Original Equipment Manufacturers:** ROEL Electronics, Samway Electronics, Seletron Software & Electronics
- ✓ **MEMS: Nanom-Mems srl**
- ✓ **Cyber security, blockchain technology and A.I. systems:** CryptoDATA, Syswin Solutions
- ✓ **IT&C Services, Software Development, Cloud Based Services and Data Management:** AlfaTrust, Computas, SoftTehnica, Tensor, SunCommunications, Intelligence Act, Research Technology, Positive Productions, Syswin Solutions
- ✓ **Automatization**, Giga Electronic International, Elarom, Pro Optica, CETTI
- ✓ **Electronic Manufacturing Services**: Mibatron, ROEL Electronics, CETTI
- ✓ **Industrial automation**: Luca Electric, Seletron Software si Automatizari
- ✓ **System integrators**: BEIA Consult International, Electro Optic Components, Electrorom Impex, Radio Consult, Rond Electric, 2NCOMM Design, Concept Electronics,
- ✓ **Research Centers**: IPE, CCA-AOS, CEMS, CETTI, CCO, ECOMET, IHP, Pro Optica
- ✓ **Training & Education**: L&G Advice Serv, UPB, SBS Solutions
- ✓ **Consulting**: Alma Engineering, Elinktron, Magnum CCC, SBS Solutions
- ✓ ***Automated systems for measurements and monitoring (telemetry):*** *Top GEOCART*

Technological / research environment

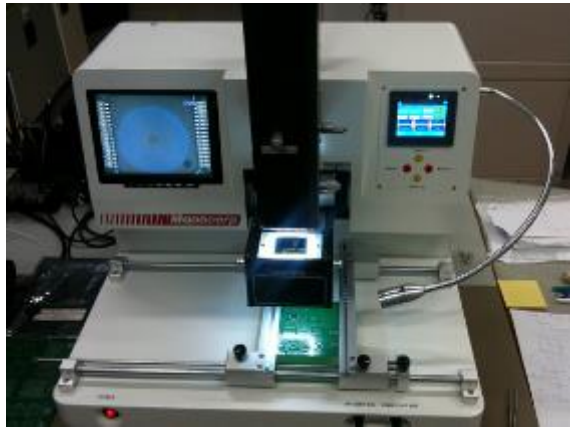
SMT- line,
used by SMEs for manufacture their own developed products.

Printer manual ZelPrint, LPKF;
Pick-and-Place , Cuptor IR/C SMRO 0252
DIMA, masina Vapour Phase SLC309, IBL,
Statie SMT/BGA X-410, PDR

WIRE BONDER

HB 16D Thermosonic Wire Bonder for Wedge & Ball & Die Bonding. The HB 16D is a bench top size wire bonder, easy to operate and ideal for laboratories.

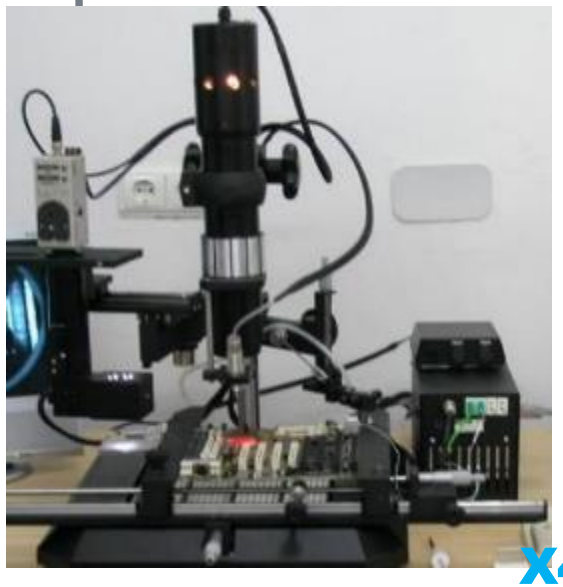
Quick Overview Precise Mounting of BGA, µBGA, CSP, Flip Chips and Fine Pitch QFPs MO-100 split-vision SMT placement system adds high-precision placement capability to manual surface mount assembly operations.



MO-100 SPLIT VISION SMT PLACEMENT

REWORK AND REPAIR STATION, SMT/BGA

Rework Station with heating power in IR-Technology over an area of 185x245mm². It has four high resolution sensor inputs for thermo-couples (Type K).

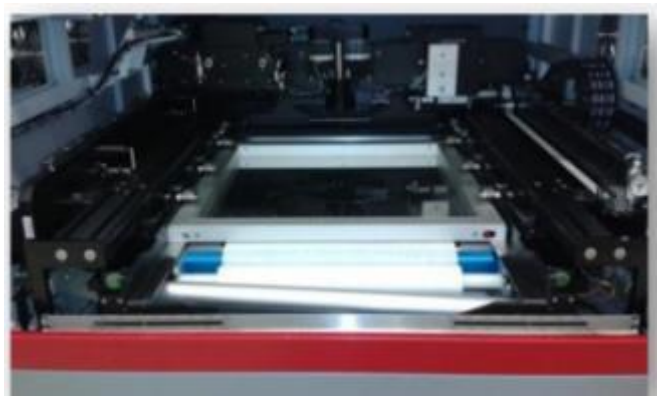


The PDR-X410 SMT/BGA rework system, using PDR's patented Focused IR technology, has been specifically designed to cope with the challenges of repairing today's PCB assemblies.

X410 IR REWORK STATION

DEK HORIZON 8

DEK's Horizon platforms offer a comprehensive array of sophisticated features as standard, including optimised printer frame technology, fast product changeover, 2 Cpk print process capability and 6-sigma production performance.



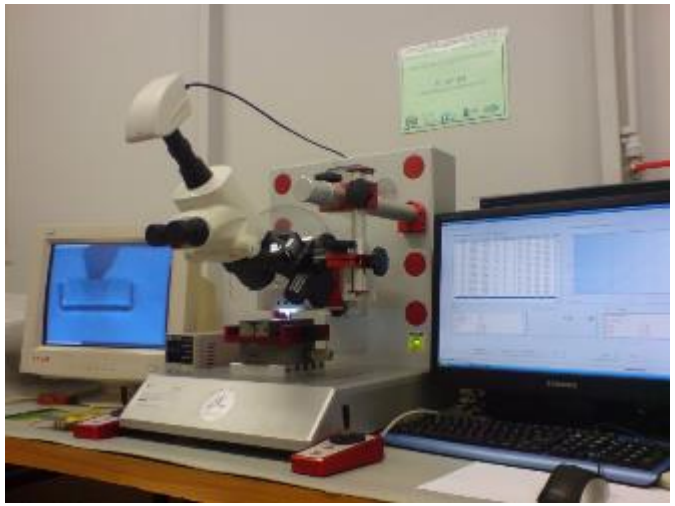
VAPOR PHASE SOLDERING MACHINES

SLC 309 Vapour phase soldering machine is suited excellently for all cases where quickly and reliably heat has to be supplied for soldering.
Because of that, it is possible to heat up large quantities safely. The heat thereby will be transferred by the means of a condensing vapour.

OPTICAL INSPECTION

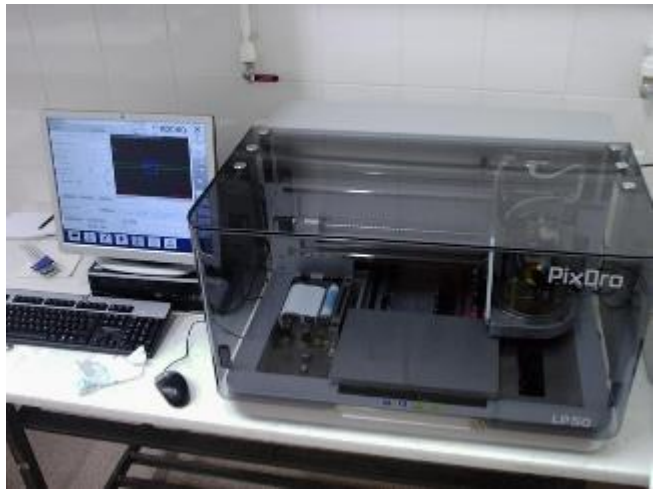
MULTI FUNCTIONAL SHEAR/PULL TESTER

Multi Functional Bond Tester Push, Pull and Shear test unit designed for your application. Automatic selection of test tools and measurement sensors by using a Revolving Measurement Unit (RMU). High accuracy due to integrated 16 bits AD converter.



INKJET PRINTER FOR RESEARCH IN ORGANIC ELECTRONICS

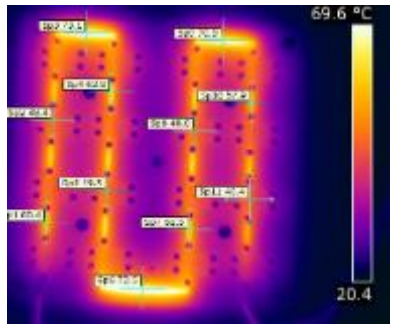
The LP50 inkjet printer is an advanced R&D inkjet printer for evaluation and development of inkjet materials, processes and applications. The availability of numerous standard modules enables the user to easily configure/setup the system to his/her requirement.



THERMAL INVESTIGATIONS

FLIR SYSTEM SC640

thermo-vision camera

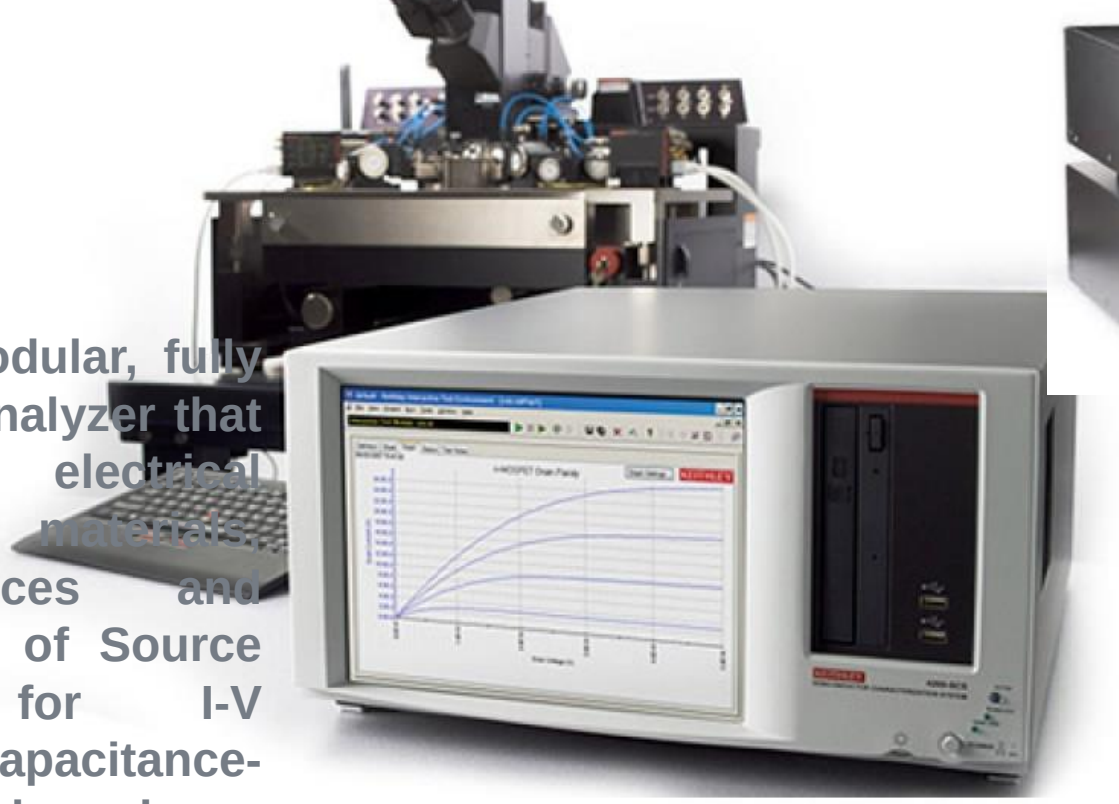


CLIMATIC CHAMBER

ESPEC SH-241

KEITHLEY- 4200 SCS (SEMICONDUCTOR CHARACTERIZATION SYSTEM)

The 4200-SCS is a modular, fully integrated parameter analyzer that performs electrical characterization of materials, semiconductor devices and processes. Consisting of Source Measure Units for I-V characterization, Capacitance-Voltage module for AC impedance measurements, and Ultra-fast Pulsed I-V that performs waveform capture, and transient IV measurements, the 4200-SCS provides the researcher or engineer with critical parameters needed for materials research, semiconductor device design, development or production.



High precisions measurements instruments

KEITHLEY 2612B SOURCEMETER SMU INSTRUMENT, 2-CHANNEL

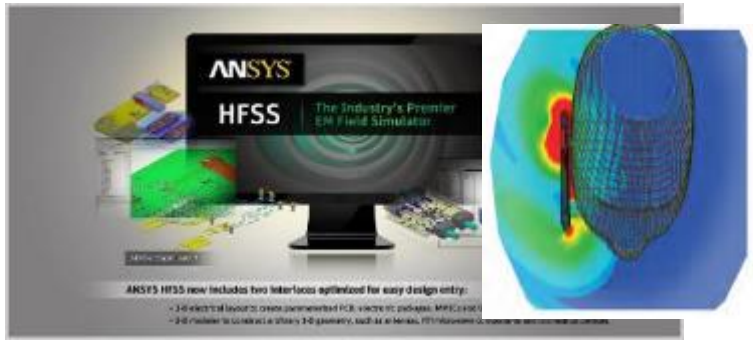
Dual channel model with 60W power output (30W/channel) - 4 quadrant source/measure with 6½-digit resolution - Current Max/Min: 1.5A DC, 10A pulse/ 100fA - Voltage Max/Min: 200V/ 100nV The 2600B SMU instruments significantly boost productivity in applications ranging from benchtop I-V characterization through highly automated production test.

GIGAHERTZ-OPTIK BTS2048-VL

High speed spectroradiometer with a wide dynamic range for CW and pulsed measurements of irradiance/illuminance, spectrum, luminous color, and color rendering index.

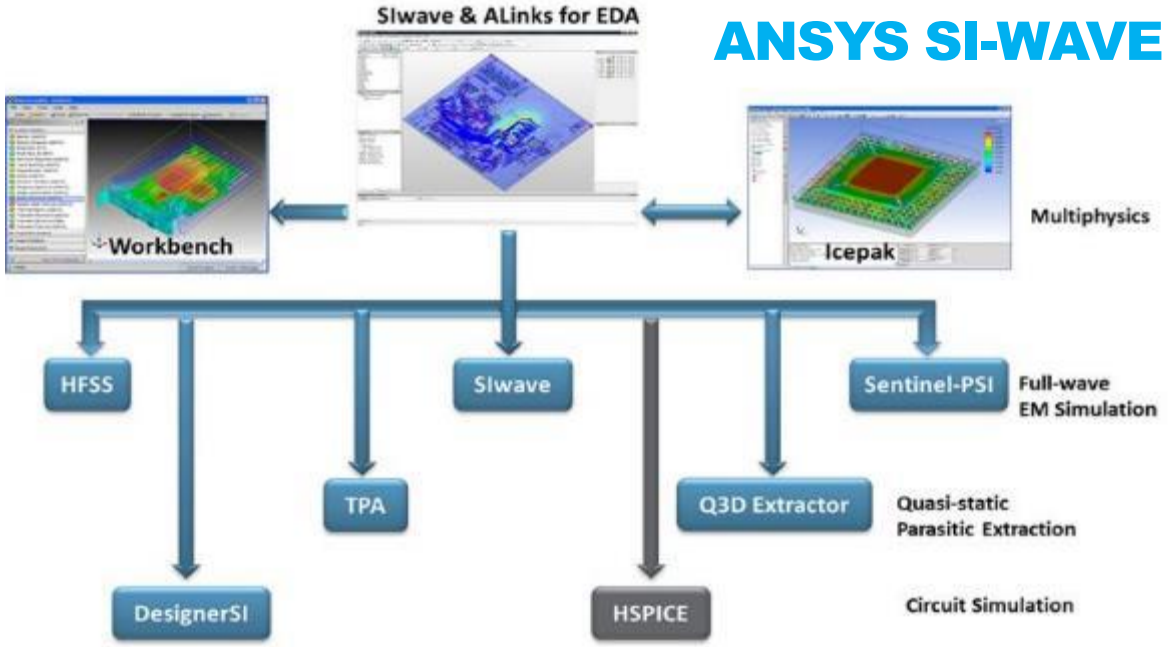
Features: Turn able Integrating sphere with 100cm diameter, auxiliary lamp and a hemispherical shell for opening and closing, compact spectral light meter with Bi-Tec sensor for accurate measurement of the luminous flux, spectral radiant power, CCT, CRI, chromaticity coordinates, etc.

ANSYS HFSS



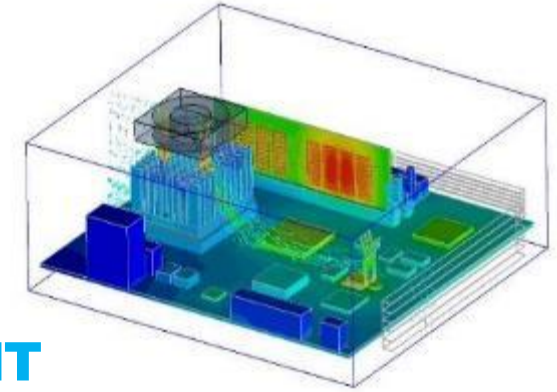
Ansys HFSS offers several types of solution technologies such as the finite element method, integral equations and the advanced hybrid method (finite element and integral equations) for the analysis of a wide range of applications. Ansys HFSS solvers incorporate a powerful and automatic solution process, requiring the establishment of a minimum set of information: geometry specification, material properties and output data. With Ansys HFSS, the model defines discretization and not the other way around.

ANSYS SI-WAVE



The Ansys SIwave platform *allows engineers to customize the design cycle by using any of the following solution methods: signal integrity (SI), power integrity* (PI), or electromagnetic interference (EMI). The SIwave platform can also be seen as a link between the most popular EDA formats in Altium, Cadence, Mentor, Zuken and the Ansys Multiphisycs suite of applications.

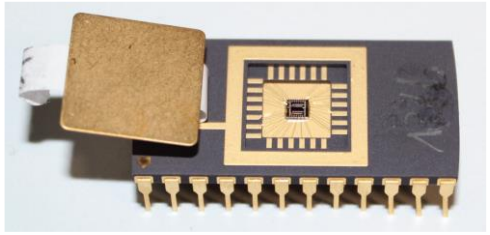
THERMAL MODELLING & SIMULATIONANSYS ANSYS ICEPAK

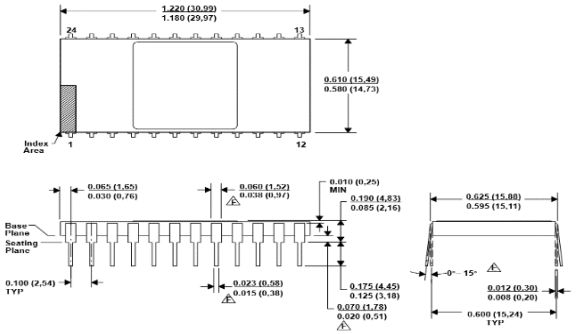


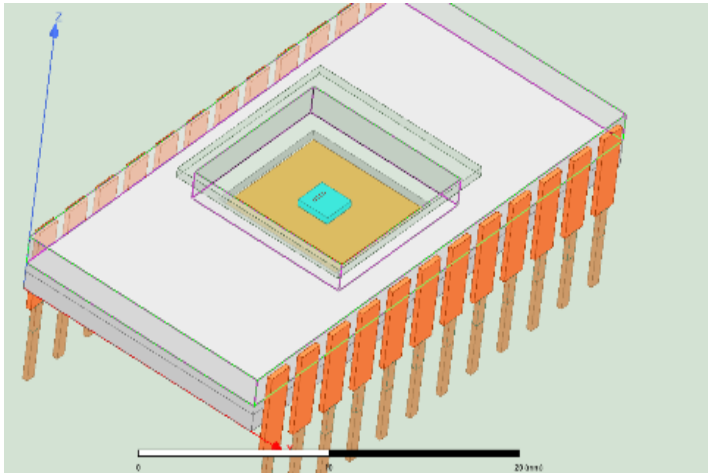
Manages all heat transfer modes: Conduction, convection (natural and forced)& radiation (thermal and solar)

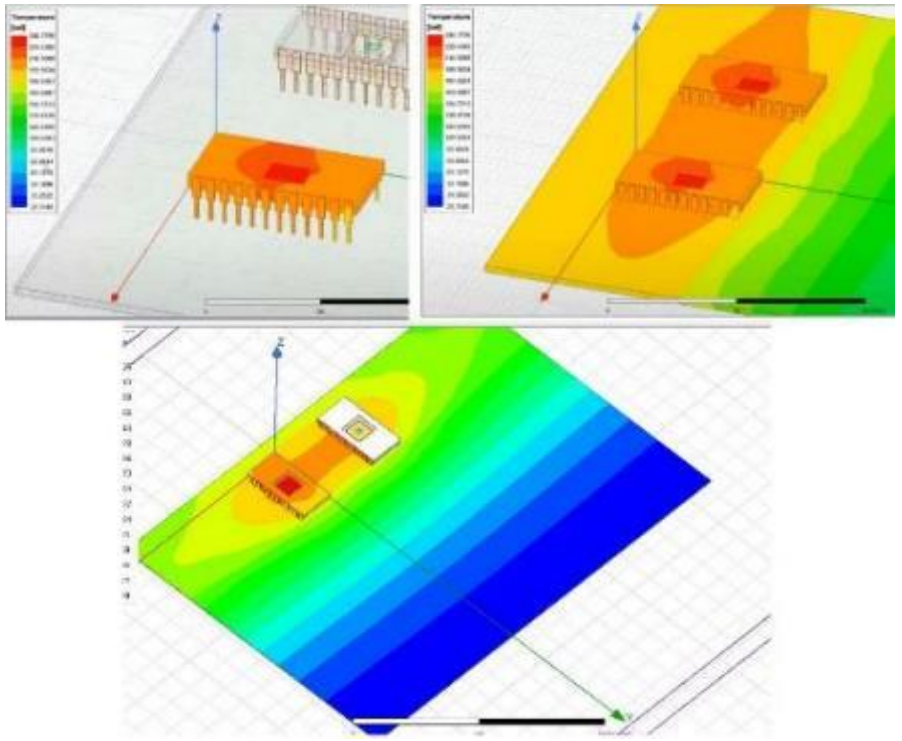
It simulates both the laminar flow REGIME AND THE TURBULENT REGIME

ANSYS Icepak is a complete interactive tool for thermal analysis used by design engineers in the electronics industry.









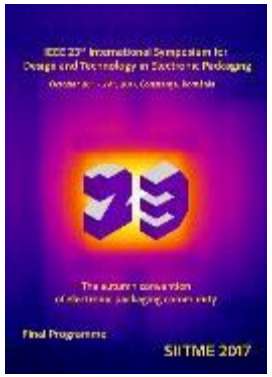
SIITME Conference and exhibition

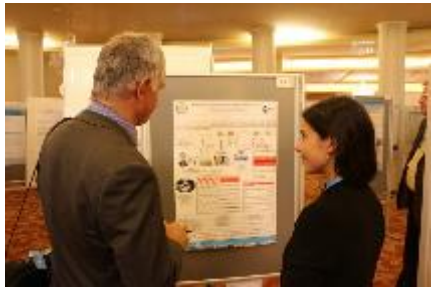
siitme.ro

SIITME 2019

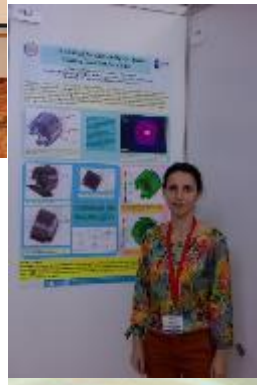
IEEE 25th International Symposium for Design and Technology in Electronic Packaging, 23rd – 26th of October, Cluj-Napoca, Romania

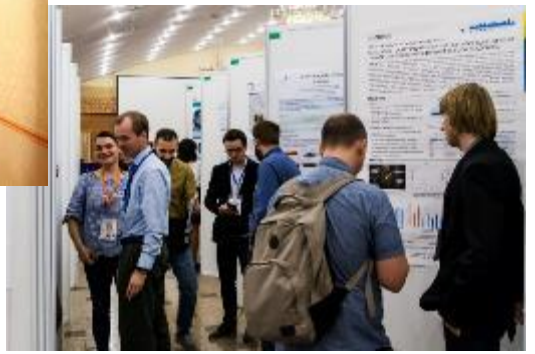
siitme.ro

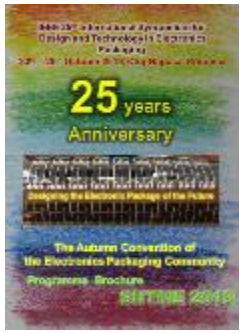

SIITME 2017

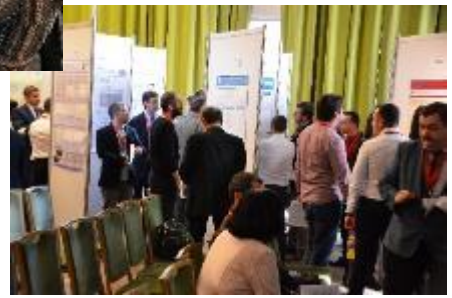


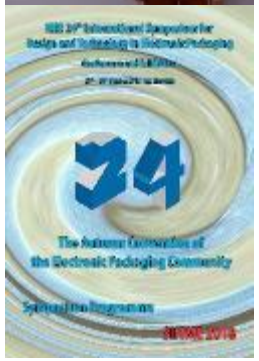

SIITME 2016
Abstract Proceedings



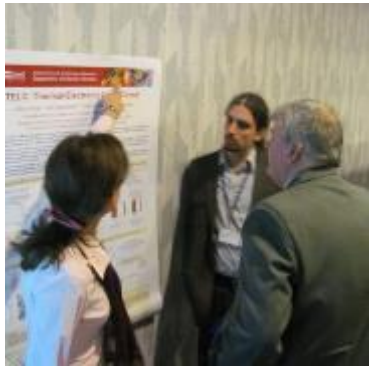



25 years
Anniversary
The Autumn Convention of
the Electronics Packaging Community
Programme Brochure
SIITME 2016



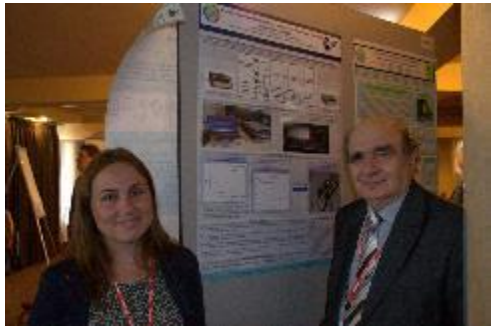

34
The Autumn Convention of
the Electronic Packaging Community
SIITME 2016

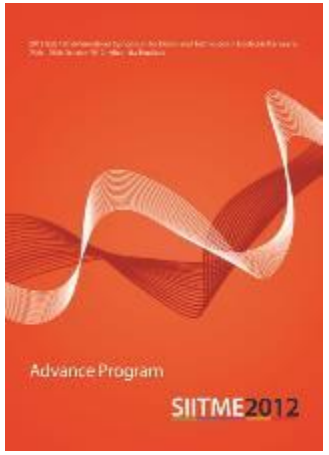

2. AI assisted Education 4.0 Process

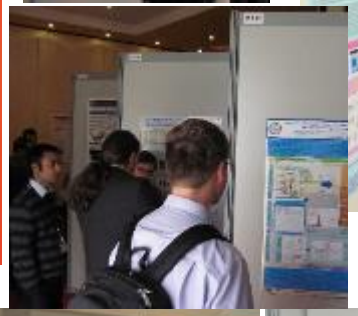


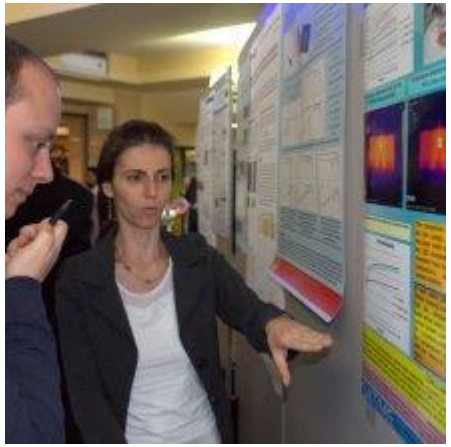

Conference Program
SIITME2013

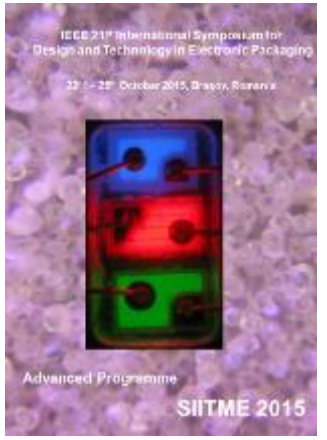

SIITME2

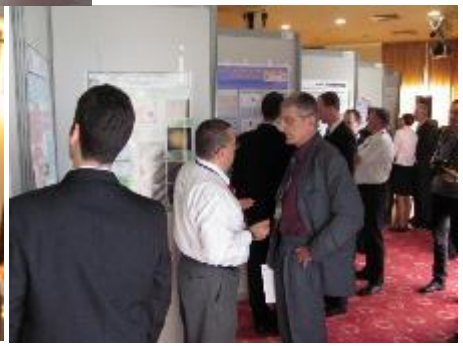


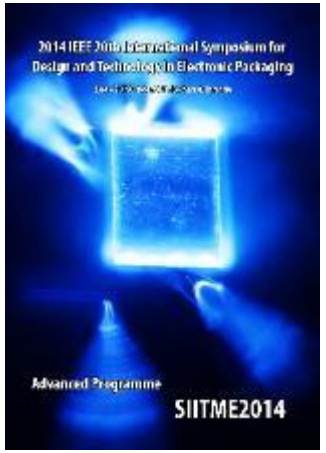

Advance Program
SIITME2012

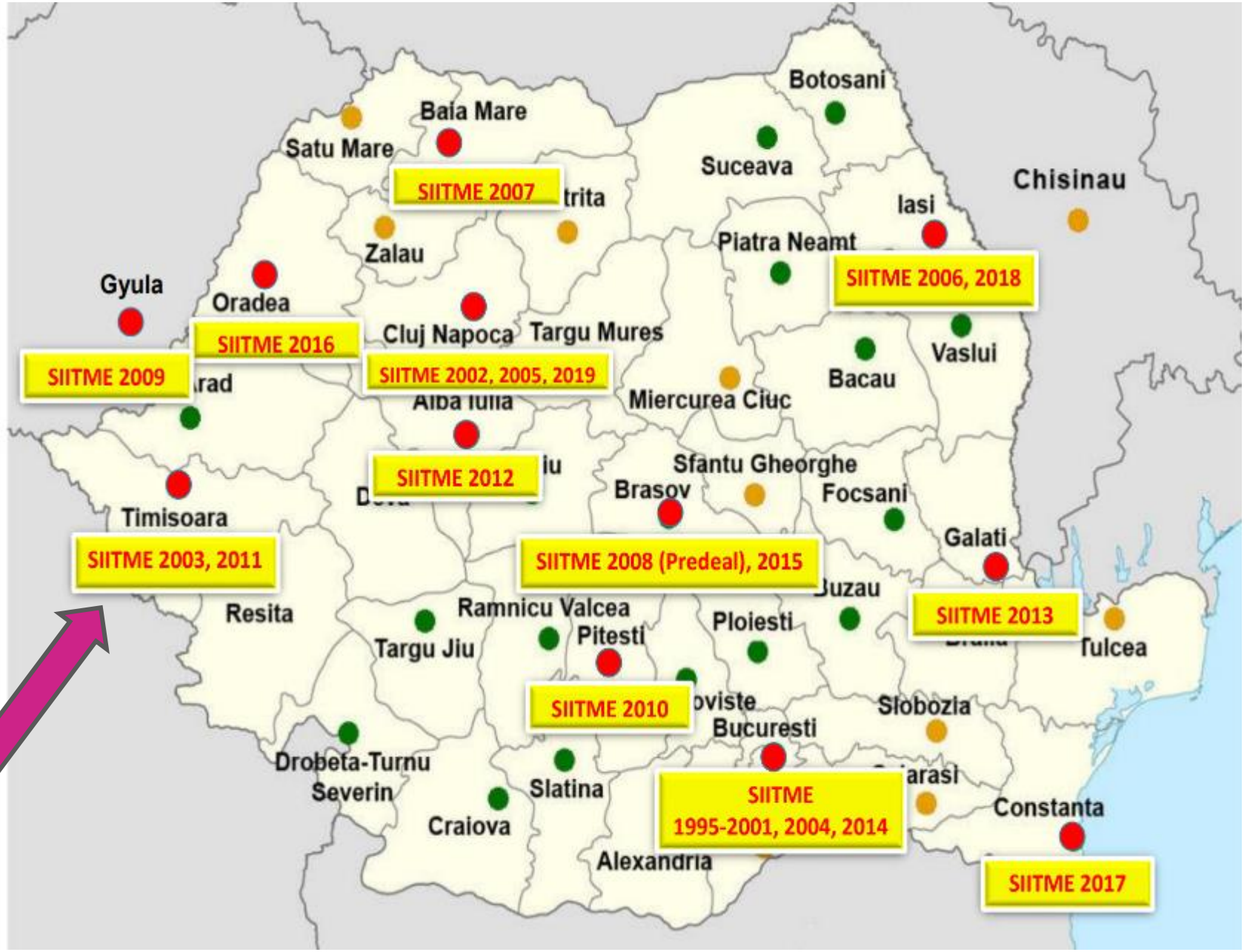





Advanced Programme
SIITME 2015




Advanced Programme
SIITME2014

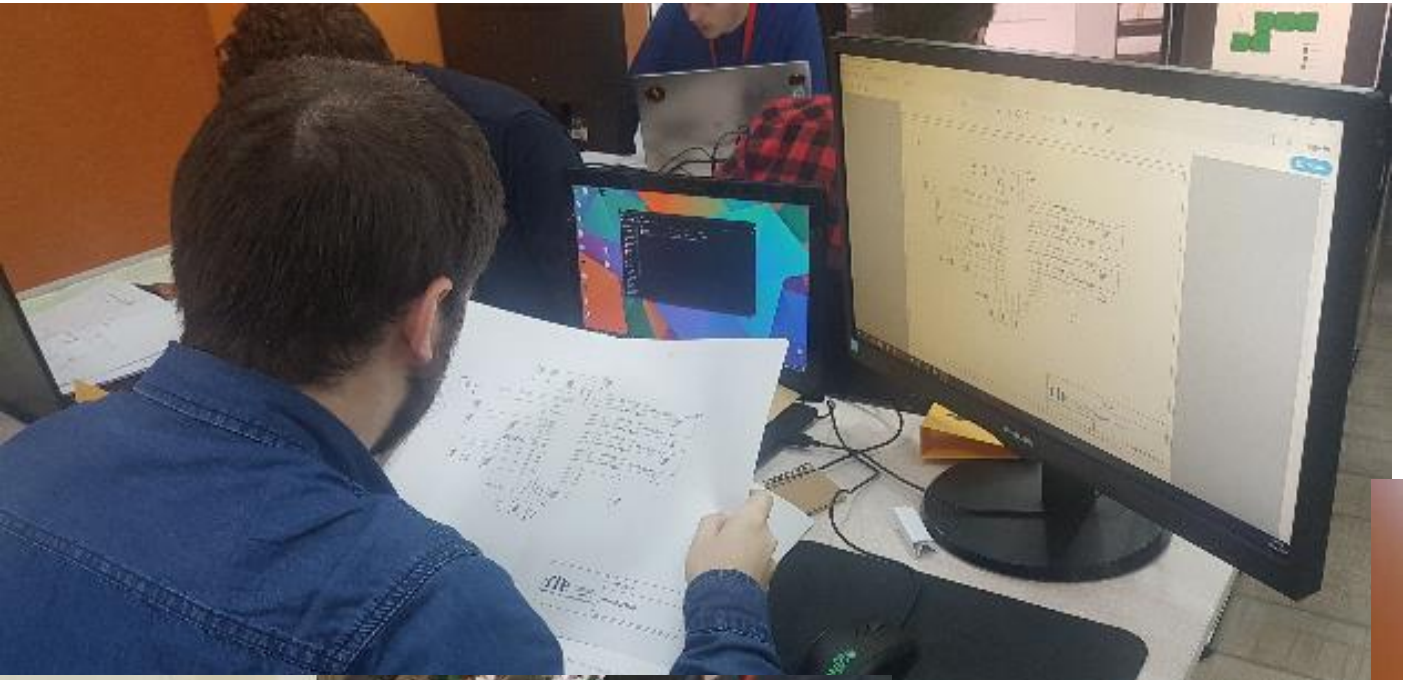


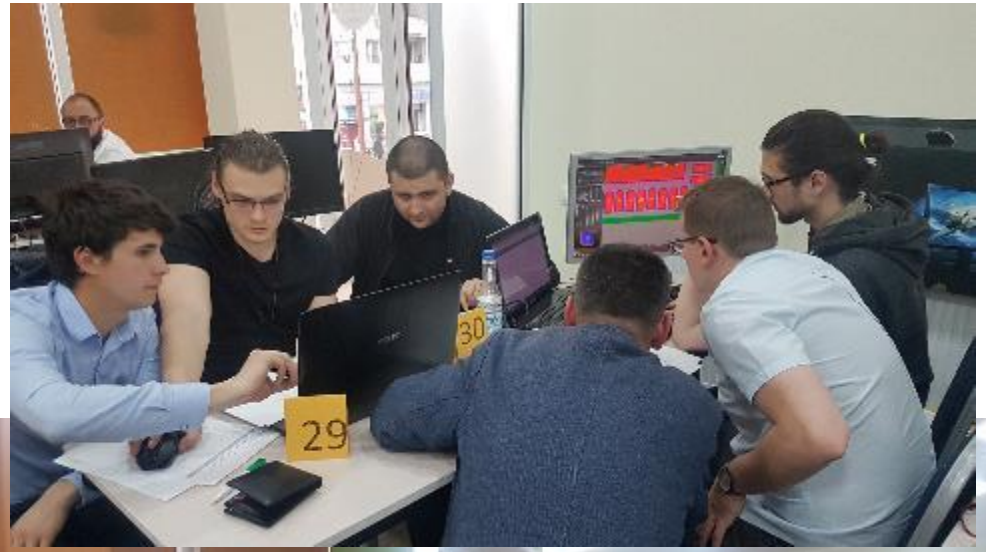
SIITME Roadmap 1995-2020

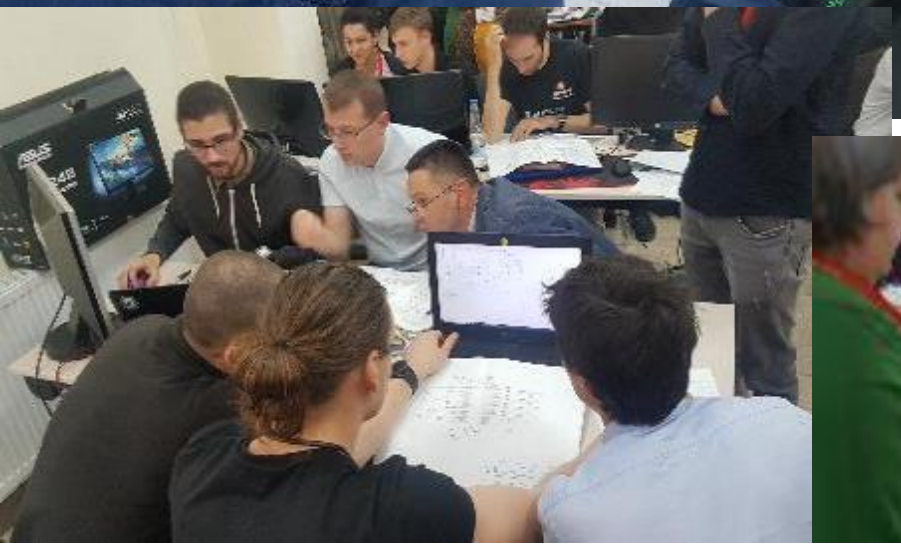
-next: Timisoara 2021

TIE, Professional student contest

DESIGN OF ELECTRONIC MODULES & ASSEMBLIES
www.tie.ro
A WAY to turn your HOBBY into PROFESSION







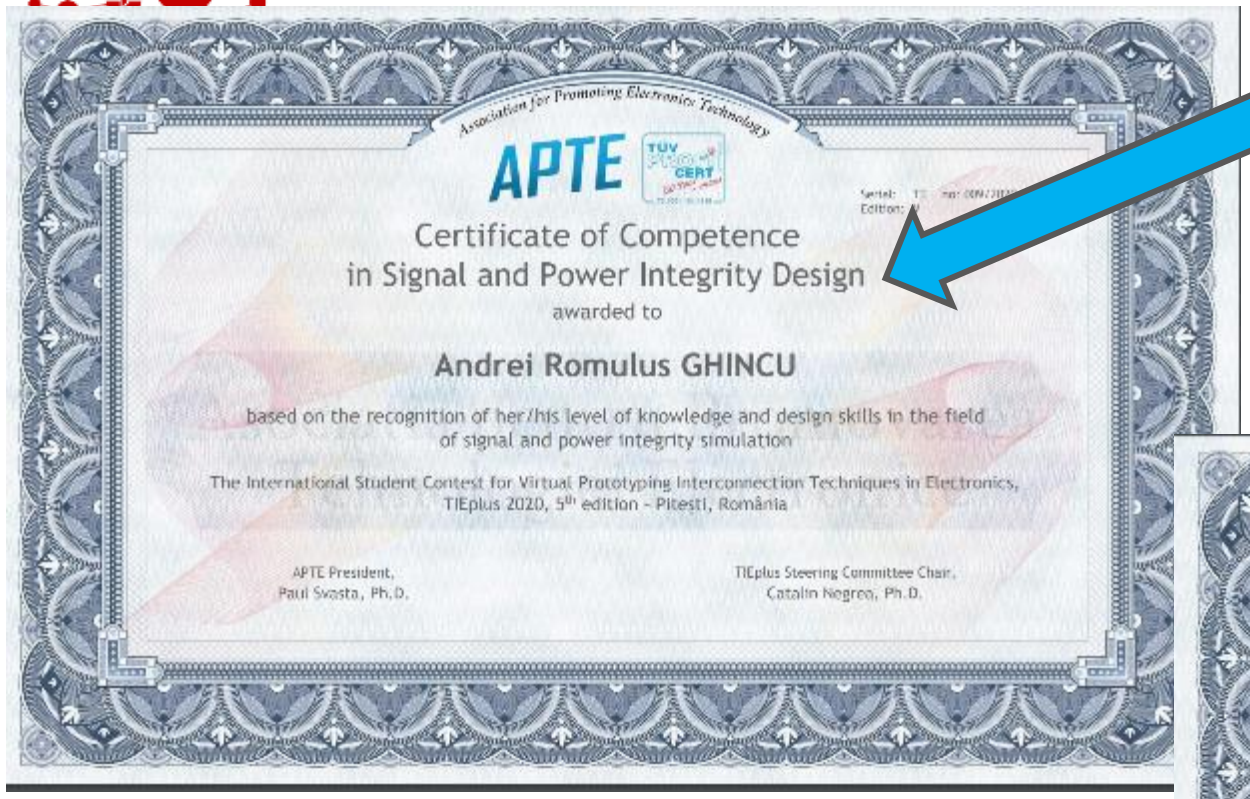
TIE

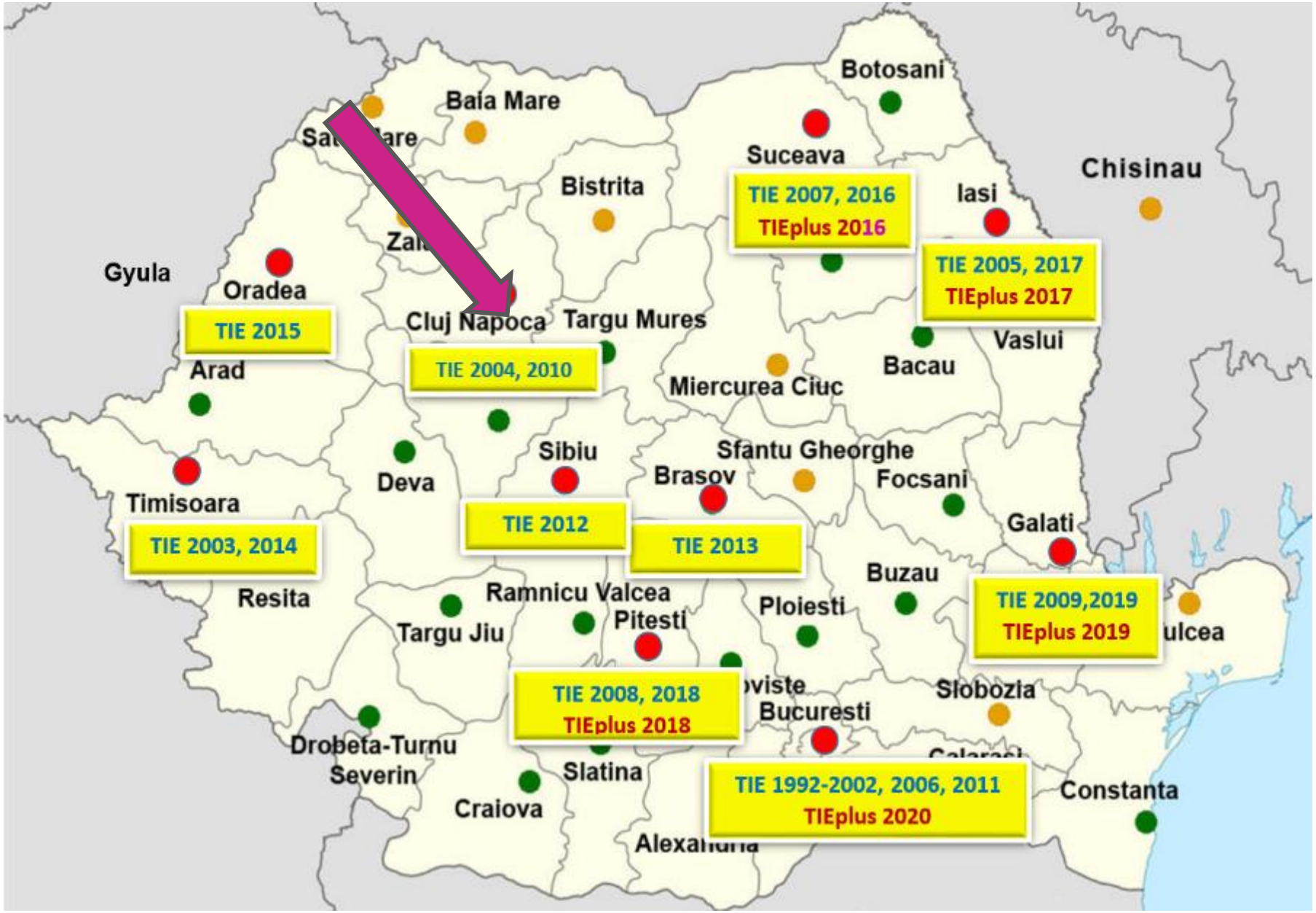
DESIGN OF ELECTRONIC
MODULES & ASSEMBLIES

www.tie.ro

A WAY to turn your HOBBY into PROFESSION

Certification by the industry of students design competence





TIE/TIE Plus Roadmap 1992-2020

-next: Cluj-Napoca 2021

DA-SPACE Project

2017 - 2019

Interreg
Danube Transnational Programme
DA-SPACE

Germany | Czech Rep | Bulgaria | Romania | Slovakia | Serbia | Croatia

Public Administration
Universities
Companies
Transnationality

Open Innovation

Challenges

Young Talents

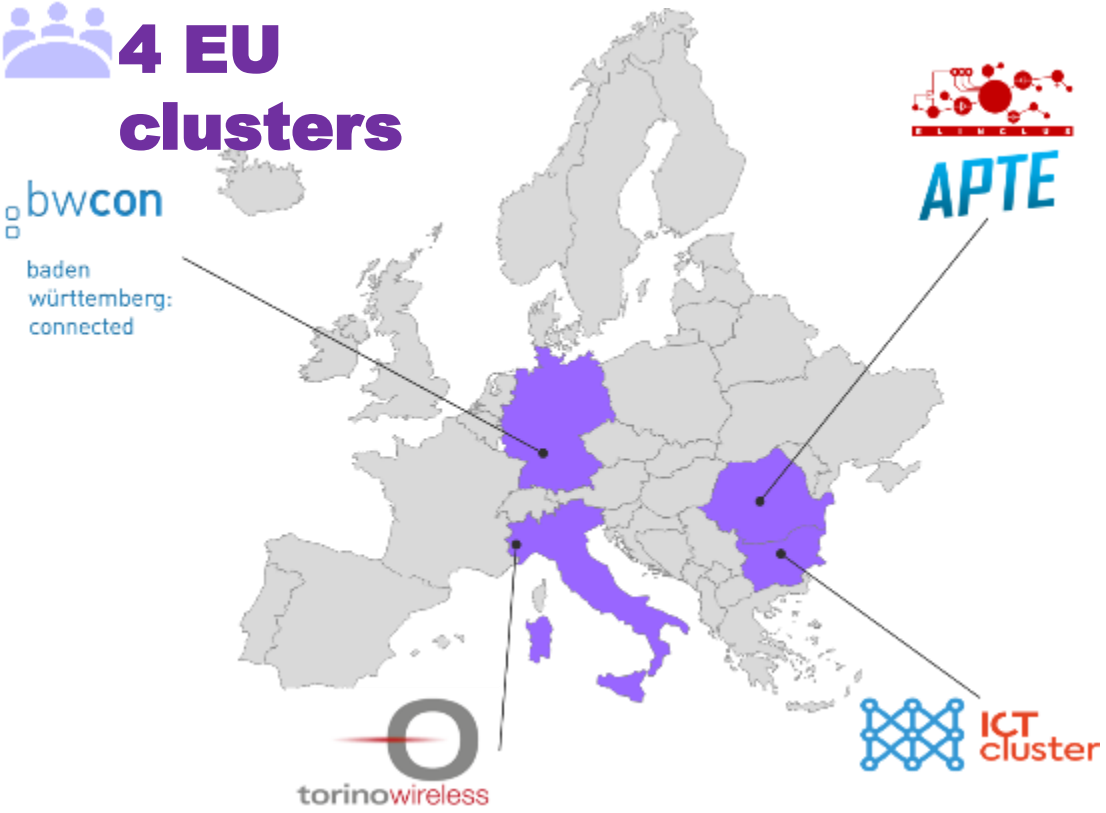
Entrepreneurship training

Solution

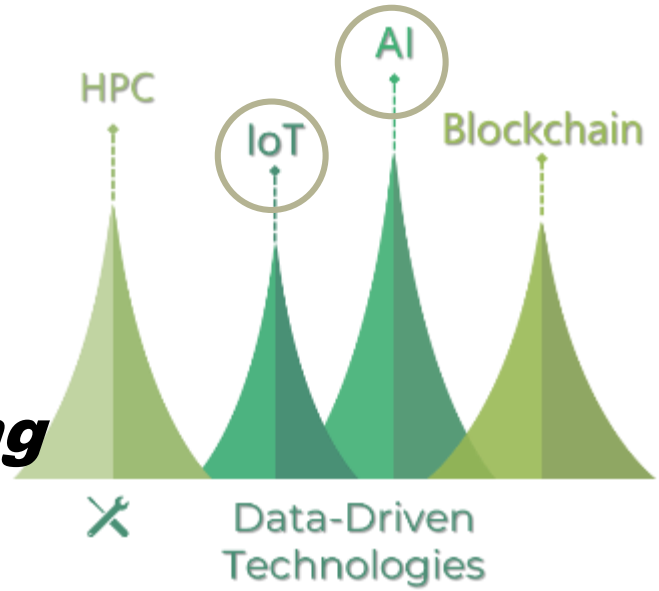
Staff Exchange

BRIDGE: Building Relations to go International for Data-Driven Growing Enterprises (start-ups and SMEs)

4 EU clusters



European SMEs and Start-ups *offering*



- **to develop a joint internationalization strategy (co-designed by BRIDGE clusters and their SMEs) by:**

1) **Sharing knowledge and expertise on state-of-the-art of the Data-Driven Industry with specific focus on AI and Blockchain techs and their potential application in different market domains.**
2) **Building a portfolio of competitive services to support start-ups and SMEs.**

20 months: *Sept. 2020 – April 2022*

This project is co-funded by the COSME Programme of the European Union

Conclusions

- Innovation represent a major factor for the economical development of the society;
- The partnership between the Academia and the Industry lead to a win-win situation;
- Clusters represent the adequate environment for SMEs collaboration;
- Intra and inter cluster cooperation contribute to the prosperity of the cluster ecosystem environment and stimulate the open innovation.

Thank you for your attention.

Contact:

APTE Association for Promoting Electronic Technology

President: Prof.DHC mult. Paul Svasta PhD.

Paul.Svasta@apte.org.ro

Executive Manager: Bogdan Mihailescu PhD.

Bogdan.Mihailescu@apte.org.ro

Address: Splaiul Independenţei nr. 313, 060042 BUCHAREST, ROMANIA

E-mail: **office@elinclus.ro**

Web page: **www.elinclus.ro**