Photonics Sensors @ CSEM

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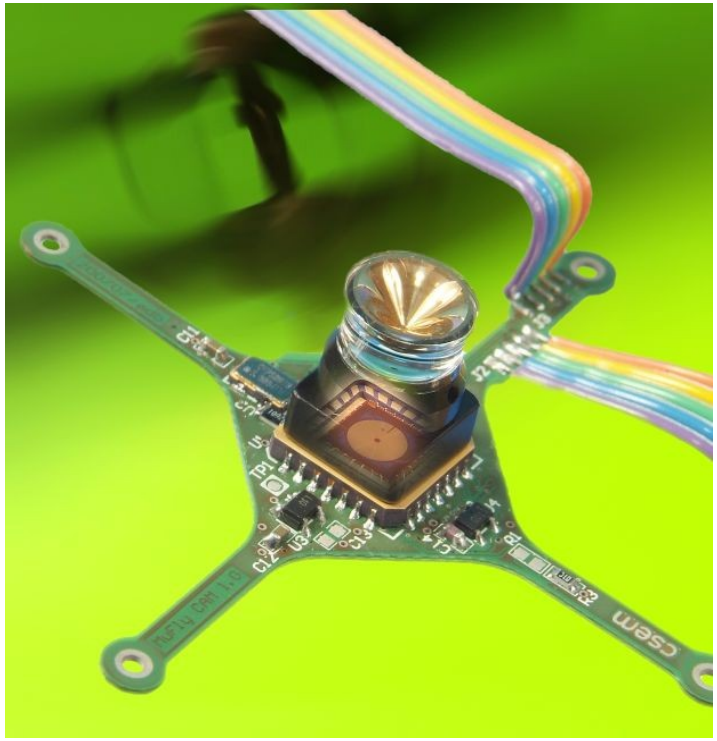
VP- Photonics

17.09.2009



360° camera

Agenda

- High performance sensors
  - High speed
  - High sensitivity and Dynamic Range

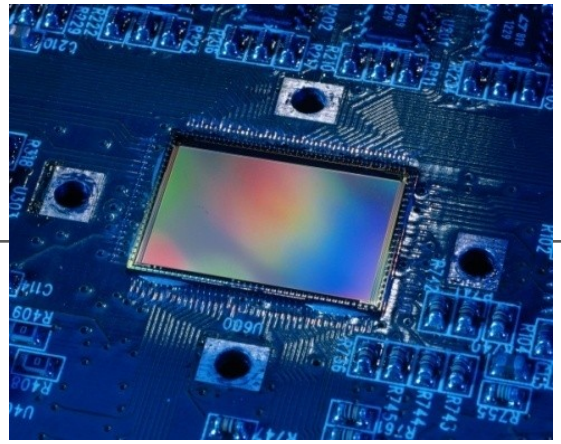
- Smart Sensors
  - 3D imaging in real-time
  - Vision System on Chip (SoC)

High-Speed: 2D Imaging

- Spatial resolution: 768 x 1024 pixels
- Interpolated: 1536 x 1024 pixels
- Die size: 20 x 14 mm^2
- Output rate of **1’000 frames/s**

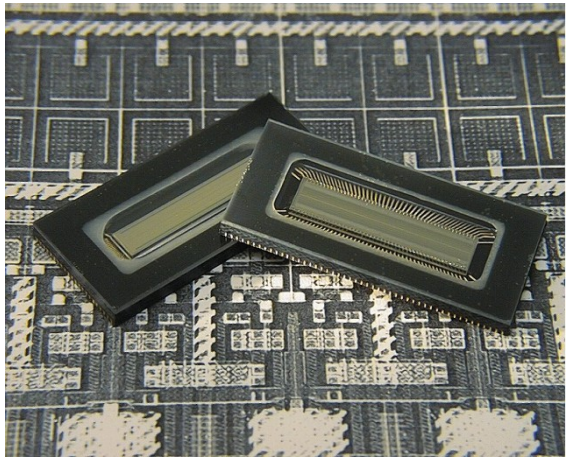
- SpeedCam Visario 1500
- SpeedCam Visario G2

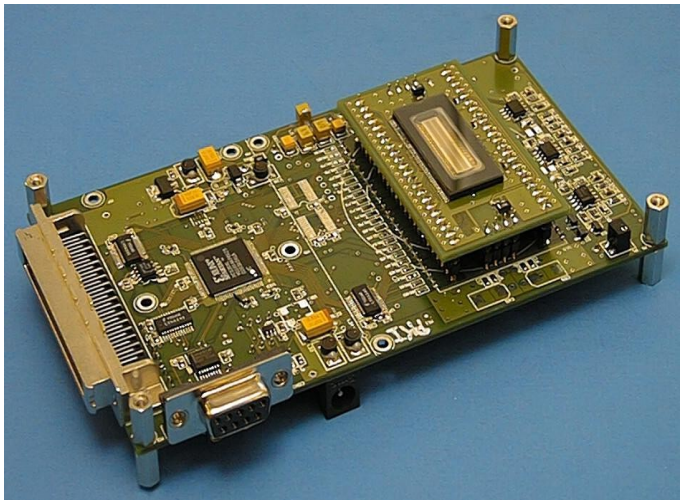
- **Next Generation**
  - > 1 Megapixels, **2’000 fps, digital output**



High-Speed: Line sensor

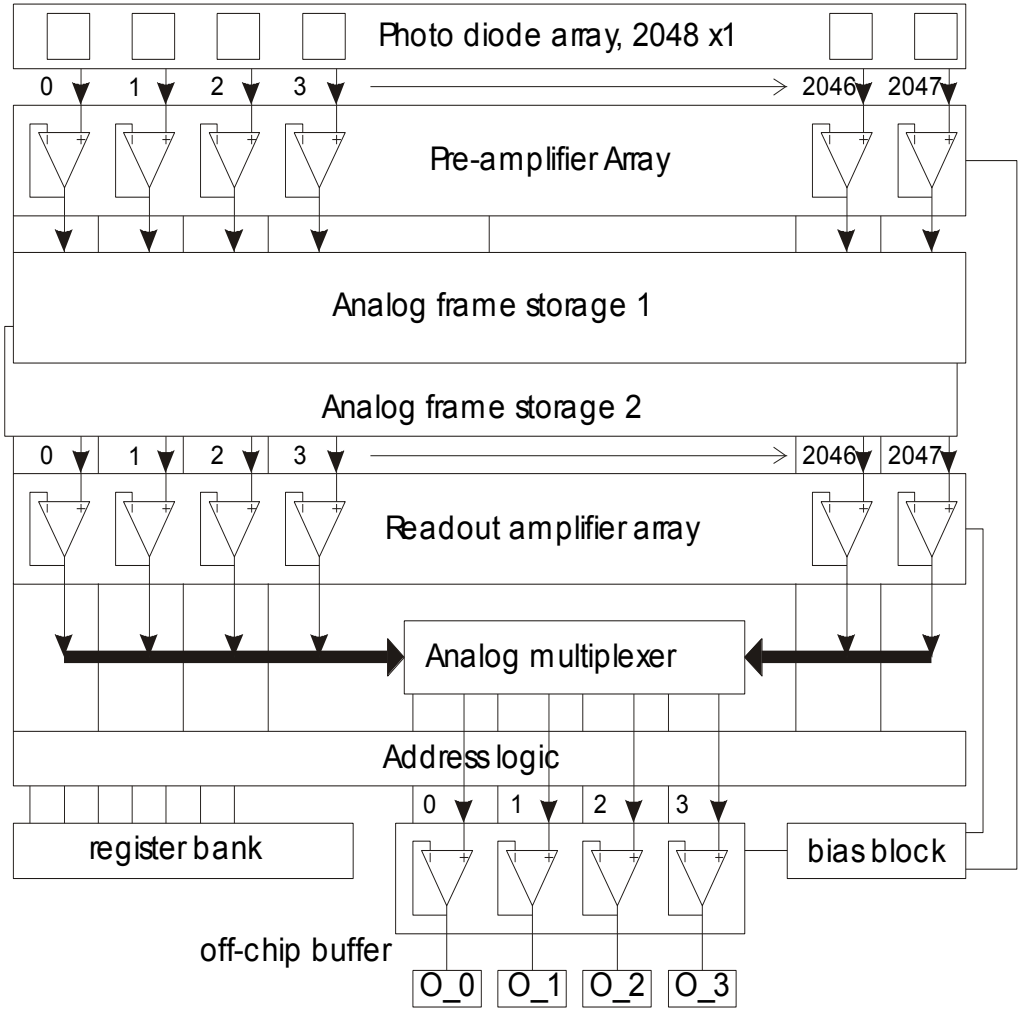
- Resolution 2 x 2048 pixels
- Pixel pitch 9.5x9.5 μm
- Optical fill factor > 90 %
- Pixel rate > 320 Mpixels/s
- Frame rate **80’000 frames/s**
- Power consumption 170 mW
- Concurrent integration and read-out





- Among the fastest line sensors world-wide

Architecture of High Speed Line Sensor



Double sampling

+

Parallel read-out

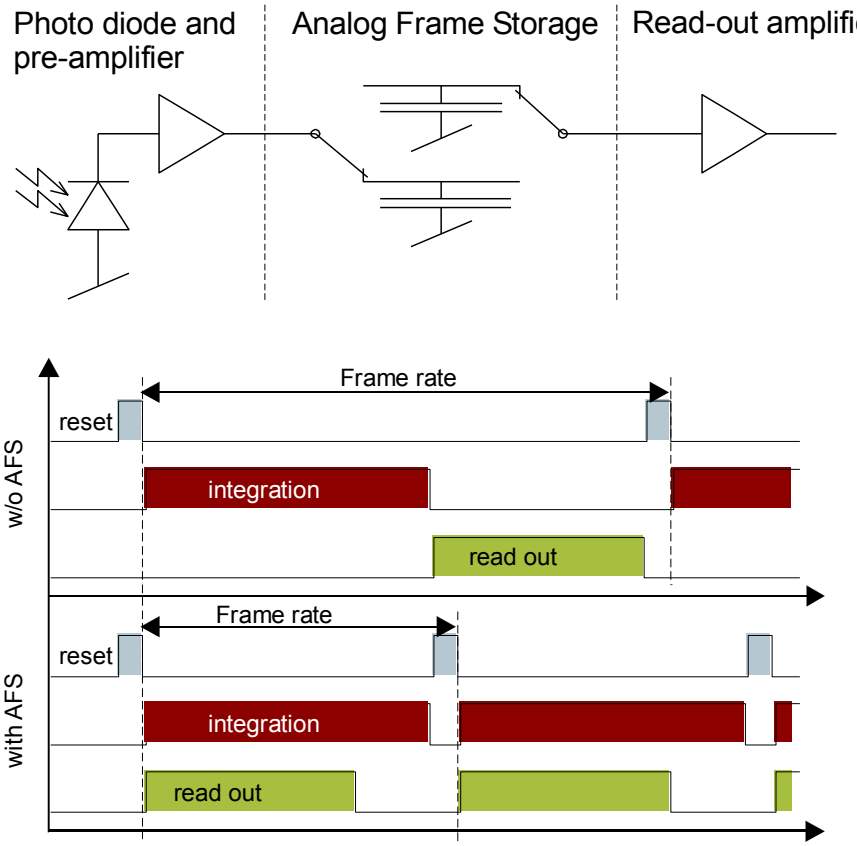
+

Analog multiplexing

–

2 x 4 analog outputs channels

Ping-Pong Structure for Integrate-while-Read-Out

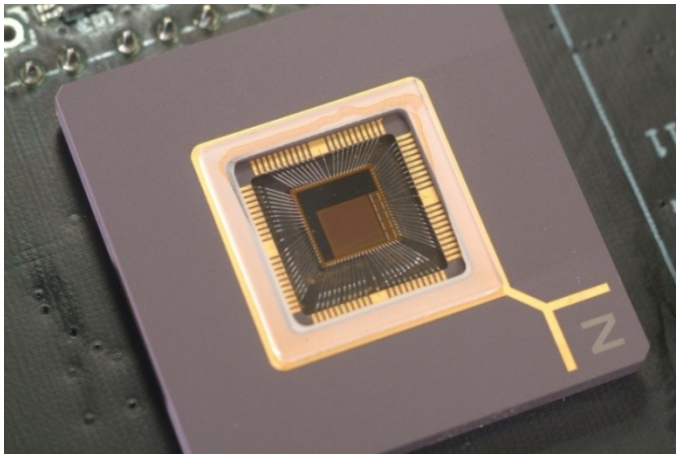


- Two analog frame storage (AFS) blocks are built in
- Pixel amplifier stores signal on either of the two AFS while read-out amplifier selects the other AFS as source
- Integration and read-out can therefore be done a the same time
- Global shutter

No time is wasted for integration while reading out the gathered signal

High sensitivity / Low-light

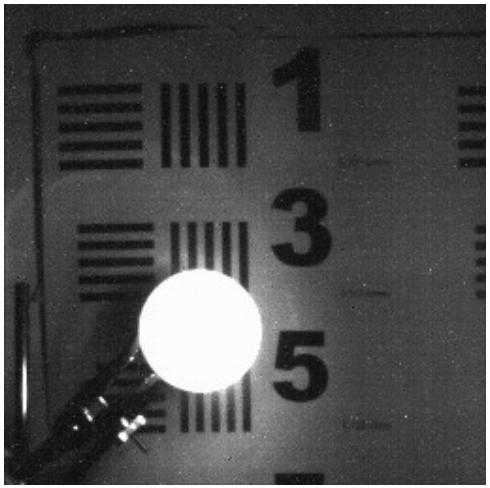
- Test chip 256x256 pixels



- **Readout noise** **< 2 e_{rms} @ RT**
- 3-5 photons / pixel

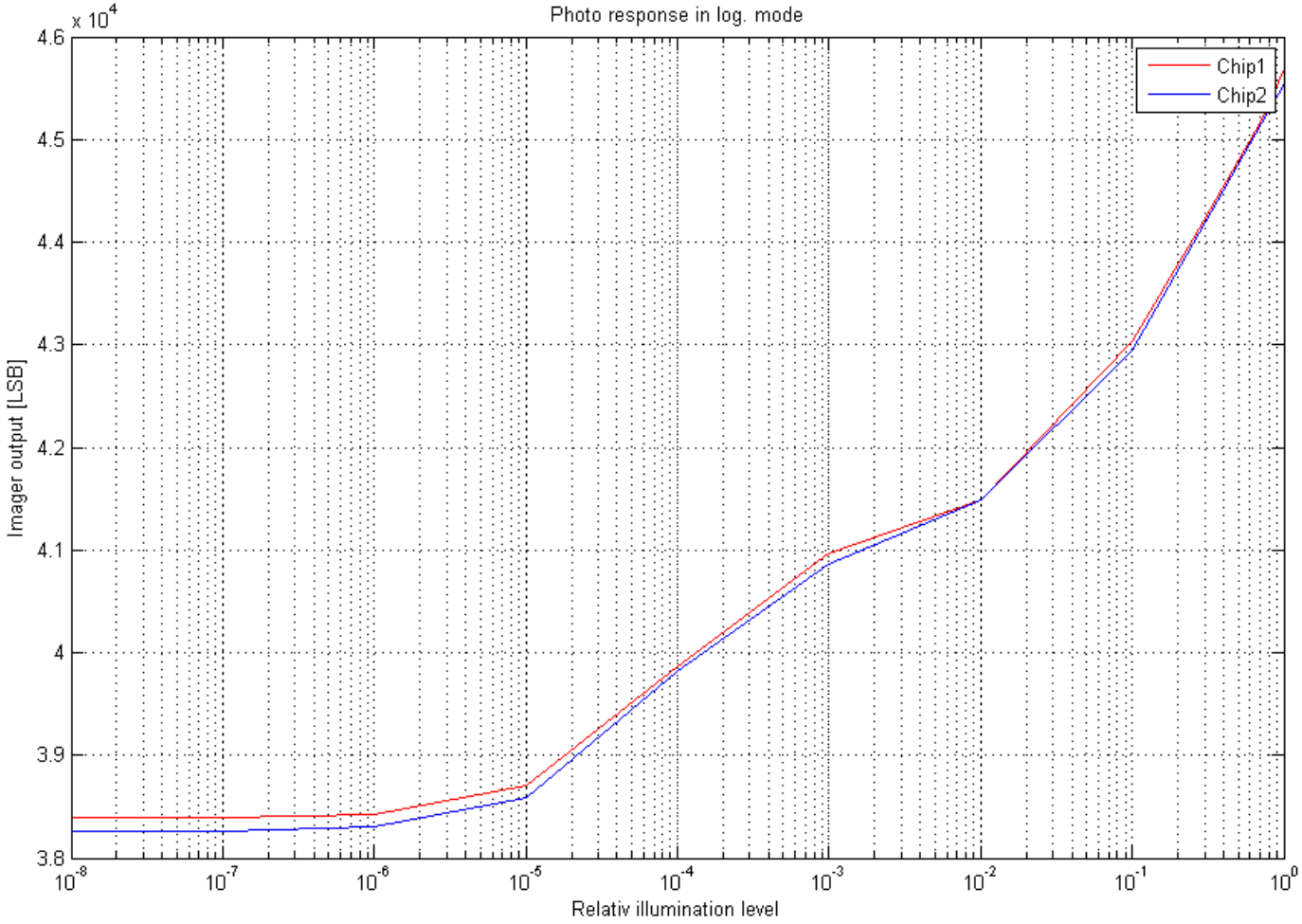
- One of the most sensitive CMOS sensor world-wide (without Avalanche Photo Diode)

- Close to single-photon detection in combination with high Dynamic Range
  - **Dynamic Range** **> 140db**



High-dynamic scene

High Dynamic Range

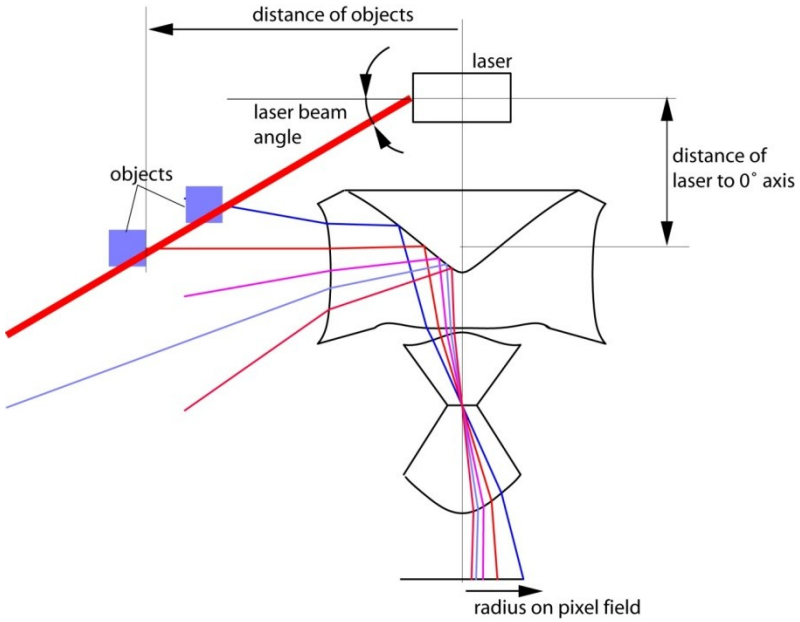


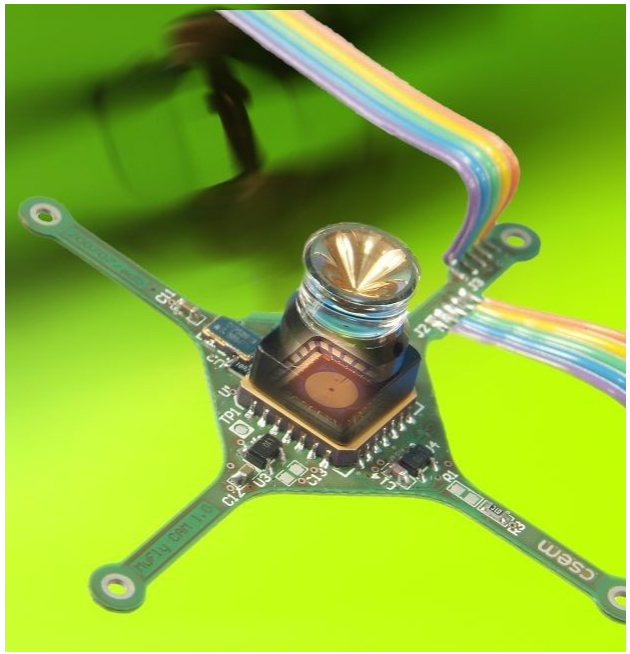
Camera for autonomous flying helicopter

muFly

Objective

- Development of a fully autonomous miniaturized helicopter
- Development of a 360° camera system for collision avoidance

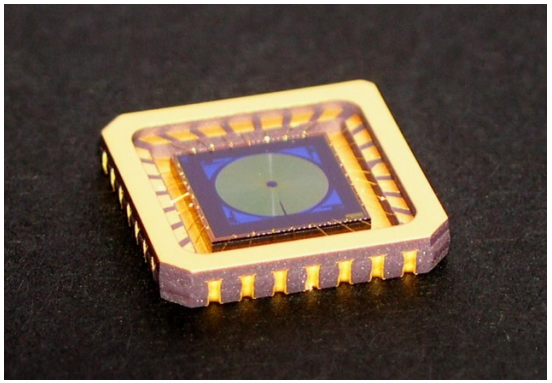


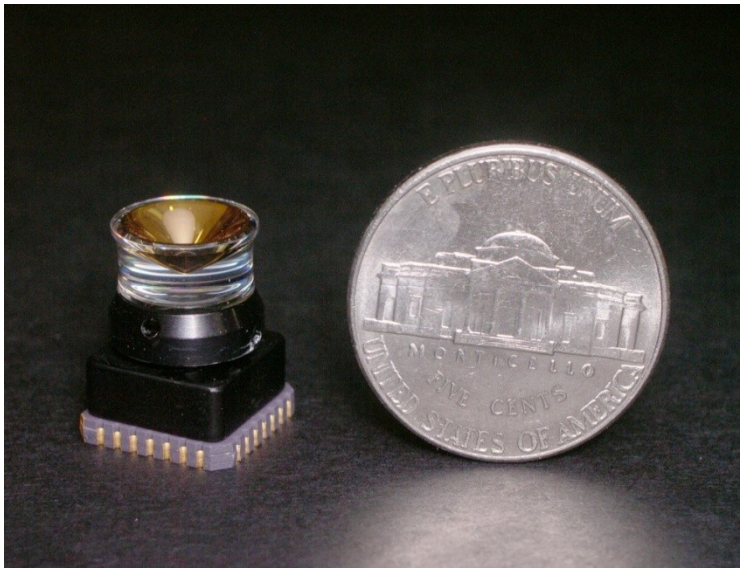


Camera for autonomous flying helicopter

muFly

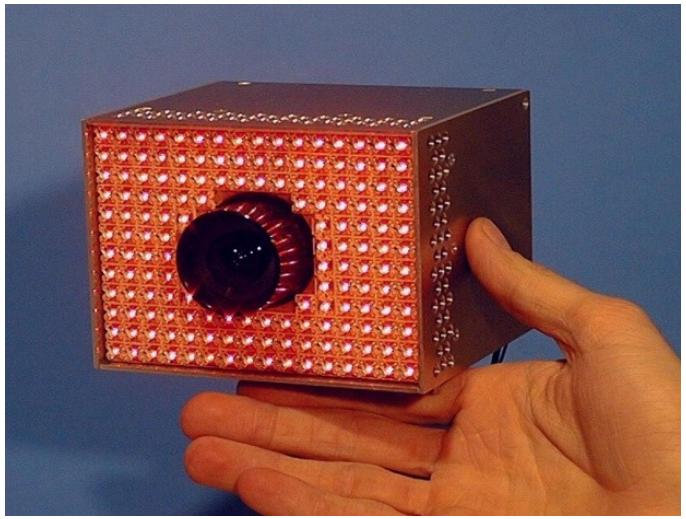
- Omni-directional view
- < 5g
- Dimensions: 14 x 14 x 10 mm
- Field of view: +10 / -35 degrees
- Polar pixel field: 64 circles and 128 radials
- Progr. frame-rate of up to 40 fps
- **140 dB** dynamic range (ProgLog)
- Ultra-low power (**core <1mW @1.2V**)

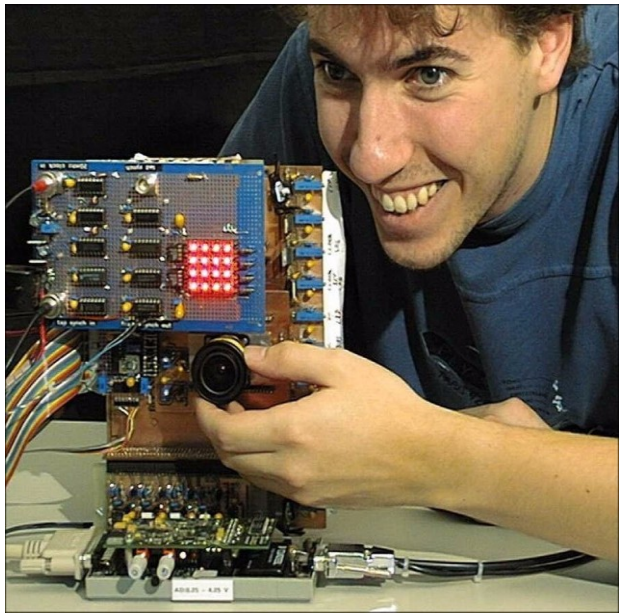


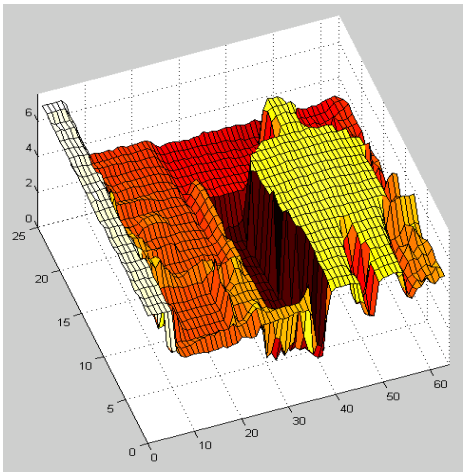


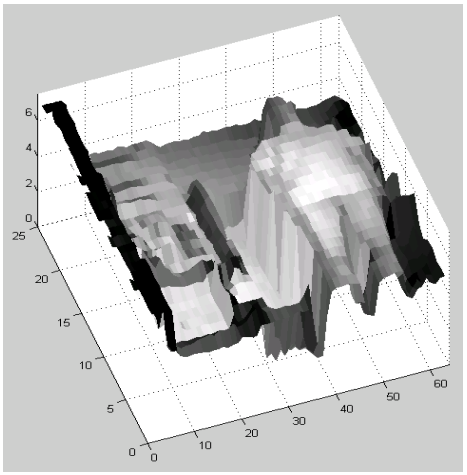
Time-Of-Flight camera for 3D imaging in real-time

- First 3D range camera without moving parts
- 25x64 pixels
- 10-60 fps



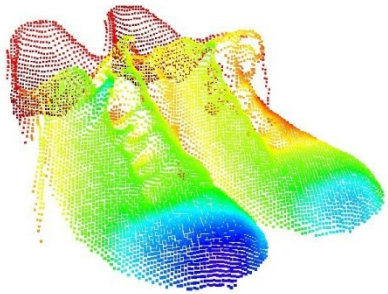


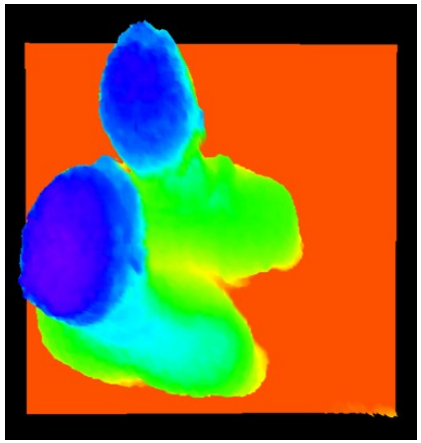




The SR-3000 and SR-4000 cameras

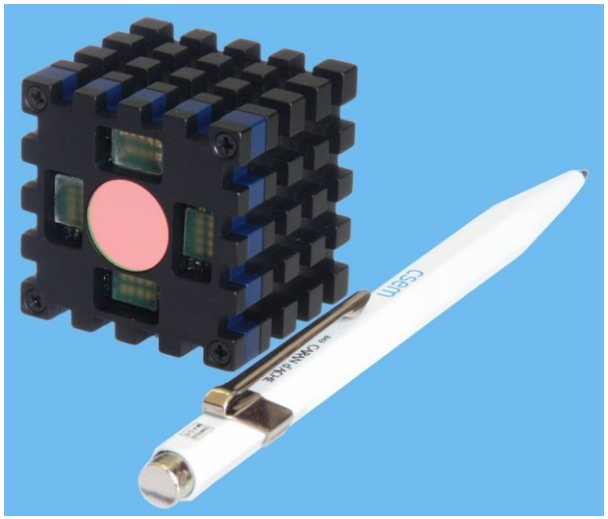
- Broad range of applications
  - **Security – protect areas / automatic doors**
  - **Counting – passenger / components**
  - **Quality control (shape)**





ARTTS 3D TOF Camera

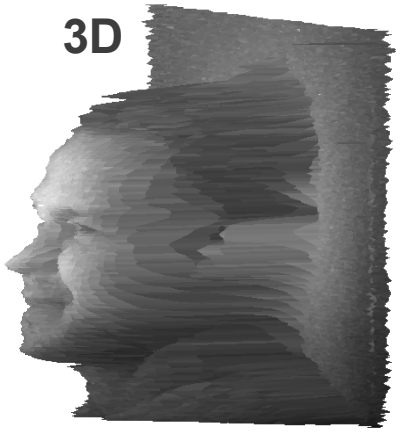
- Spatial resolution 176 x 144 Pixels
- Depth resolution mm to cm
- Low power USB2.0 powered
- Miniaturized < 4x4x4cm^3
- http://www.artts.eu/



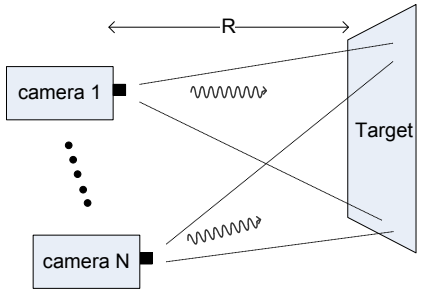
- Two chips successfully developed
  - 3D TOF Sensor
  - Digital controller

2D

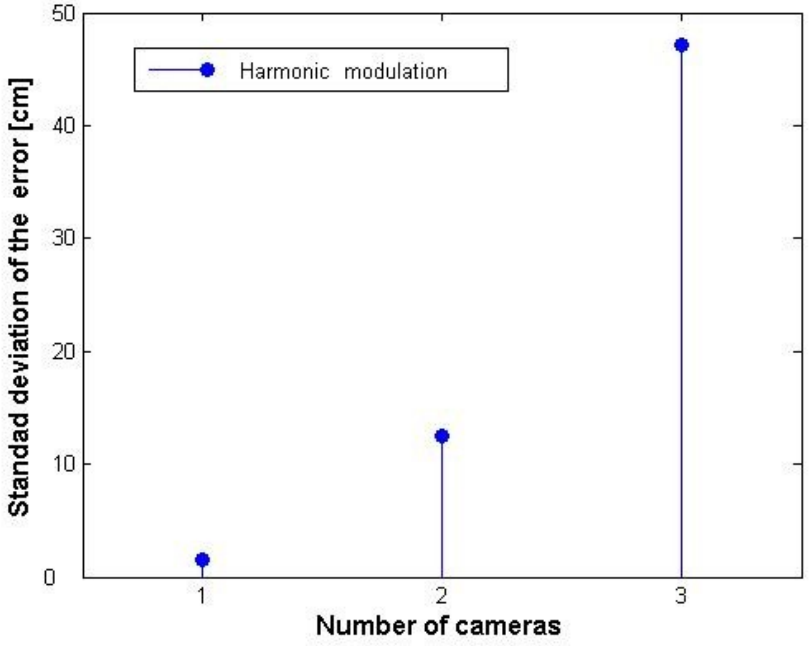
3D

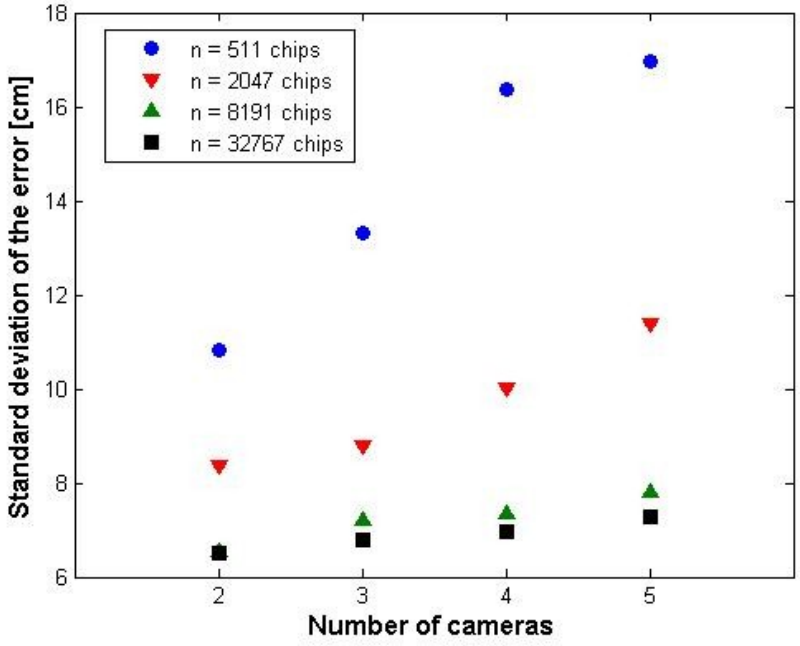


Multi Camera Environment



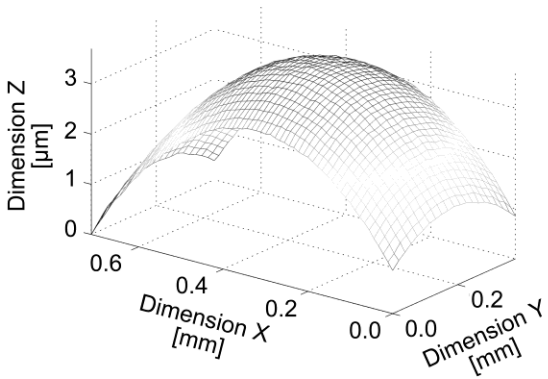
- For sine-wave modulated TOF cameras, the distance accuracy decreases dramatically with an increasing number of (interfering) cameras
- With pseudo-noise sequences, the camera is insensitive / less sensitive to other TOF cameras

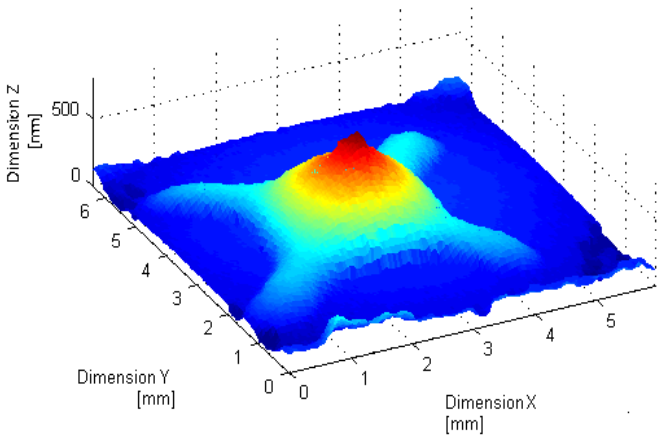




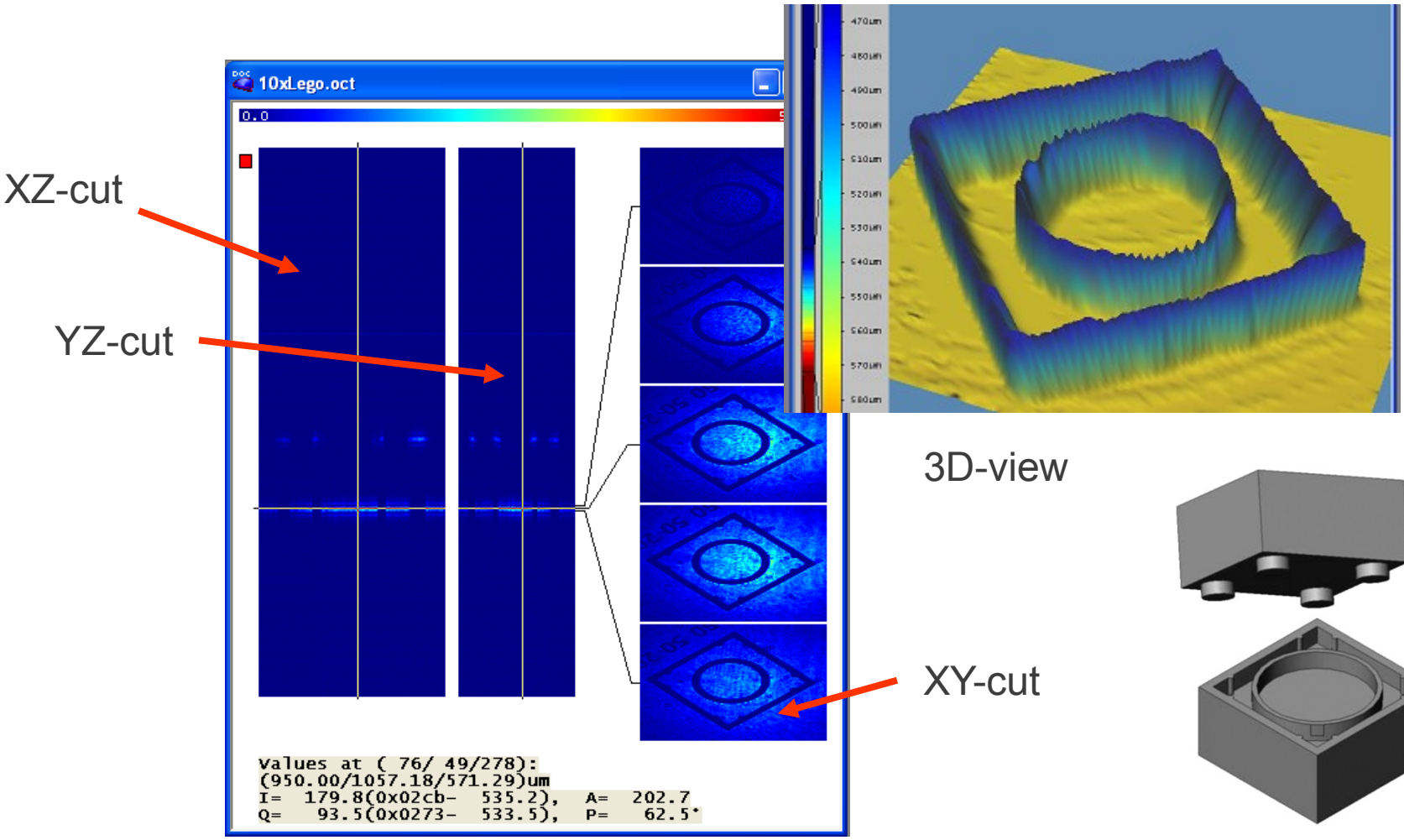
Systems: 3D imaging at the μm scale in real-time

- Parallel optical coherence tomography / white light interferometry
- High spatial resolution: 1 – 10 microns, down to a few 10nm
- Detection of **amplitude and phase** of an interferometric signal in every pixel
- Application: Quality control of optical elements, volume of glue in die bonding





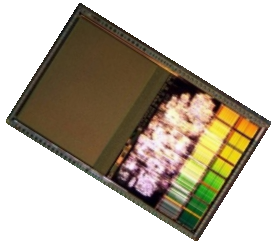
3D Measurement of a Ring-clip

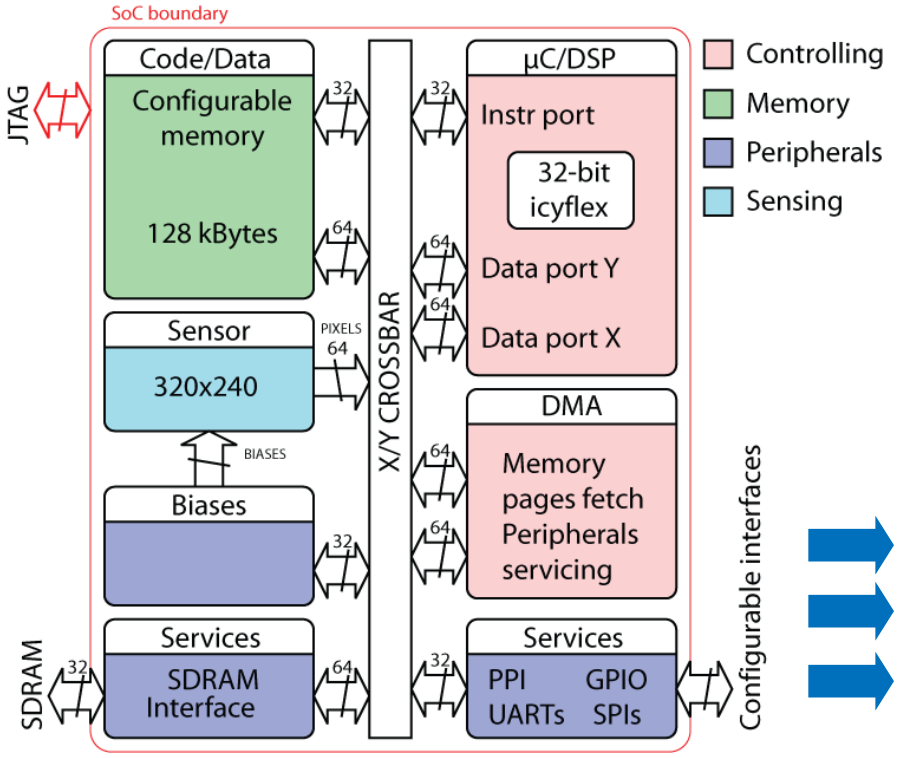


CSEM Vision SoC

A complete low power Vision System on 43 mm^2

Combination of a Digital log pixel Array and a 50 MHz DSP system





- Optical front-end of 320 x 240 pixels (QVGA)
- High Dynamics 130 dB (23 bits)
- Digital Log representation of the luminance
- Contrast
- 3 bit orientation
- 50 MHz icyflex uC/DSP
- Programmable with gnu C

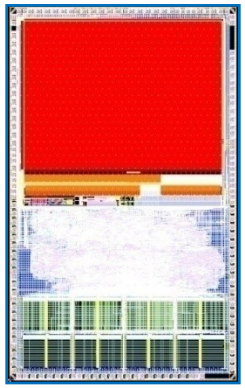
Insensitive to strong light changes

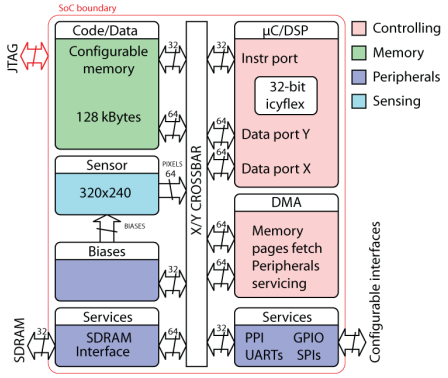
System power and cost reduction

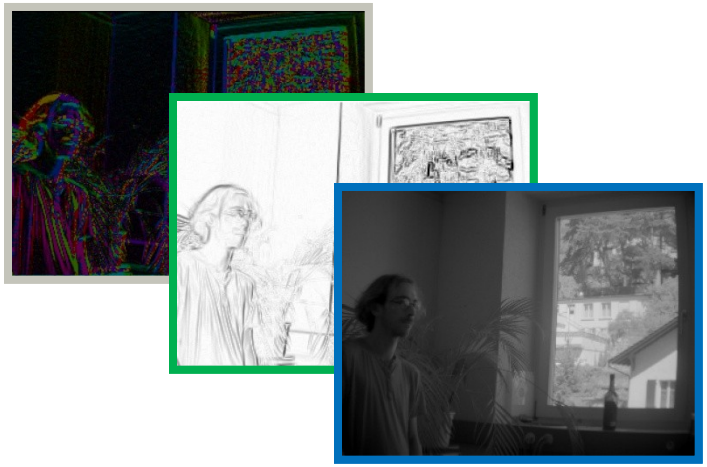
Flexible: 1 SoC many applications

Characteristics of the SoC

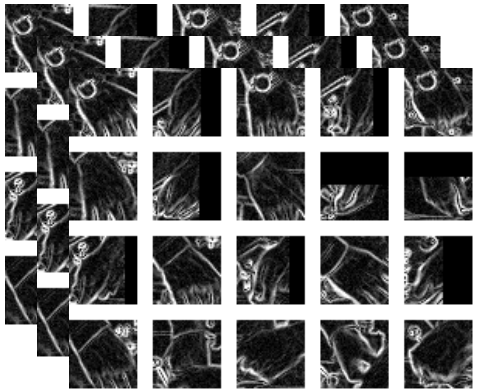
- Technology: 0.18 µm
- Pixel size: 14 x 14 µm^2
- Fill factor: 20 %
- Frontend: 320 x 240 pixels (QVGA)
- Die size: 43 mm^2
- Luminance: **digital log representation**
- Contrast: **magnitude and orientation (M e$^{j\Theta}$)**
- Dynamic range: 130 dB
- DSP: 50 MHz DSP icyflex
- Memory: 128 Kbyte on chip SRAM
- I/Os: UART, SPI, PPI, SDRAM, ..
- Programmable: GNU tool suite (gcc, gdb, gas)
- Power supply: 1.8 V (core) - 3.3 V (analog)





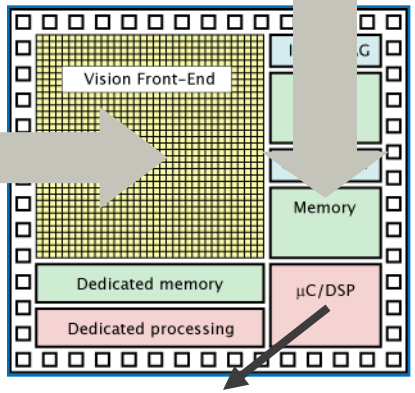


Tree - classifiers



Train off-line the classifier. Find efficiency-robustness tradeoff

Off-line

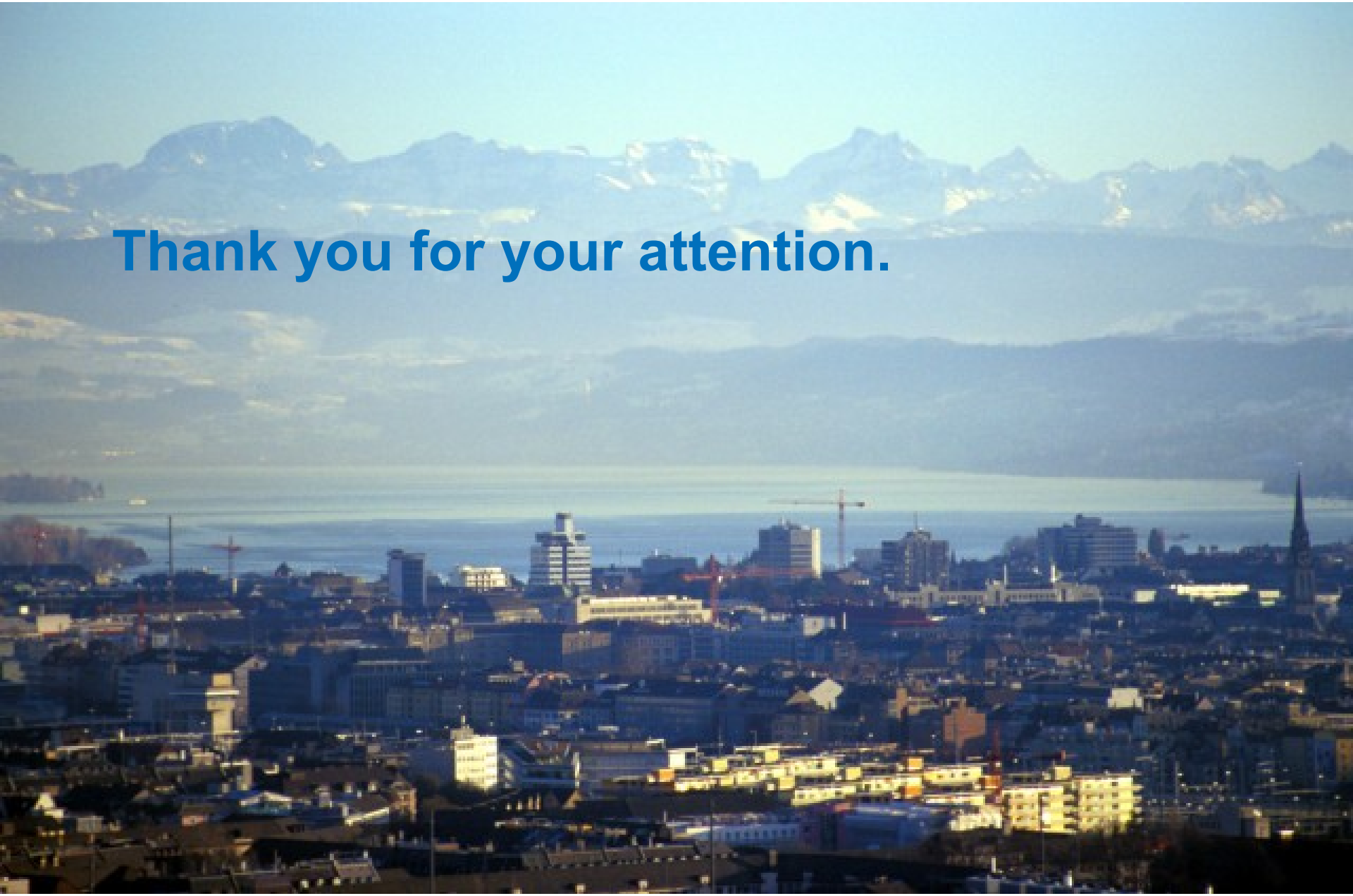


On-line

Answer: “hand, or no hand”

Conclusion

- High performance imaging based on CIS image sensor process offers unprecedented performance in terms of
  - Speed (in excess of gigapixels /s)
  - Dynamic Range (> 140db)
  - Sensitivity (close to single photon detection)
  - Functionality (user defined)


Thank you for your attention.