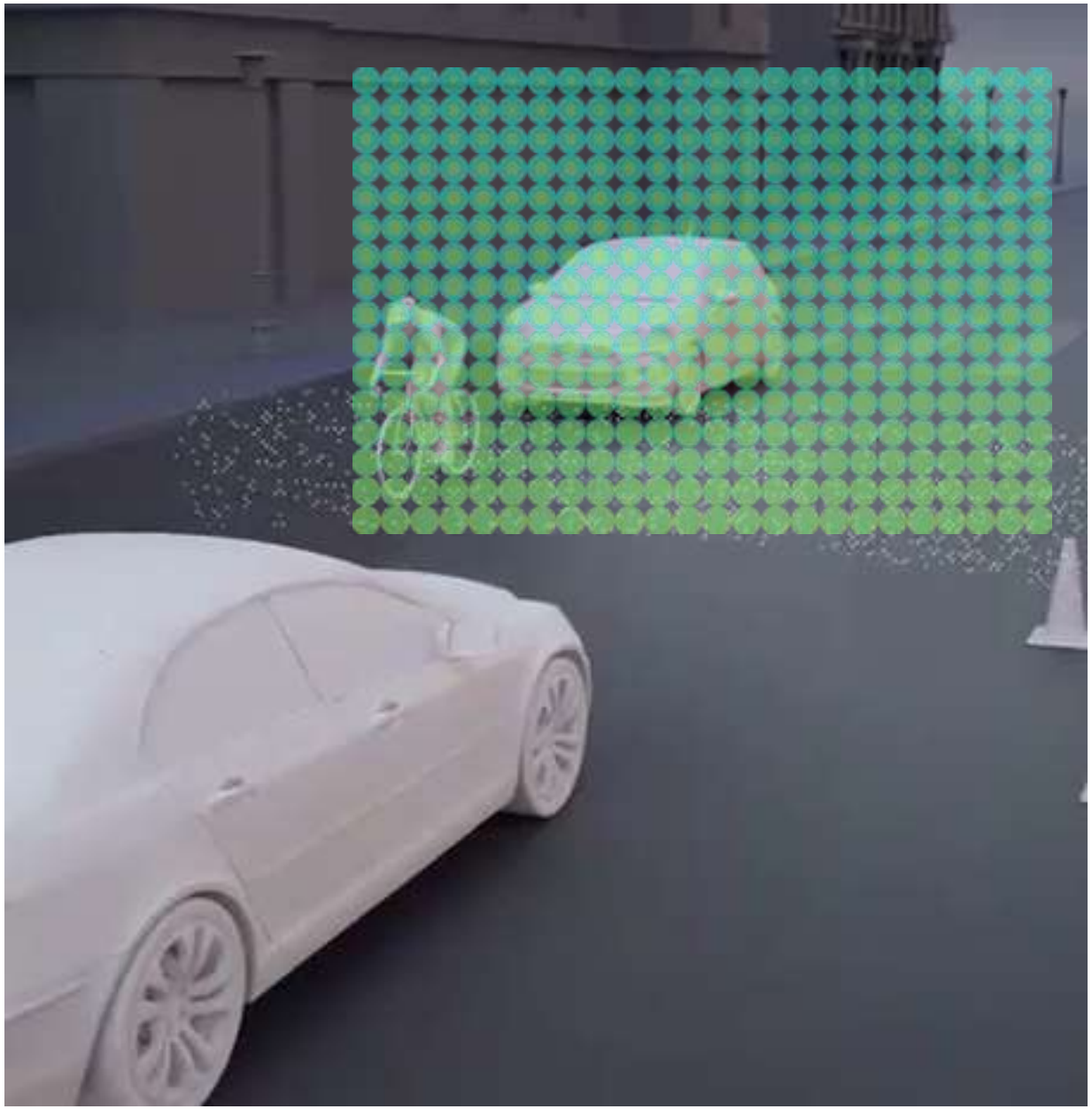

Flash Imaging Miniaturization

Near-range / low latency detection using 3D-stacked CMOS technology

Claude Florin
CEO, co-founder

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2022, 2017

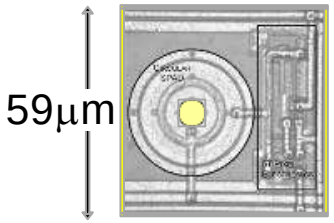
fastree 3D

Outline

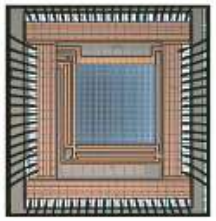
- Fastree3D and EPFL collaboration history
- Flash LiDAR miniaturization module
- CMOS SPAD miniaturization trends
- 3D wafer-level stacked circuits evolution and performance
  - EPFL prototypes with TSMC
- Towards software-defined Flash LiDAR
  - Integration plan, optimization points
- Value proposal

Fastree3D / EPFL collaboration history

2005 — Cristiano Niclass



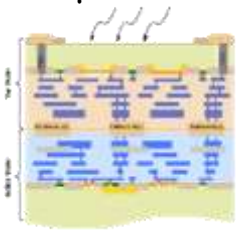
2009 — Lucio Carrara



2014 — Samuel Burri, 256 px LinoSPAD

2018 — Augusto Ximenes

19µm / 3D IC



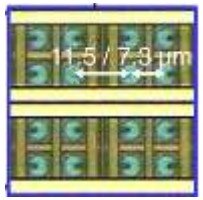
2020

7µm

256x128 px
+ Coincidence
Preethi Padmanabhan

2021

9.4µm cells



1024 x1000 px
(9.4µm) 1000fps

2022

Adrian Fiergolski
2Kpx Falcon

4D imaging

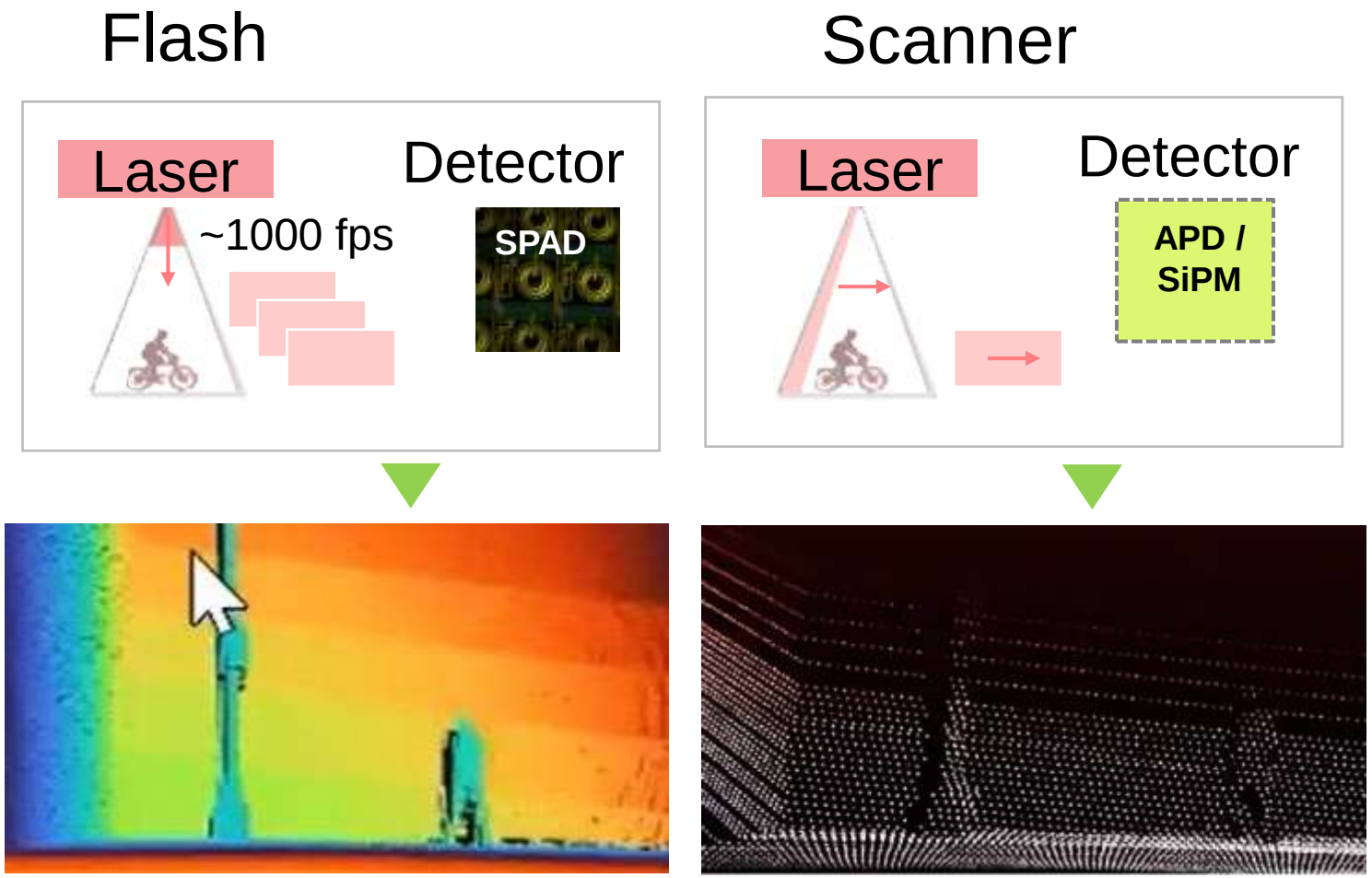
① CMOS SPAD ② World 1st miniaturization ③ World performance

** ISSCC is the "Olympics of Semiconductor industry", SPIE is the Iworld's #1 photonics association*

EPFL aqua lab, R. Charbon 2021

Flash LiDAR miniaturization approach

Animation



Images acquired from the web for illustration only

Flash

- High 2D pixel count

Photon counting

- Fast acquisition (MHz)
- Lower optical power

Digital chip

- Cost-effective implementation
- Software-defined

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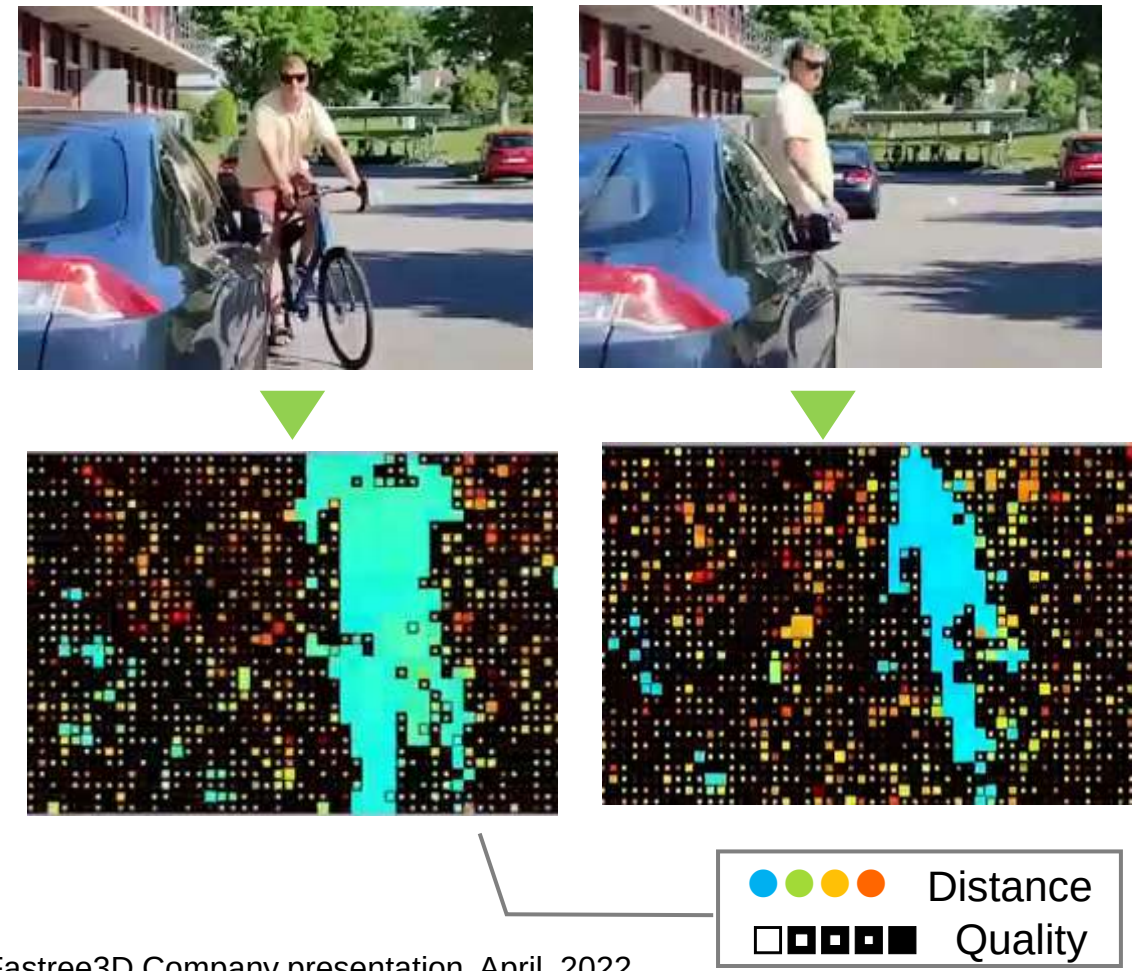
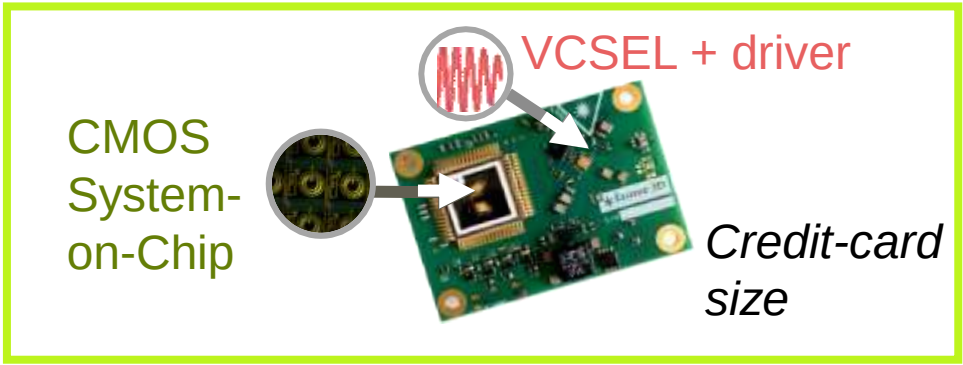
Flash LiDAR module miniaturization



- ✓ Software-defined
- ✓ CMOS SPAD detector
- ✓ Flash illumination (VCSEL)
- ✓ Range 40m @ 10%r, 60klux



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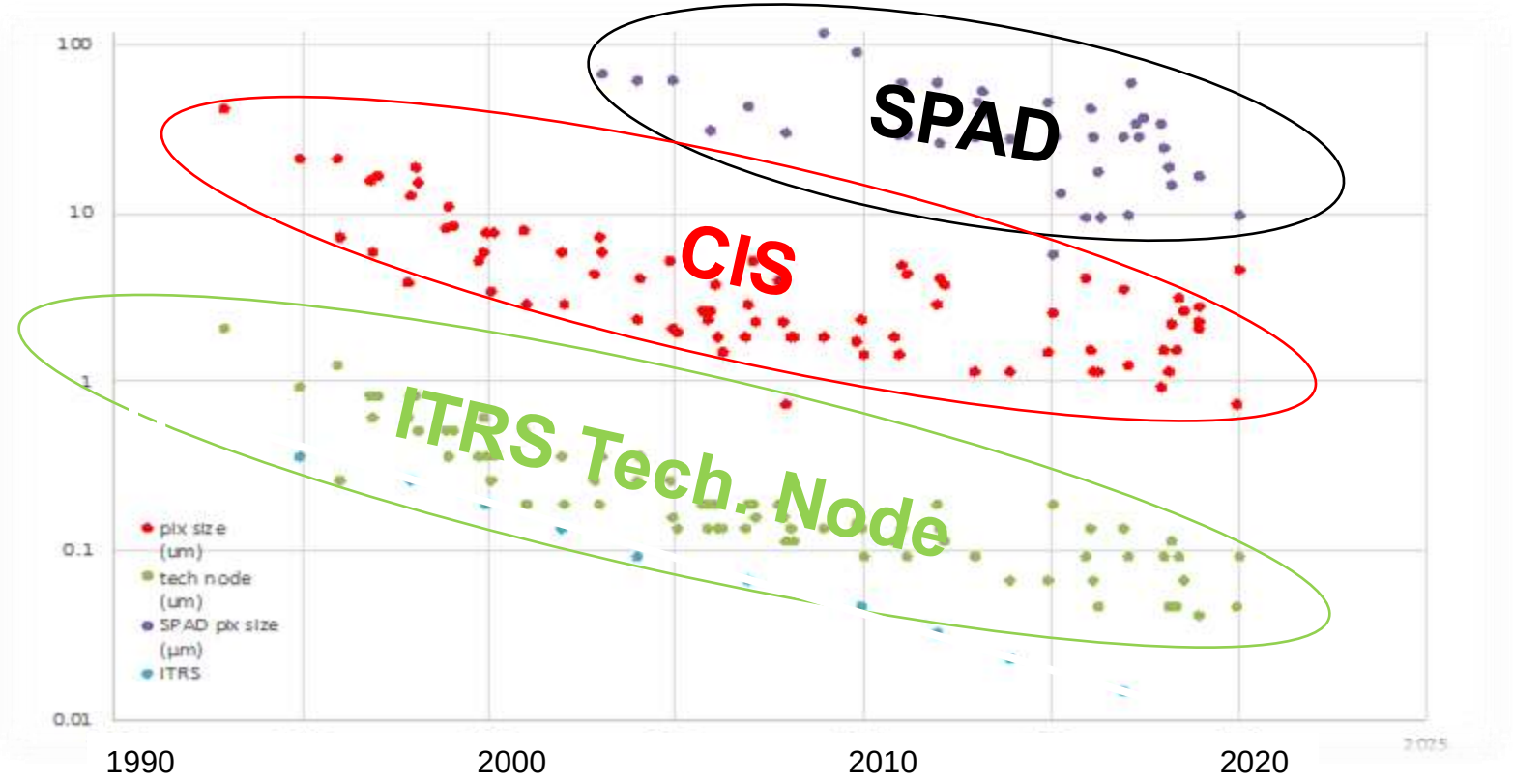
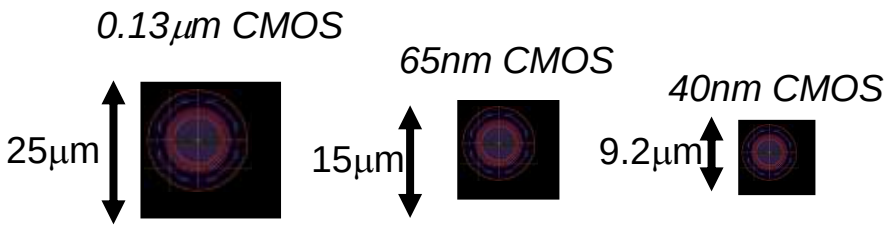
CMOS SPAD miniaturization trends





- Delays reasons
  - High voltage (older nodes support)
  - Guard rings
  - Lack of backside illumination process
  - Lower production volume
- Evolution
  - Low pitch
  - High fill factor
  - 3D-IC high performance

Source: Albert Theuwissen, Harald Homulle, Edoardo Charbon

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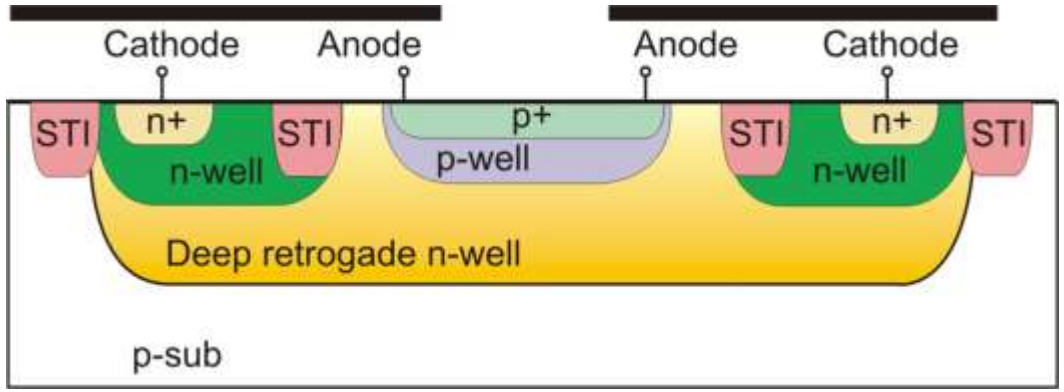
From monolithic to 3D stacked circuits

Monolithic implementations

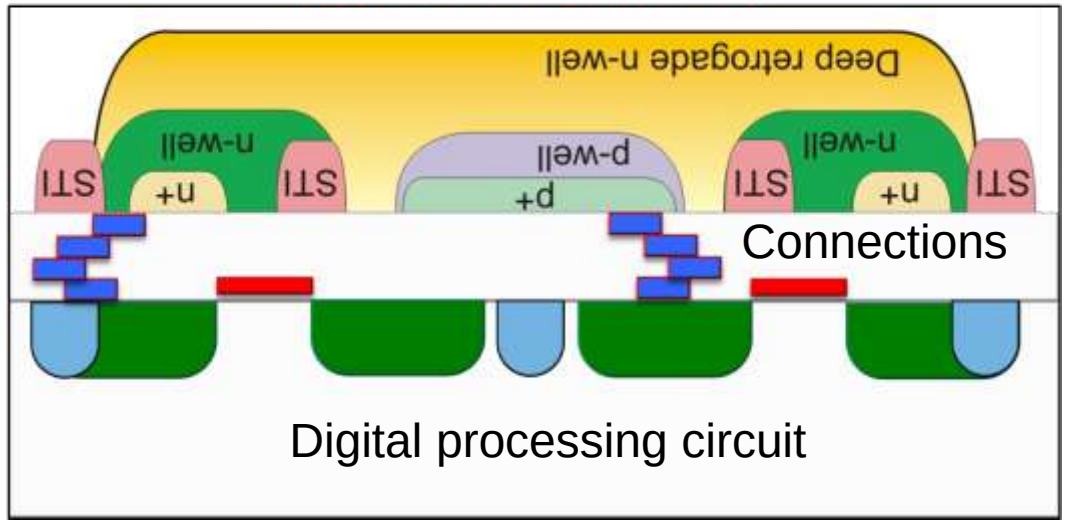


- ✓ Simple electronics
- ✓ Lower costs

Sources : David Stoppa, Richard Henderson (schamatics)

3D-stacking at wafer level

Back-side illumination (BSI)



- ✓ Fill factor increase → sensitivity improvement
- ✓ Smaller pitch → higher pixel count
- ✓ Optimized CMOS for electronics → performance

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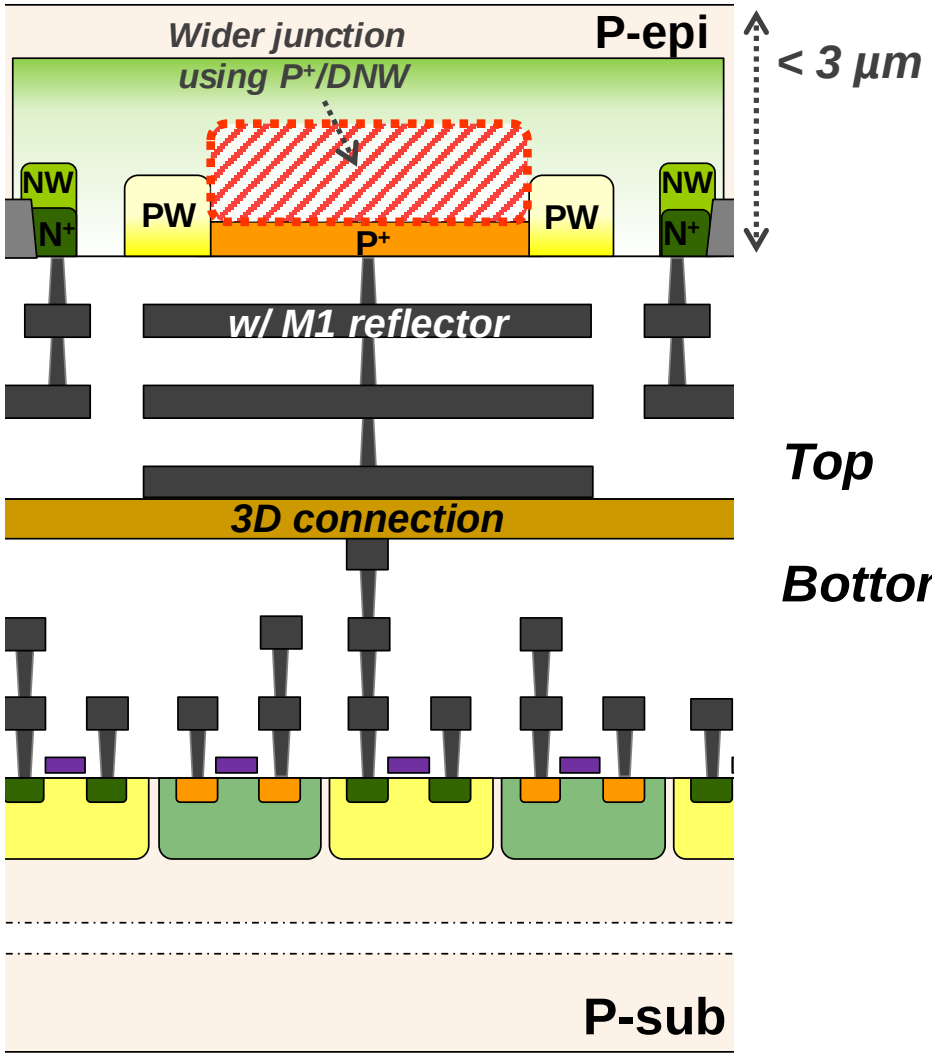
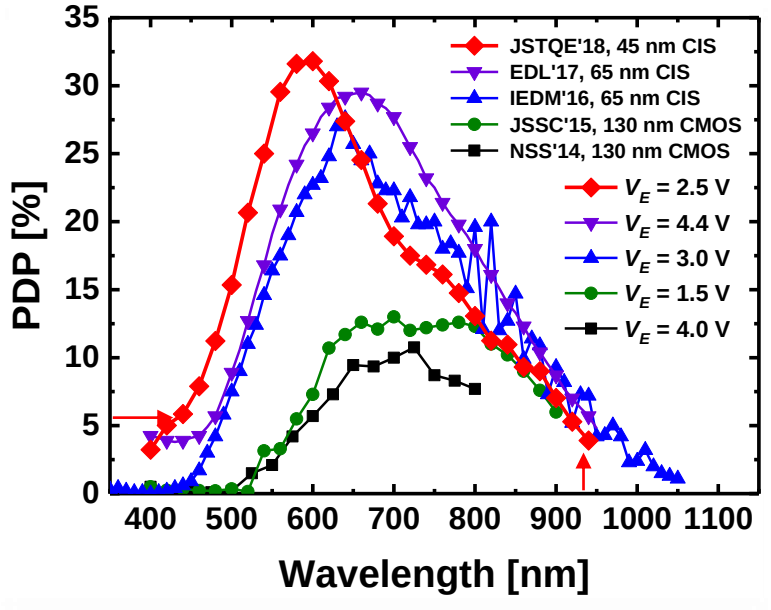
3D wafer-level stacking evolution



Top

Bottom

- SPADs (TSMC 65nm)
- TSV-less connections

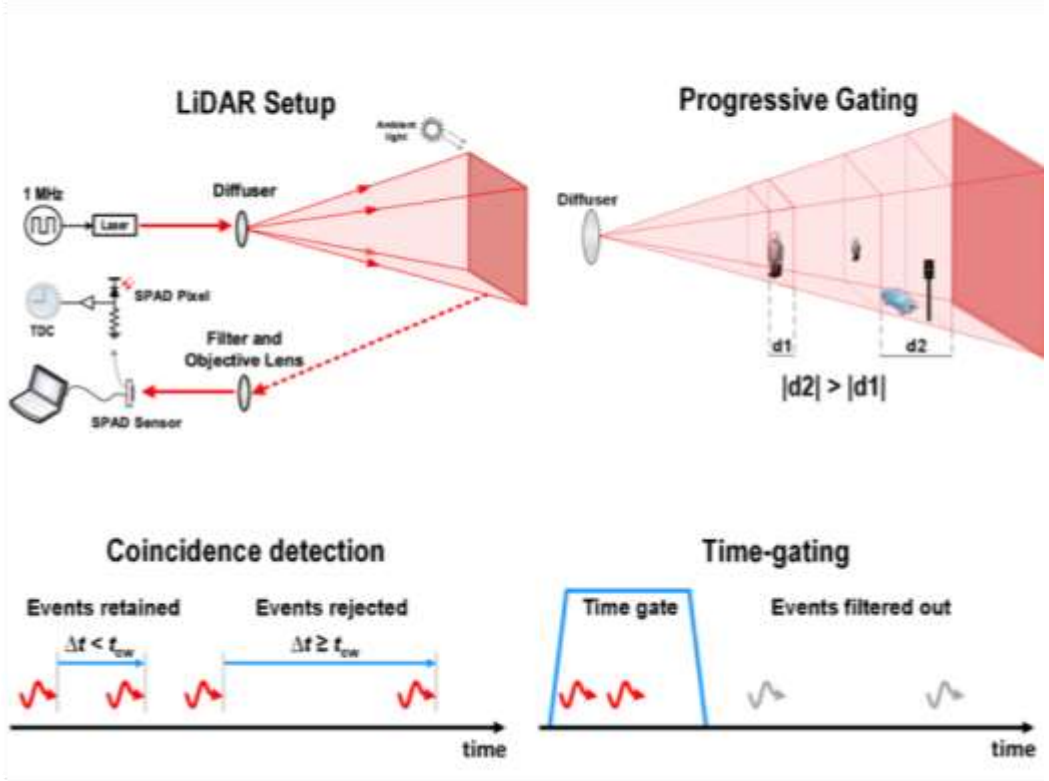


- Electronic circuits (TSMC 45nm)
  - Quenching & recharge
  - Masking, region of interest
  - TDC (low power coupled oscillators)
  - Digital processing, coincidence management

Sources : EPFL - A. Ximenes, P. Padmanabhan, ISSCC18, M.-J. Lee & Charbon, JSTQE18 + ., Jpn. J. Appl. Phys'18, P. Padmanabhan, ISSCC21

EPFL fastree 3D

3D-stacking performance improvement



- Coincidence detection
  - 8x16 clusters
  - 7-level t_{CW} 500ps-2.2ns
  - Sunlight rejection
- Adaptive gating
  - 6 progressive ranges
  - 1.3ms exposure
- Interference suppression
  - SNBR increase >31dB

Source : Padmanabhan et al. A 256 × 128 3D-Stacked (45nm) SPAD FLASH LiDAR with 7-Level Coincidence Detection and Progressive Gating for 100m Range and 10klux Background Light", IEEE ISSCC, 2021

EPFL

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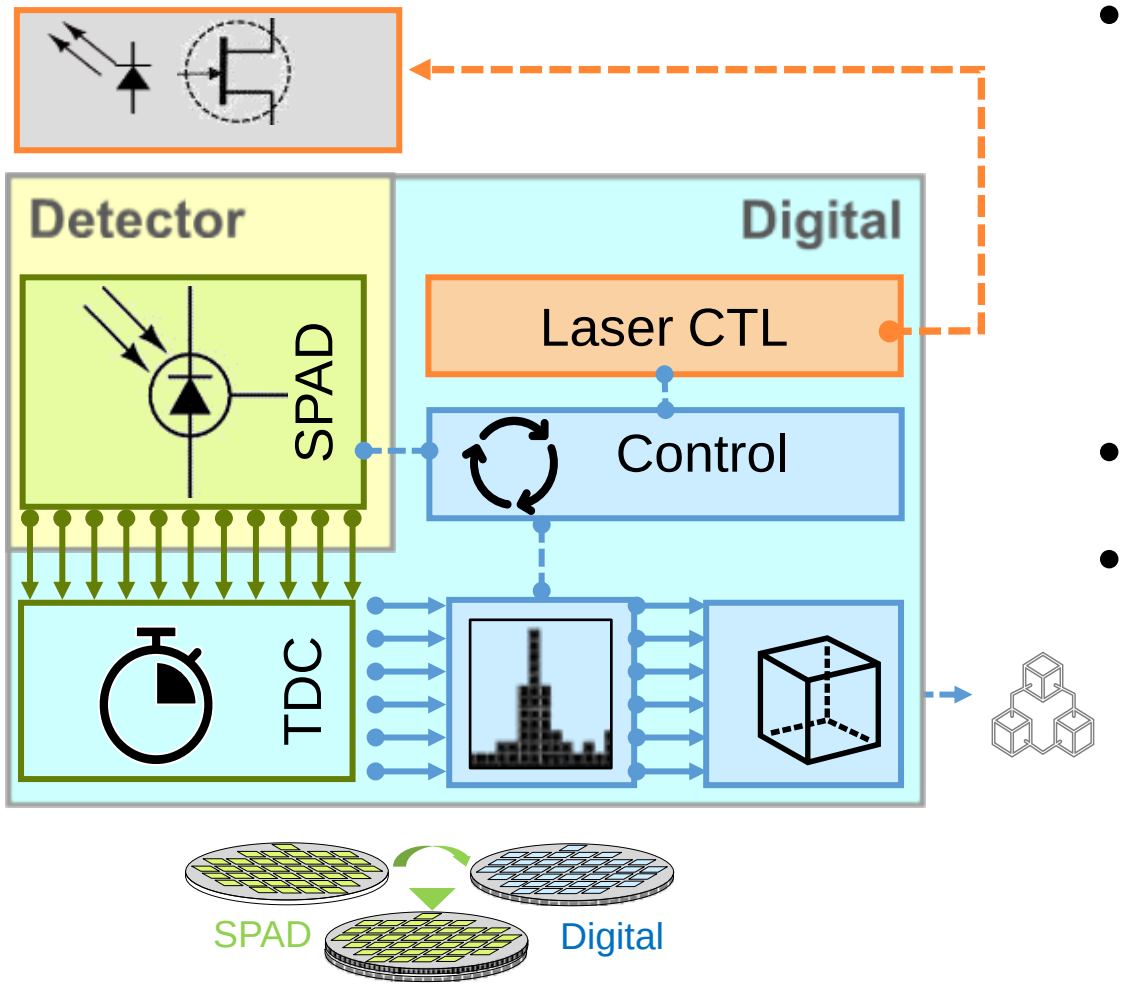
3D-IC software-defined implementation



- High-resolution detection
  - Lower pitch size <7µm
  - Detection efficiency, gain > 10^6
  - 256 x 64-256 x 4 SPADs
  - Global shutter
- Hybrid Cu-Cu wafer bonding
- Digital processing & control
  - Time-gating
  - Coincidence for sunlight suppression
  - ToF processing
  - Adaptive illumination and RoI
  - Lower cost / pixel

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Software-defined Flash LiDAR

Technology integration

① **Large** SPAD array

② **Sunlight** / interferences

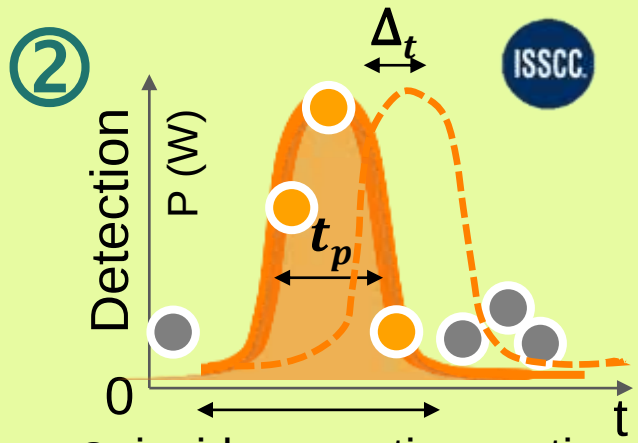
③ **TDC** resolution / power

④ **Digital 3D-IC**

⑤ **Laser** eye-safe power

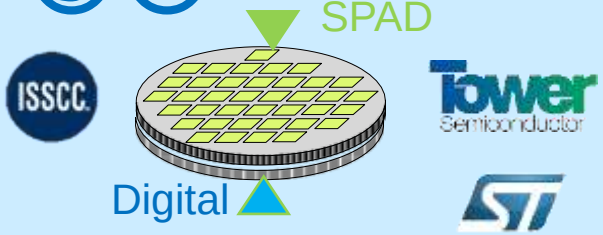
Real-time control

① **Resolution** scaling
1 Mpx 7 µm

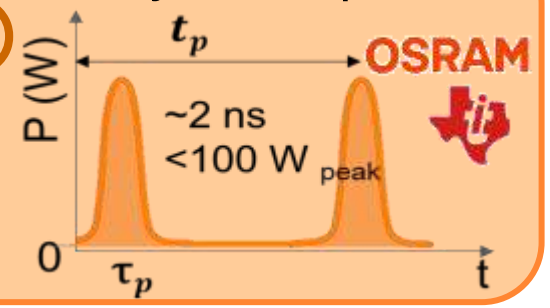
② 

Coincidence + time gating
Discrete time delay codes

③ ④ ToF read-out



Short eye-safe pulses

⑤ 

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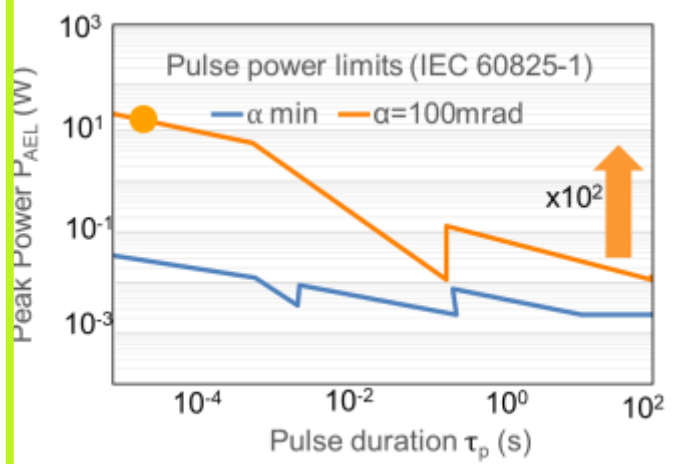
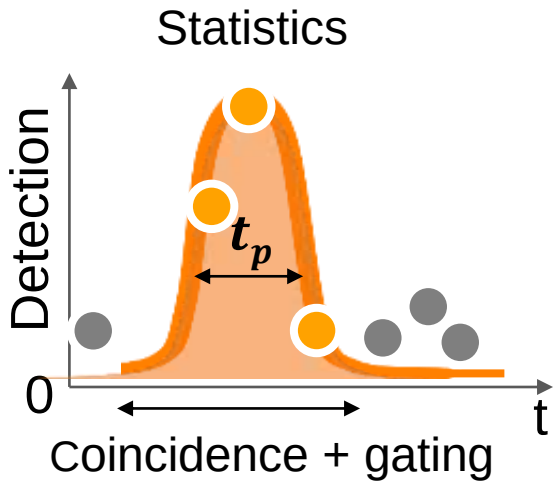
Software optimization in real time

Illumination to 50m



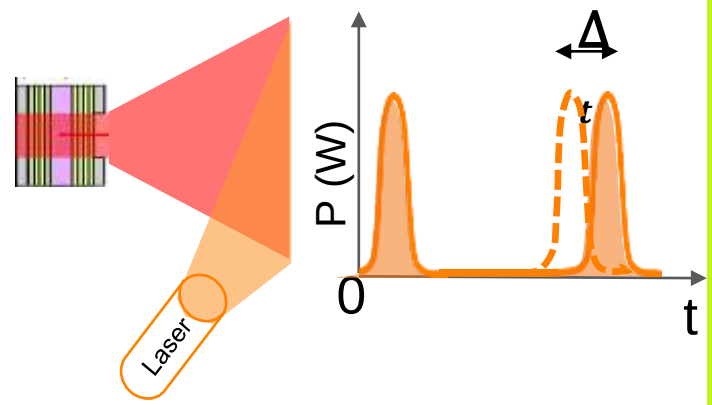
Eye-safe emission control

Sunlight removal



- Coincidence photon
- Noise photon (sunlight)

Interference removal



- Delay coding
- Decorrelation Tx/Rx
- SNBR > 35dB

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Software-defined Flash LiDAR value

Fast

Motion sensing for emergency collision avoidance

Lowest latency

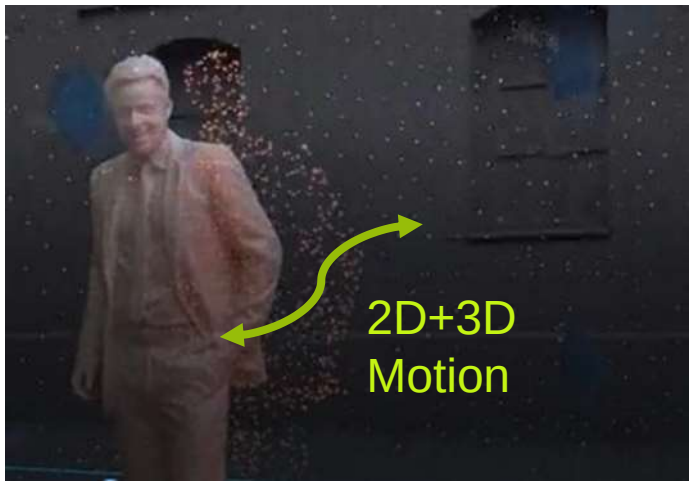
Safe

Low false detections under adverse lighting conditions

Quality control

Smart

3D + 2D actionable information for effective sensor fusion



Edge computing

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Thank you

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claude.florin@fastree3d.com

Automotive safety

Autonomous vehicles

fastree 3D