First Sensor

SILICON PHOTONIC SENSORS APPLICATIONS AND CHALLENGES

DR. MARC SCHILLGALIES

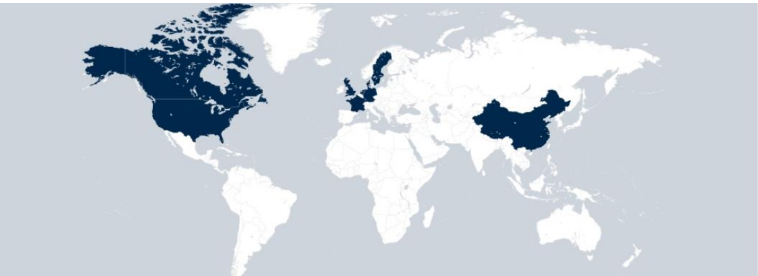
WORLD PHOTONICS TECHNOLOGY SUMMIT 2019

AUGUST 30, 2019

SILICON PHOTONIC SENSORS

Company Overview

First Sensor

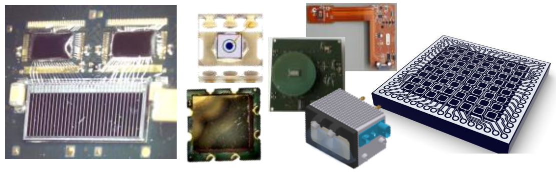
Short facts	Capabilities	Markets & Products
		
– Founded 1991 in Berlin, Germany – 970 employees – 155 Mio€ revenue 2018 – Stock-listed in Germany	– 7 clean room production sites: wafer fab and assembly facilities – Automotive, medical and aerospace certifications – Development and production of customized and standard sensors – Complete sensor value chain from die to system in one company	– 3 target markets: industry, automotive, medical – Sensor products for photonics, pressure, flow and inertial measurement – Cameras and integrated manufacturing services for imaging sensors

SILICON PHOTONIC SENSORS

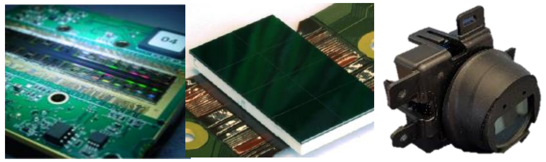
Product Overview

Photonics

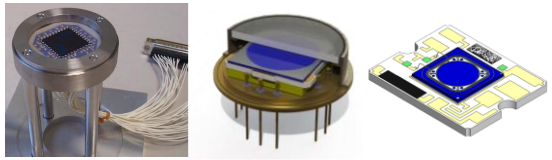
LiDAR



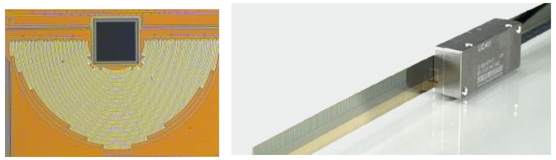
Digital Imaging



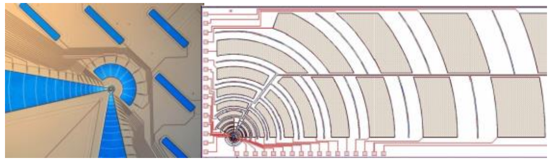
Aerospace Sensors



Position Sensor



Optical Analysis



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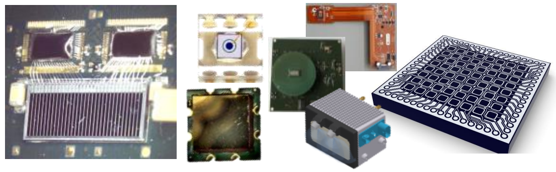

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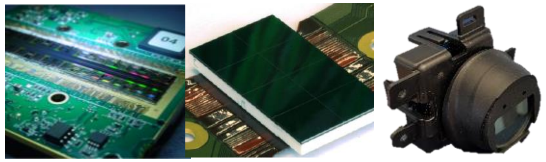
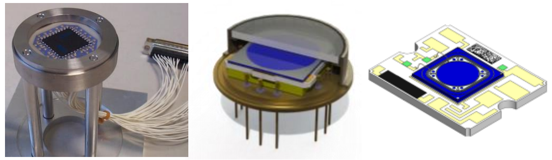


Aerospace Sensors



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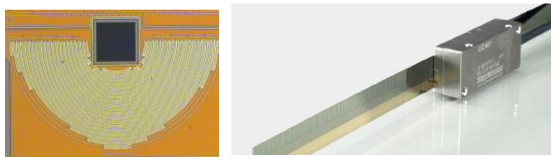

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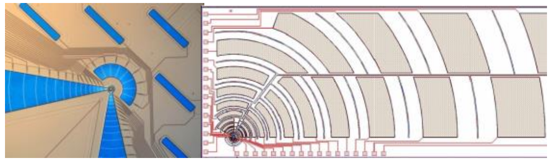
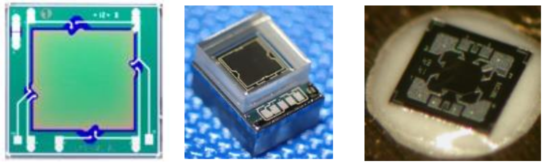


Pressure

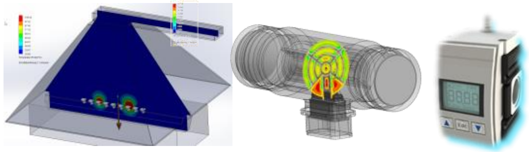
Pressure sensor element



Pressure compo-nent

Digital pressure sensor

Digital flow sensor



Actuators

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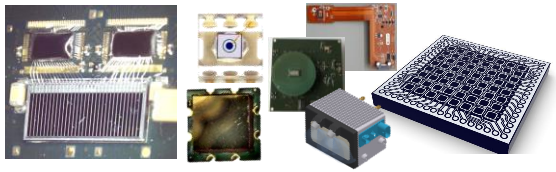

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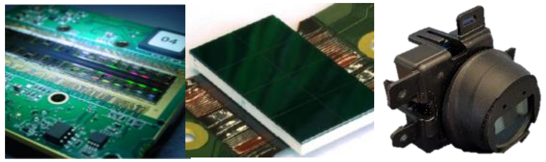
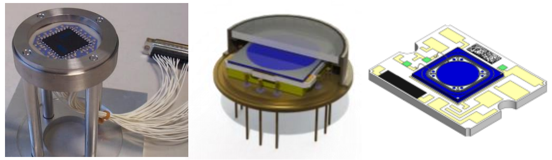


Aerospace Sensors



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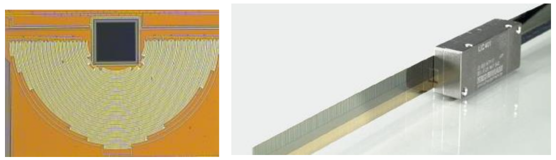

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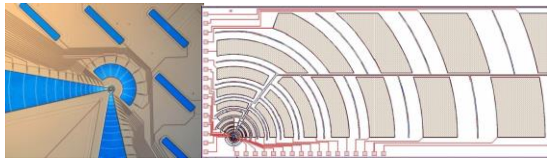

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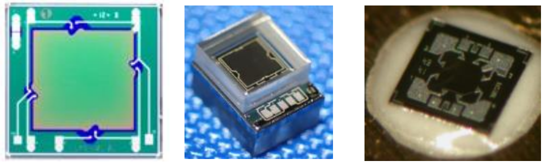

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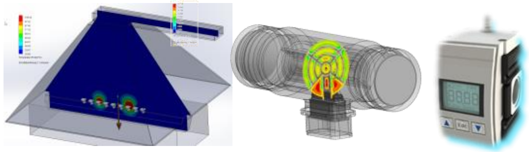
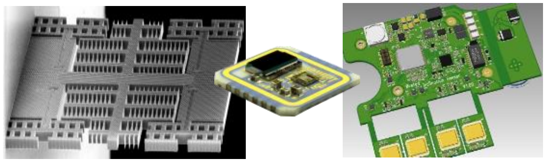


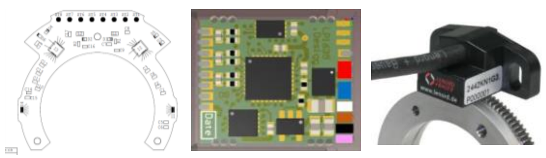
Actuators

Advanced Electronics

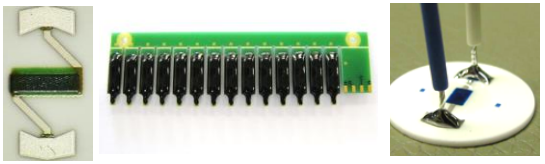
Inertial sensor solutions



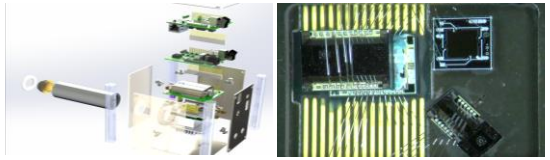
Magnetic sensor solutions



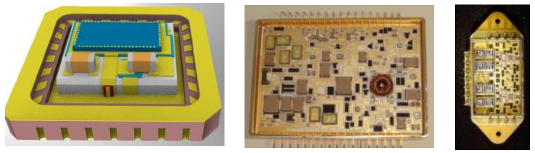
Temperat sensor solutions



Multi sensor systems



Solutions without sensor



SILICON PHOTONIC SENSORS

LiDAR Receivers: Technology and Applications

Technology

– Avalanche Photodiodes for 905nm in larger arrays with improved resolution, dark current, cross talk and yield

– Scalable automotive grade low cost package platform for receiver incl. ASIC

– Forward integrated receiver and sender solutions

First Sensor Value Proposition

– Automotive-grade, high volume APD and packaging technologies with best SNR

– Heritage/experience and customization along value chain

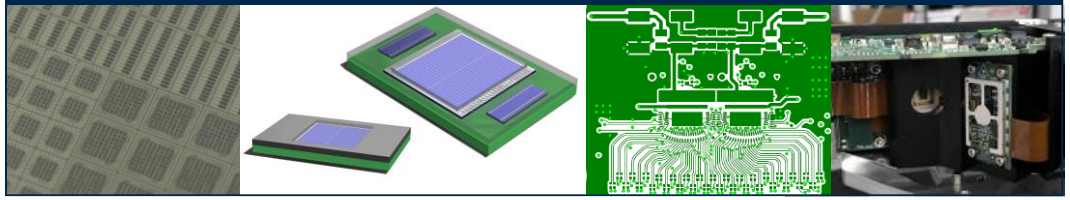
Applications

– Automation in manufacturing, logistics, traffic, security, maps

– Autonomous transport and delivery from drones to trucks

– Driver assistance/automation/MaaS up to level 5 cars

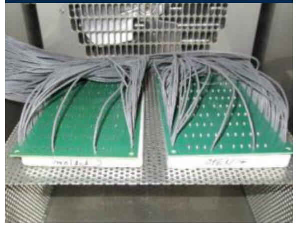
New chips, new packages, electronic designs and integrated systems



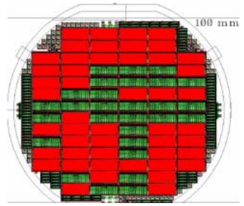
Initiatives

Tiger Team

Quality



Yield & Cost RM



Marketing

Ecosystem partnerships

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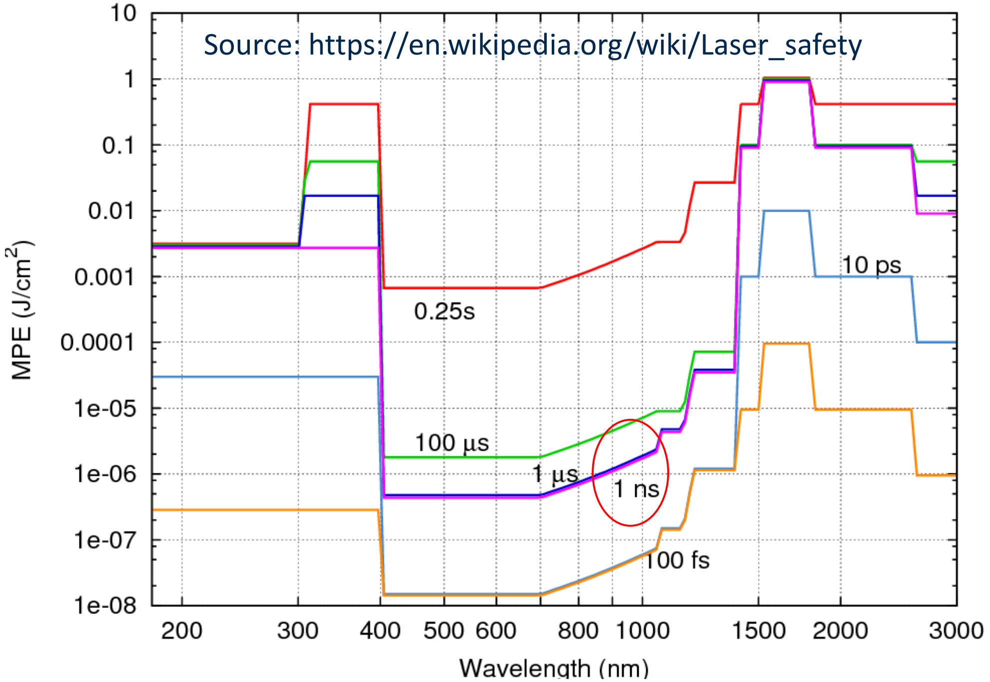
LiDAR Receivers Challenge 1: Bandwidth vs Sensitivity vs. Excess noise of APD

Maximum permissible exposure



- Maximum permissible exposure roughly doubles going from 905nm -> 980nm
- Resolution requirements need short pulses of 1ns...5ns, i.e. fast detector

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LiDAR Receivers Challenge 1: Bandwidth vs Sensitivity vs. Excess noise of APD

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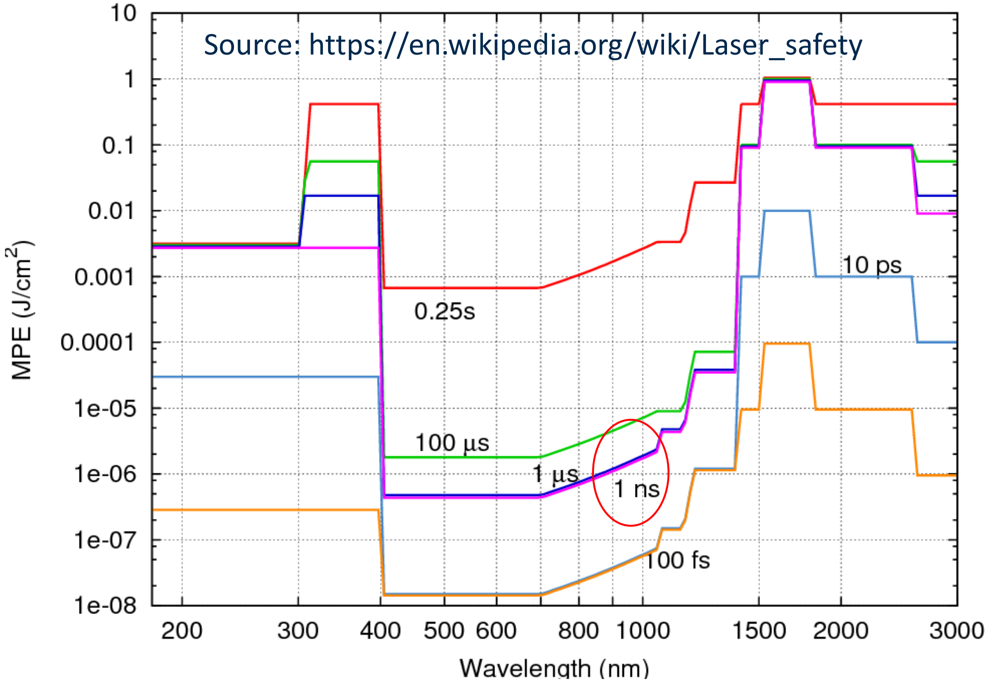
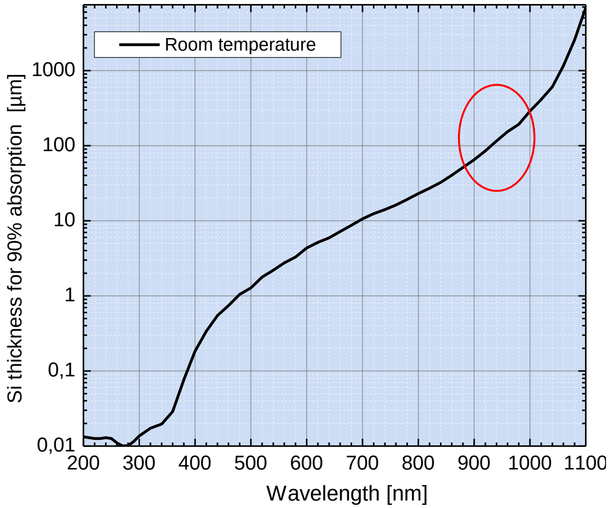
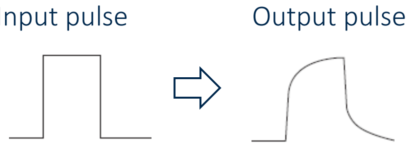
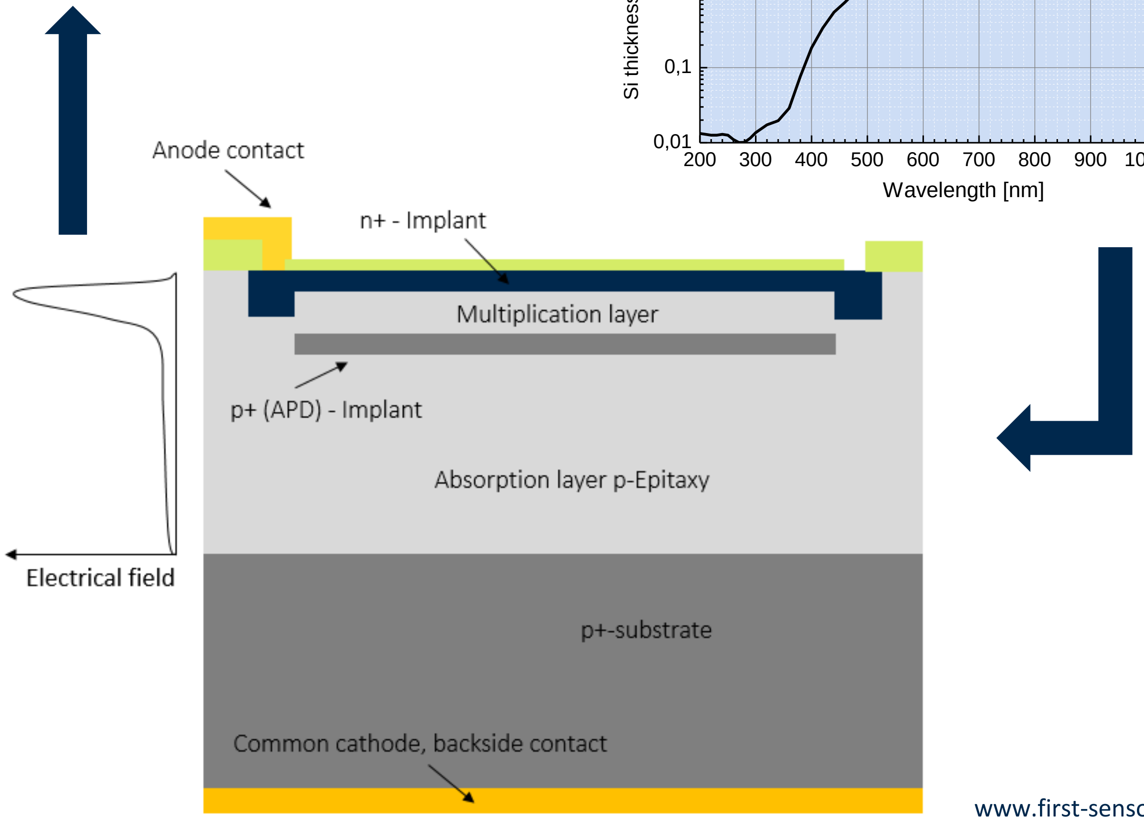


- Maximum permissible exposure roughly doubles going from 905nm -> 980nm
- Resolution requirements need short pulses of 1ns…5ns, i.e. fast detector (drift speed limits!)







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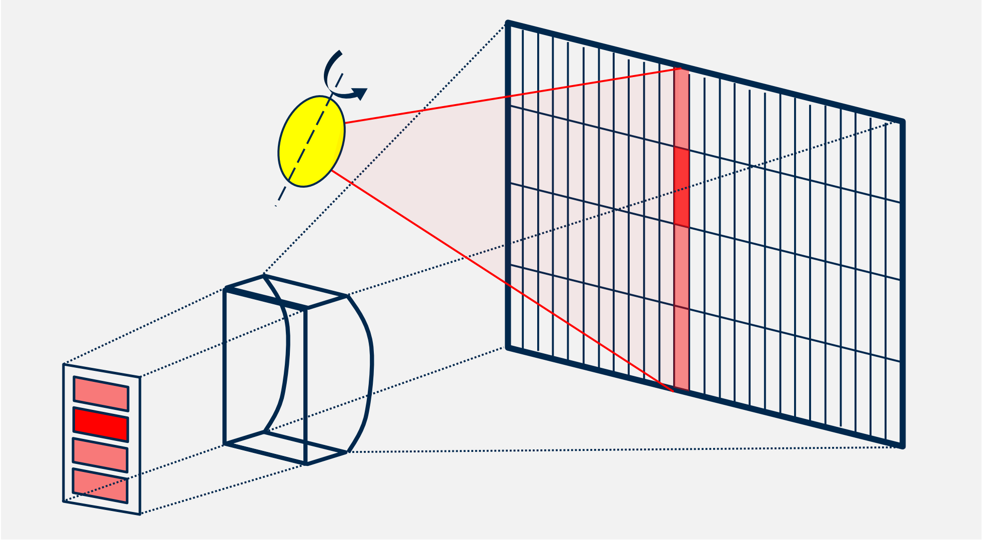
LiDAR Receivers Challenge 1: High resolution vs fill factor vs crosstalk

Common solid state LiDAR schematic for 1D MEMS



- Demand for high resolution LiDAR and optimal SNR in case of strong ambient light require higher pixel count
- This has two challenges:
  1) Properties of small pixels and small gaps
  2) Routing of signal traces vs fill factor

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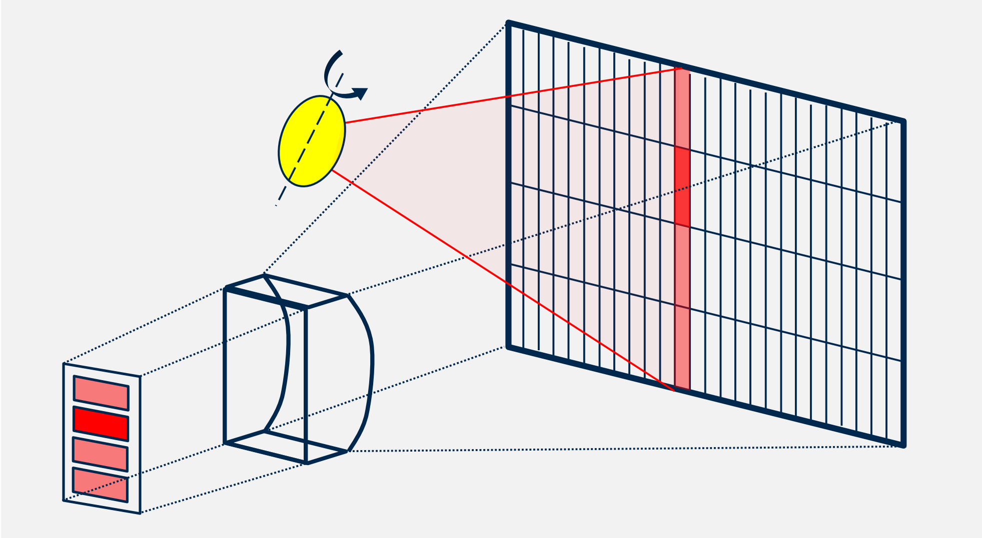
LiDAR Receivers Challenge 1: High resolution vs fill factor vs crosstalk

Common solid state LiDAR schematic for 1D MEMS



- Demand for high resolution LiDAR and optimal SNR in case of strong ambient light require higher pixel count
- This has two challenges:
  1) Properties of small pixels and small gaps
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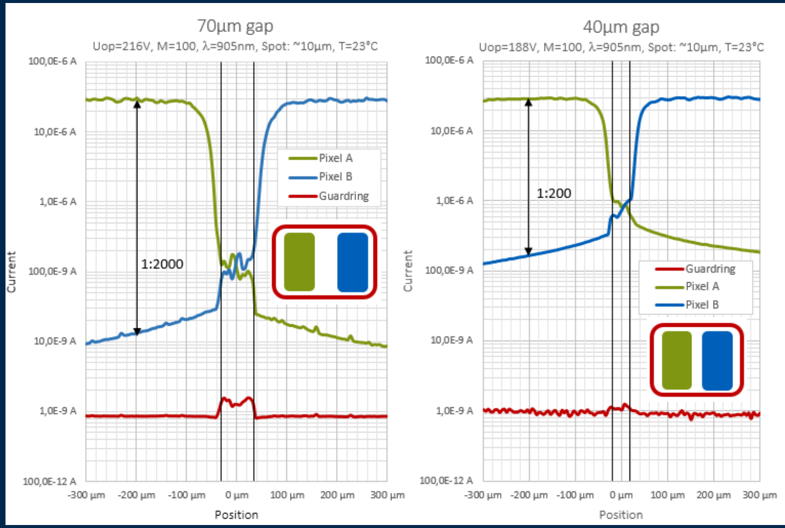
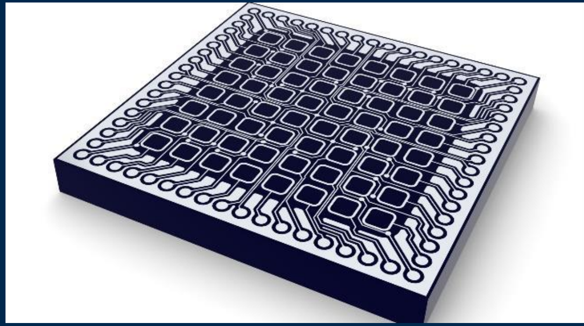
Pixel distances < Epi layer thickness

Proximity increases cross talk



Inner pixels need traces in gaps

More than 8 rows reduces fill factor significantly



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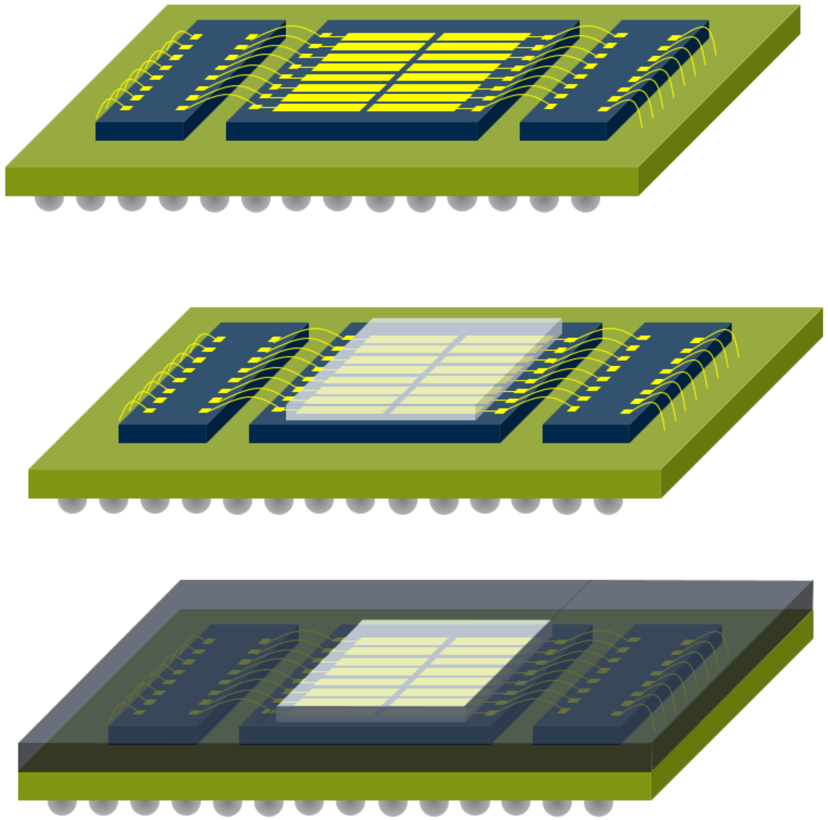
LiDAR Receivers Challenge 3: ~200V operation + non-hermetic packages + AEC-Q



- In many cases IR-optimized detector and readout IC are different technologies
- System in a package is well established in electronics, necessity for optical window reduces number of available or economically attractive technologies
- Example: film assisted molding of detector with glued glass and ROIC
- Proximity of ROIC requires thermal management

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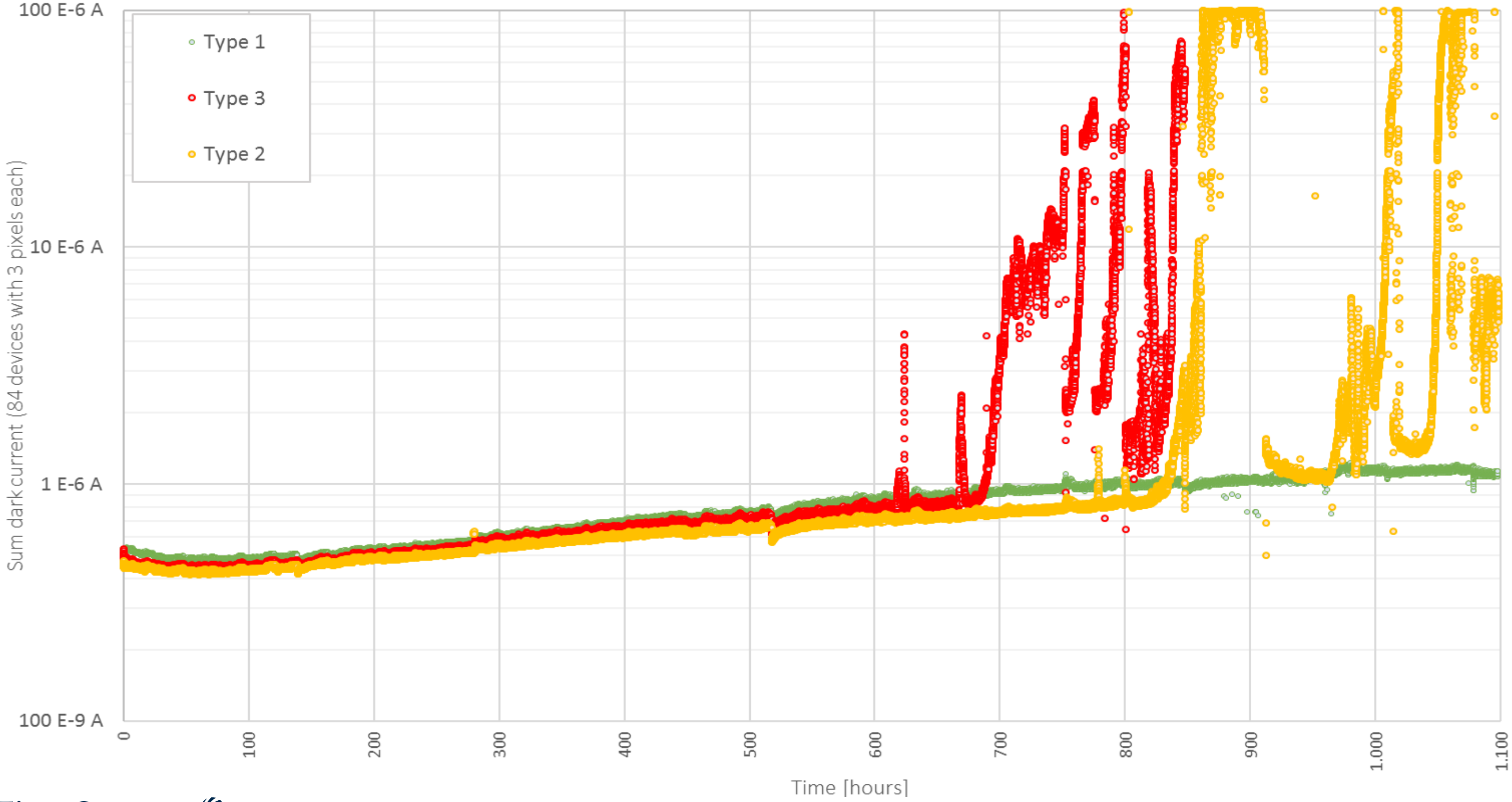
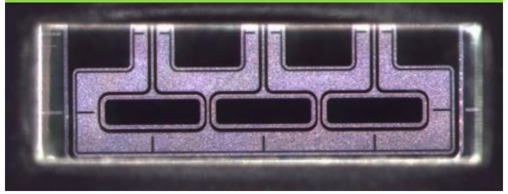
LiDAR Receivers Challenge 3: ~200V operation + non-hermetic packages + AEC-Q

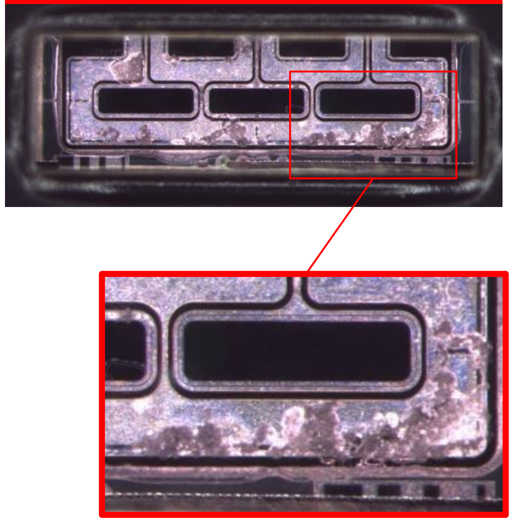
Influence of humidity: AEC-Q-Test H3TRB (Bias 100 V, 85 °C, 85 % r.h.)



Without corrosion



Corrosion causes leakage paths



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Imager assemblies: Technology and Applications

Technology

– PCB or ceramic substrate chip-on-board-technology (COB) in combination with surface mount technology (SMT) on panel

– Chip&wire; TSV/flip chip BGA high density interconnects

– Various direct optical interfaces (e.g. prisms, filters etc)

First Sensor Value Proposition

– Fulfilling extreme mechanical requirements even for largest dies (low warp/50µm flatness, 5µm position accuracy) with cost efficient COB techn., high density/small gap connects

– Being able to combine COB with optics, SMT, etc

– Clean-room (ISO 5-8) from dicing to final test

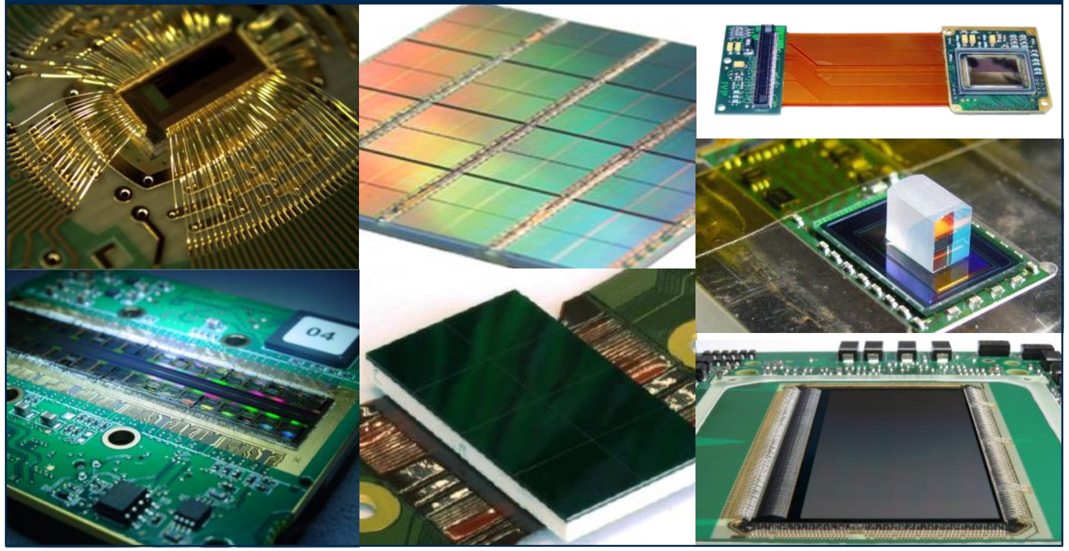
Applications

– Cameras for industrial process control, endoscope, automotive/ADAS/MaaS, aerospace

– Medical imaging (radiation detector arrays) for X-ray and PET

Dicing, die attach, chip&wire / flip chip/ SMT, optics aligment, singulation, test

Medical imager arrays, large imagers, endoscopes, TOF cameras



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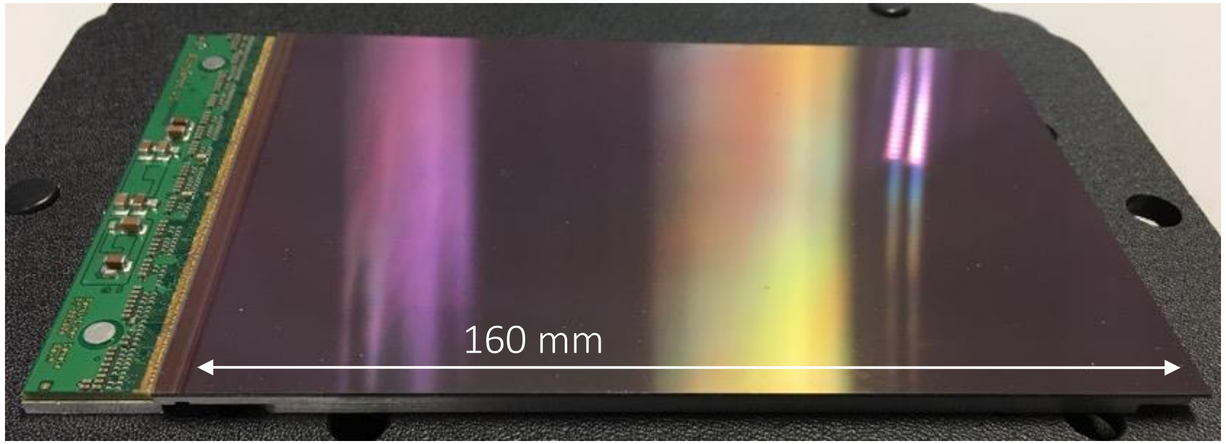
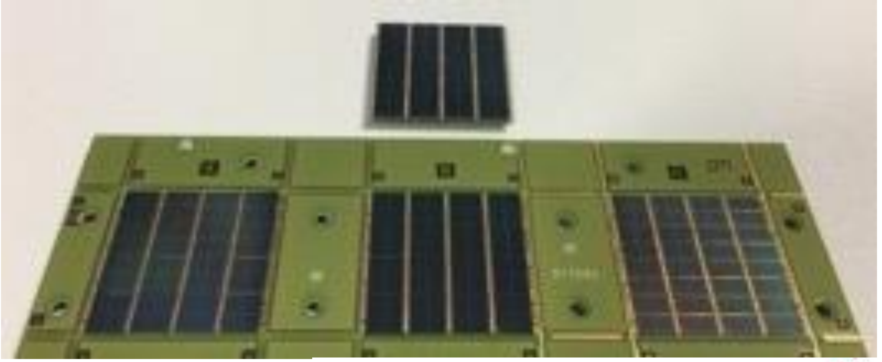
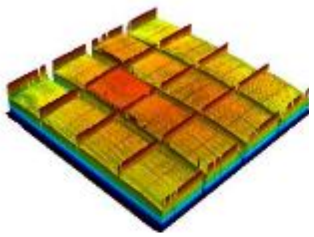
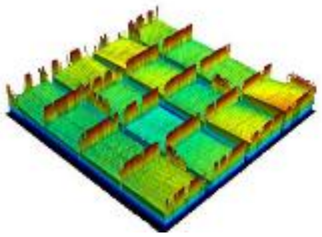
Imager assemblies: Challenges



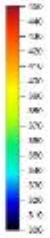


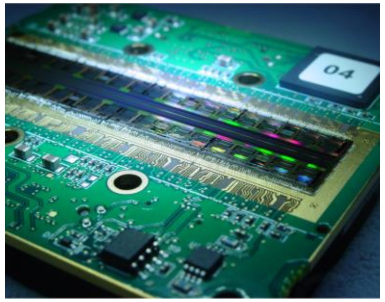


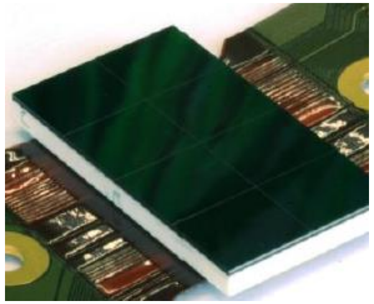
Soldered with SAC,
max bending 45µm



Soldered with SnBi,
max bending 45µm







Challenge

- Large imagers -> CTE-mismatch to substrate -> Warp, TC,...
- COB+SMT technology with passives and imager on same board -> meeting of different worlds w.r.t. particle contamination specs
- Tiled detectors (e.g. medical imaging) require exceptional position tolerance

Solution

- Design, materials, processes must go hand in hand

Aerospace sensors: Technology and Applications

Technology

- APDs and large quadrant photodiodes in n- and p-type high resistivity silicon for 1064nm; small pitch photodiode arrays
- Hermetic assemblies with high optical and mechanical precision, partially thermal control
- Space-grade large imager array assemblies

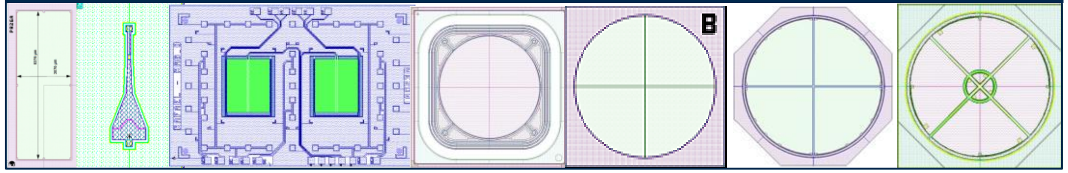
First Sensor Value Proposition

- Photodiodes with excellent performance for 1064nm
- Manufacturing in Germany + all aerospace certifications

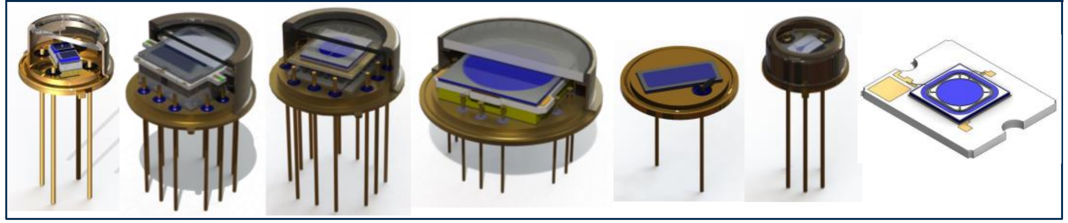
Applications

- Laser guidance and laser warners
- Proximity detectors and distance measurement, encoders
- Receiver assemblies for satellites/areal surveillance

Large area photodiodes for 1064nm



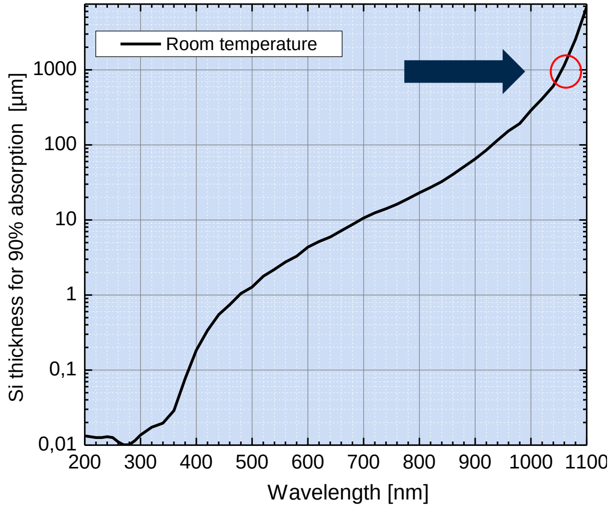
Optical assemblies



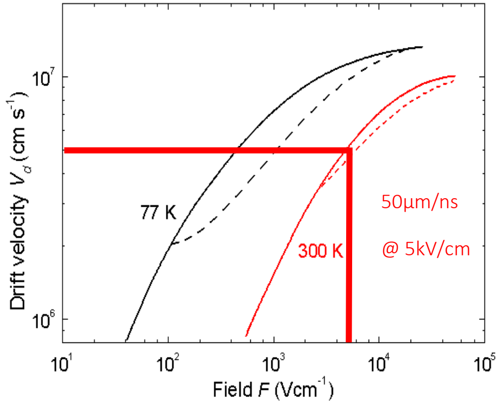
Opto-electronic assemblies

Aerospace sensors challenge 1: Silicon sensitivity

Challenge

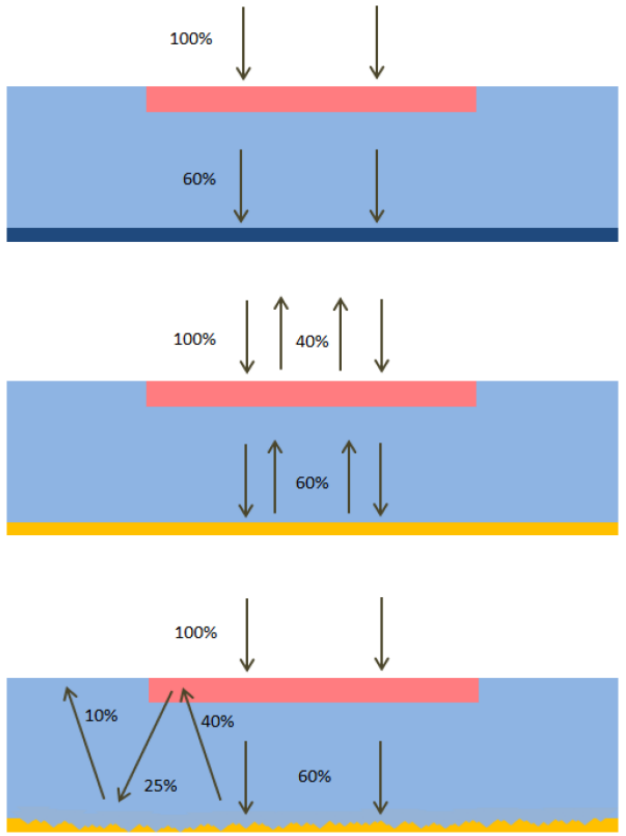


Source:
http://www.ioffe.ru/SVA/NSM/Semicond/Si/electric.html



- Many aerospace applications work with 1064nm (strong lasers, low CMOS sensitivity) and large detector areas
- 100% absorption would require ~1 mm thick absorption
- Typical pulse widths < 10ns demand for detector thickness < 400µm @200V (drift speed limits bandwidth)

Solution



400µm silicon

400µm silicon

Cat-eye detector

400µm silicon

Diffusor mirror

(requires tight process control on roughness)

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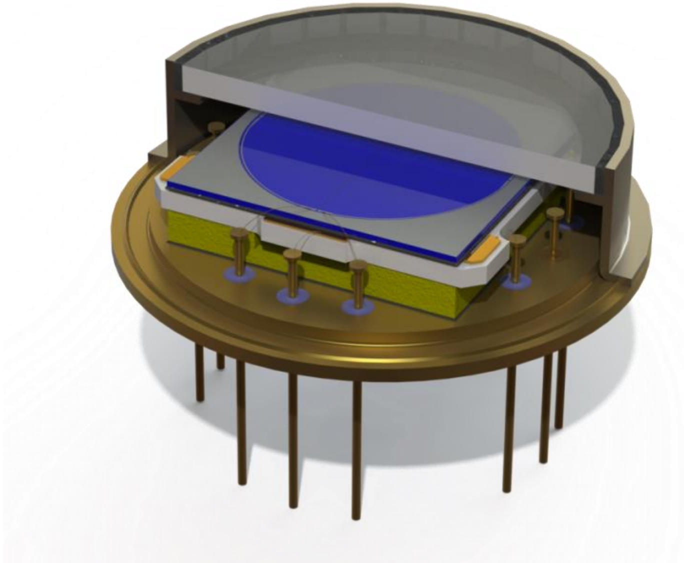
Aerospace sensors challenge 1: Large hermetic TO packages with glass window

Quadrant photodetector for laser guidance

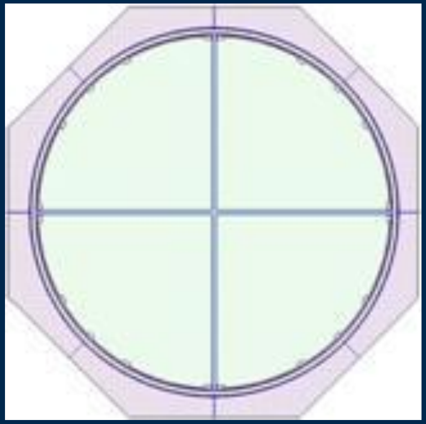


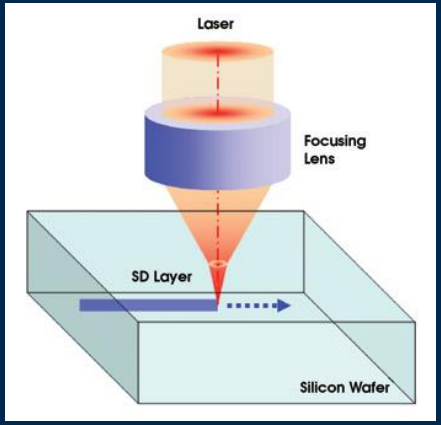
- Aerospace industry likes hermetic TO packages with large diameters

Maximum active area in round package

↓

Octagonal chips

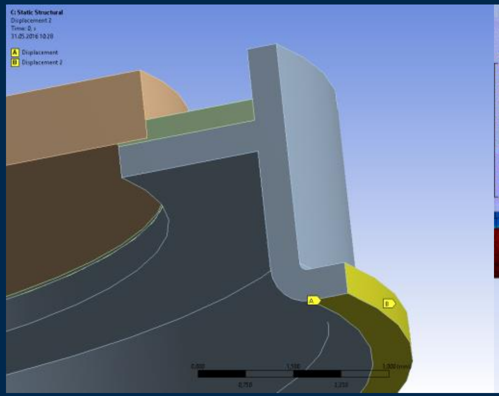


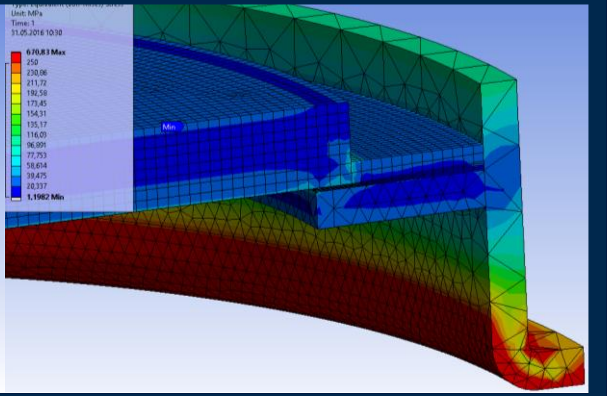


Large welded package

↓

Mechanical strain can lead to glass damages





SILICON PHOTONIC SENSORS

Polymer Photonics: Technology and Applications

Technology

– Automated and scalable assembly-technologies for components on „Polyboards“ using SMD equipment

➔ *Close to existing production equipment / processes*

First Sensor Value Proposition

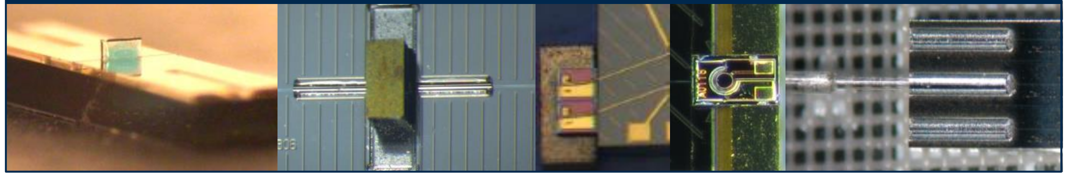
– Lower assembly costs than classical approaches due to self alignment and use of electronic assembly equipment

Applications

– First project Wavelength-tunable 10G WDM-Transceiver for Fiber connection/ backhaul to 5G network, fiber to home for

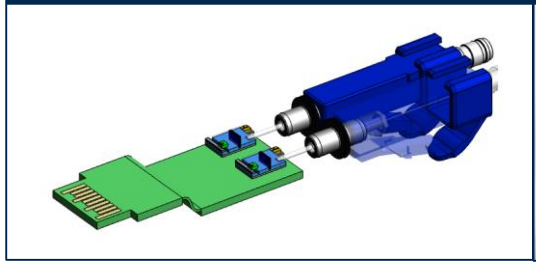
– Technology platform will be used for other cost-efficient fiber applications in datacon & sensors

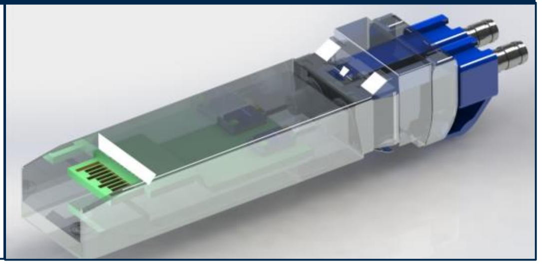
Optical elements



Polyboard

Fiber Transeiver





SILICON PHOTONIC SENSORS

Polymer Photonics Challenge 1: Integration of optical filters

Functional realization

Thin film filters made of complex layer systems in defined "thinness" (15 ... 20µm), which are inserted directly into the slots of the polymer board

Motivation

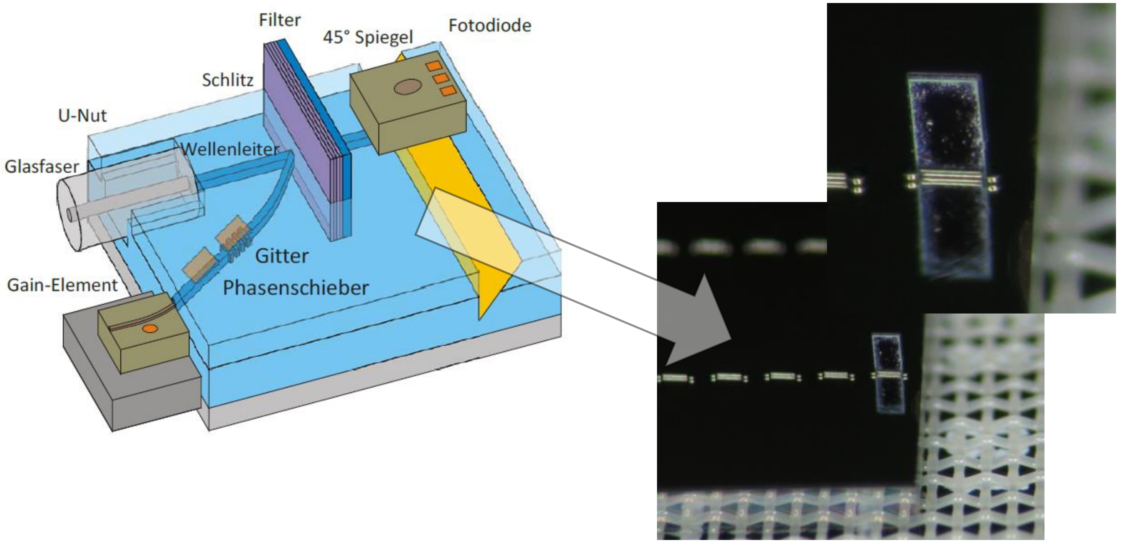
Integration of highly complex filter functions
Low coupling losses
Easy to process on **wafer and panel level**

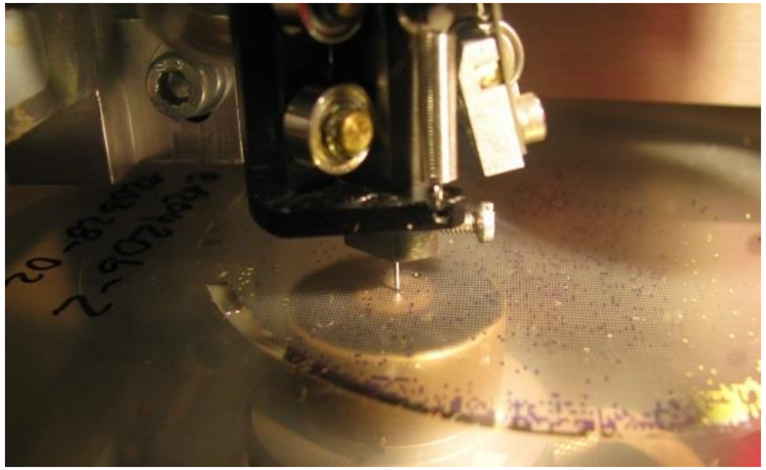
Challenge

How to realize the pickup from the wafer and the **90 ° rotation** of the filter?

Solution

Use of common pick & place equipment for bare dies with adapted **"pick&flip" process**



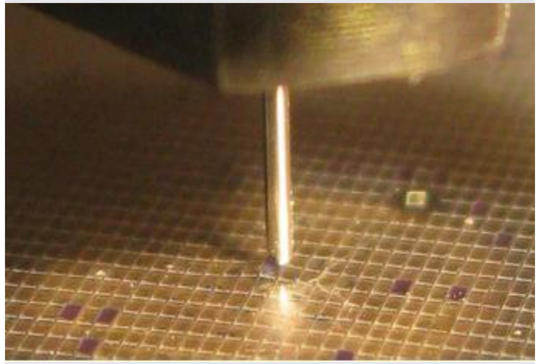


Automatic pick-and-place assembly of the filter elements

Polymer Photonics Challenge 1: Integration of optical filters

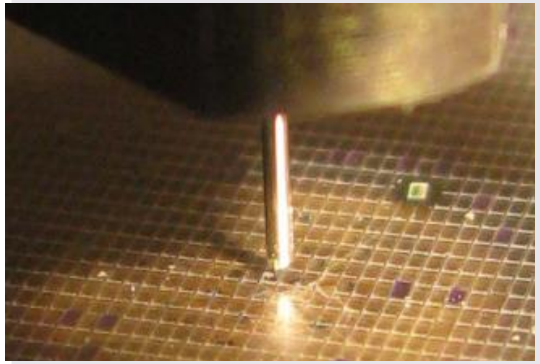
Step 1

Punching system ejects and tilt Thin-Film-Filter from tape



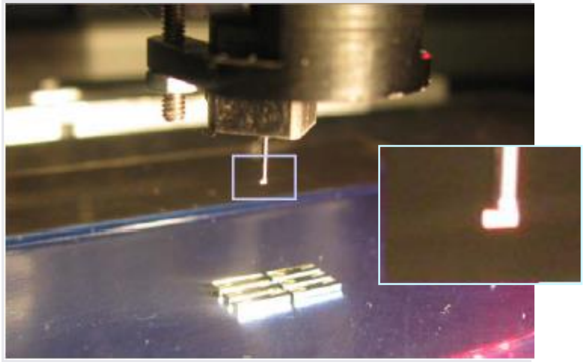
Step 2

Dedicated Pickup-Tool with lateral vaccum flow sucks in filter and flip it 90°



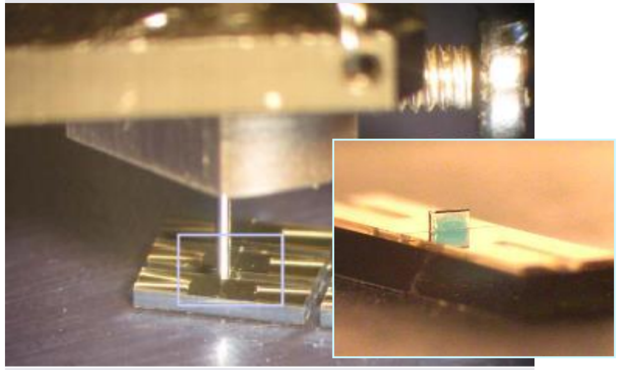
Step 3

Machine vision alignment of Filter and slot in Polyboard



Step 4

Pushing filter in slot, UV-gluing



Polymer Photonics Challenge 1: Integration of µ-optical elements

Functional realization

High-precision (<1µm) etched "U-grooves" in the poly boards for mating SM fibers or optical elements and adjust them to the waveguide of the poly-boards

Motivation

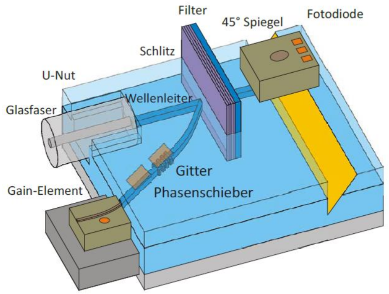
Integration of optical functions and connections
Low coupling losses due to "interference fit“
Passive adjustment of the elements possible
Easy to process on **wafer and panel level**

Challenge

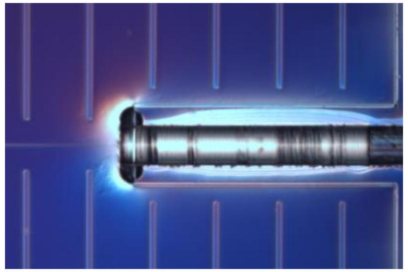
Are machines with high process speed usable?

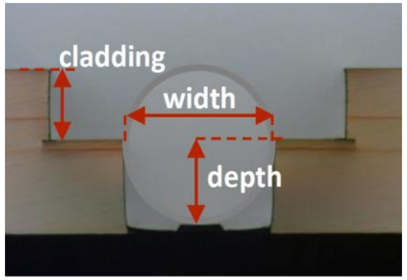
Solution

Use of pick & place machines for MEMS Assembling

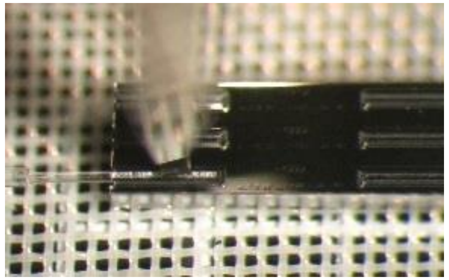



Polyboard with U-grooves


Fiber in U-groove



U-groove in cross section



Panellevel Assembling of fiberends

SILICON PHOTONIC SENSORS

Challenges

LiDAR

- SiGe APD-Arrays
- Flip-chip-APD-Arrays
- Materials für automotive packaging of high voltage devices

Digital Imaging

- Low warp assemblies with large Chips
- Particle contamination in COB+SMT
- High position accuracy

Aerospace Sensors

- 1064nm sensitivity + bandwidth of large area Si detector
- Large hermetic TO packages

Polyphotonic Tranceiver Boards

- Using standard high speed electronic assembly equipment for photonic circuits

THANK YOU.

Dr. Marc Schillgalies
First Sensor AG
www.first-sensor.com

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