Photonic Integrated Circuits for LiDAR: Enabling 4D Machine Vision with PICs

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June 2024 – Zurich

OUTLINE

- Company introduction
- Introduction to FMCW ranging
- Introduction to FMCW focal plane arrays
- Challenges associated with large scale, high density PICs
- Latest results and development directions

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COMPANY

Fabless PIC/IC company developing coherent 4D imaging solutions using a Silicon Photonics platform

- Fabless photonic integrated circuits company
- Develops LiDAR based 4D imaging technology using Silicon Photonics
- Operations in US and Europe, experienced engineering team, significant IP portfolio
- Fabrication using large scale commercial processes from top tier manufacturing partners

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COMPANY - KEY MILESTONES

From basic principles to technology proof of concept and further, to large scale commercial chipsets

Q1/2017
- Pointcloud Inc incorporation

Q2/2020
- 16x16 monostatic & 32x16 bistatic array –pointcloud demo

Q1/2021
- Bistatic architecture results published*

Q1/2022
- Pointcloud GmbH incorporation

Q3/2024
- Engineering samples: QVGA class & 192x64 pixels array, short & mid range

Q1/2026
- Engineering samples: QVGA/HVGA class array, short, mid & long range

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Source: Pointcloud

*Rogers et al., A universal 3D imaging sensor using a silicon photonics platform, Nature, Feb. 2021

Coherent ranging combined with scalability of array technology: performance, simplicity, versatility

Performance

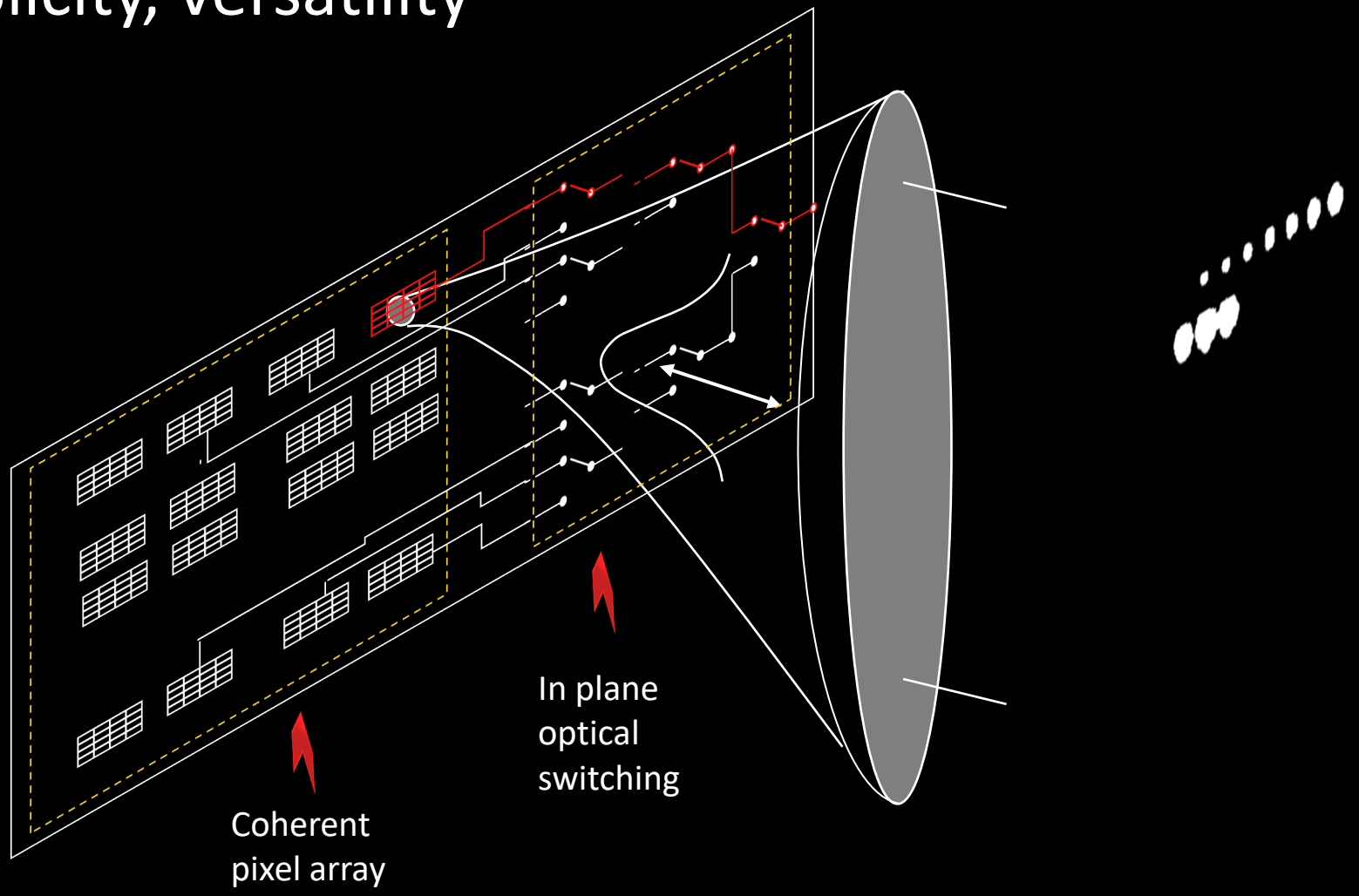
no compromise 4D imaging:
resolution, range, accuracy,
velocity measurement

Simplicity

one chip, one lens
no complex alignment
silicon CMOS manufacturing

Versatility

from mobile consumer to
industrial and automotive



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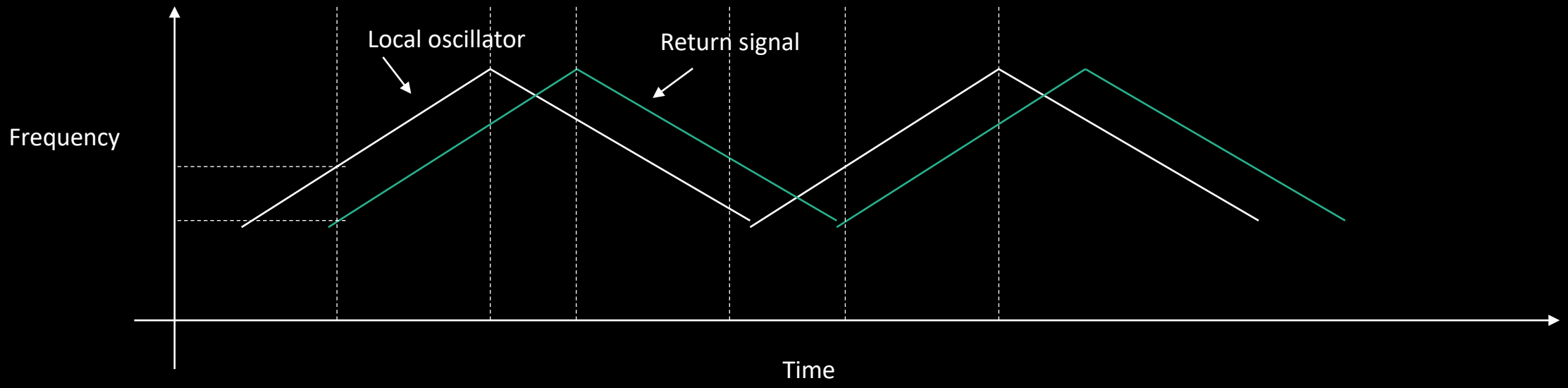
FMCW

Frequency modulated continuous wave ranging: measurement of the difference in frequency between a probe and local oscillator



- Transmitter emitting a frequency modulated optical probe signal
- Return signal combined with local oscillator generates a beatnote at the frequency difference
- Beatnote frequency is proportional to distance to target

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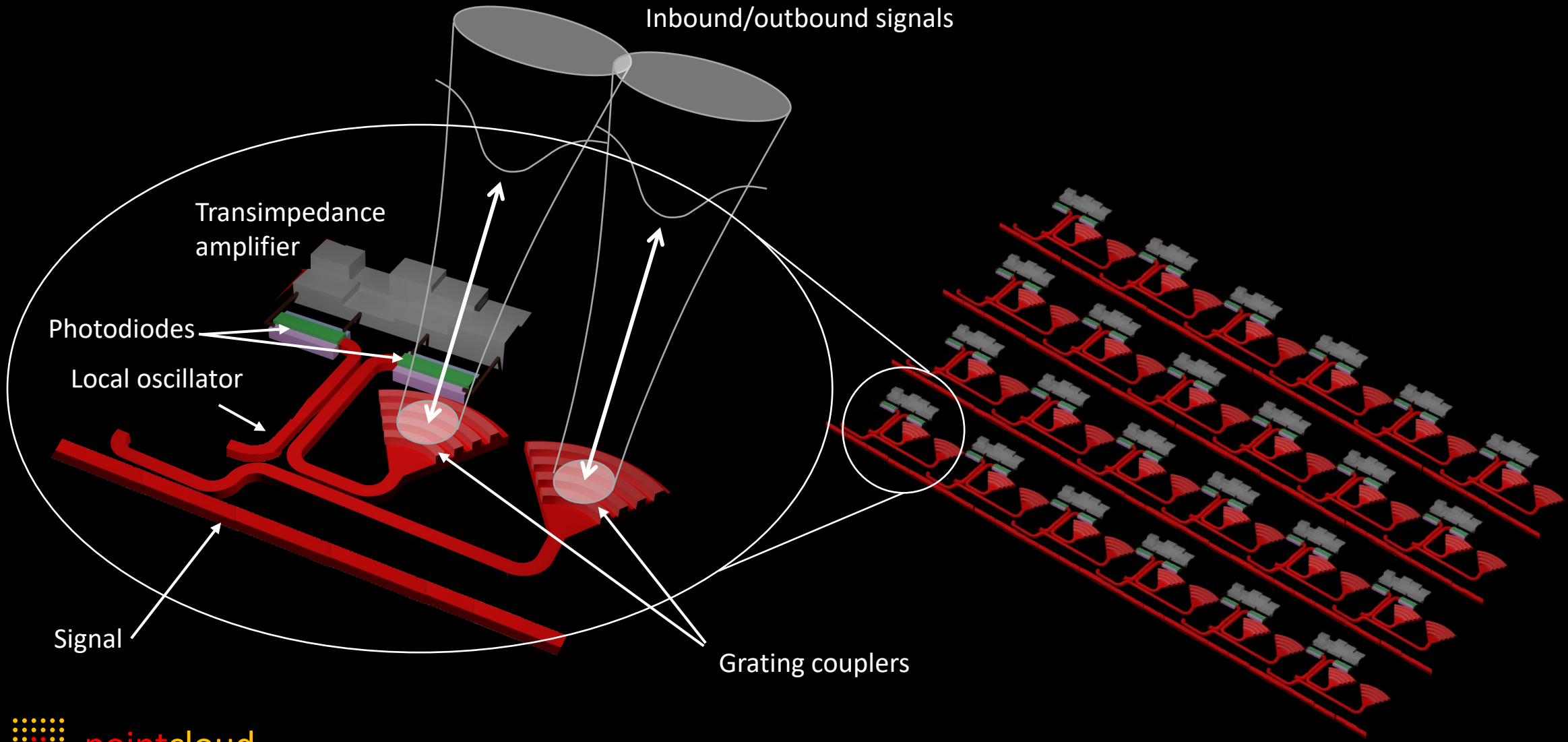
MONOSTATIC IMPLEMENTATION

Coherent detection pixel



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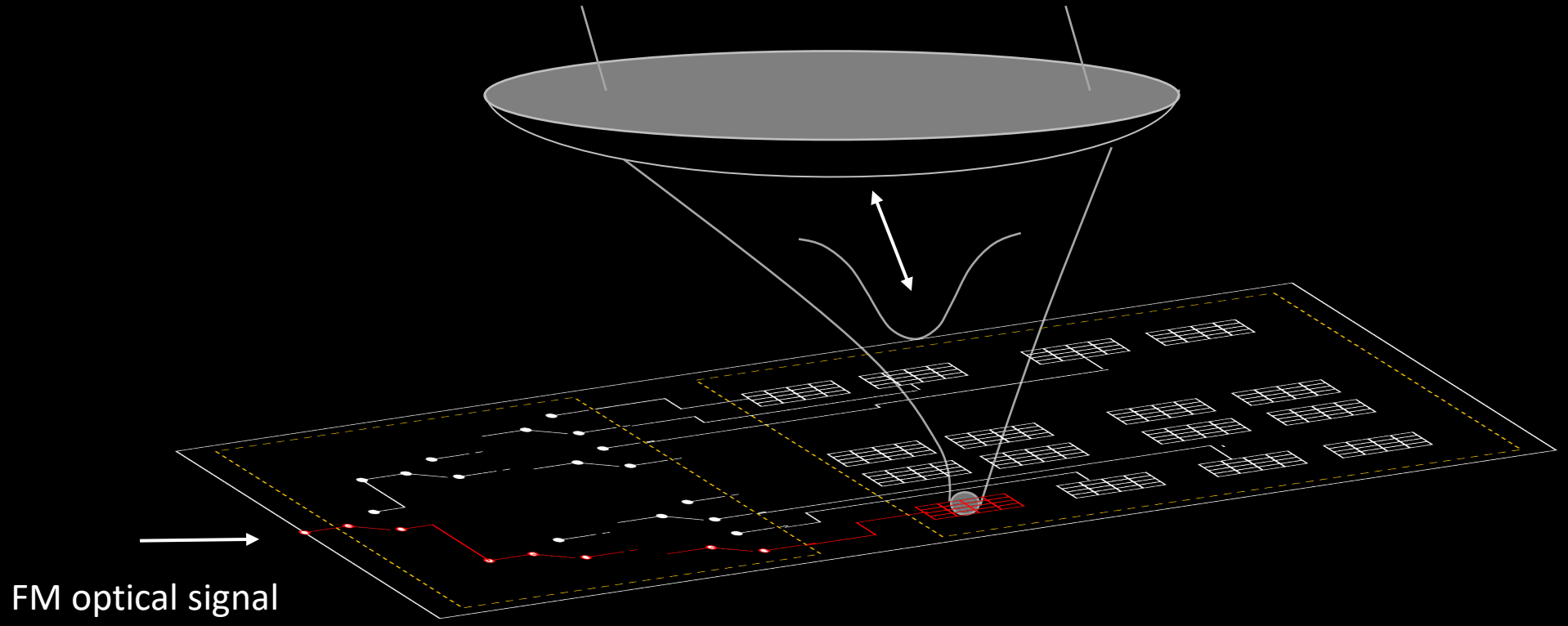
MONOSTATIC IMPLEMENTATION

Focal plane array of coherent Tx/Rx pixels



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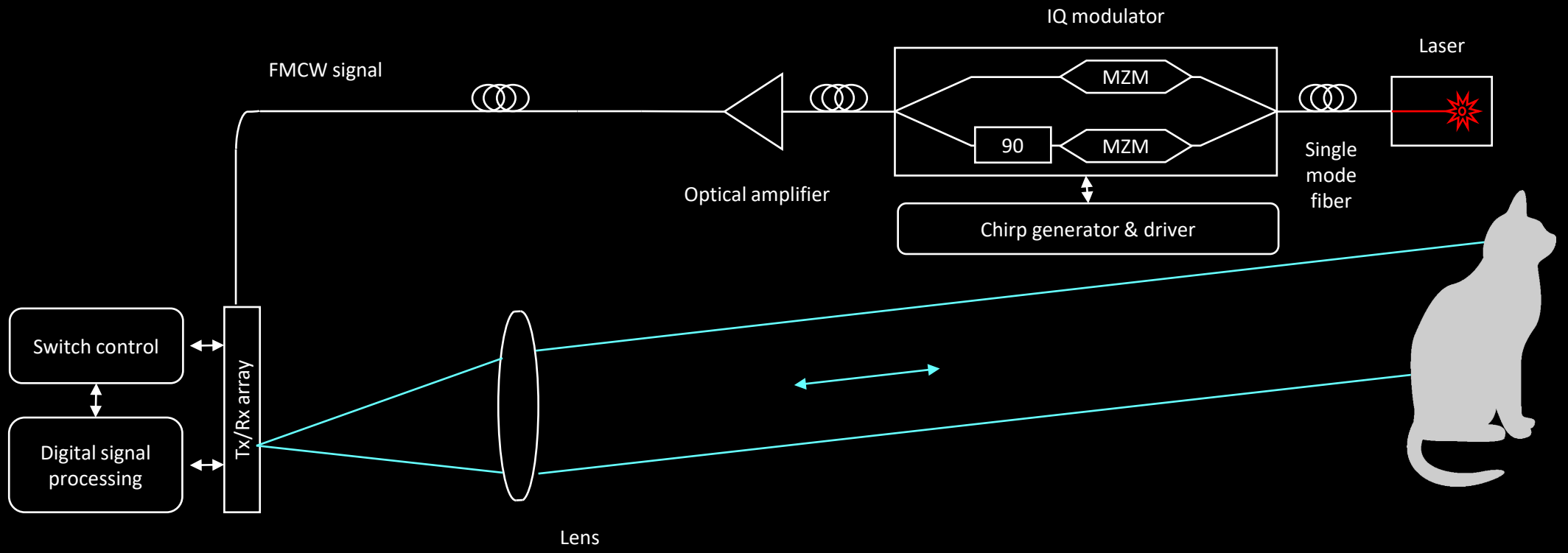
MONOSTATIC IMPLEMENTATION

System level diagram



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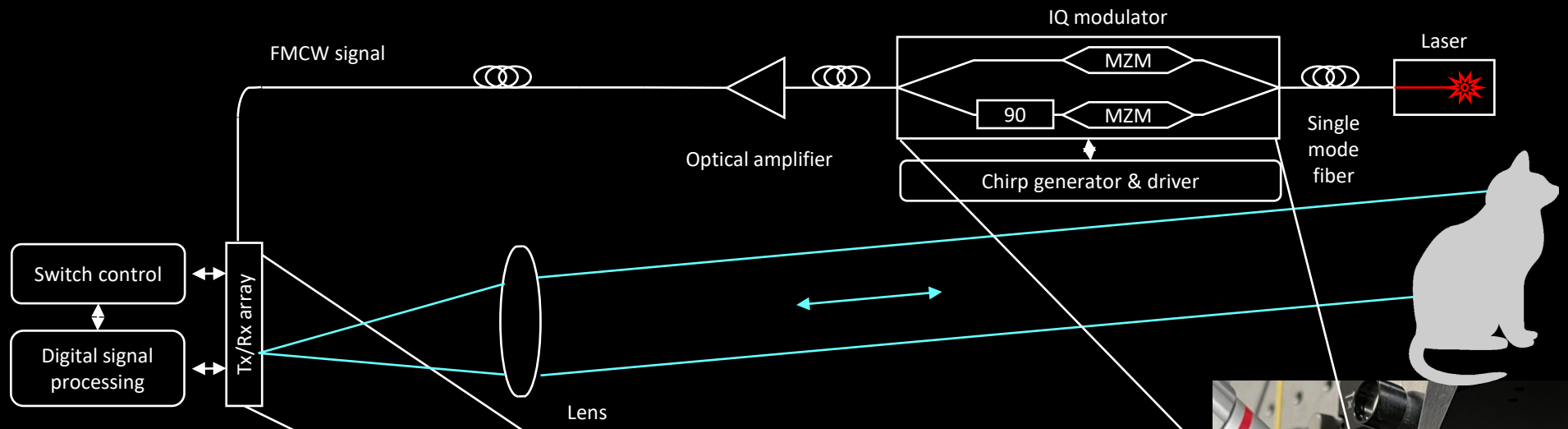
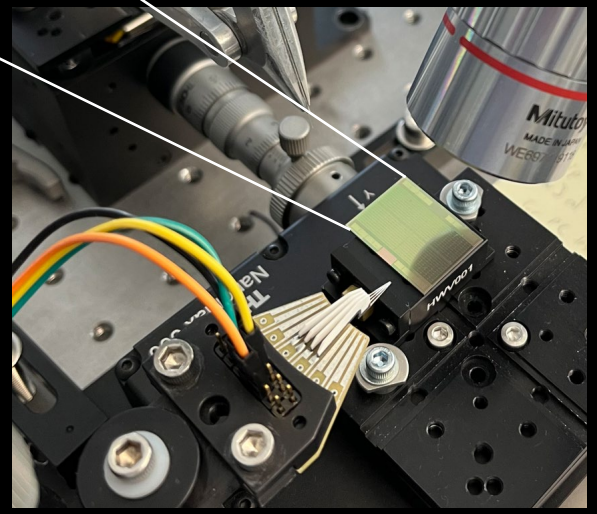
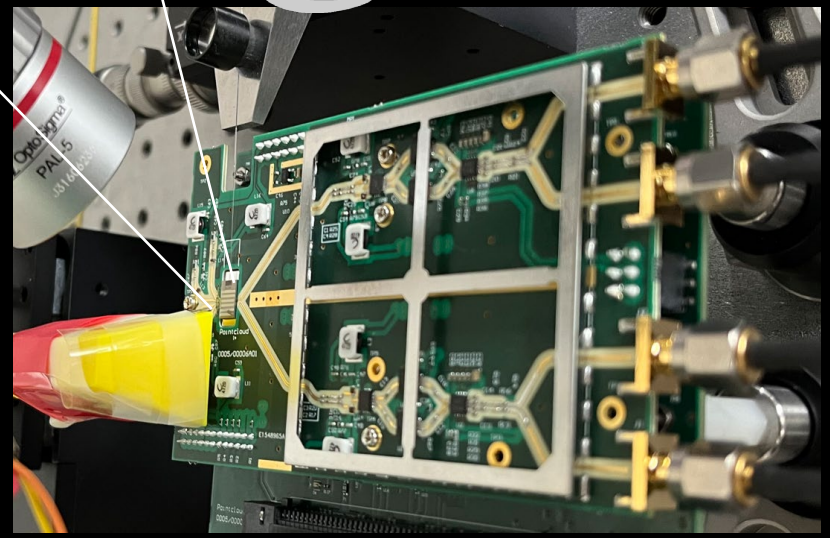
MONOSTATIC IMPLEMENTATION

Monostatic architecture transmitter/receiver focal plane array using sequential flash illumination – experimental setup







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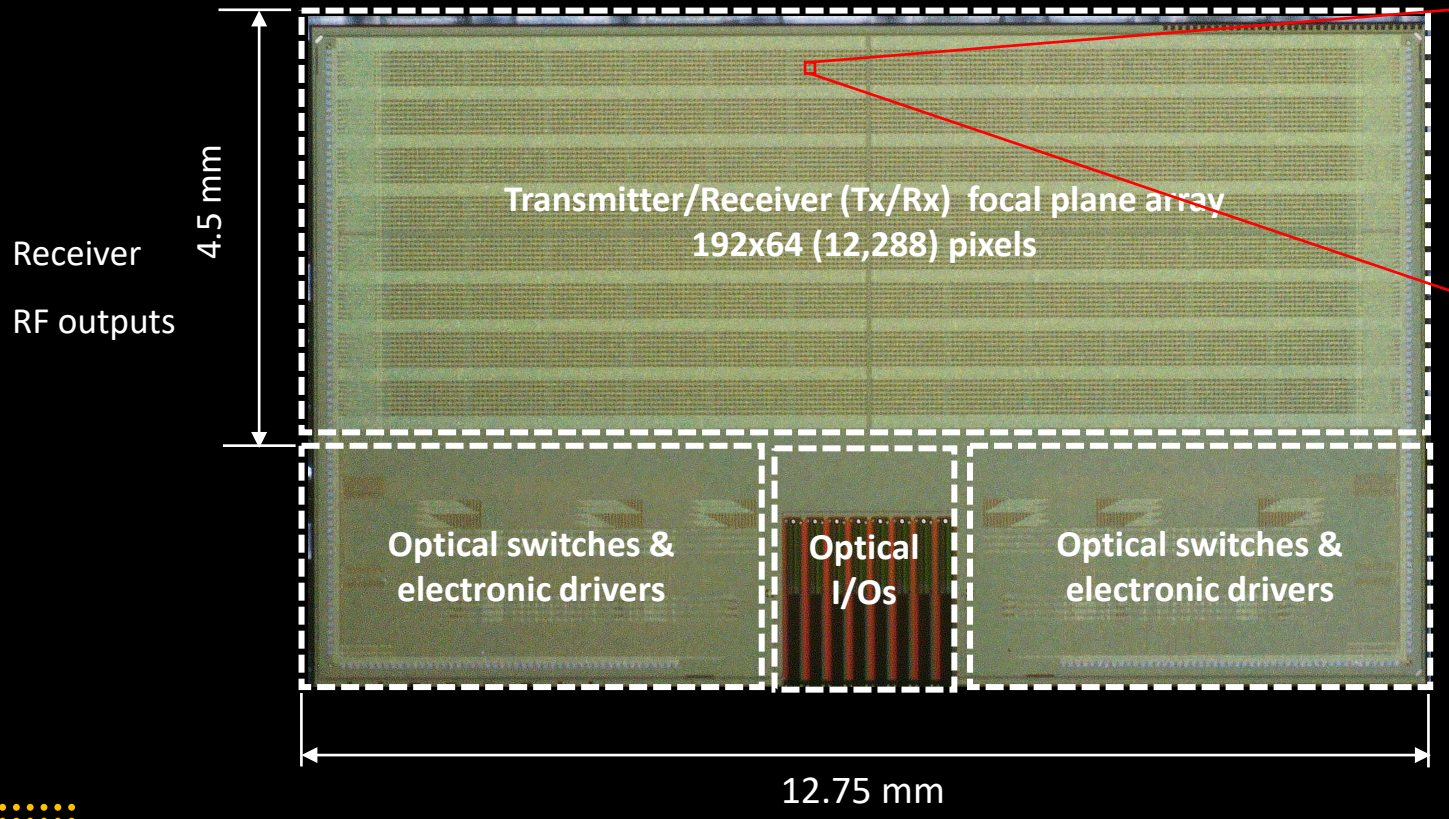
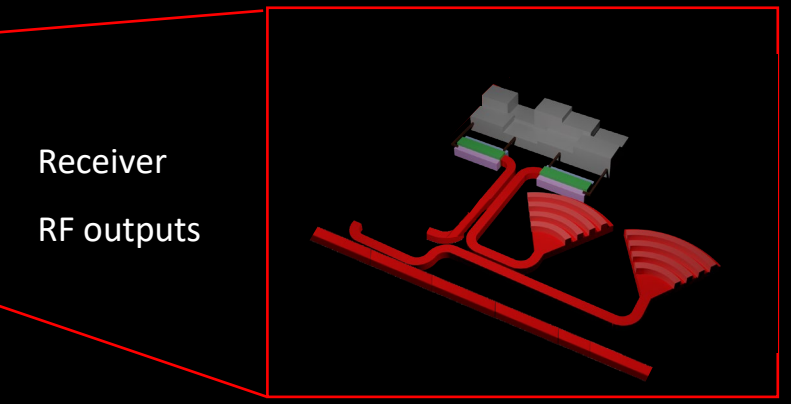
MONOSTATIC IMPLEMENTATION

Monostatic architecture transmitter/receiver focal plane array using sequential flash illumination: 192x64 (12,288) pixels sensor

192x64 pixel coherent Tx/Rx array with integrated optical switches & driving electronics



Detail – coherent Tx/Rx FPA



- Pixel pitch: 53 um
- Tx/Rx FPA with integrated amplifiers
- LO and Tx signal switches with integrated electronics

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CHALLENGES

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DESIGN CHALLENGES

From customer requirements to design implications

Customer requirements	Technical implication	Design/architecture choice
• Low cost sensors with high resolution i.e. large number of pixels	• Small pixel -> small cross section waveguides to be used to create very compact pixels	• Almost exclusive use of Si layer in the pixel due to compactness requirement and accommodated by the low power
• Long range	• High optical power in routing waveguides necessary or long integration time	• Use of SiN waveguides for optical routing and in main optical busses • Avoidance of Si waveguides in all but low power (pixel) or active sections
• Low power consumption	• Low optical loss budget • Highly efficient detection	• Optical component optimization combined with high quality manufacturing • System design to avoid onset of non linear effects leading to non linear losses • High efficiency detectors, tight integration of photodetectors with electronics to reduce noise

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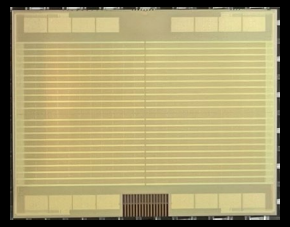
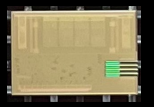
PRODUCT

Chip characteristics and availability summary - 2024

2024 imaging arrays:

- 1310nm wavelength

	~QVGA class array*	12k (192x64) array	1K (64x16) array
			
Expected range**	~**short/mid range	~50-70m	~150-200m
Framerate	NA*	20fps	20fps
HFOV	>90°	60°	20°
Availability	Q3/2024*	Q3/2024	Q3/2024

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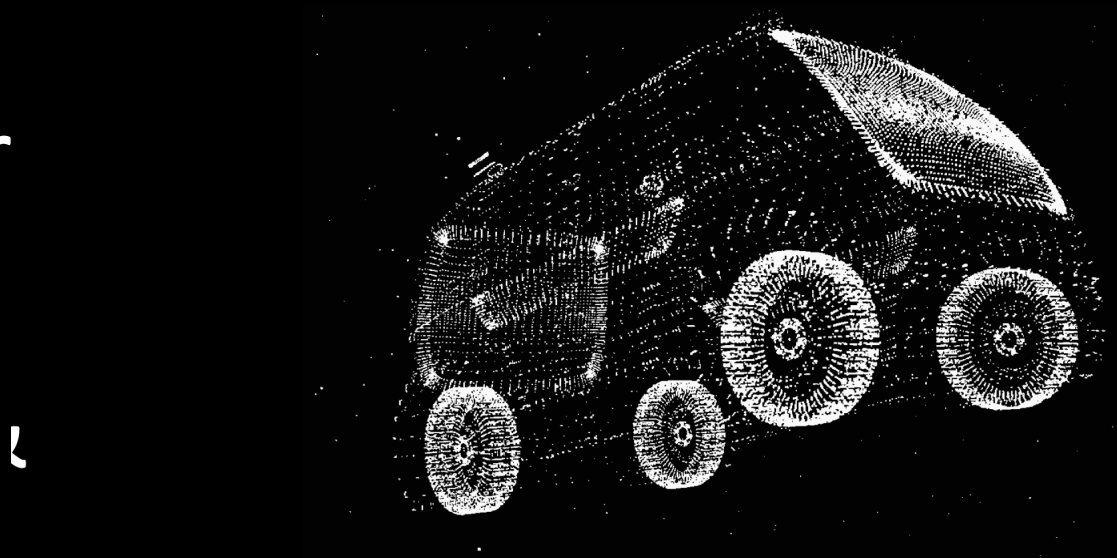
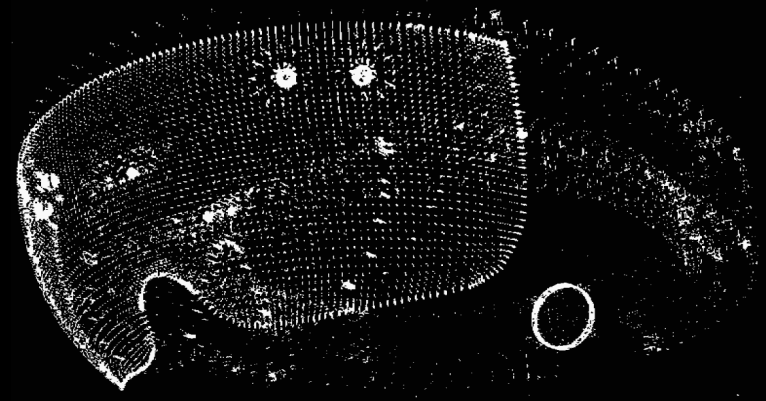
**custom chipset – select availablity; details proprietary to customer*
*** at 10% reflectivity*

Ubiquitous 4D cameras for autonomous mobility, industrial & consumer





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