The landscape of automotive LiDAR

Continental
Business Unit Advanced Driver Assistance Systems
Heiko Leppin

SensePlanAct

Agenda

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Motivation

60+ startups

All Tier1's work on it

>$1B investments

What is LiDAR actually

So many solutions

How do I navigate this space?

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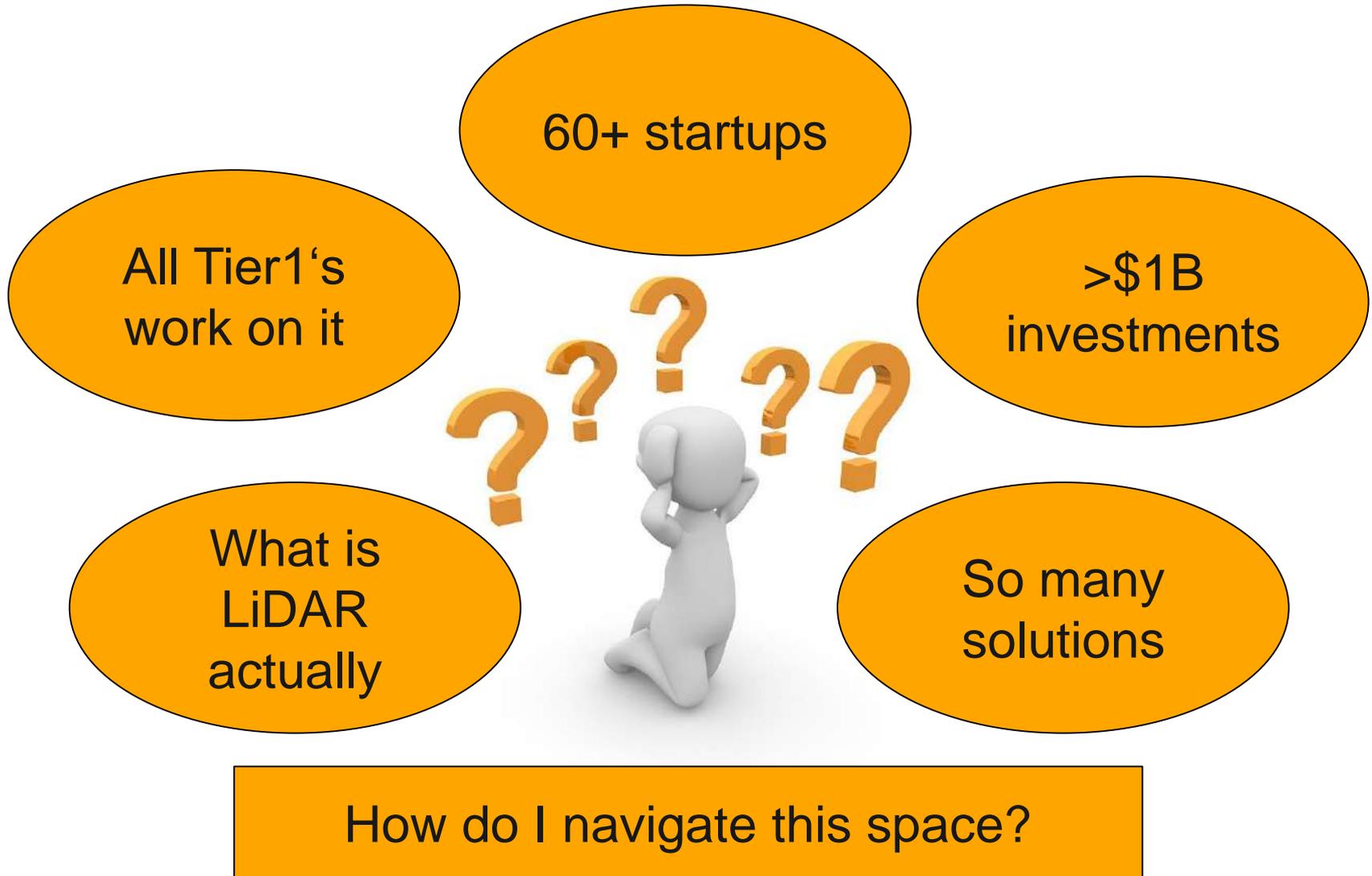
What is LiDAR?
Light Detection And Ranging
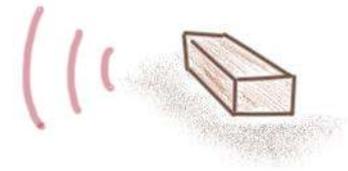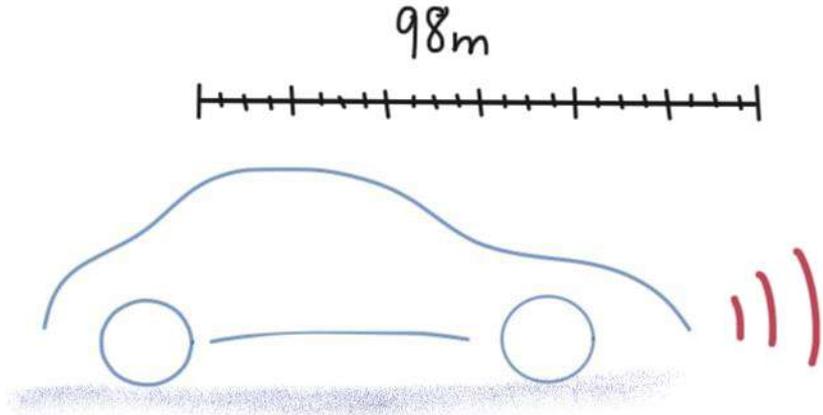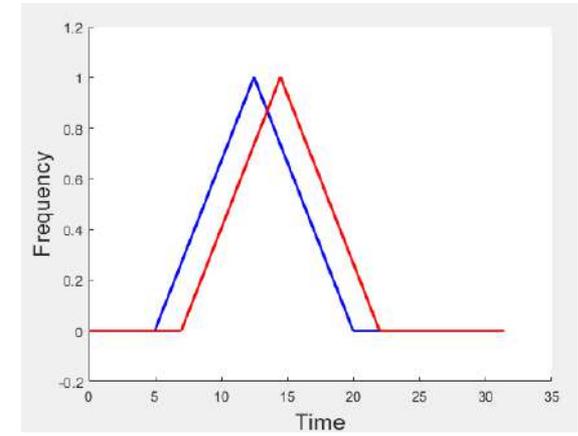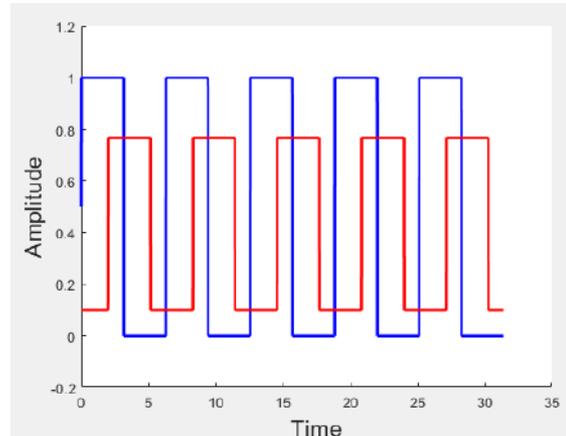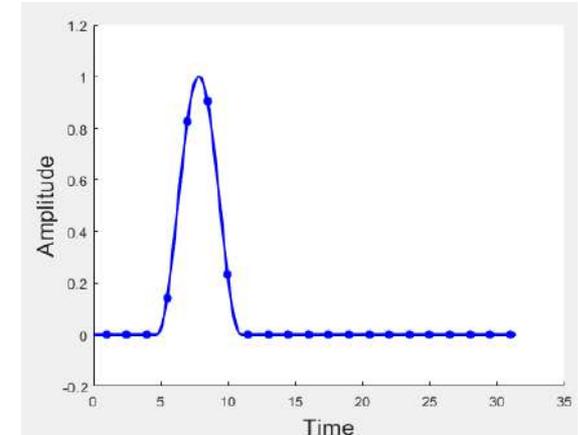

› Sends out light

› Detects returned reflection

› Calculates distance from delay

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What is LiDAR?
Calculating the distance

› Many different methods to detect the time of flight (ToF)

  › Trigger on level

  › Sample amplitude

  › Measure phase

  › Measure variing polarization

  › Measure variing carrier frequency (FMCW)
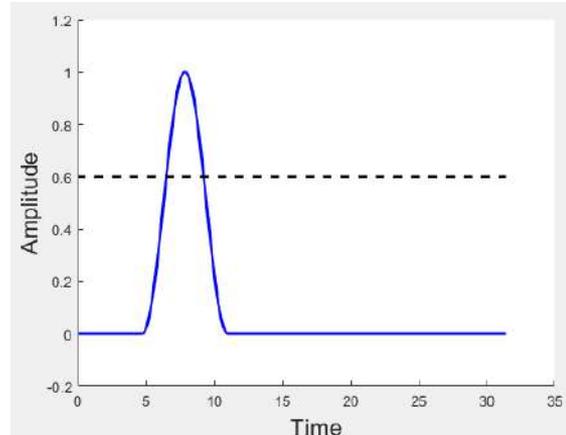
What is LiDAR?
Different scale projects

› Depending on the use case cost and complexity can vary a lot

100M's €	1M's €	100's €	10's €

Image credit: NASA   Image credit: USGS, Riegl

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LiDAR architectures

› Vehicle function defines FoV and range

› Safety aspects define the detection robustness

› Operating environment defines the reliability

› Architectures differ in how they span the FoV
  and how they measure the range

FoV creation
Static LiDAR
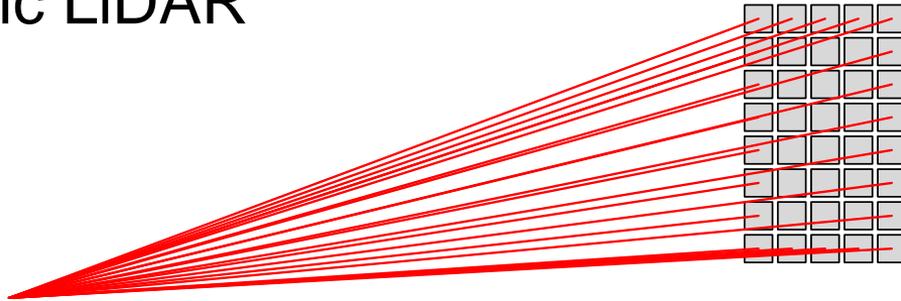
› All ranging segments of the FoV are measured at the same time

› N x M segments require N x M individual reveiver channels

› All segments are illuminated by one powerful source

Pro:	Con:
Whole frame at once	Requires high power laser
High reliability	Limited FoV
No detection gaps	Large detectors

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FoV creation
Scanning LiDAR

› The ranging segments of the FoV are measured consecutively
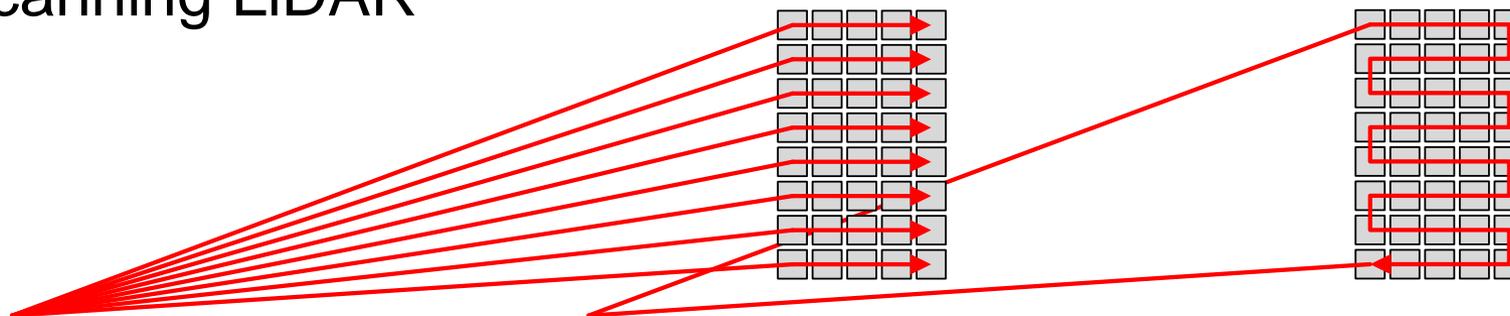
› Only one receiver channel is neccessary

› The light source is pointed at the ranging segments one after an other

› Often a few reciever channels and light sources are used in paralell to reduce measurement time and/or complexity

Pro:	Con:
Simple components	Motion blur
Big FoV	Durability concern
Lower cost	Bad scaling of cost

Sensing principle
Incoherent LiDAR

› The range information is derived from the time delay of the returned signal

› The LIDAR sends out one (or more) pulses

› A reciever detects the amplitude of the reflected energy

› A processing unit determines the time difference between transmition and reception

　› Time to digital

　› Phase detection

　› Peak detection/reconstruction
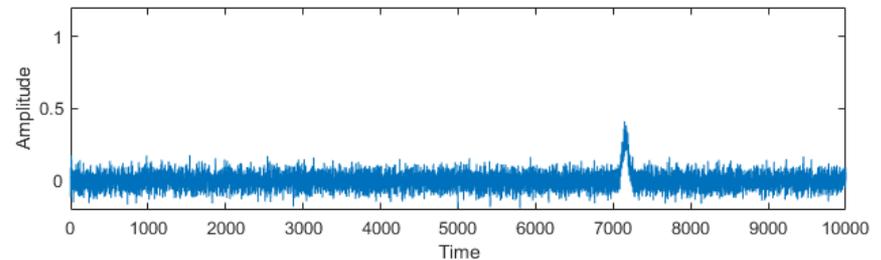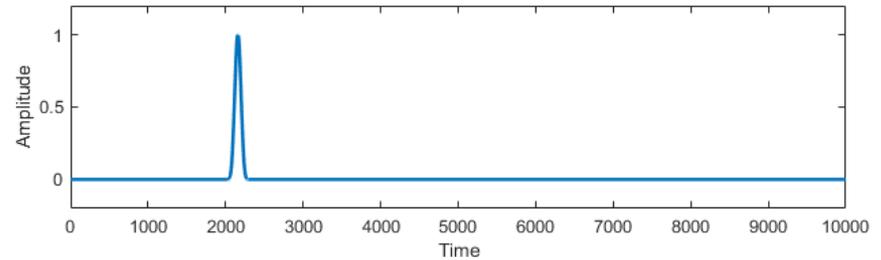
| Pro:	Con:
Simple Laser source	Sun light suppression
Direct range	
Good dynamic range	

Sensing principle
Coherent LiDAR

› The range information is derived from the phase relationship between transmitted and recieved signal

› The LIDAR sends out a signal with varying frequency

› The reflected signal is combined with the transmitter signal.

› The detector measures the amplitude of the interference signal. A processing unit determines the frequency.
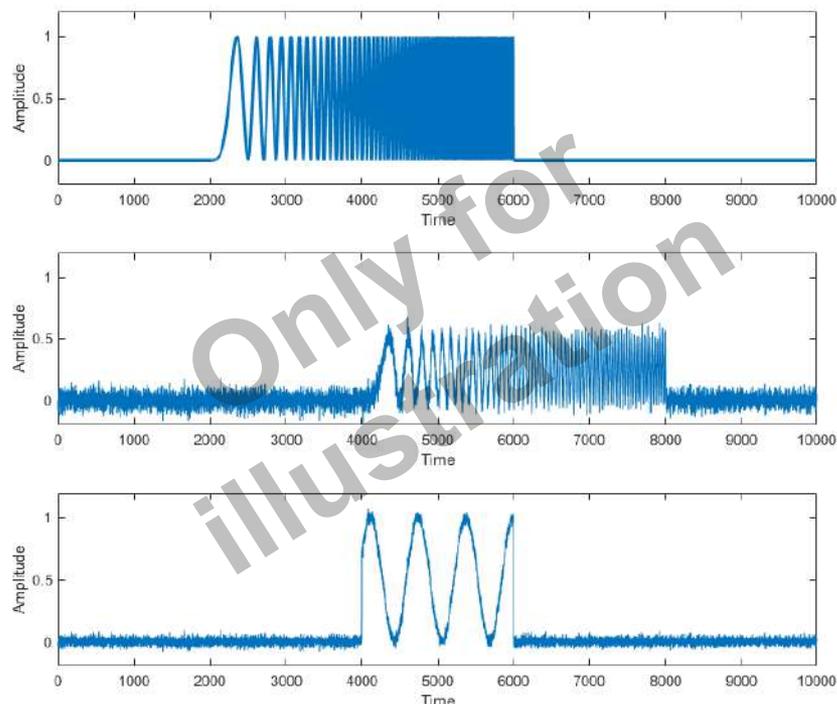
Pro:	Con:
Range and Speed	complex Laser control
Noise suppression	Diode saturation
Slower signal decay	Laser stability

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LASERs

Edge emitting diodes	Surface emitting diodes
› Horizontal cavity	› Vertical cavity → VCSEL
› Faces have to be coated after cleaving	› Fully functional on wafer level
› Long cavity length → high power	› Thin gain medium → lower power
› Stripe shape → oval light profile	› Round cavity → symmetric light profile
	› Low dλ/dT
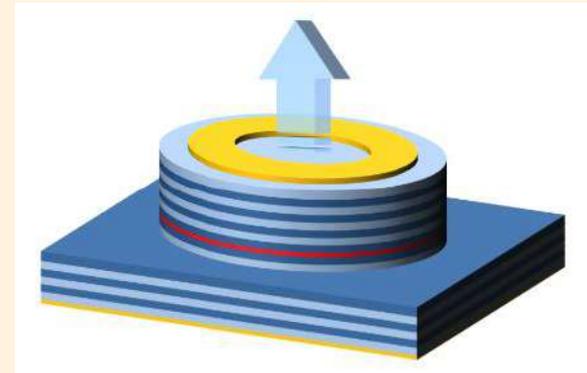
Image credit: https://www.wsi.tum.de/sub_group.php?group=Amann

Photo detectors

Photo detectors

PIN
› Current generated by photons
› Responsivity no function of bias voltage
› Large active area
› No gain
› Available as single elements, lines, arrays

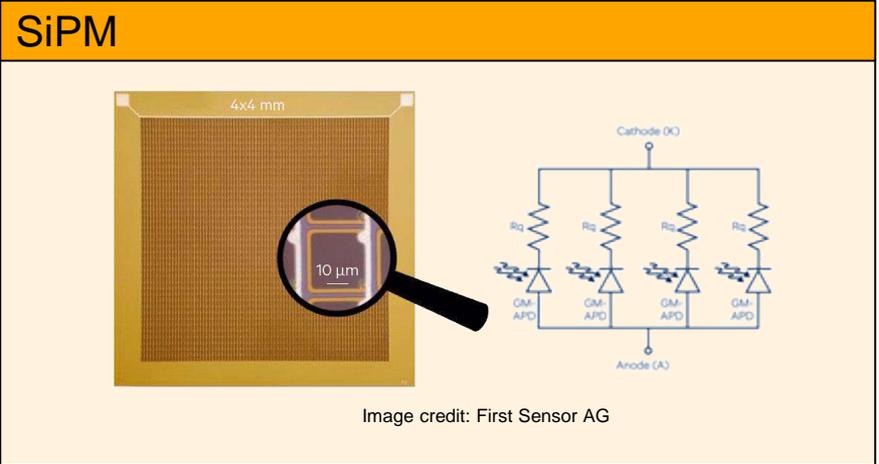| APD |
|---|
| › Two modes |
| › Intrinsic gain |
| › Temp dependency, dark current? |
| › High, stable bias voltage required |
| › Available as single elements, (few arrays) |

SPAD
› Tiny APD in Geiger mode
› Digital device (photon counting)
› Dead time (quenching)
› Available as single elements, lines, arrays

SiPM
› Array of SPADs
› Quasi linear output signal
› Dead time only relevant near saturation
› Available as single elements, lines

Beam stearing
MEMS Mirrors

› Micro Electro-Mechanical System

› Manufactured with wafer precesses

› Bearings with torsion springs

› Actuators with Coulomb force or bending with deposited piezo matrial

› Only elastic deformation

› Small masses (moment of inertia)

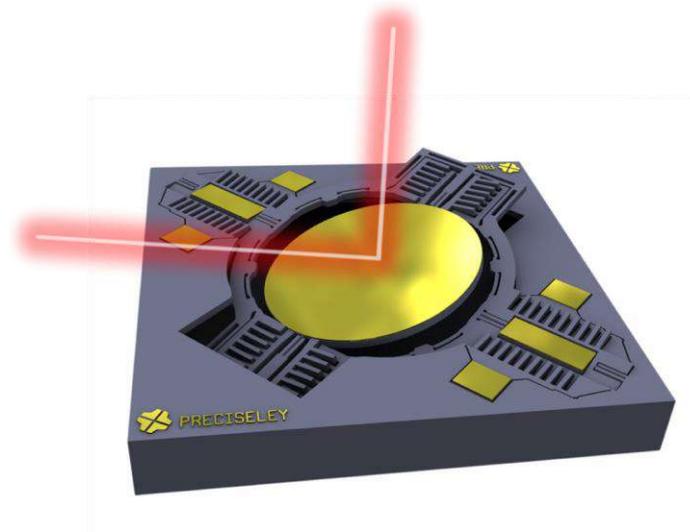Image credit: Preciseley, microtechnology corp.

Pro:	Con:
Wafer processing	Small aperture
No friction	Vibration sensitive
Small SWaP	Limited scalability

Beam stearing
Optical Phased Arrays

› Micro antennas emit the light

› The phase relationship between the antennas define interference pattern

› With many antennas the interference pattern is a directed beam

› Changing the phase relation between the antennas changes the beam direction

› Effects on phase:

  › Wavelength change

  › Thermo-optical

  › Electro-optical

Image credit: Martijn Heck, University Aalborg
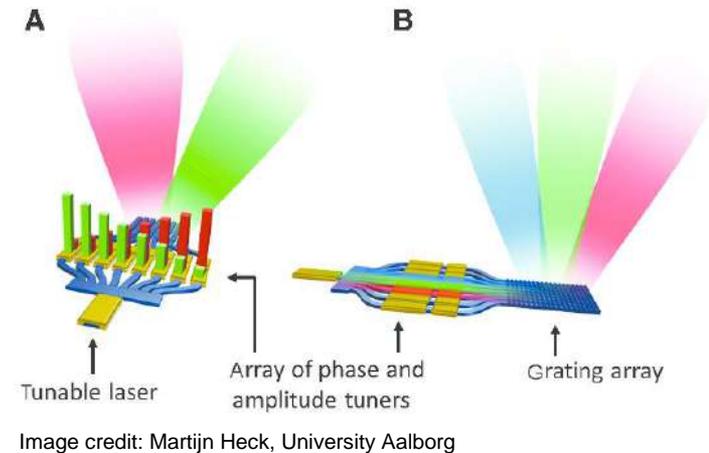
Pro:	Con:
Wafer process	Low resolution
No movements	Tunable Laser req.
Small SWaP	Temperature control

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Automotive LiDAR landscape

› Yole estimates a market size of 6B€ in 2025 and 14B€ in 2030

› Few established Tier1s deliver LiDAR today

› Many companies are attracted by this market

› Technologies are competing for OEM and Tier1 attention

› No technology won the race so far

› Small companies are seeking for partners for industrialization
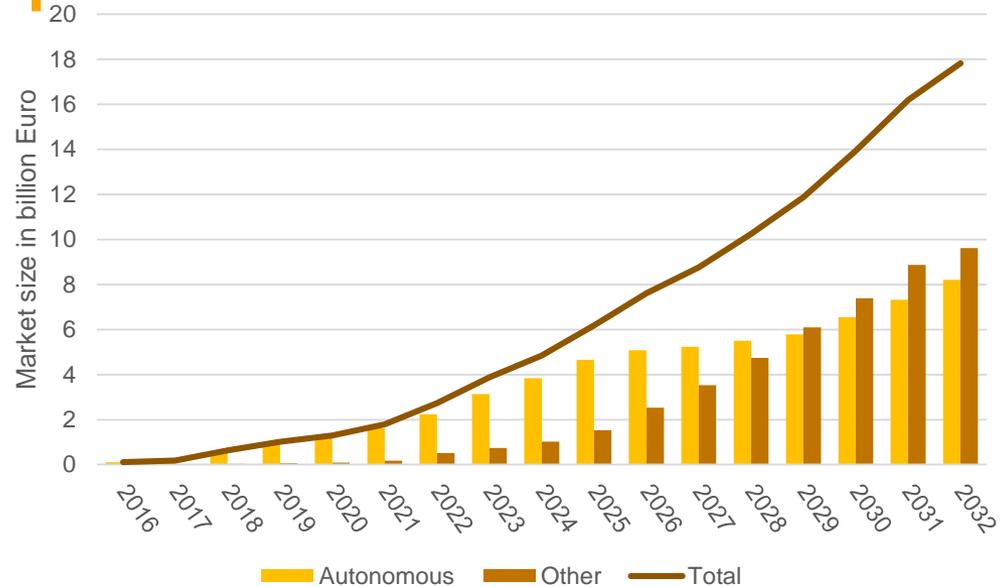
Data according to Yole Développement

Image credit: Yole développement

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LiDAR technology map

› LiDAR market can be very confusing
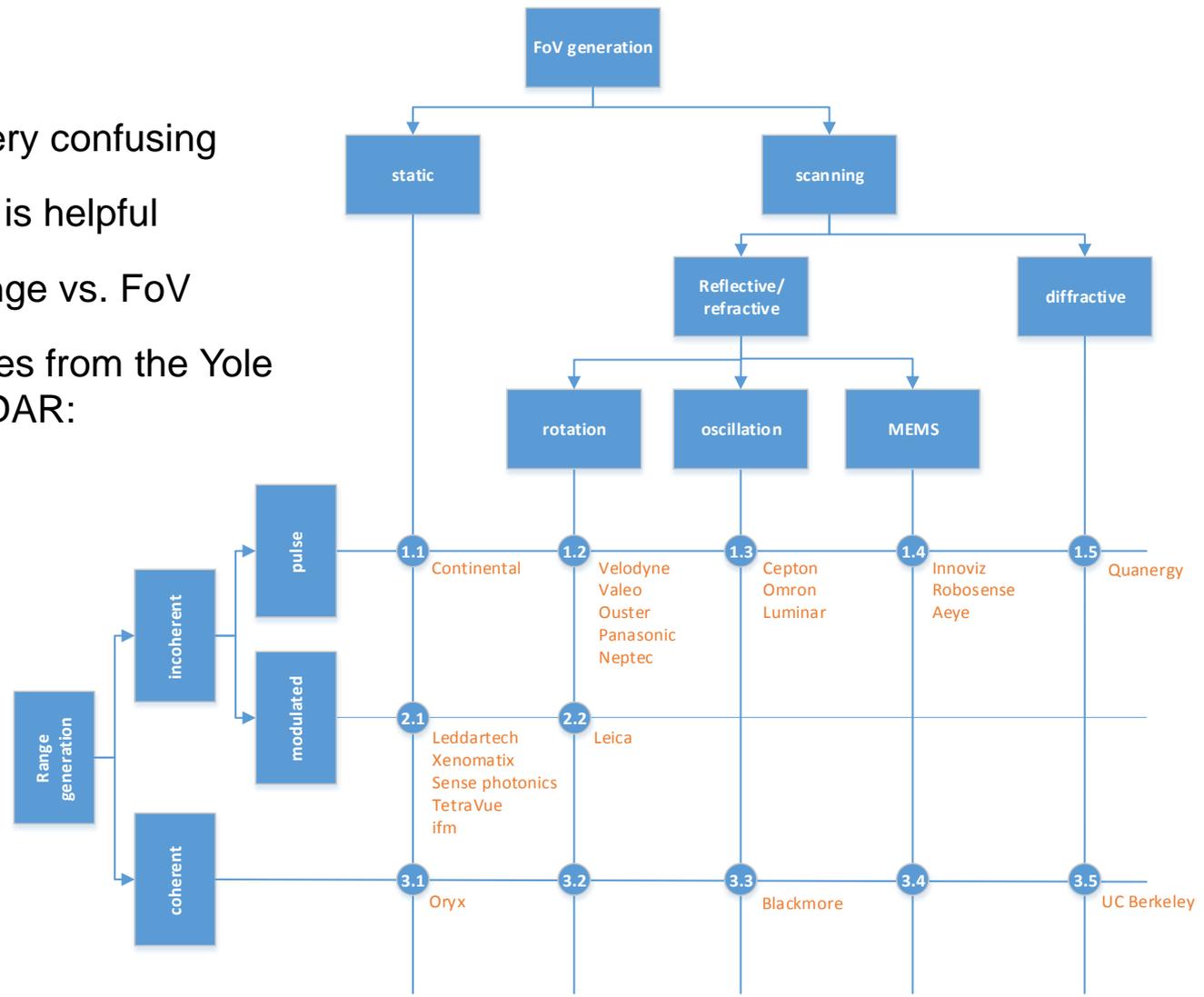
› To gain overview a map is helpful

› I propose to display Range vs. FoV

› …

Image credit: Yole développement

LiDAR technology map

› LiDAR market can be very confusing

› To gain overview a map is helpful

› I propose to display Range vs. FoV

› Shown are the companies from the Yole report on automotive LiDAR:

› Extend as you prefer

FoV generation

static

scanning

Reflective/ refractive

diffractive

rotation

oscillation

MEMS

Range generation

incoherent

pulse

modulated

coherent

1.1 Continental
1.2 Velodyne Valeo Ouster Panasonic Neptec
1.3 Cepton Omron Luminar
1.4 Innoviz Robosense Aeye
1.5 Quanergy

2.1 Leddartech Xenomatix Sense photonics TetraVue ifm
2.2 Leica

3.1 Oryx
3.2
3.3 Blackmore
3.4
3.5 UC Berkeley

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Summary

› Different LiDAR architectures have been shown

› Laser sources, photodetectors, and steering conponents are all available on the market

› The market size is about 14B€ by 2030

› The traditional dominance of few Tier1's is missing

› The size of the market attracts many companies and is very diverse

Safe and Dynamic Driving
towards Vision Zero
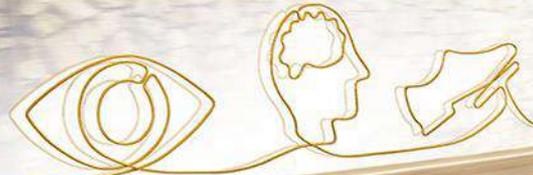
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