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Automotive LiDAR at Veoneer – Optical design paths

Dr Olov von Hofsten, Eclipse Optics
Team Lead Optics, Veoneer LiDAR

a proud part of VINN*

WE ARE ECLIPSE

Specialists – Product developers – Partners

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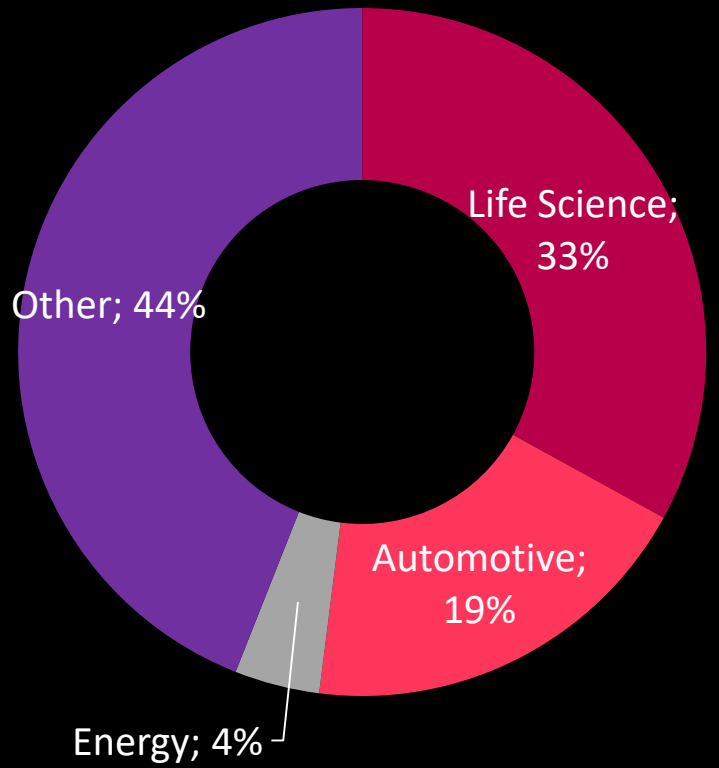
Eclipse Optics

- 2 M € Turnover
- 17 Employees
- Working in-house and at customer site
- 70 projects during 2018
- Main areas
  - ✓Life science
  - ✓Automotive



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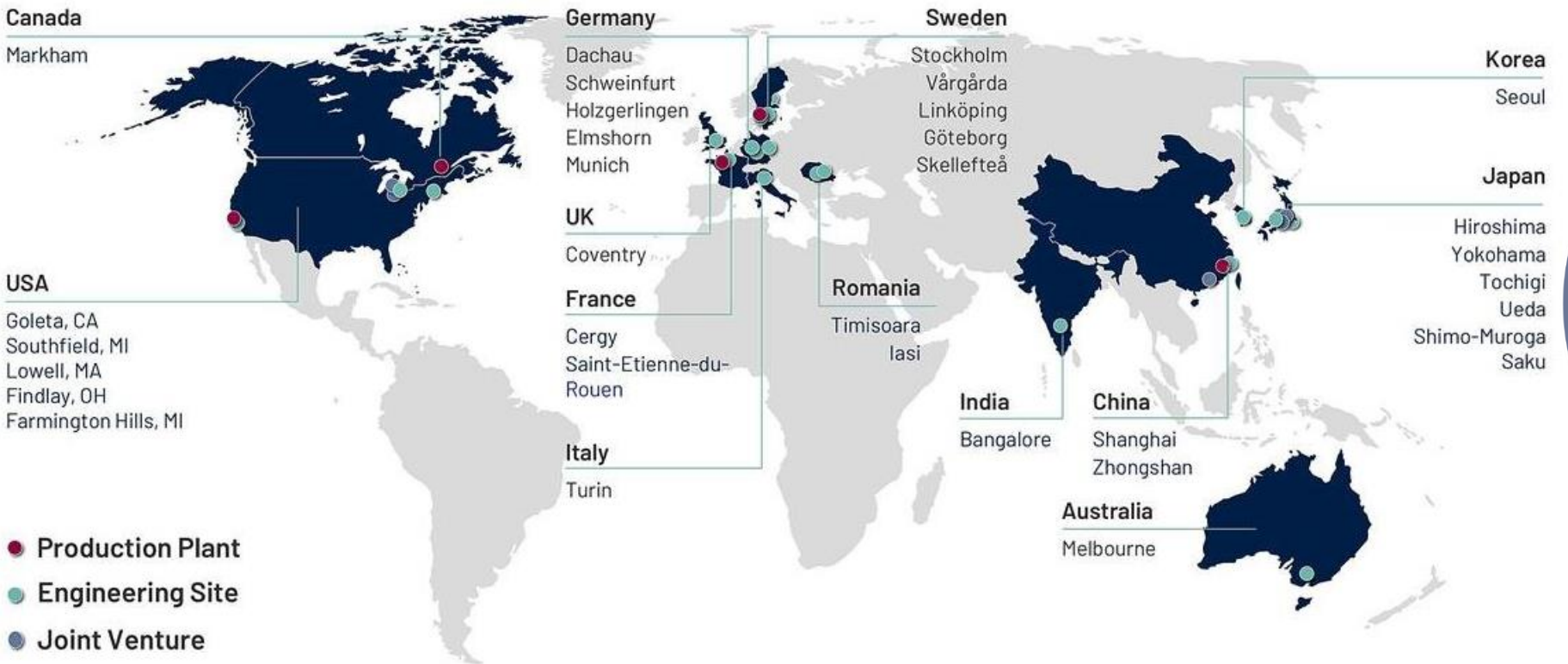
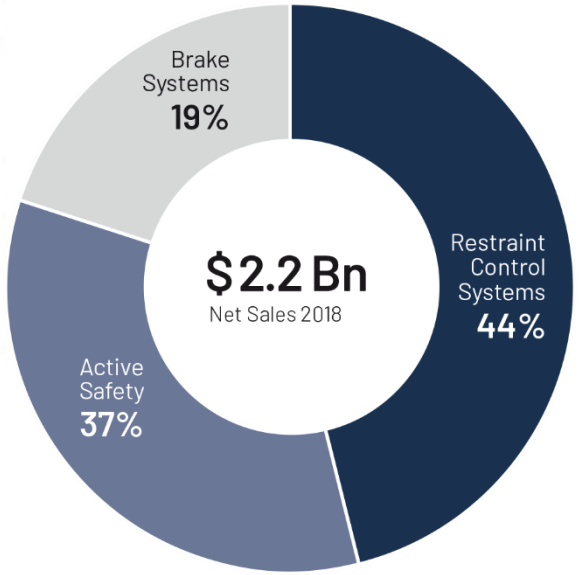
This is Veoneer

- The world's largest pure-play company focused on Safety Electronics, Advanced Driving Assistance **Systems (ADAS), Collaborative and Automated Driving (AD).**
- Design, develop, manufacture and sell state-of-the-art sensors, control units, software and systems for active safety, autonomous driving, occupant protection and brake control.
- Founded in 2018, built on close to 70 years of automotive safety development
- 9,200 employees in 13 countries
- Headquartered in Stockholm, Sweden
- Listed on the New York Stock Exchange and on the Nasdaq Stockholm

A Global Footprint



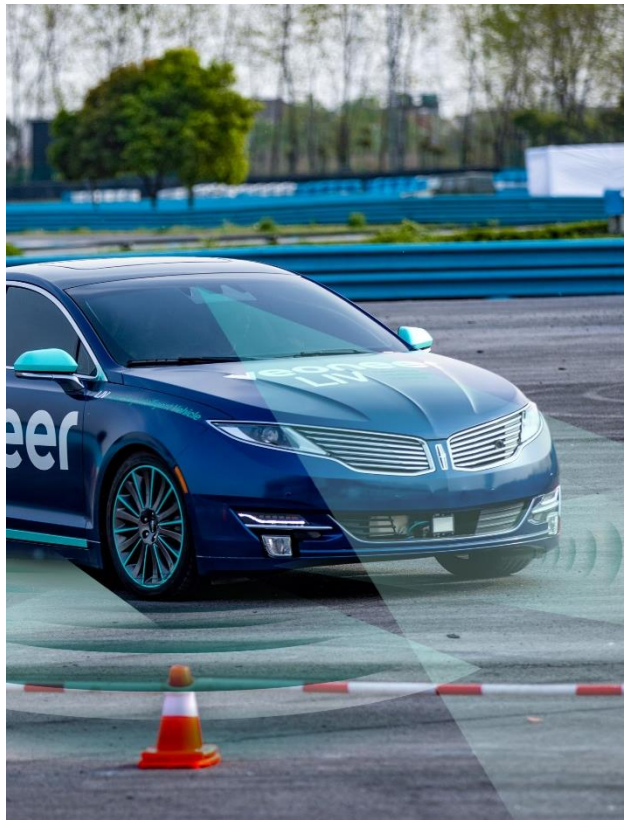


9,200 ASSOCIATES
~5,200 in R,D&E

13 COUNTRIES
10 MANUFACTURING SITES
26 TECHNICAL CENTERS

1,100 ENGINEERS
HIRED DURING 2018

A Tech Company Delivering Automotive Grade



More than 4 million
Camera Sensors Delivered

>33 million
Radar Sensors Delivered

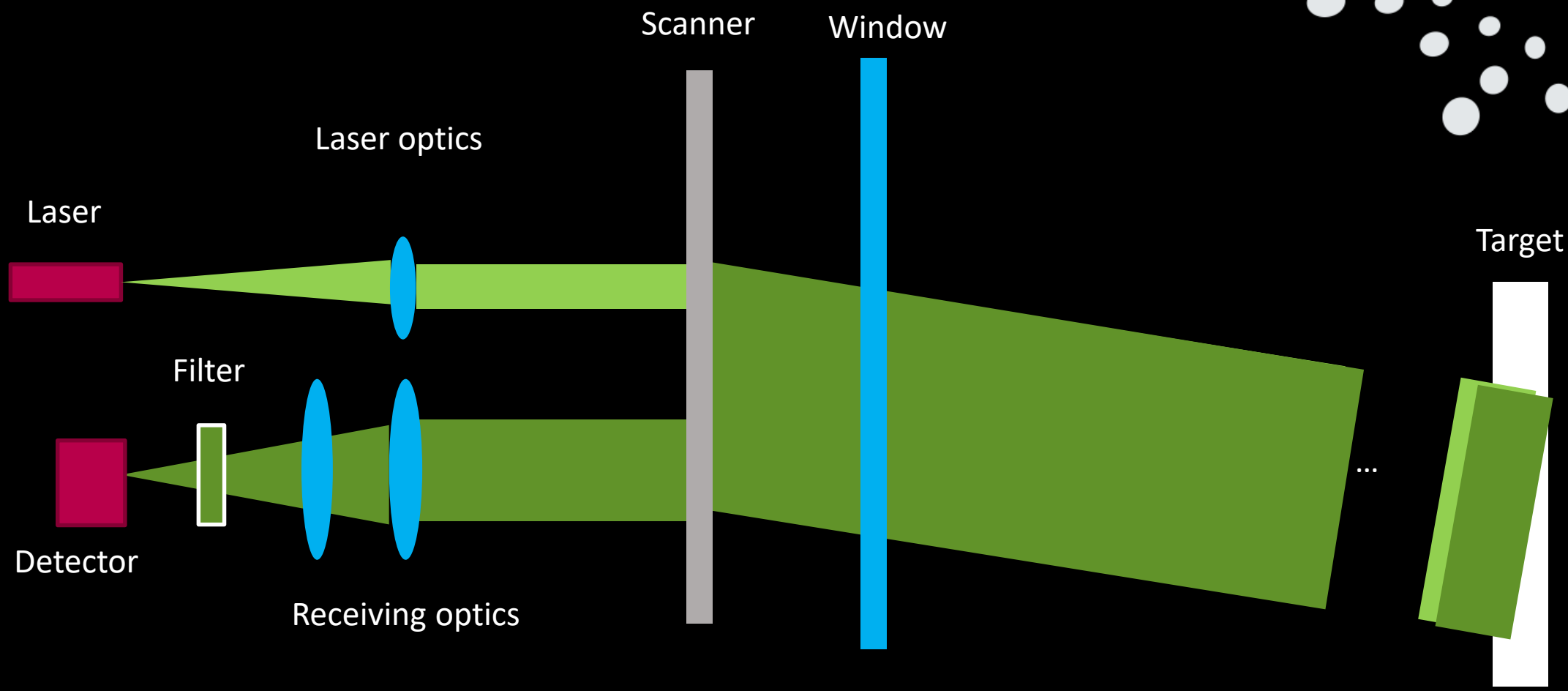
~750 million
Airbag ECUs and Crash Sensors Delivered

Delivered during the past decade, as Veoneer and as part of Autoliv

Automotive grade requirements

- Lifetime
  - Expected lifetime of personal car: 8-12 years, 100 000 - 300 000 miles (~4000 hours)
  - Expected lifetime for robotaxi: 3-4 years, 500 000 miles (~30 000 – 40 000 hours)
- Temperature and humidity
  - -40° to 105° C functional
  - -20° to 85° C operational
- Temperature cycling
- Shock/Vibration of individual components
- Traceability
- Lots of paper work…

Optical parts of a LiDAR



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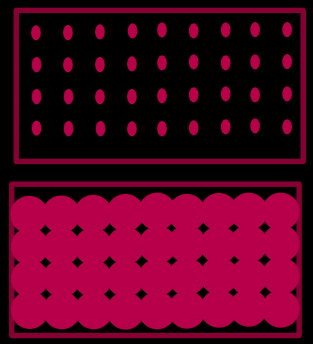
Design choices

- Biaxial or coaxial?
  - Biaxial suffers from parallax, and requires separate alignment of source and laser channels
  - Coaxial suffers from strong zero pulse
  - Coaxial system requires a coupling mechanism: Polarisation, spatial…
- Field-of-view: Affects point rate
- Frame rate: 10 Hz minimum (typically)
- Resolution
  - Example tire 100 m away yields ~0.05 degree
  - Gaps accepted? Overlap accepted?
- Simultaneous firing or consecutive?
  - Simultaneous firing can give cross-talk
  - Consecutive firing limited to 1 MHz for 150 m (distance ambiguity)
  - Extreme scan speeds can give beam wandering on sensor
- Laser and detector technology



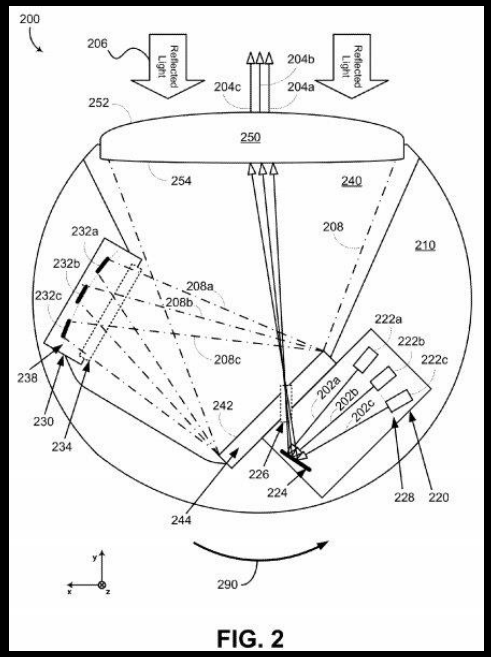


FIG. 2

Waymo Patent (coaxial LiDAR)

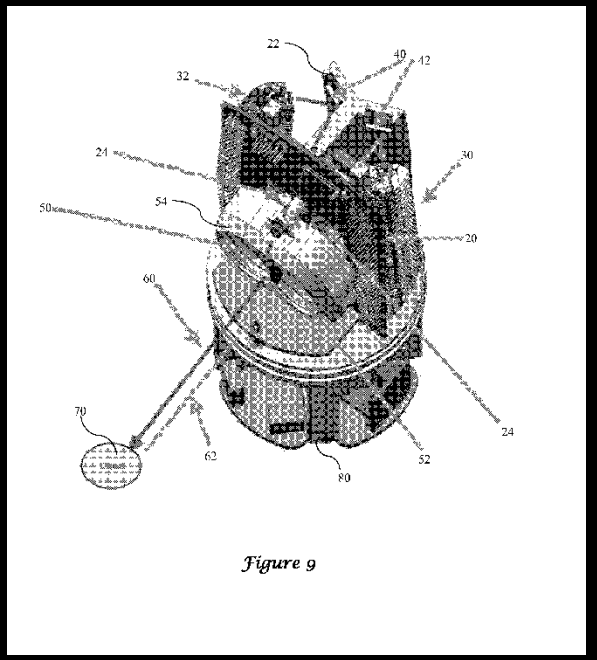


Figure 9

Velodyne Patent (biaxial LiDAR)

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Light source

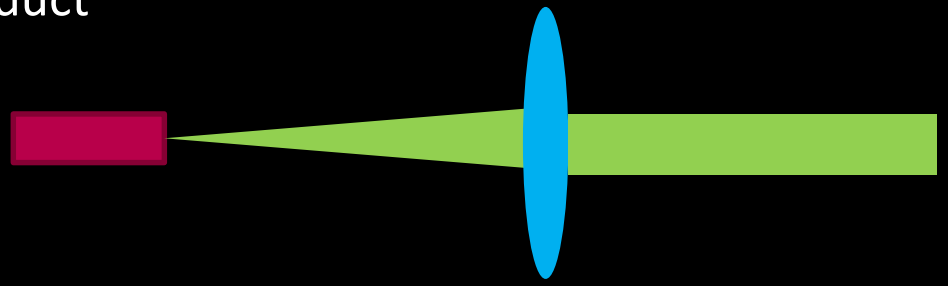
- Fast: 1-10 ns pulse
- Stable, low jitter
- Good wallplug efficiency
- Eye safe (also involves optics and mechanism)
- Temperature stable
- Low cost

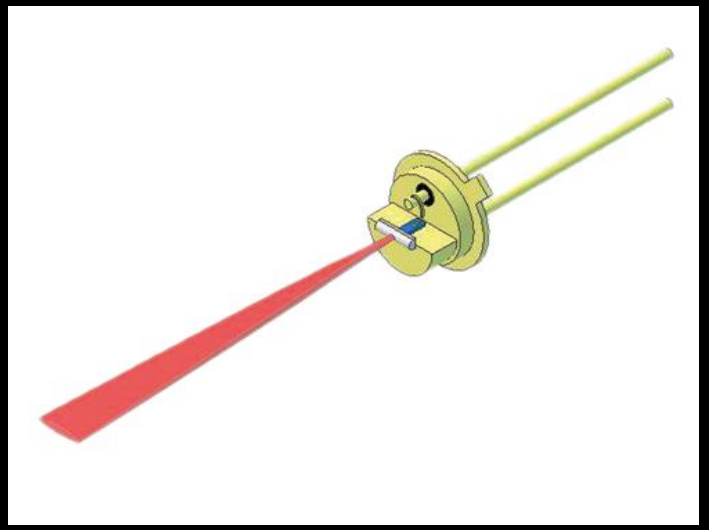
Example of fiber laser

Example of laser diode (bare die)

Laser optics

- Collimate laser beam
- Output light with high efficiency
- Direct beam
- Create a eye safe product





Source: Laser Components

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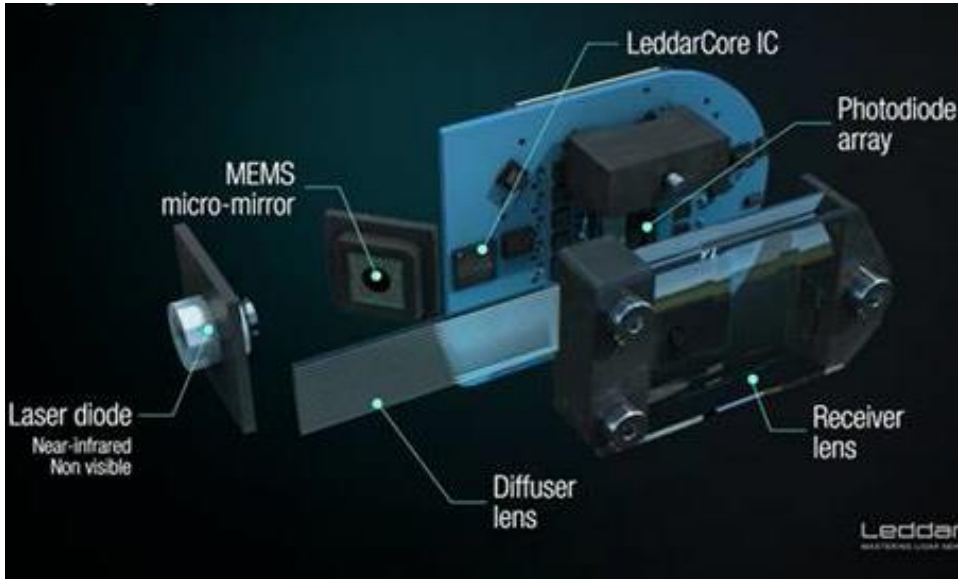
Scanning mechanism

Requirements

- High speed (Point rate>500 kHz)
- Low power consumtion
- ”Solid state” preferred since moving parts not robust
- Coaxial systems require large aperture (>10 mm?)

Alternatives

- MEMS
- Mechanical scanning (galvo)
- Rotating mirrors
- Rotating assembly
- Phased arrays



LeddarTech presentation

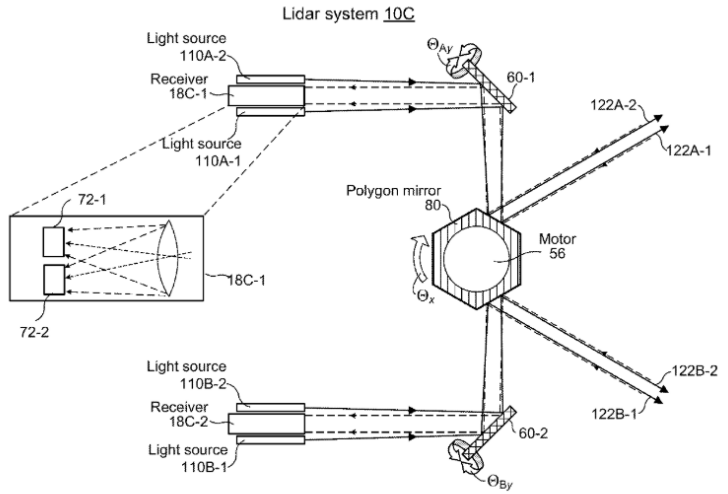
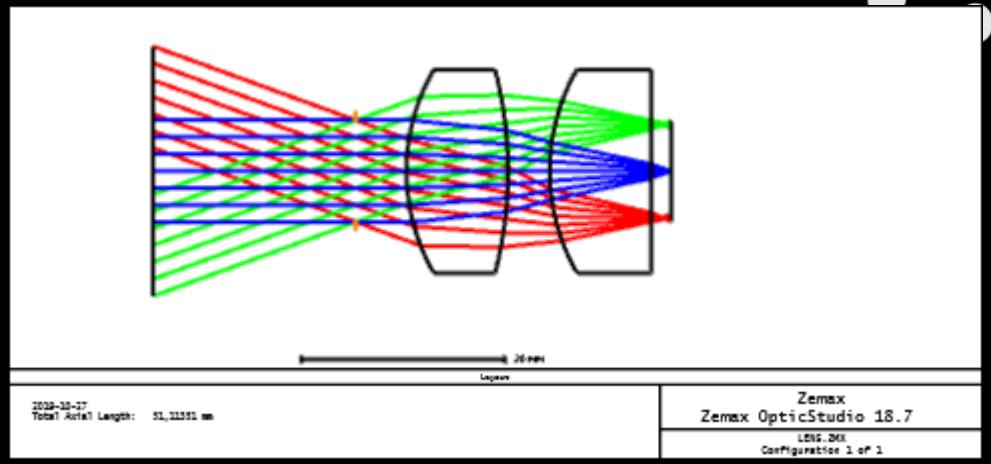


Figure 4

Luminar patent

Receiving optics

- Purpose: Collect as much light as possible, focus it to as ”small” as possible spot (detector size usually 100s of µms)
- External entrance pupil to avoid large scan mirror size
- Cost drivers: Aspheric surfaces, cylindrical surfaces, cut lenses, number of optical surfaces
- Manufacturing
  - Grind and polish
  - Molding
  - Coating
- Temperaure stabile



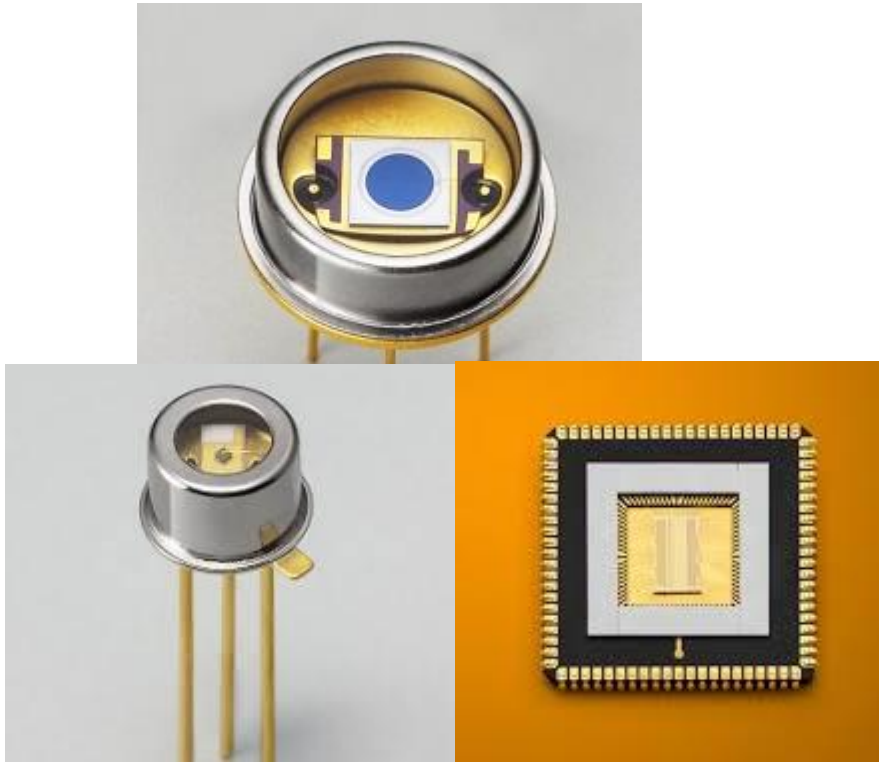
Laser power

Laser wavelength
Glass thickness
Aluminum thickness

Refractive index
Detector noise
SNR

Other optical components

- Mirrors: High reflectivity required
- Detectors: APD or SPADs
- Windows: High AR for high angles, hard coating, hydrophobic…
- Bandpass filters
  - Steep edge
  - High transmission for design wavelength over temperature, angle, laser wavelength variations
  - Low transmission for wavelength outside
  - Low shift over angle



Enemies of the LiDAR performance

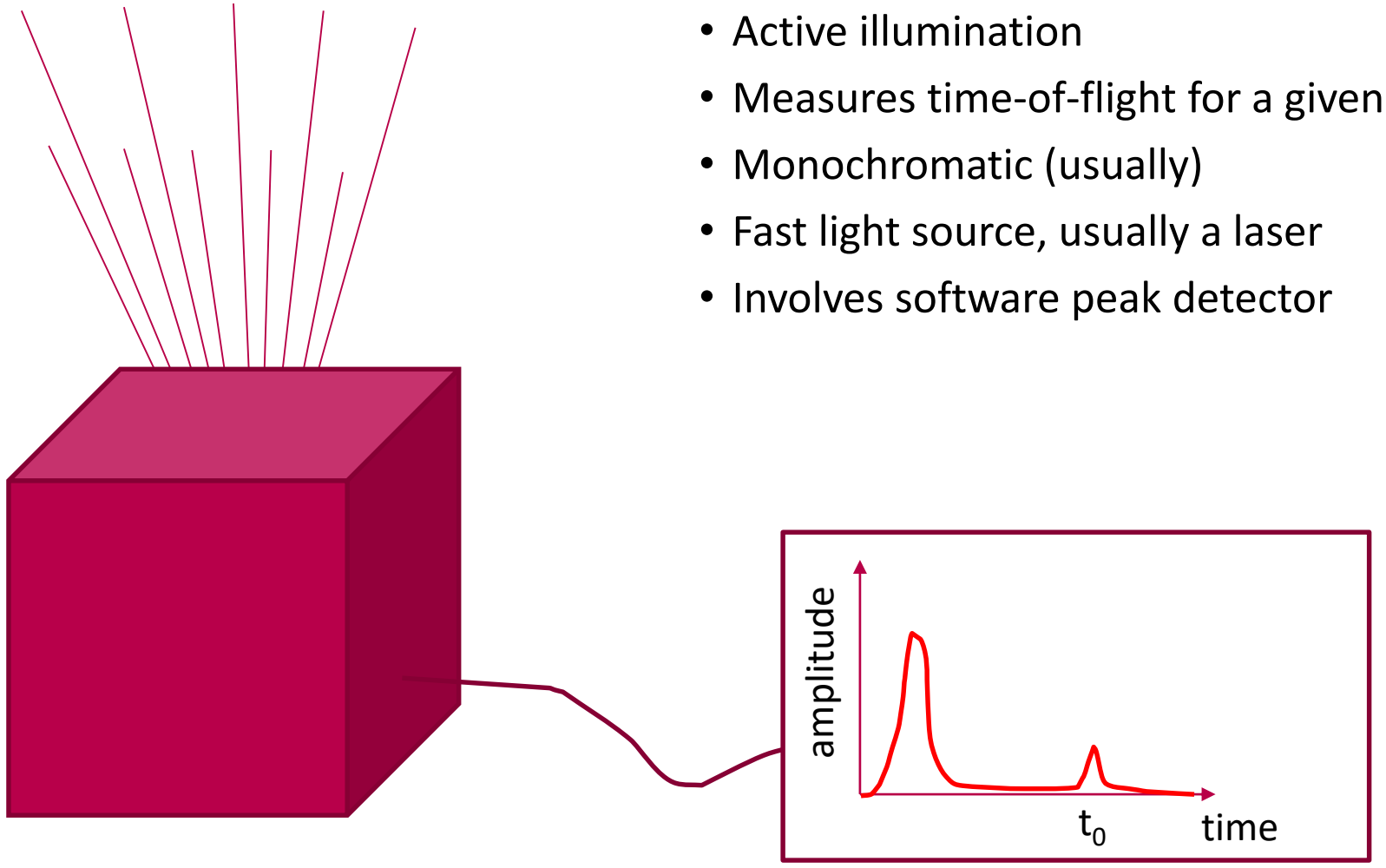
Veoneer needs...

- Fast, cheap, robust, efficient scanning mechanism
- Automotive grade suppliers
- SPADs with higher QE in NIR
- Packaging
- Low cost black coatings

Eclipse can help you...

- Optical design resource
- Test equipment
- Evaluations, workshops

Scanning LiDAR



Basic design input

- Active illumination
- Measures time-of-flight for a given point
- Monochromatic (usually)
- Fast light source, usually a laser
- Involves software peak detector

$$d = \frac{c * t_0}{2}$$

This presentation was presented at EPIC Meeting on LIDAR Technologies for Automotive 2019

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