# AUTOMOTIVE ENVIRONMENT SENSORS

Lecture 11

LIDARs

Dr. Szilárd Aradi

MŰEGYETEM 1782

BME KÖZLEKEDÉSMÉRNÖKI ÉS JÁRMŰMÉRNÖKI KAR
32708-2/2017/INTFIN SZÁMÚ EMMI ÁLTAL TÁMOGATOTT TANANYAG

# LIDAR introduction

- Light Detection and Ranging or Laser Imaging, Detection and Ranging: is a surveying method that measures distance to a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor (Time of Flight).
- Laser: light amplification by stimulated emission of radiation.
  - Spatial coherence allows a laser to be focused to a tight spot
  - Lasers can also have high temporal coherence, which allows them to emit light with a very narrow spectrum
  - In this usage, the term "light" includes electromagnetic radiation of any frequency, not only visible light


By The original image was uploaded on de.wikipedia as de:Bild:THEL shoot2.jpg, from US Army Space & Missile Defense Command, Public Domain, https://commons.wikimedia.org/w/index.php?curid=738559


By US Missile Defense Agency - Selected ALTB Photos. Airborne Laser Test Bed. MDA. Retrieved on 29 June 2013., Public Domain, https://commons.wikimedia.org/w/index.php?curid=26465745

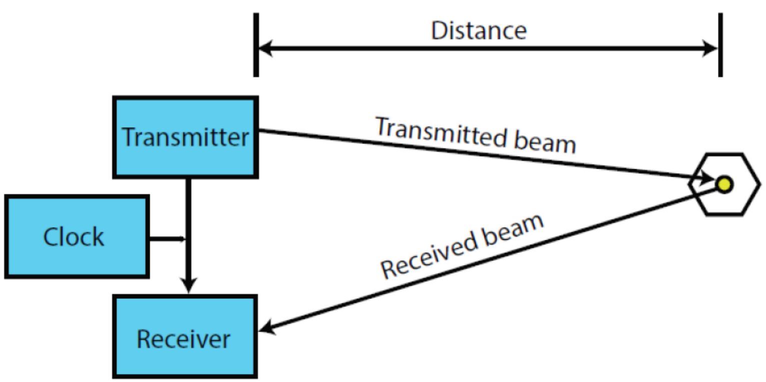
# LIDAR (and laser) history

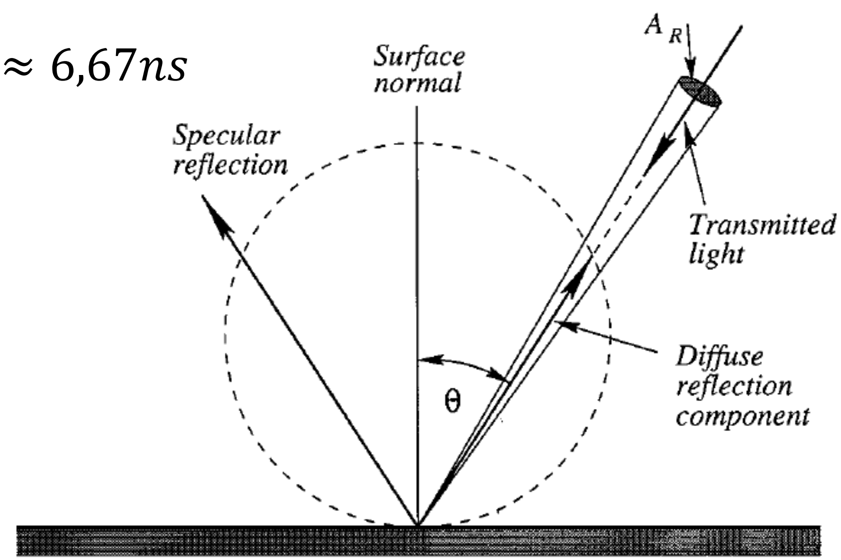
- In 1917, Albert Einstein established the theoretical foundations for the laser and the maser
- In 1953, Charles Hard Townes and graduate students James P. Gordon and Herbert J. Zeiger produced the first microwave amplifier, a device operating on similar principles to the laser, but amplifying microwave radiation rather than infrared or visible radiation
- On May 16, 1960, Theodore H. Maiman operated the first functioning laser.
- In 1962, Robert N. Hall demonstrated the first laser diode device (Ge).
- The general public became aware of the accuracy and usefulness of lidar systems in 1971 during the Apollo 15 mission.
  - Lunar Laser Ranging experiment measures the distance between surfaces of Earth and the Moon using laser ranging. Astronauts planted retroreflectors which were aimed from the Earth.
- Lidars are extensively used in meteorology, geography, robotics etc.
- The vehicle industry started utilizing LIDARs for the autonomous researches. First bigger projects were DARPA Grand Challenge and the Google Self-Driving Car.

# LIDAR basics

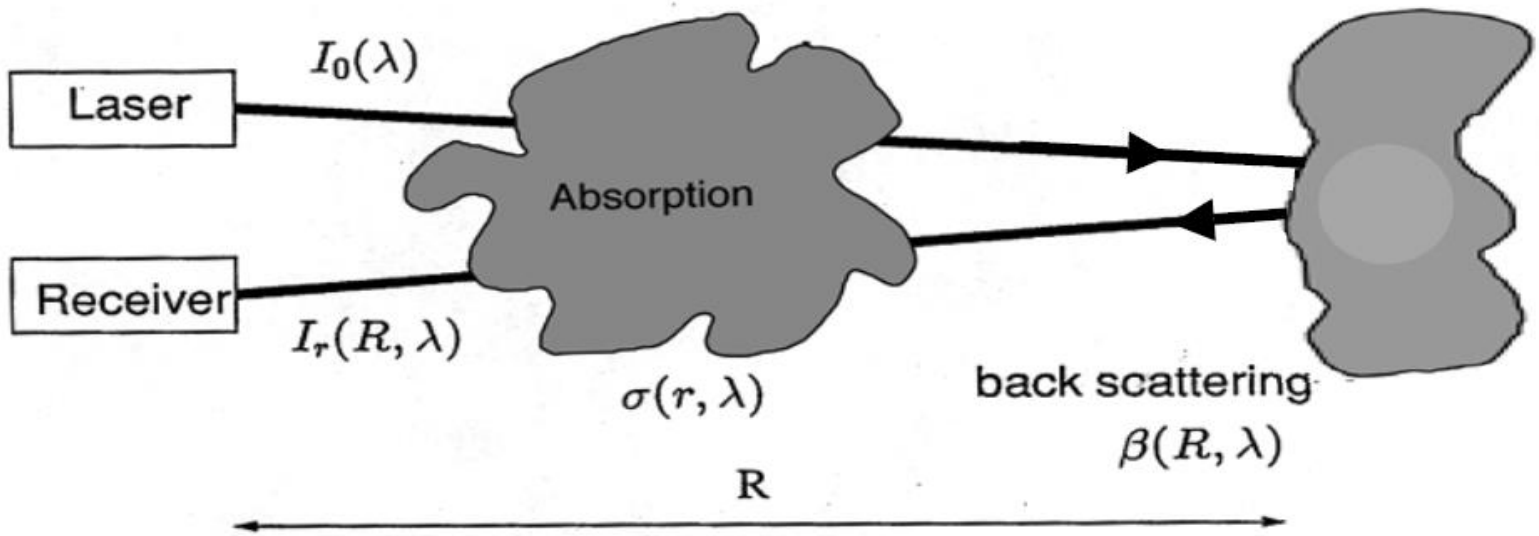
- Based on the time of flight, speed of light
  - The sensor sends short pulses like pulse radars
- Reflection of light is either specular (mirror-like) or diffuse (retaining the energy but losing the image) depending on the nature of the interface.
- Uses diffuse reflection (can't detect mirrors)

$$s = \frac{c \cdot t}{2} \qquad t = \frac{2 \cdot s}{c} = \frac{2 \cdot 1m}{299\,792\,458 m/s} \approx 6{,}67 ns$$



# LIDAR equation




$$I_r(R,\lambda) = I_0\eta\frac{A}{4\pi R^2}\beta(R,\lambda)\exp(-2\int_0^R \sigma(r,\lambda)dr)$$

I – Intensity

η – Receiver efficiency

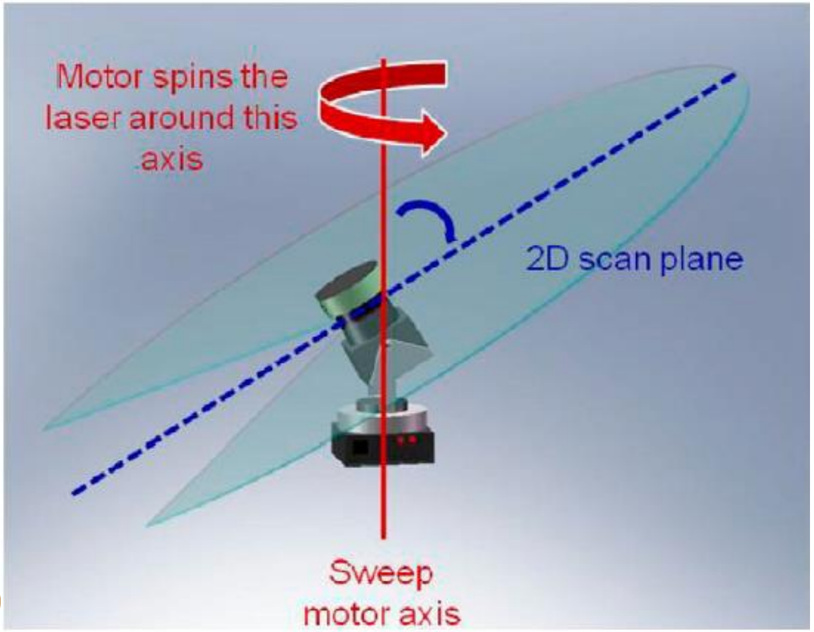
β – Reflection coefficient

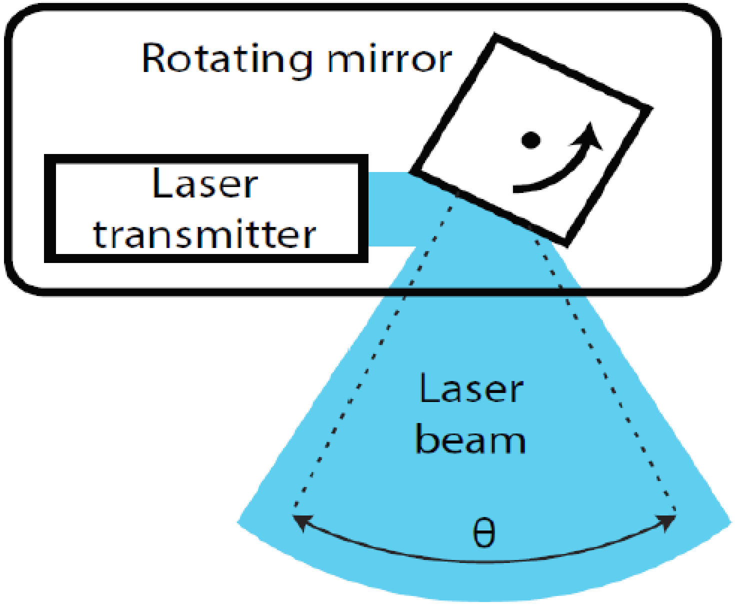
σ – Absorption coefficient

A - Area of the receiver

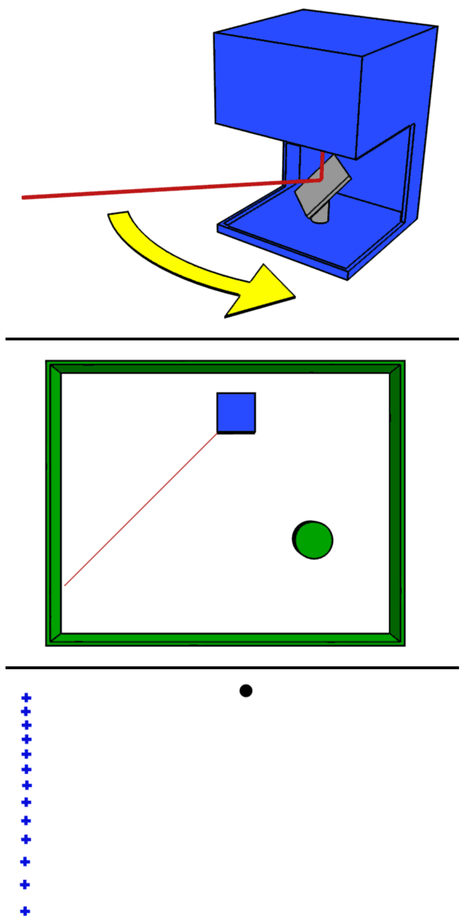
# LIDAR measurement

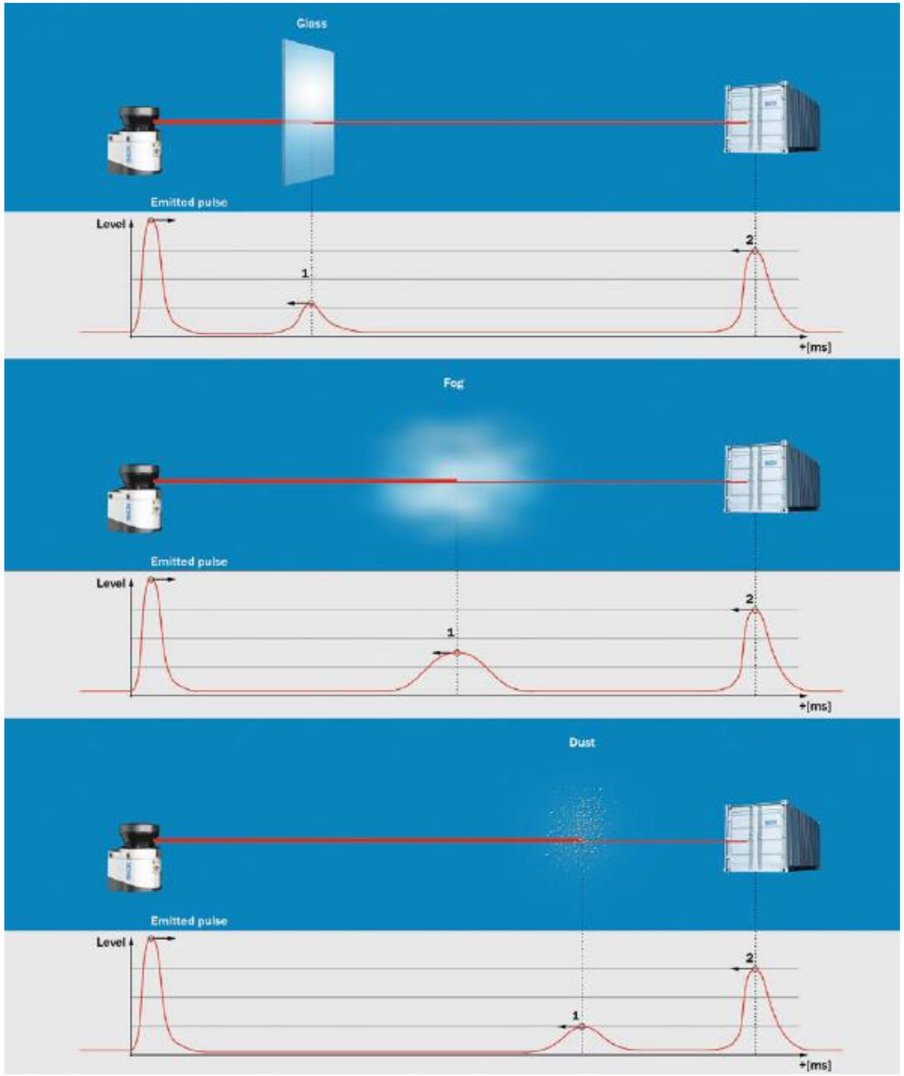
- One sensor can measure one reflection time and distance at once.
- Rotating the sensor can provide a point cloud.
- It is possible to rotate a mirror in front of the device



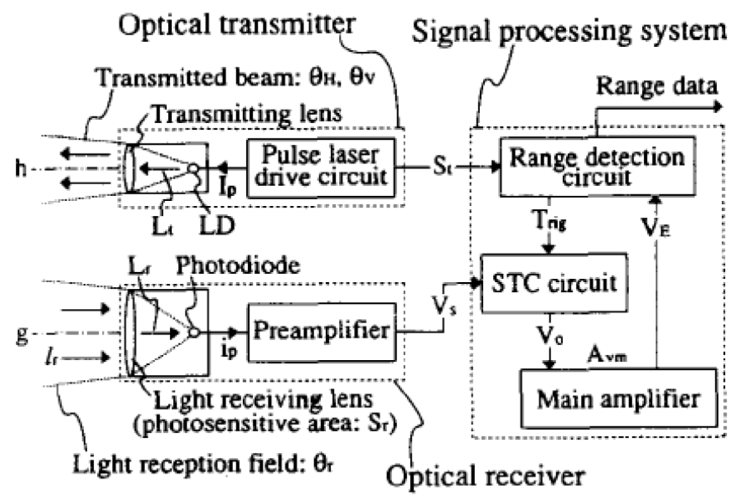
# 2D LIDAR and „multi-echo”

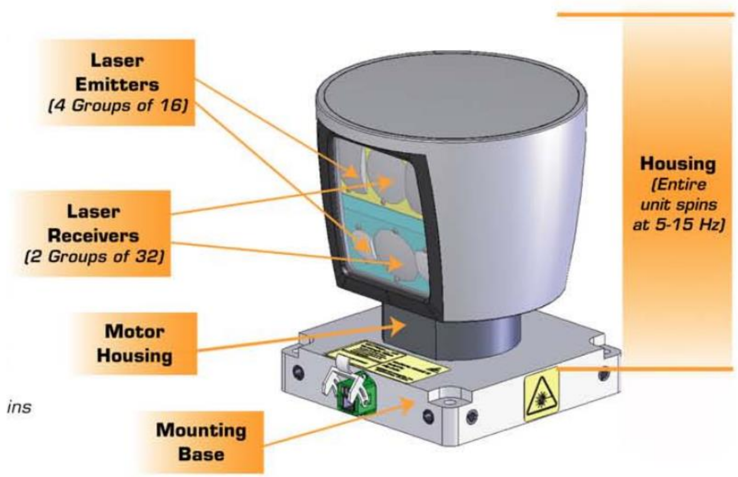




# LIDAR structure

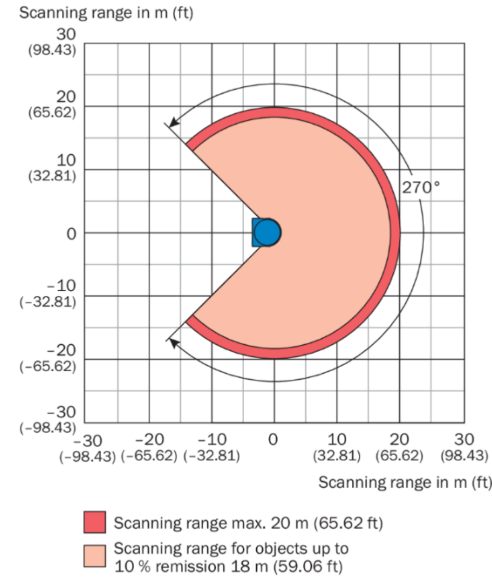
- Optical transmitter-receiver
  - Drive circuit (3-20 ns pulse)
  - Semiconductor laser or photodiode
  - Optics (polycarbonate glass, shadowing)
- Signal processing
  - STC (Sensitivity Time Control) and Main Amplifier: time proportional gain
  - Range detection circuit
- 2D LIDAR: Multiple beams or rotating mechanism
- 3D LIDAR: multiple beams and rotating mechanism
  - Multiple beams provide approx. 10 deg. cone

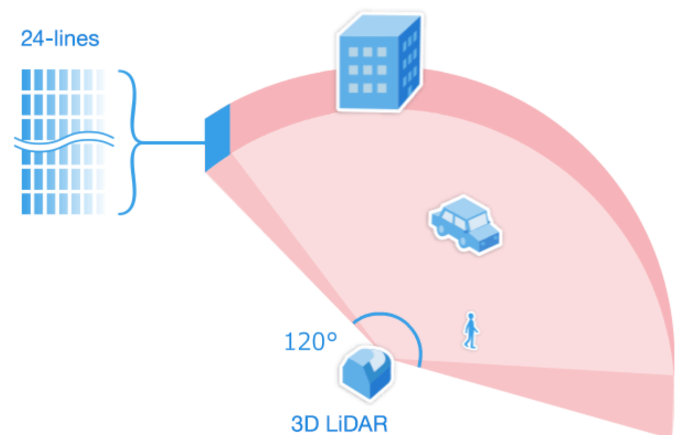


# Lidar specifications

- 2D
  - Angle
  - Range: function of remission
  - Scanning frequency: whole scans per seconds
  - Angular resolution
  - Working range: function of remission
  - Accuracy
- 3D
  - Vertical and horizontal FoV
  - Range
  - Number of channels: number of laser beams that cover the vertical field of view
  - Angular resolution: vertical FoV divided by no. of channels gives the vertical resolution
  - Rotation rate
  - Accuracy

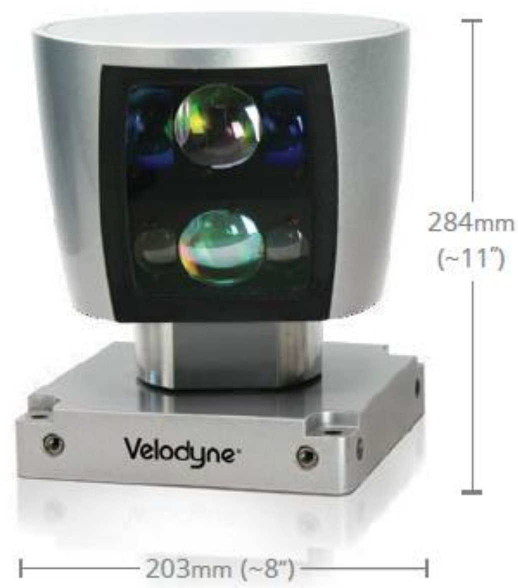


# Vehicular LIDARs I.

- Velodyne VLP-16 (Puck Lite) vs. HDL-32
  - $4000 vs. $29 999
  - Dual Returns
  - 830g (590g) vs. 1000g
  - 16 vs. 32 channel
  - 100m distance
  - 3cm vs. 2cm accuracy
  - 300 000 vs 600 000 points/sec
  - 360° horizontal angle
  - ± 15° vs ± 20° vertical angle

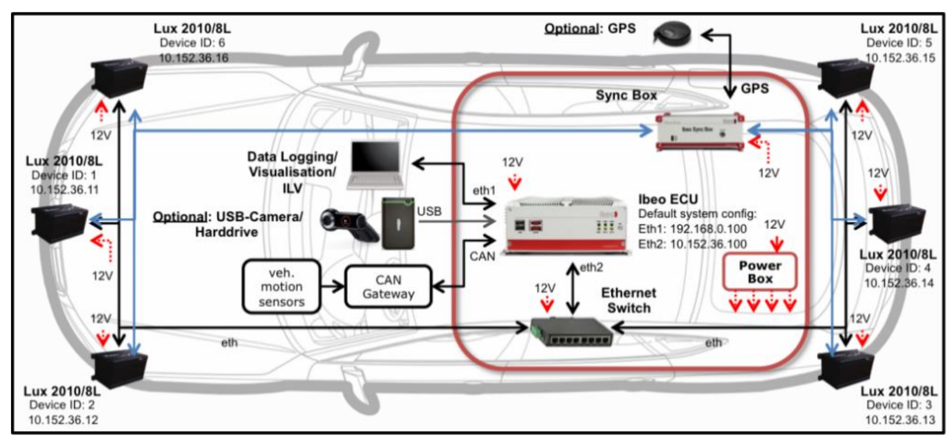




# Vehicular LIDARs II.

- Ibeo LUX family
  - 3 type 3D and 1 type 2D
  - 120-200m range
  - +50° - -60° horizontal viewing angle
  - 3.2 ° and 6.4 ° vertical viewing angle
  - 4 or 8 channels
  - 25 or 50 Hz sampling
  - 10 cm accuracy
  - Max. 65 object tracking and classification


- Ibeo Reference sensor system
  - 6 Ibeo LUX around the vehicle
  - 1 SICK LMS 500 for road scanning
  - Central Unit
  - Camera
  - GPS



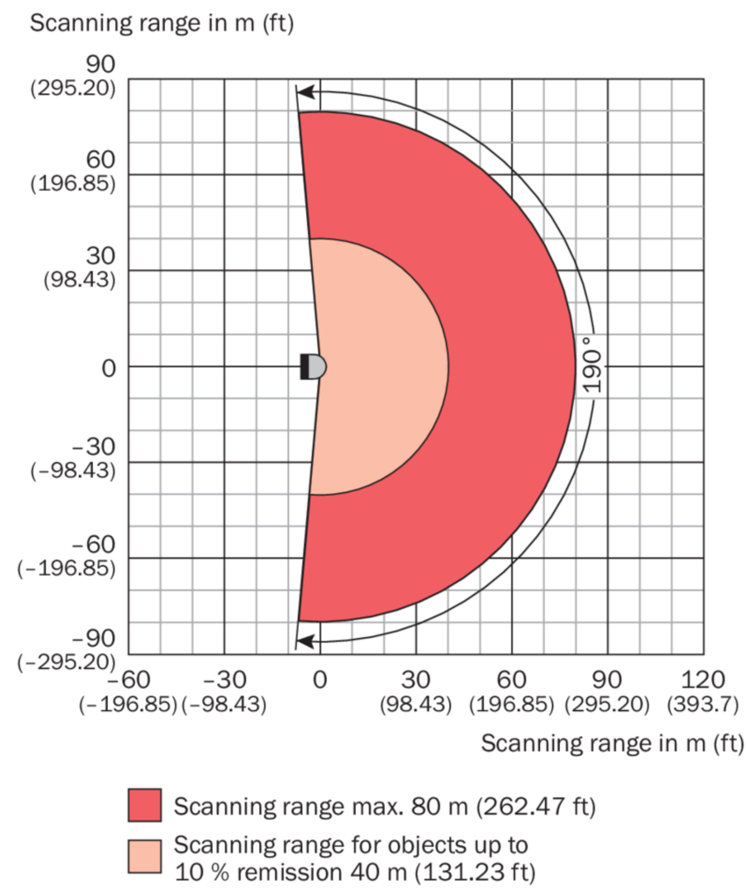
# Vehicular LIDARs III.

- Blackmore
  - Prototype FMCW lidar
  - 120x30 ° angle of view
  - 450m range
  - Calculates velocity information from Doppler shift
  - It has not released yet.
- Hokuyo, SICK
  - Professional solutions
  - For logistics and manufacturing
  - Some products are eligible for automotive use


# Special lidar example

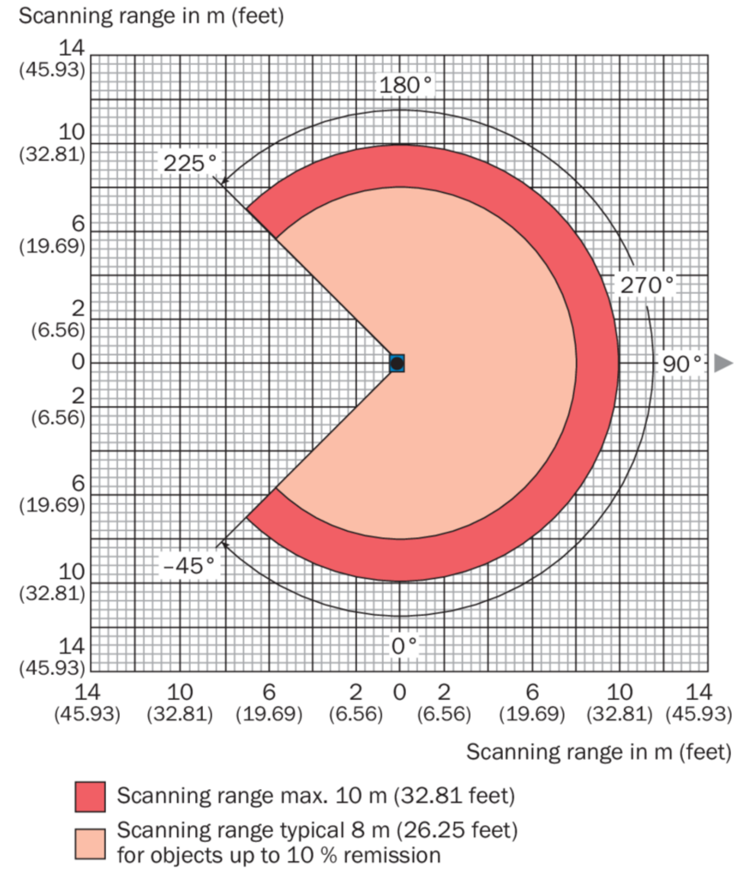
# SICK LMS511

- 2D professional outdoor lidar
- Angle: 190°
- Scanning frequency: 25 Hz / 35 Hz / 50 Hz / 75 Hz / 100 Hz
- Angular resolution: 0.167° / 0.25° / 0.333° / 0.5° / 0.667° / 1°
- Range: 80 m
- Interfaces: Ethernet, CAN, Serial, USB
- Multi-echo (max. 5 evaluated echoes)
- Filtering capabilities
- Approx. 6000 EUR



# SICK TIM551

- 2D outdoor lidar
- Angle: 270°
- Scanning frequency: 15 Hz
- Angular resolution: 1°
- Range: 8 m
- Interfaces: Ethernet, USB
- Approx. 2000 EUR



# BUDAPESTI MŰSZAKI ÉS GAZDASÁGTUDOMÁNYI EGYETEM

Dr. Szilárd Aradi

*email: aradi.szilard@mail.bme.hu*

MŰEGYETEM 1782

## Thank you for your attention!