

DVN Lidar Workshop – LiDAR Interference

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Frankfurt, September 2022



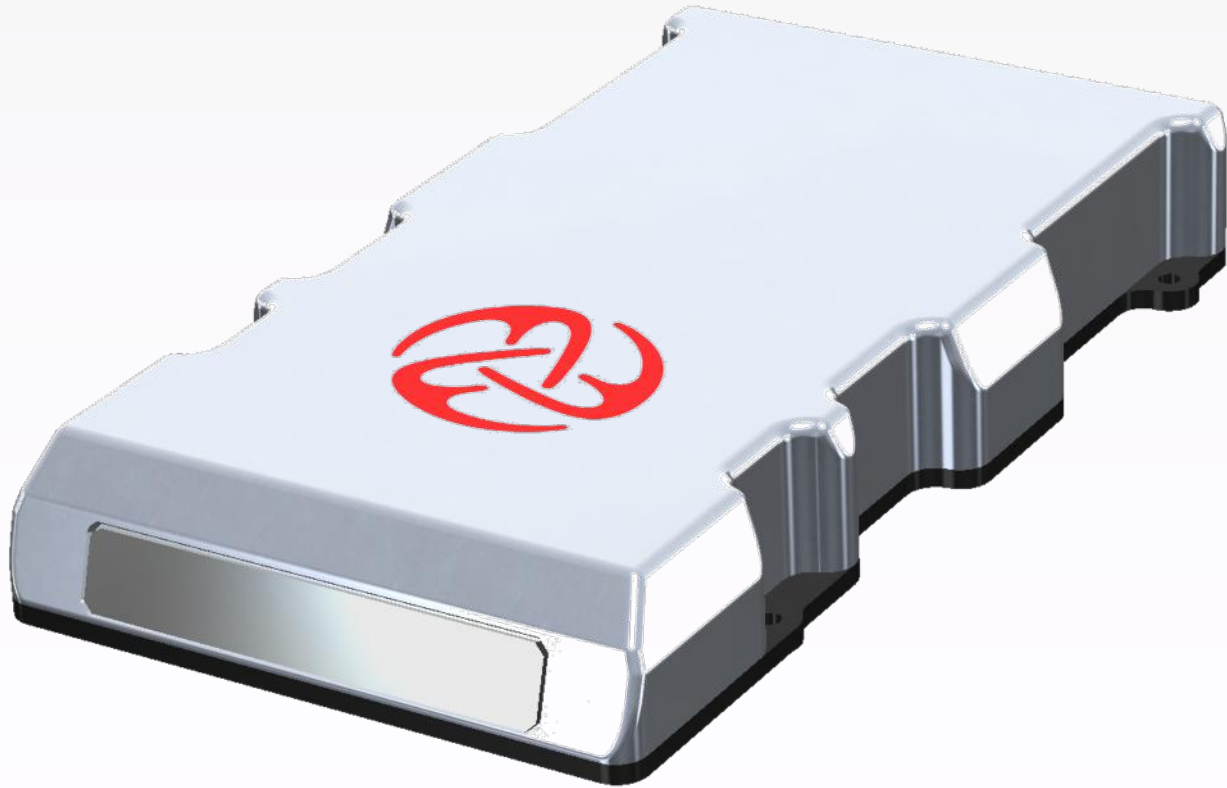


Increasing numbers of LiDAR sensors requires advanced interference mitigation



Agenda

- Basics of LiDAR interference
- LiDAR architectures and interference susceptibility
- Mitigation methods for interference



Basics of LiDAR interference

In signal detection,

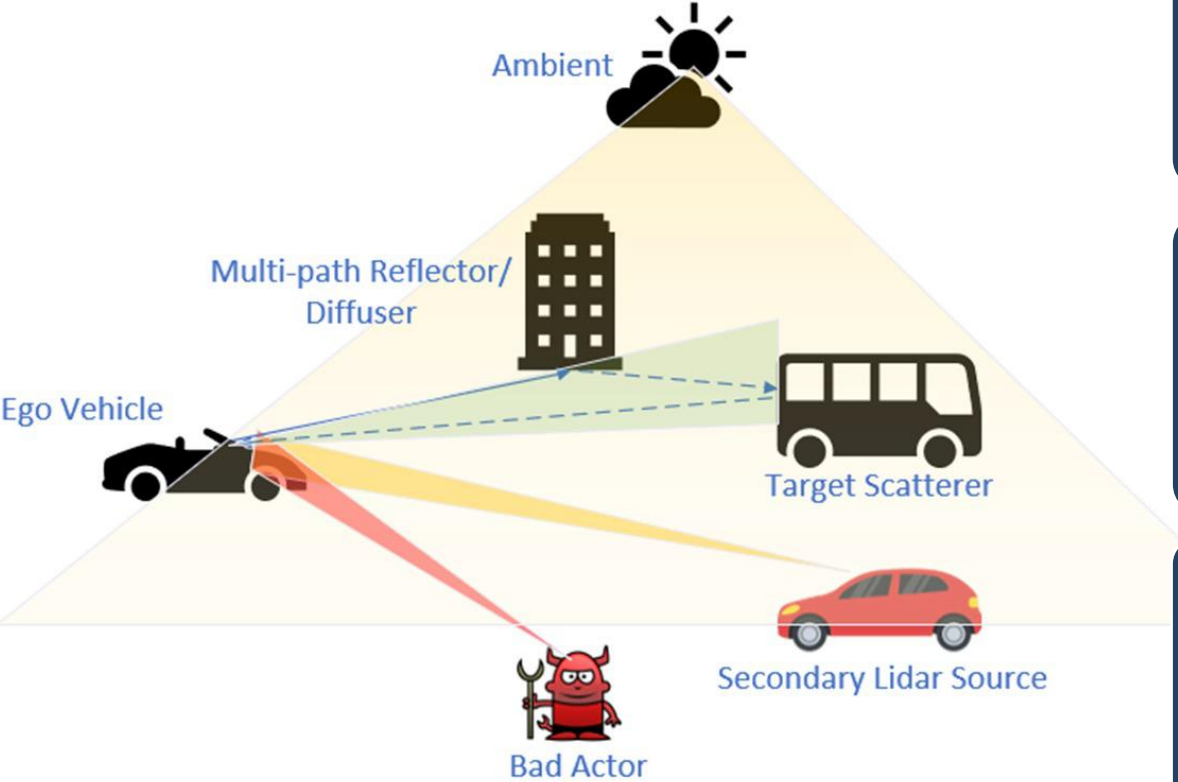
- Interference is the undesired reception of signals that distort, interrupt, or prevent the reception of a desired signal
- i.e. all effects compromising the integrity of the detected range signal

Main effects

- Increased noise floor and reduced Signal to Noise ratio (SNR)
- Missing points or areas in point cloud
- Reduced or incorrect range value
- Reduced spatial resolution
- Ghost range artifacts



Interference Taxonomy



LiDAR interference

Direct

Indirect
(scattering)

Other
LiDAR
sources

LiDAR
spoofing

Ambient
(solar
radiation)

Diffuse
or
specular
in-band
reflection

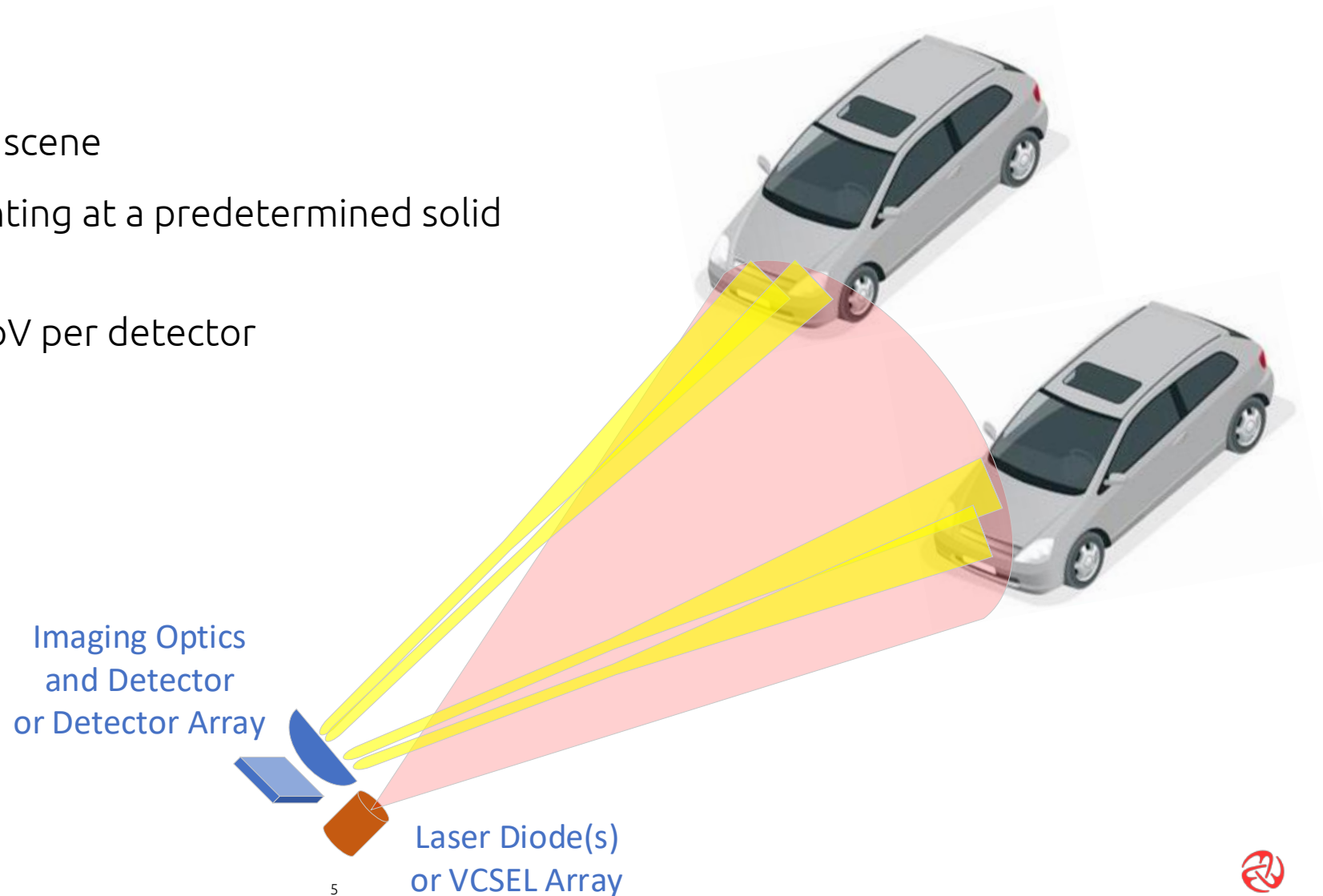
Multi-
path
reflection



LiDAR Architecture and Interference

Flash LiDAR

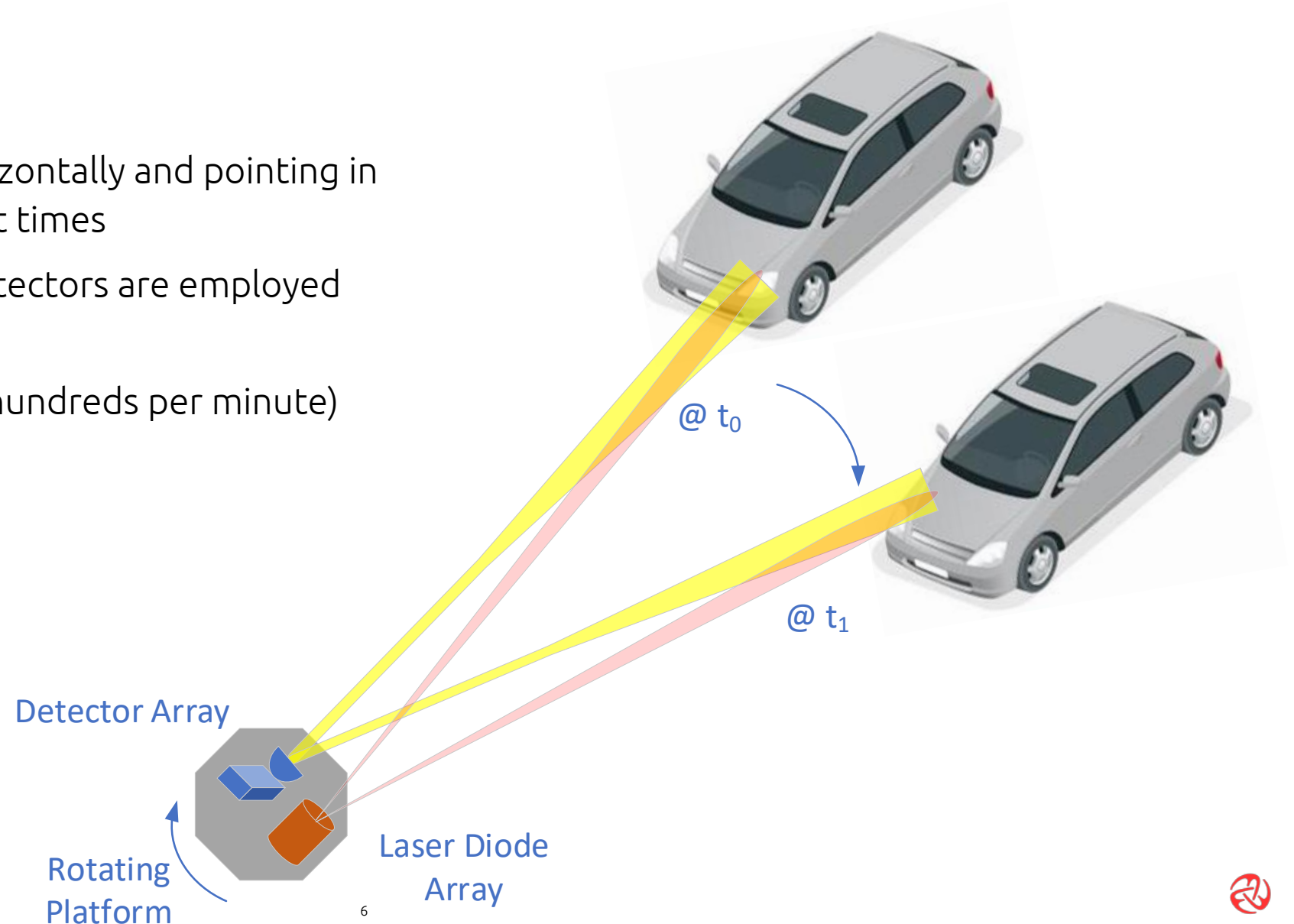
- Laser pulse illuminates complete scene
- Array of detectors with each pointing at a predetermined solid angle in space
- Limited # of detectors -> large FoV per detector



LiDAR Architecture and Interference

Spinning LiDAR

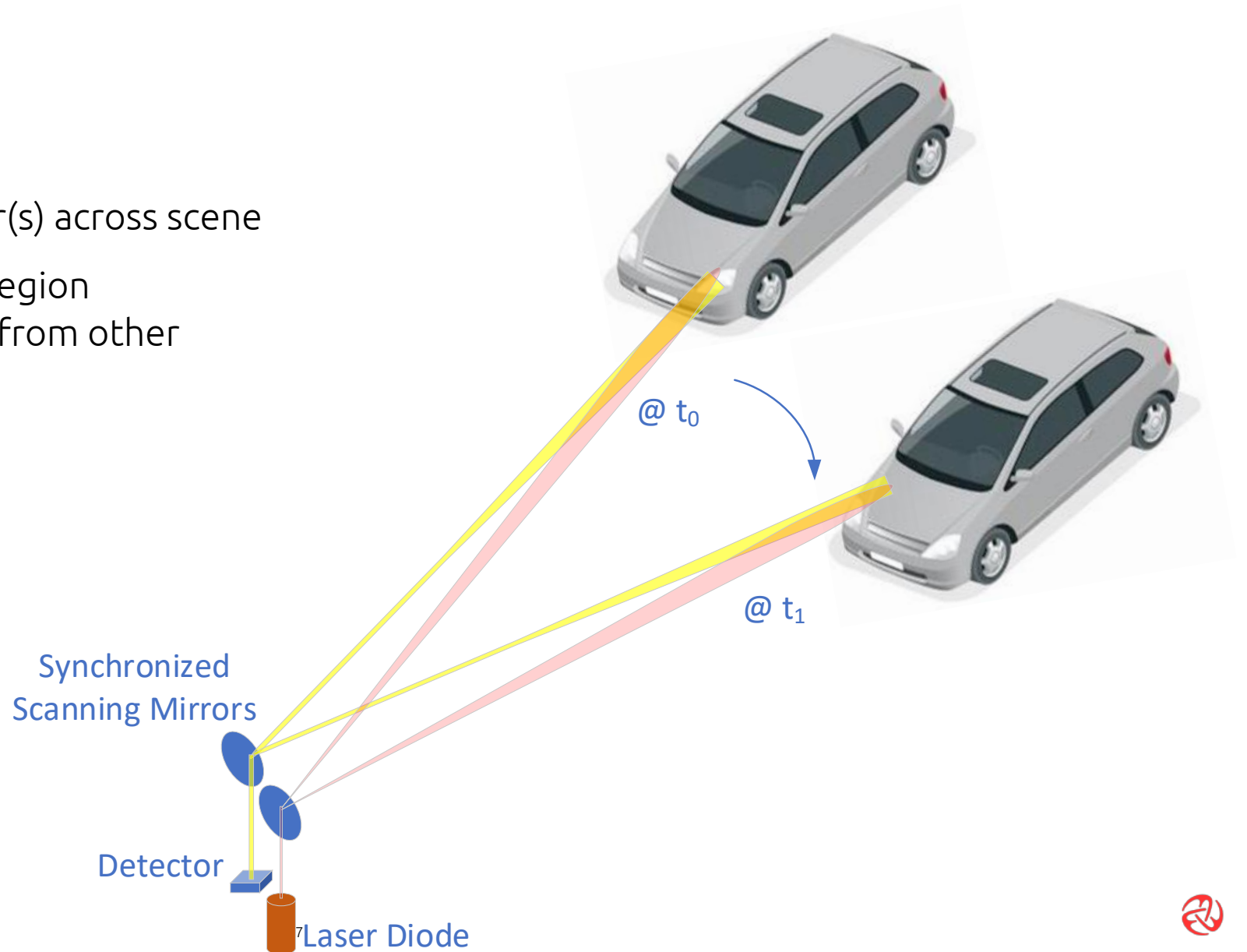
- Laser and detector rotate horizontally and pointing in the same direction at different times
- In vertical direction several detectors are employed (similar to flash LiDAR)
- High rotating speed needed (hundreds per minute)



Lidar Architecture and Interference

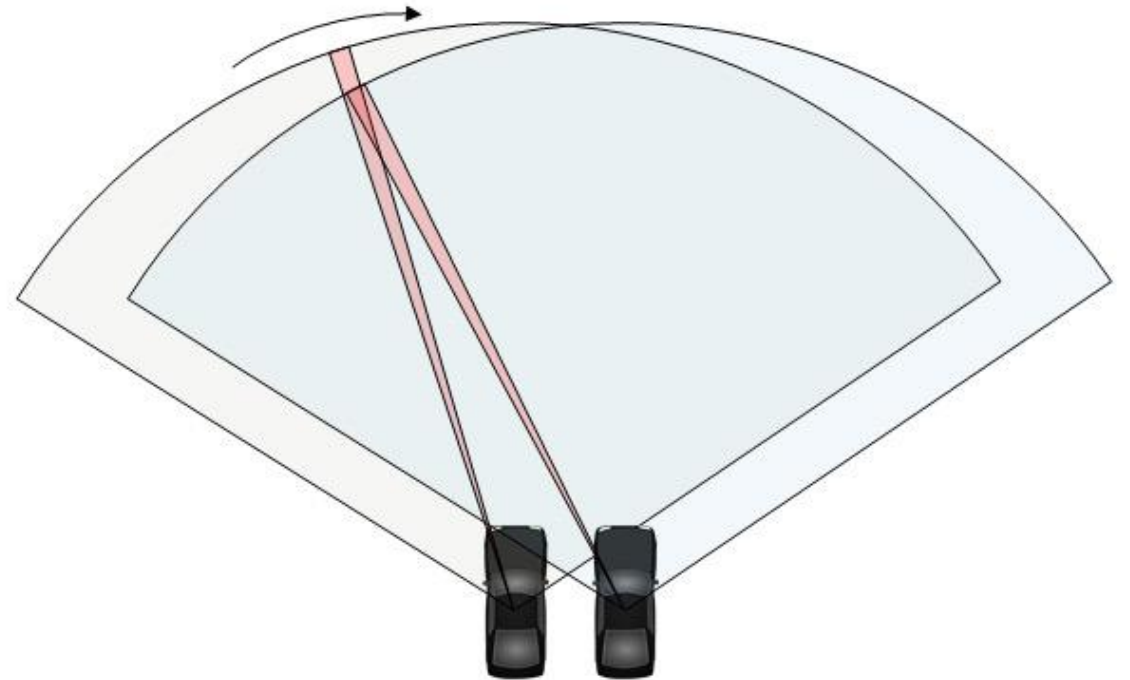
Scanning Lidar

- Laser is scanned by movable mirror(s) across scene
- Detector receives light only from region illuminated by scanned laser; light from other areas is blocked



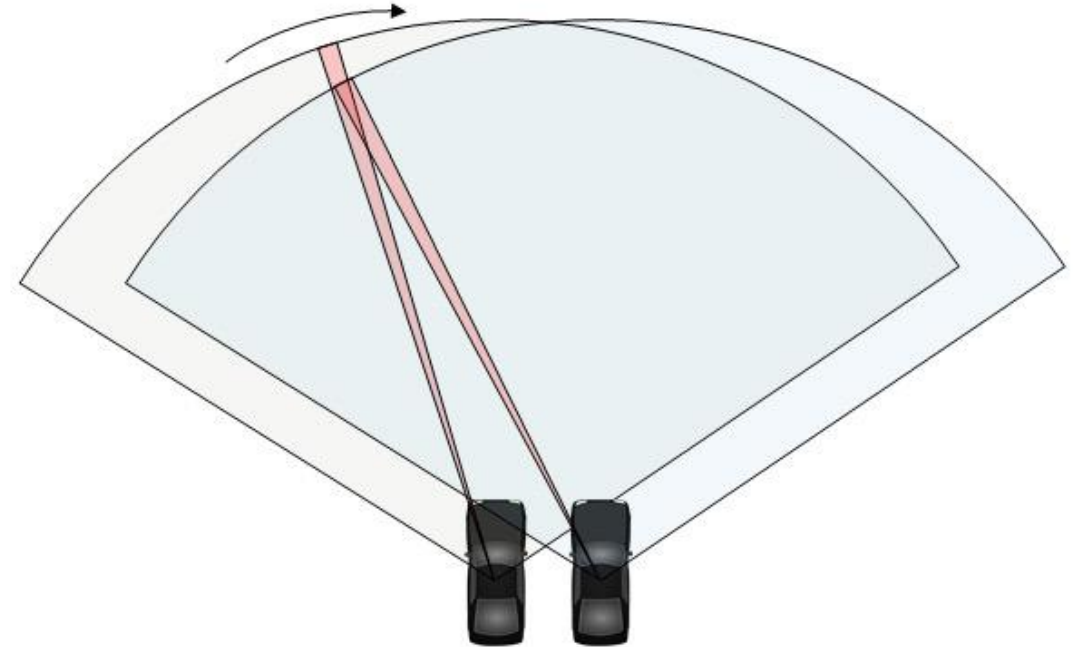
Interference by Adjacent Vehicle

- Identical sensor systems will interfere with each other at multiple distances and angles in the shared FOV
- Non-identical sensor systems will still inject noise into each other as they are in-band optical systems (i.e., spectral/wavelength overlap)



Interference by Adjacent Vehicle – Mitigation

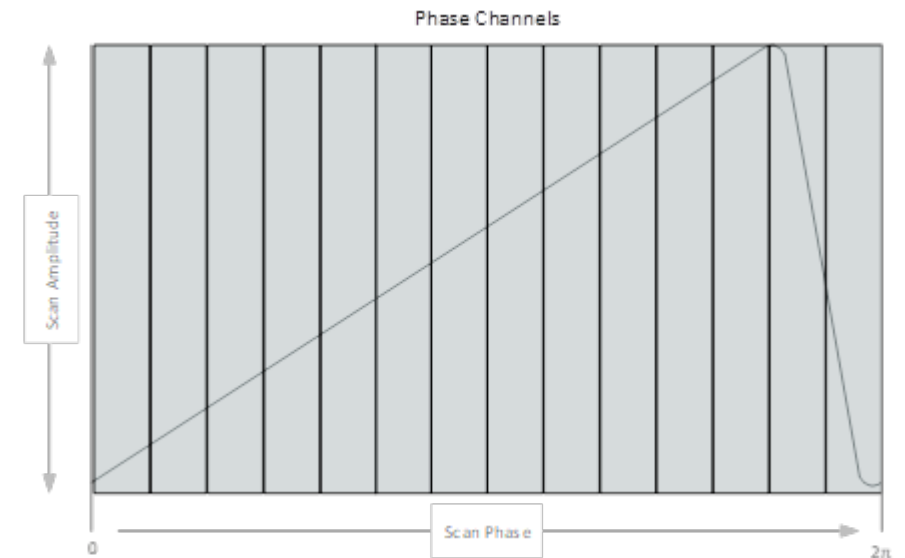
- Staring receivers (large FOV) looking at the entire scene are more susceptible
 - > reducing of FOV of receivers
- Large aperture transmitters light up large areas in the FOV and result in a raised noise / lower SNR
 - > reducing of FOV of transmitters
- For spinning systems, the rotation plane should not be horizontally, but should be tilted to avoid continuous interference
- For scanning systems where both transmitter and receiver are scanning, continuous interference is statistically improbable or low (but needs to be considered)



Interference by Adjacent Vehicle – Mitigation

Continuous Interference Detection

- If continuous interference pattern is detected on a particular phase channel (a “collision”), a collision resolution action is performed (e.g. similar to a CSMA carrier-sense multiple access scheme in WiFi).
- The interference pattern may be resolved by changing (randomly) the phase of the scan to avoid overlap.

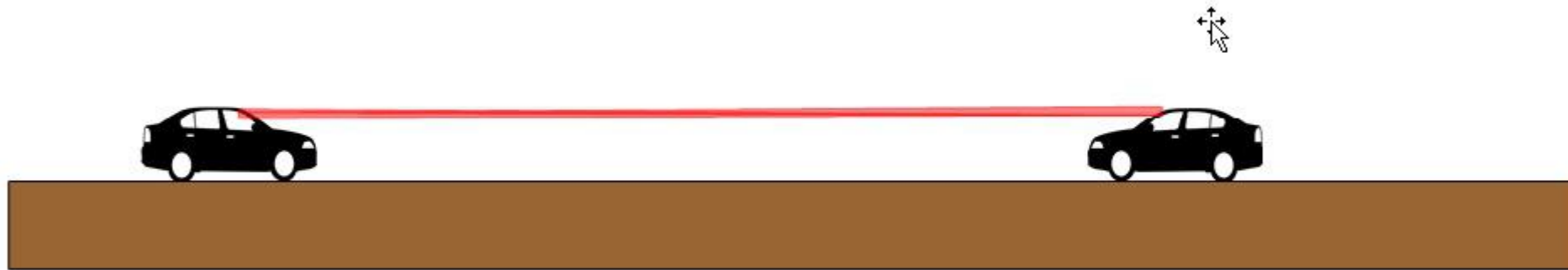


Phase Slots for Time Division Interference Avoidance Scheduling



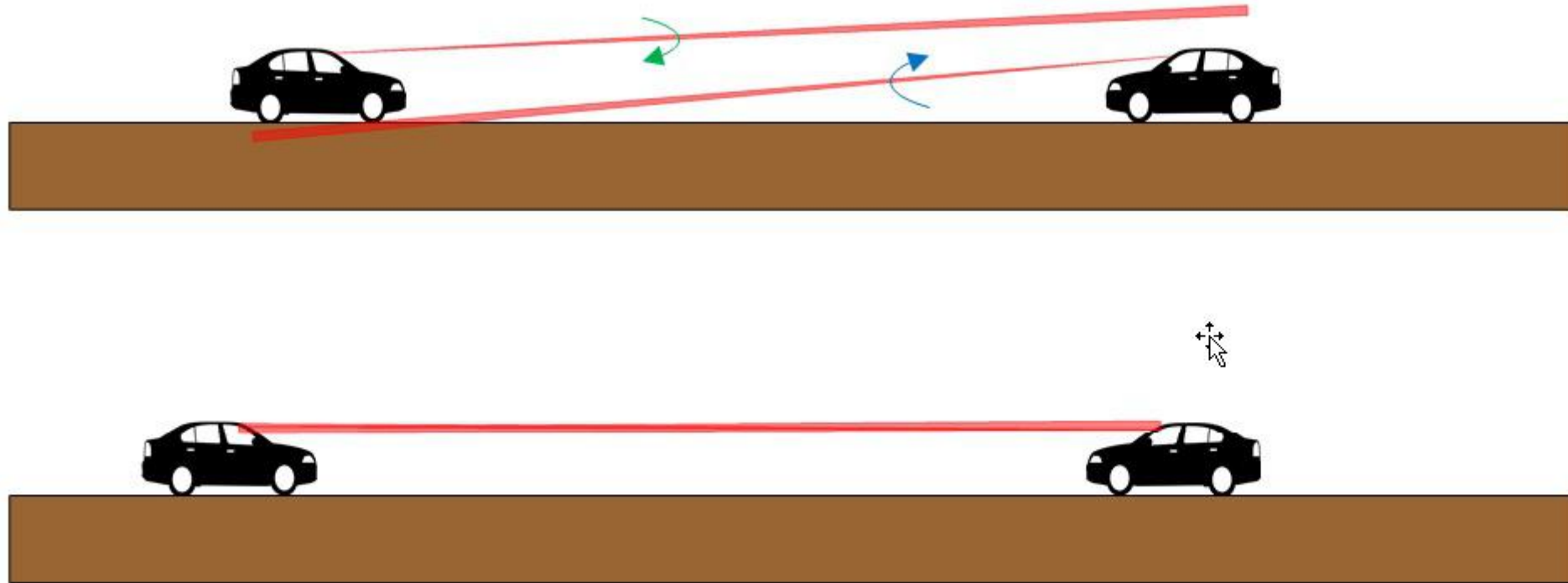
Interference by oncoming vehicle

- Opposing sensors can increase the noise floor in each other to the point that large portions of the range point cloud is garbage or has random unusable artifacts



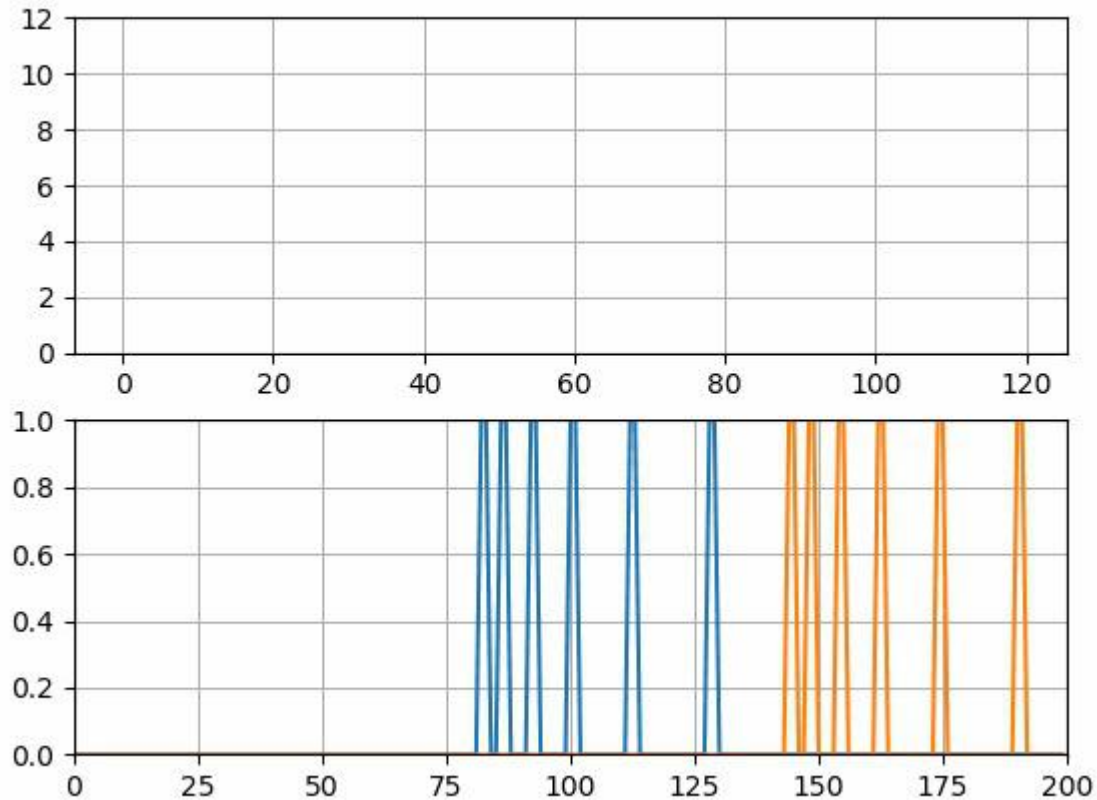
Interference by oncoming vehicle - mitigation

- Direct line of sight interference is statistically highly unlikely with scanned receiver systems
- Chief mitigation techniques can include codification of the transmitted pulses/flushes and corresponding filtering on the detector-end



Interference mitigation

Encoding of Laser Pulses and Use of Matched Output Filter Response to RX Signal



Ideal Matched Filter Demonstration

Matched Filter

- Commonly used in radar: known signal is sent out, the reflected signal is analyzed for common elements of the out-going signal
- Optimal linear filter for maximizing the signal-to-noise ratio (SNR) in the presence of additive stochastic noise



Interference by ambient light

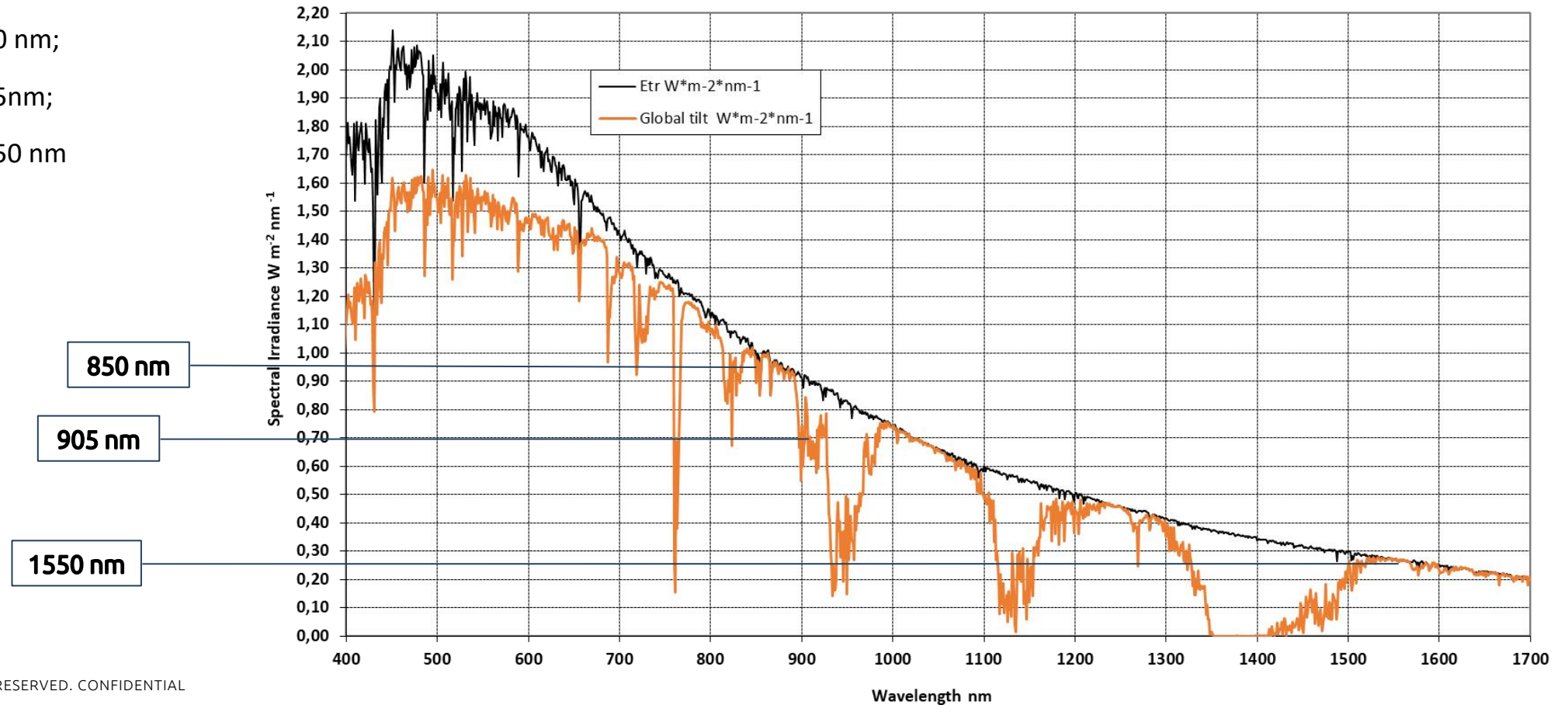
- Increased noise by strong ambient light irradiance
- Present for all relevant wavelengths
- Irradiance varies between

0,96 $\text{Wm}^{-2}\text{nm}^{-1}$ at 850 nm;

0,70 $\text{Wm}^{-2}\text{nm}^{-1}$ at 905nm;

0,26 $\text{Wm}^{-2}\text{nm}^{-1}$ at 1550 nm

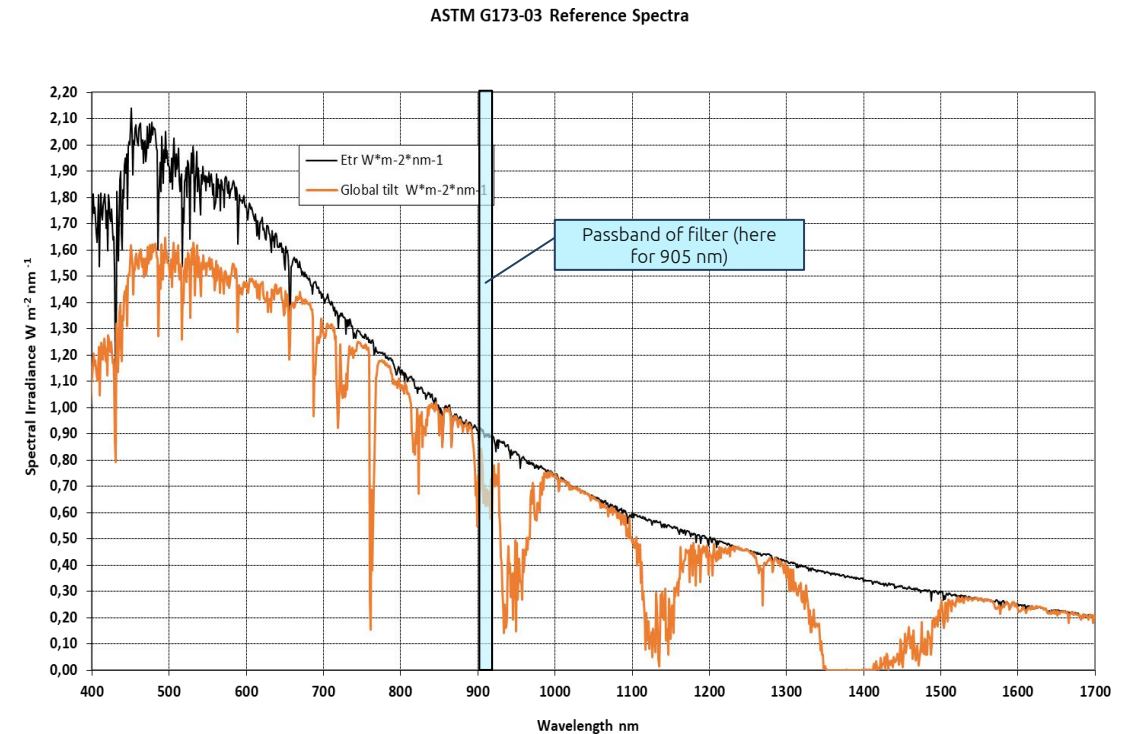
ASTM G173-03 Reference Spectra



Interference by ambient light - mitigation

Application of narrow bandpass filters

- Interference filter with full width half maximum (FWHM) as low as 0,1 nm and out-of-band blocking of -8 dB are possible
- For automotive application wide-band filters with FWHM of 25 nm and out-of-band blocking of -4 dB are more common
- Peak bandpass wavelength varies with temperature and angle of incidence and needs to be taken into account
- Wavelength shift of laser with temperature to be observed

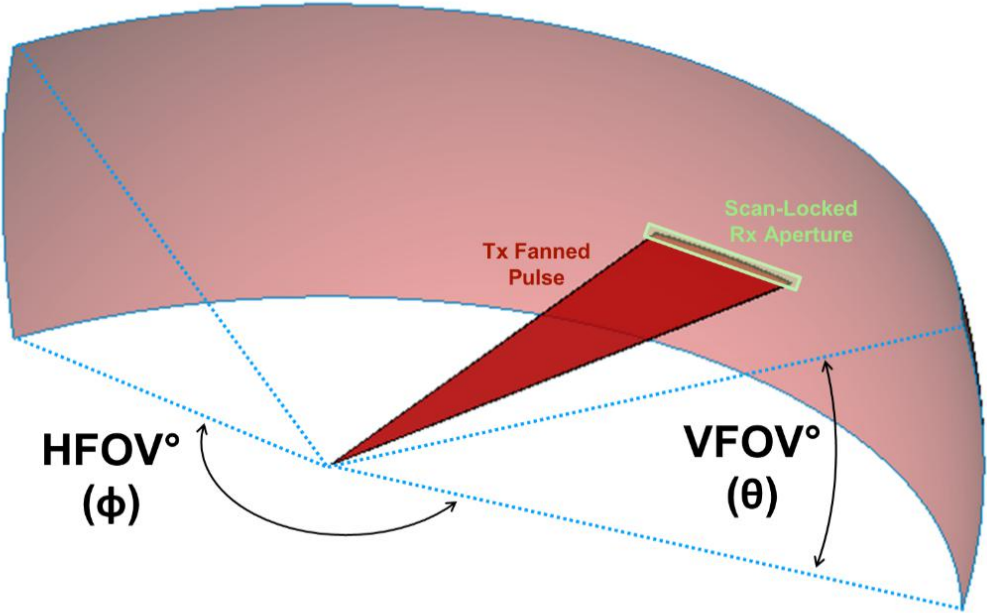


Interference by ambient light - mitigation

Reduction of RX aperture will improve drastically the SNR

Cover 0.03% of FOV with 1 fanned pulse
➔ 99.9% noise reduction

Example: scan-locked TX and RX system



Thank you!



Questions to discuss in workshop

- Is LiDAR interference a problem at all? If yes, what are the most promising interference suppression techniques?
- Which regulatory prescriptions could help most to reduce the interference by secondary LiDAR sources? Which prescriptions are most probable to occur?

