LiDAR Interference

Dr. Thomas Luce, VP Business Development

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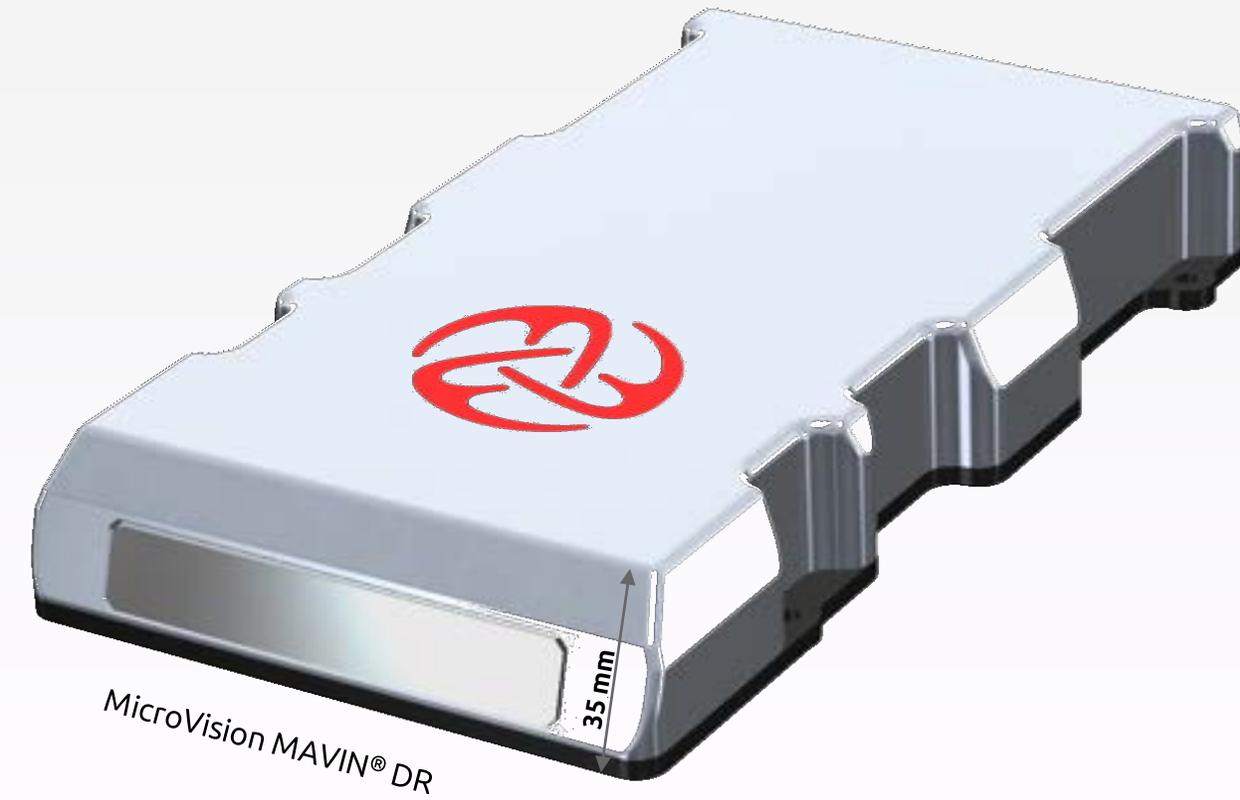
MicroVision

Increasing numbers of LiDAR sensors requires advanced interference mitigation

Agenda

MicroVision MAVIN® DR

35 mm

- Basics of LiDAR interference

- LiDAR architectures and interference susceptibility

- Mitigation methods for interference

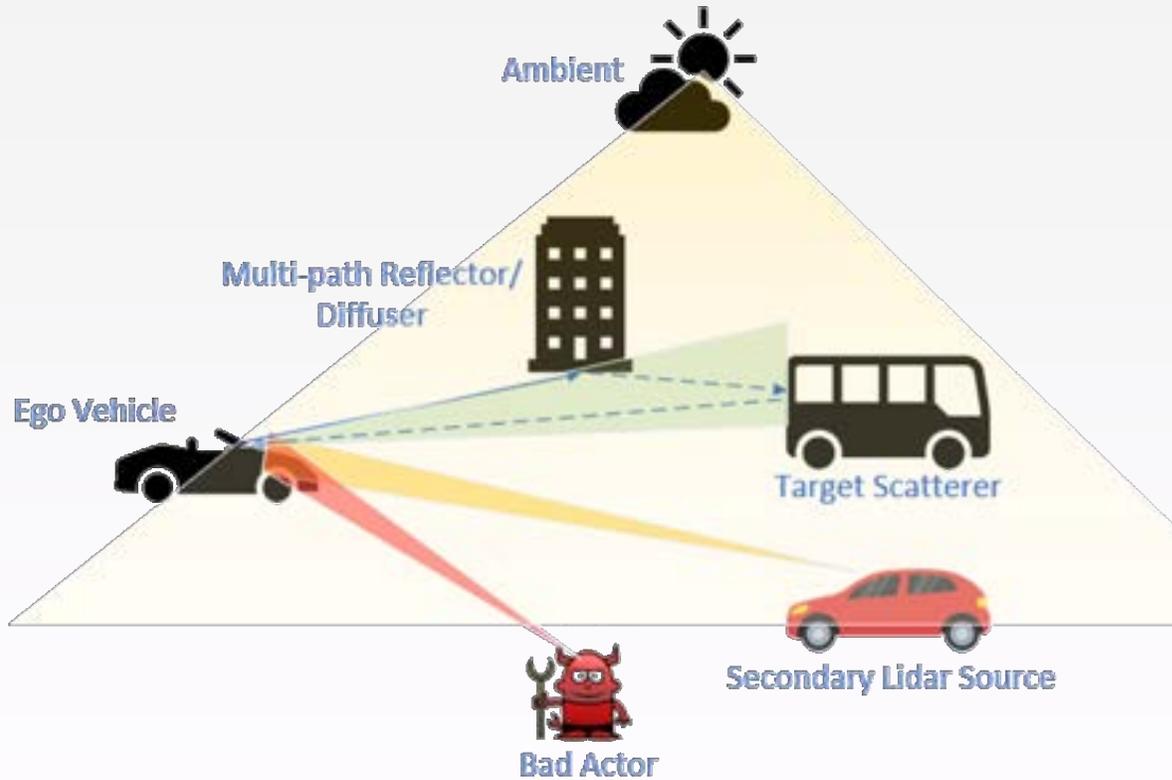# Basics of LiDAR Interference

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
- Other LiDAR sources
- LiDAR spoofing

Indirect (scattering)
- Ambient (solar radiation)
- Diffuse or specular in-band reflection
- Multi-path reflection

Diagram labels: Ambient, Multi-path Reflector/Diffuser, Ego Vehicle, Target Scatterer, Secondary Lidar Source, Bad Actor

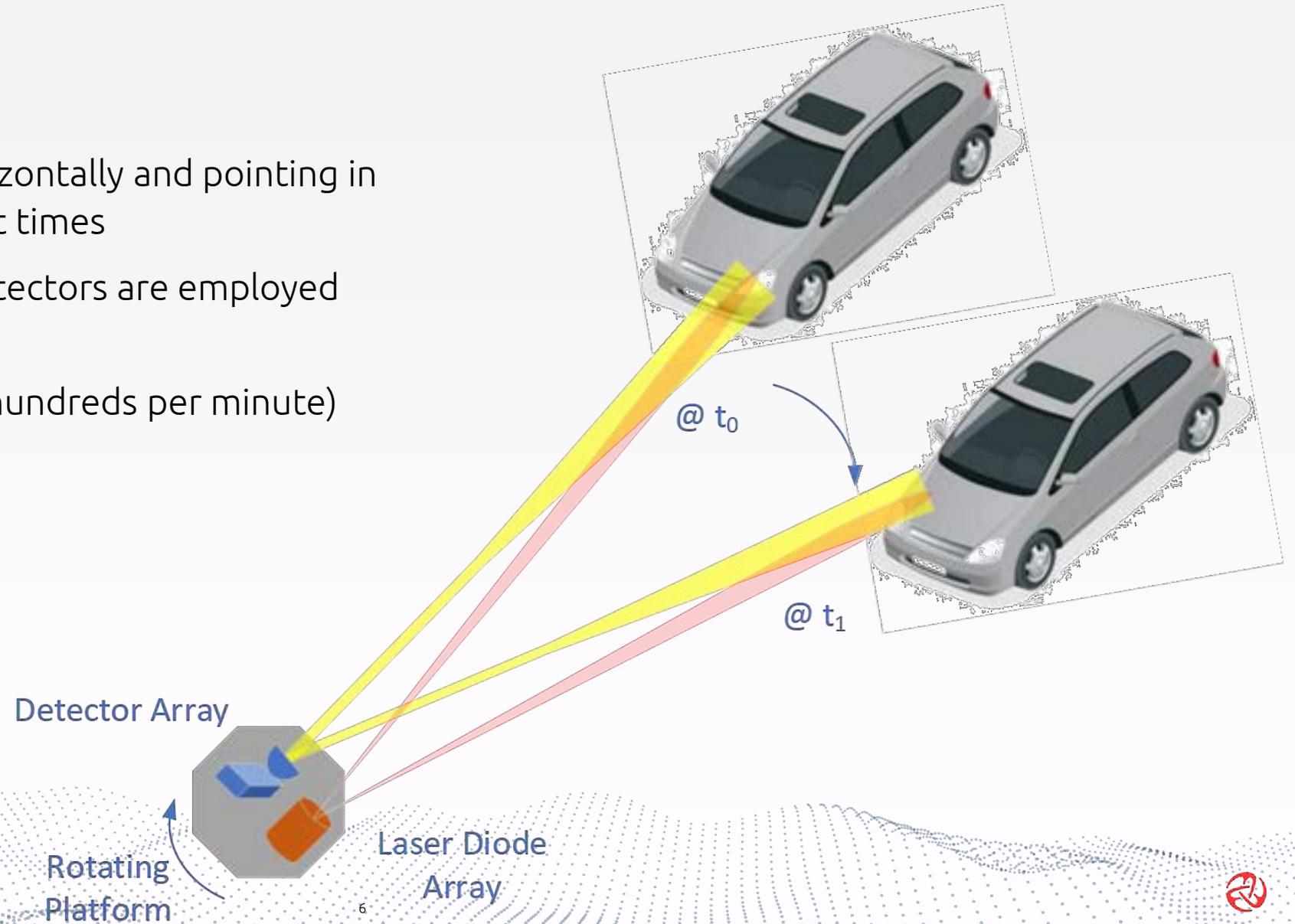# LiDAR Architecture and Interference

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

Imaging Optics
and Detector
or Detector Array

Laser Diode(s)
or VCSEL Array
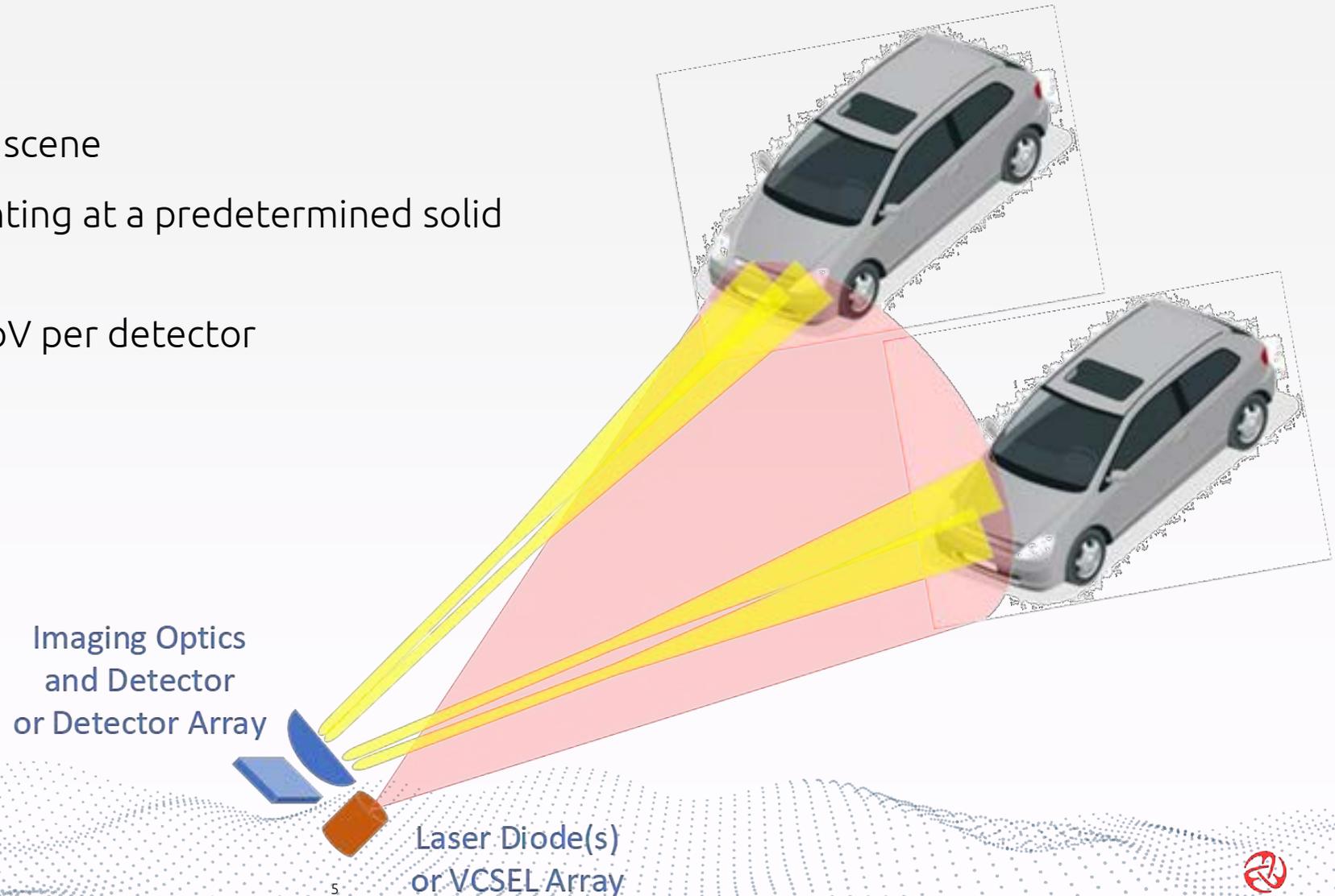
# LiDAR Architecture and Interference

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)

@ t_0

@ t_1

Detector Array

Rotating Platform

Laser Diode Array

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

@ t_0

@ t_1

Synchronized
Scanning Mirrors
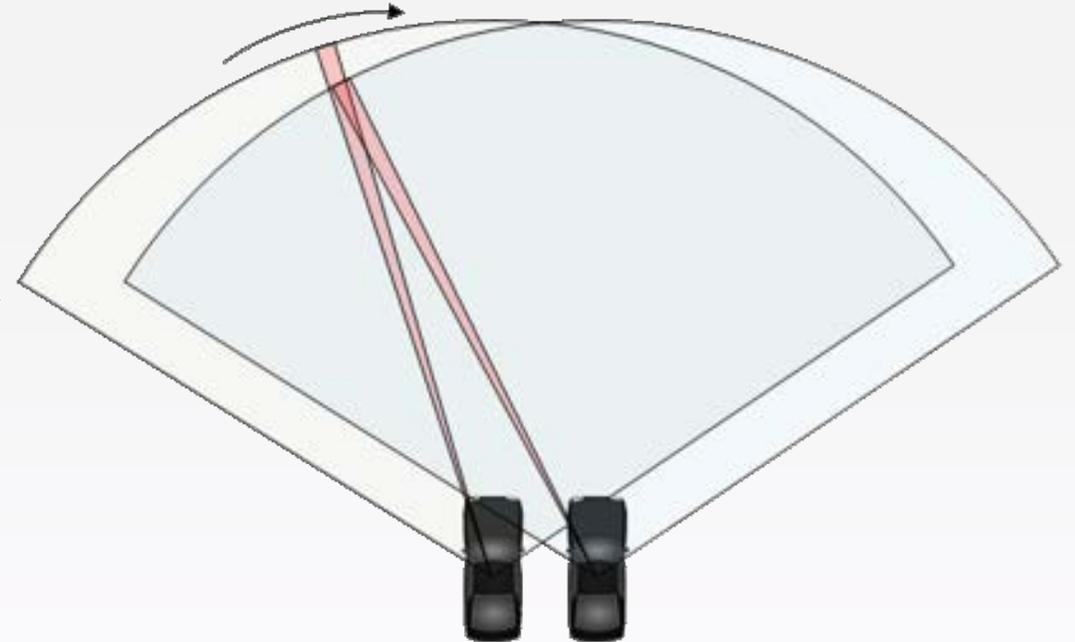
Detector

Laser Diode
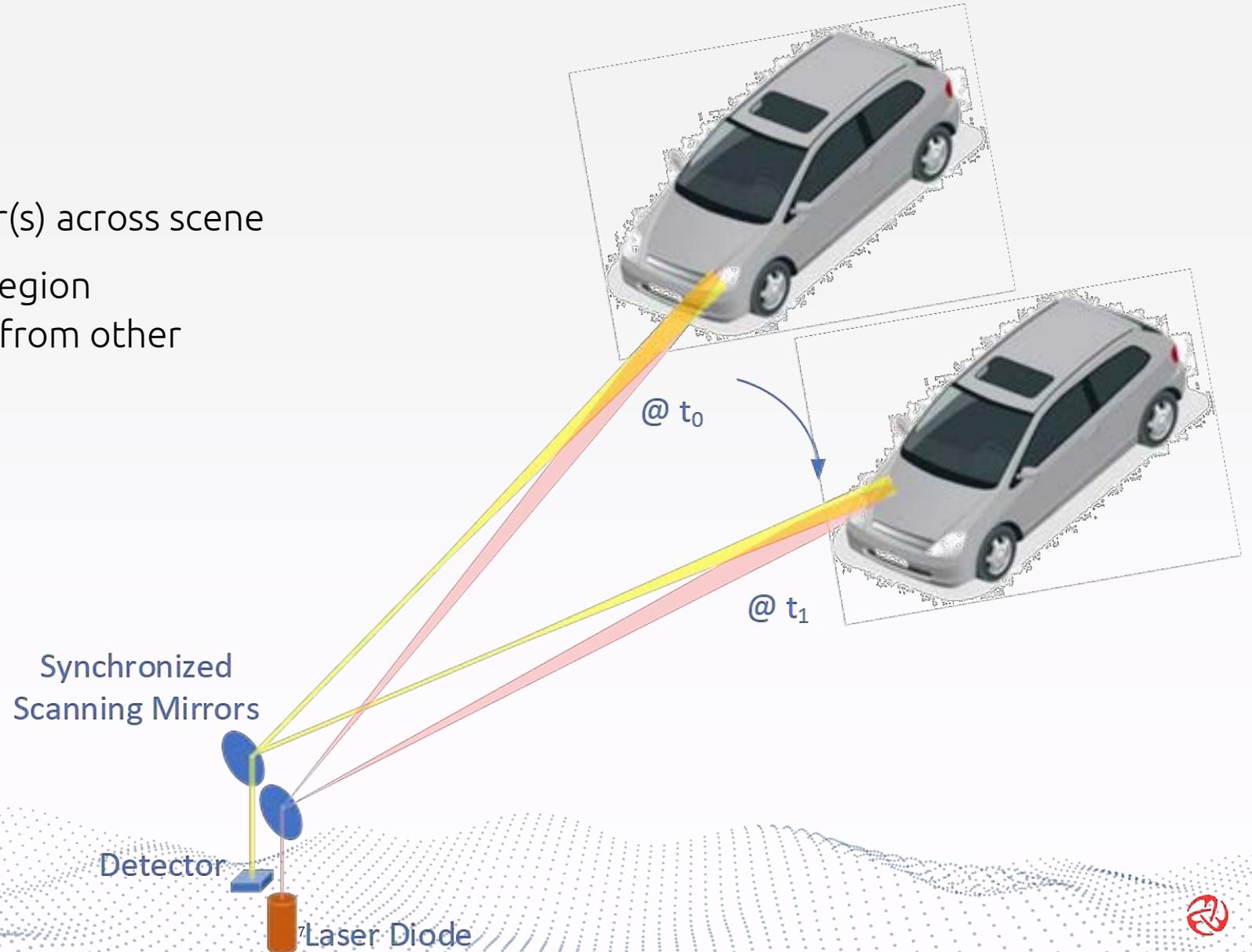
Interference by Adjacent Vehicle

- 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)
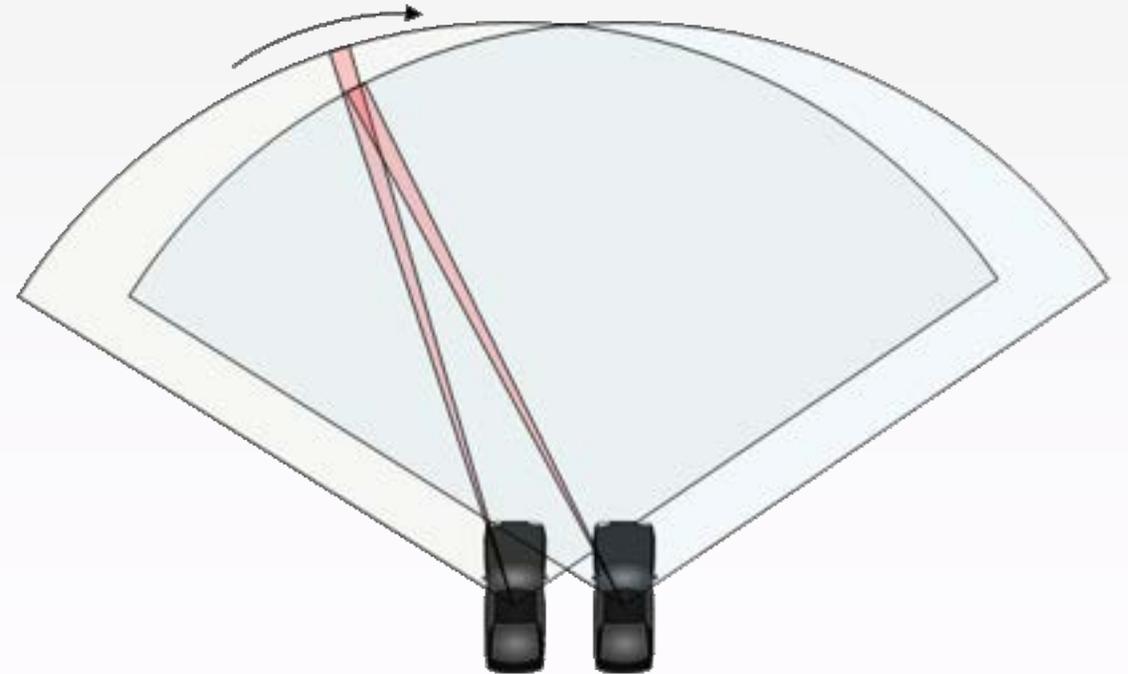
Interference by Adjacent Vehicle – Mitigation

- 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 (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.
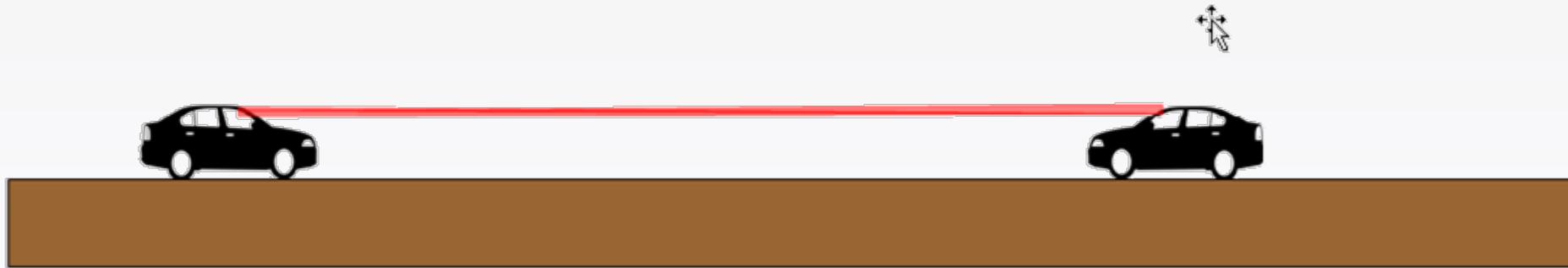

Phase Channels

Scan Amplitude

0   Scan Phase   2π
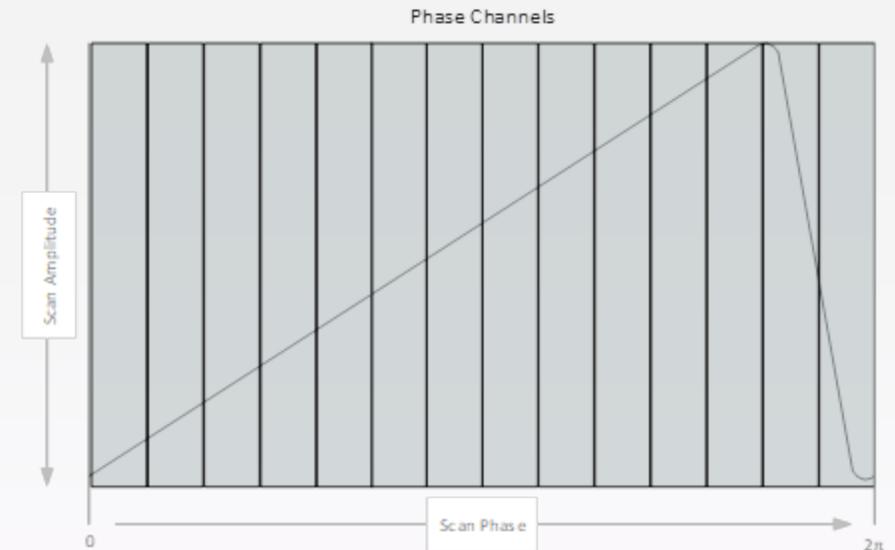
*Phase Slots for Time Division Interference Avoidance Scheduling*

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
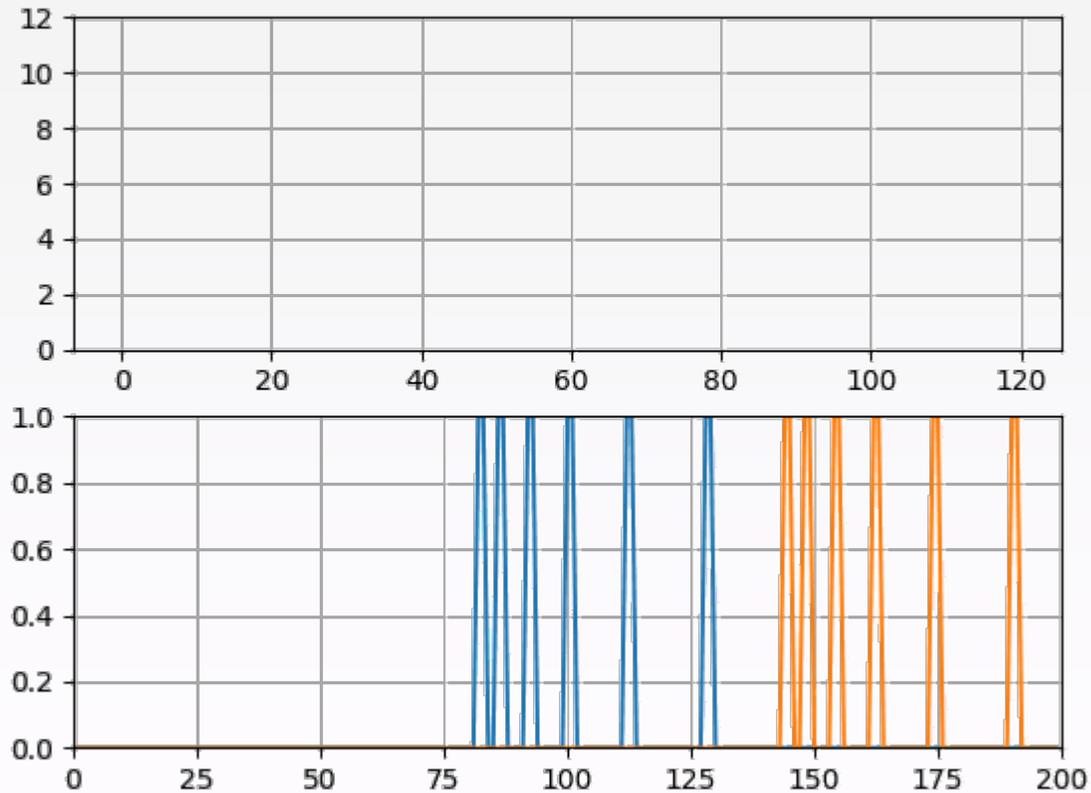
Interference by Oncoming Vehicle - Mitigation

- Direct line of sight interference is statistically highly unlikely with scanned receiver systems

- Chief mitigation techniques can include codification of the transmitted pulses/flashes and corresponding filtering on the detector-end
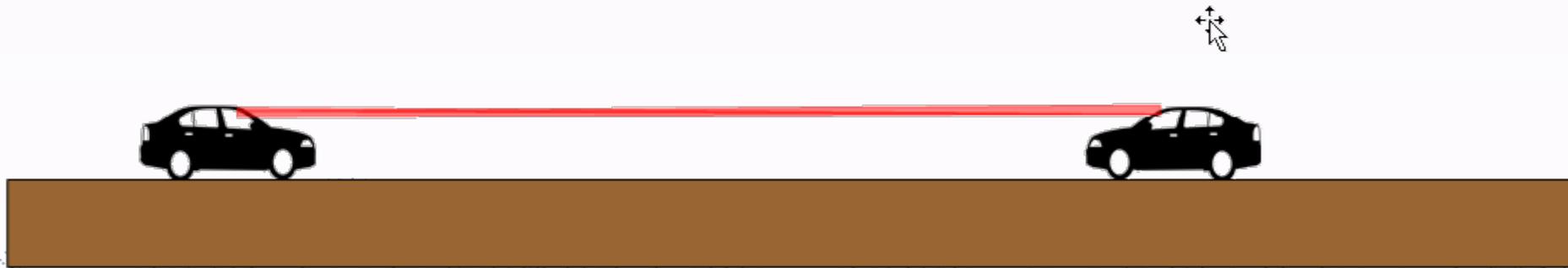
Interference Mitigation

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

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

Ideal Matched Filter Demonstration

Interference by Ambient Light

- Increased noise by strong ambient light irradiance

- Present for all relevant wavelengths

- Irradiance varies between

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

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

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

ASTM G173-03 Reference Spectra
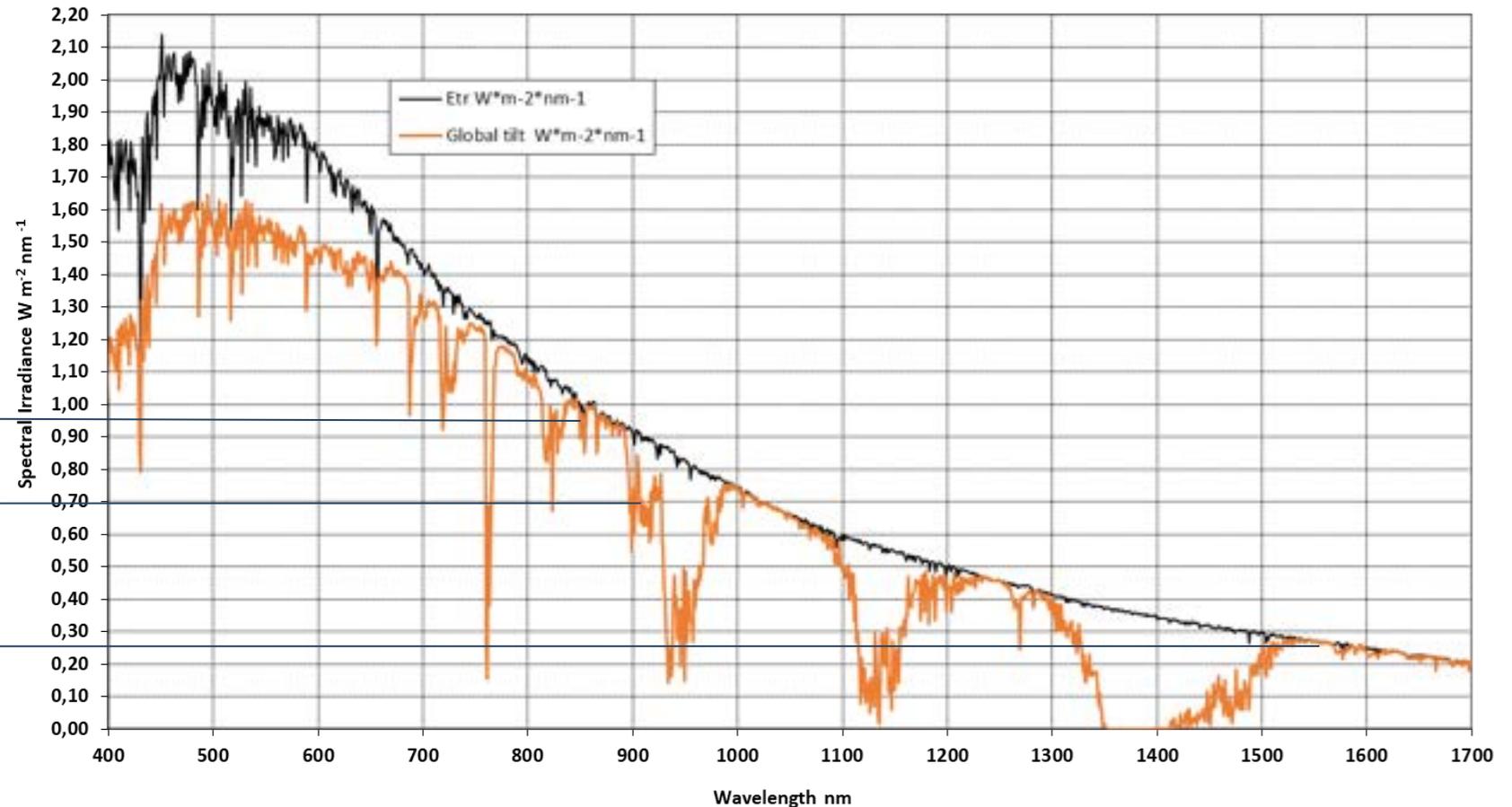
Interference by Ambient Light - Mitigation

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

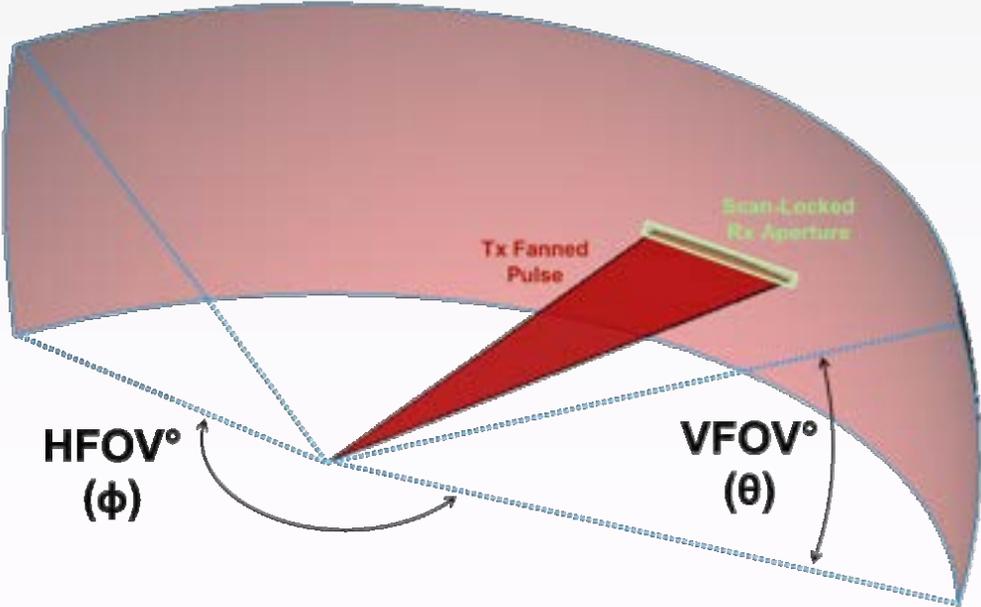- Wavelength shift of laser with temperature to be observed

ASTM G173-03 Reference Spectra

Passband of filter (here for 905 nm)
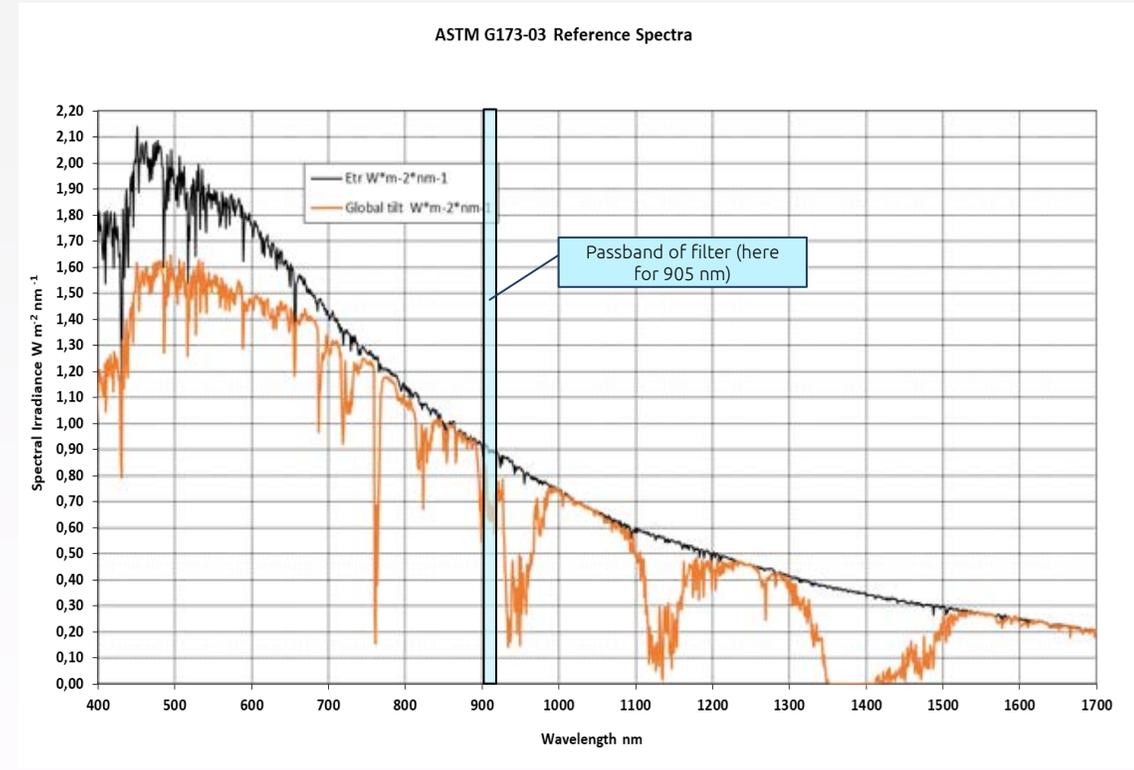
Interference by Ambient Light - Mitigation

Reduction of RX aperture will improve drastically the SNR

Example:

MicroVision scan-locked TX and RX system

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

Thank you!