Intelligent vehicles and autonomous driving

PERCEPTION SYSTEMS 2022 / 2023

Lesson 4

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RECAP

- Ultrasonic sensors
    - Time-of-flight operating principle
- Radar
    - Pulsed radar
    - Unmodulated continuous wave (UCW) radar
    - Frequency modulated continuous wave (FMCW) radar
    - FMCW radar with and without Doppler effect
    - Maximum unambiguous range & range resolution


LIDAR


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LIDAR

***LI**ght **D**etection **A**nd **R**anging*

First introduced in the 1960s in meteorology, not long after the invention of the laser itself.

Active, light-emitting sensor that assesses scene geometry and is not heavily affected by environment lighting.

Generally used to collect detailed 3D scans of the environment all around the vehicle.

SENSOR MODELS

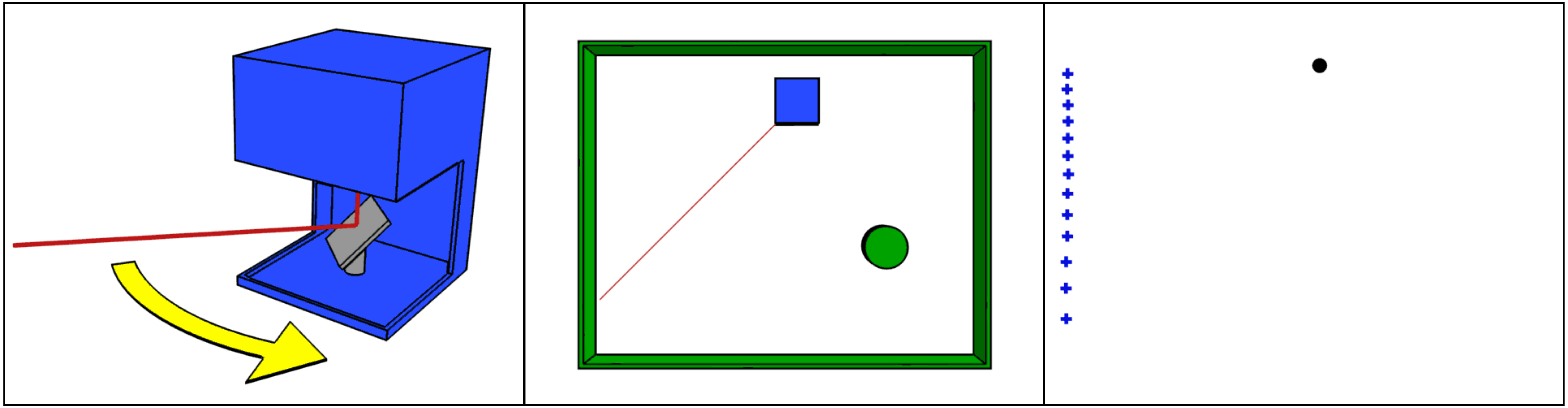
360-degree Lidar and solid-state Lidar by Velodyne

OPERATING MECHANISMS

CONVENTIONAL SCANNING LIDAR uses a laser beam that illuminates a single point at a time, and the beam is scanned to illuminate the 360-degree view point-by-point.

SOLID-STATE LIDAR has a fixed field of view and no mechanical moving parts. Some models use MEMS or optical phased arrays to steer the beams. Flash lidar models illuminate the entire FoV with a wide diverging laser beam in a single pulse.

SCANNING LIDAR



3D POINT CLOUD

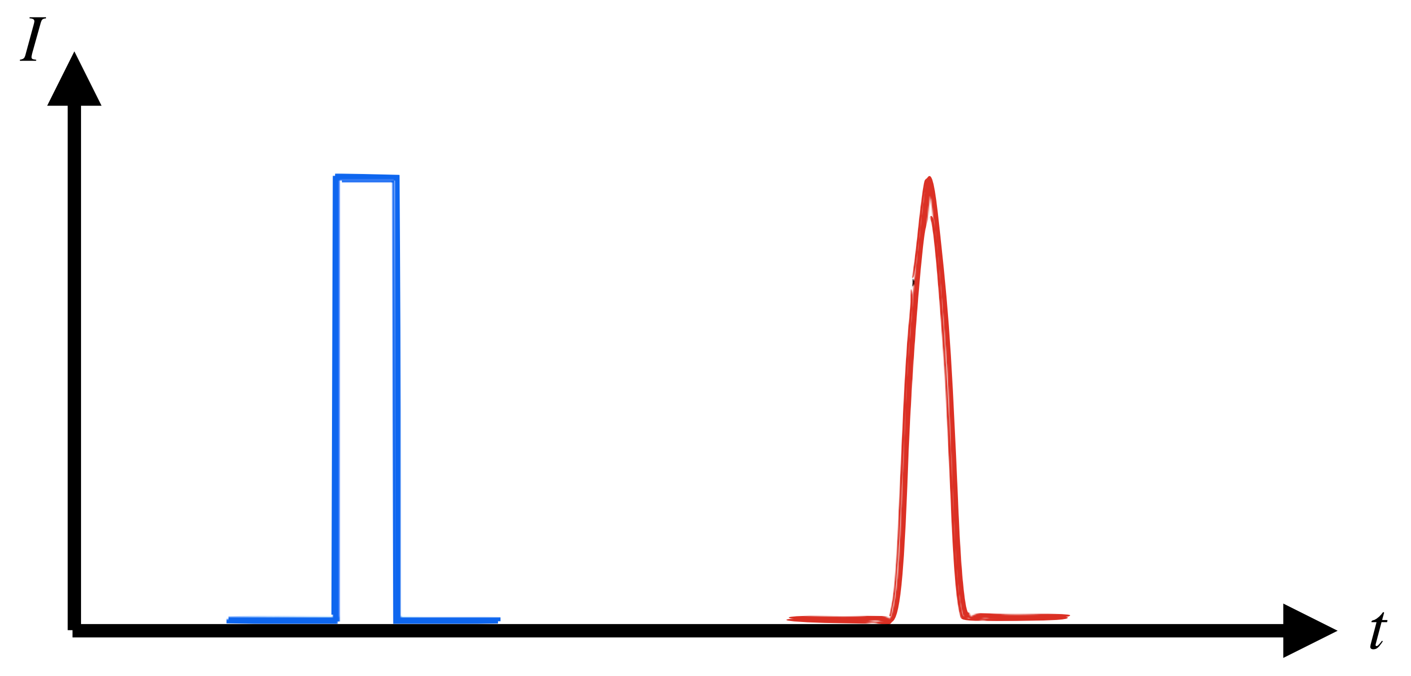
LIDAR WAVELENGTS

Two main wavelengths in automotive: 905 nm and 1550 nm.

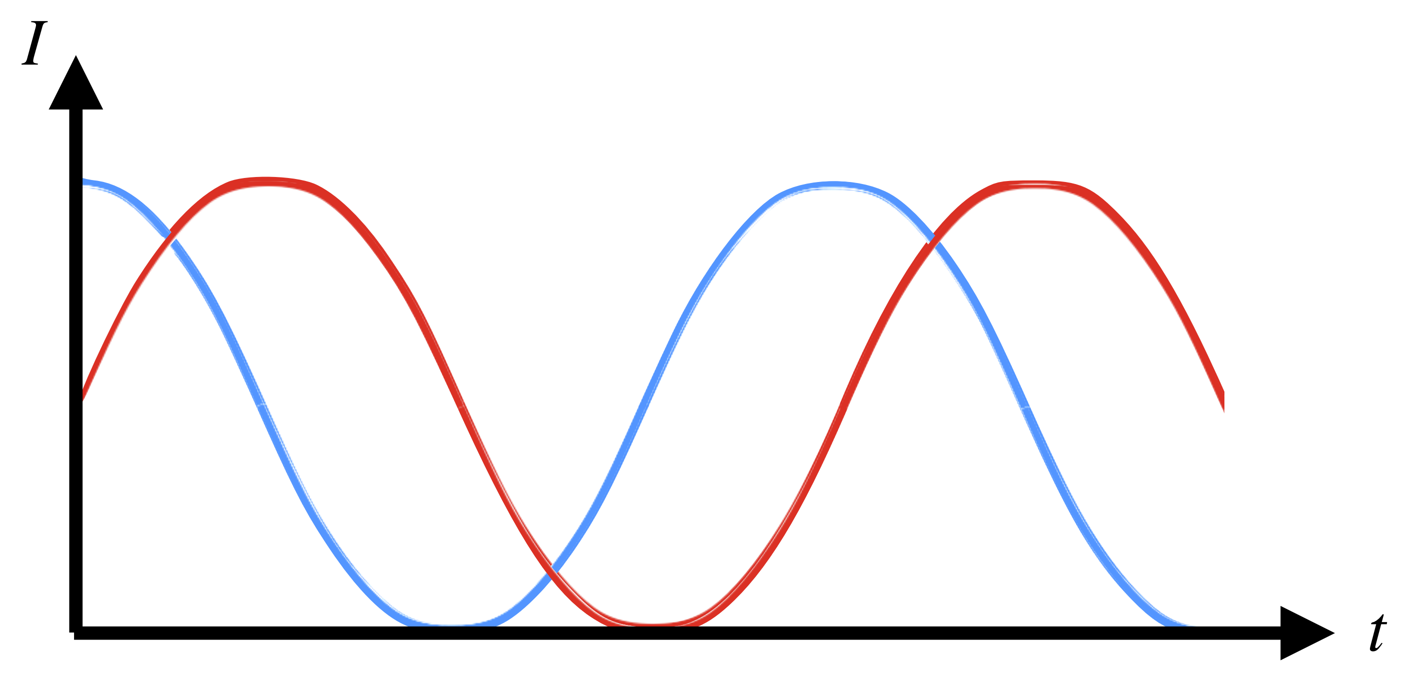
They differ in the effects of water on signal integrity, power consumption, and the availability of sensor components.

All LIDARs must achieve eye-safety certification of Class 1 level.

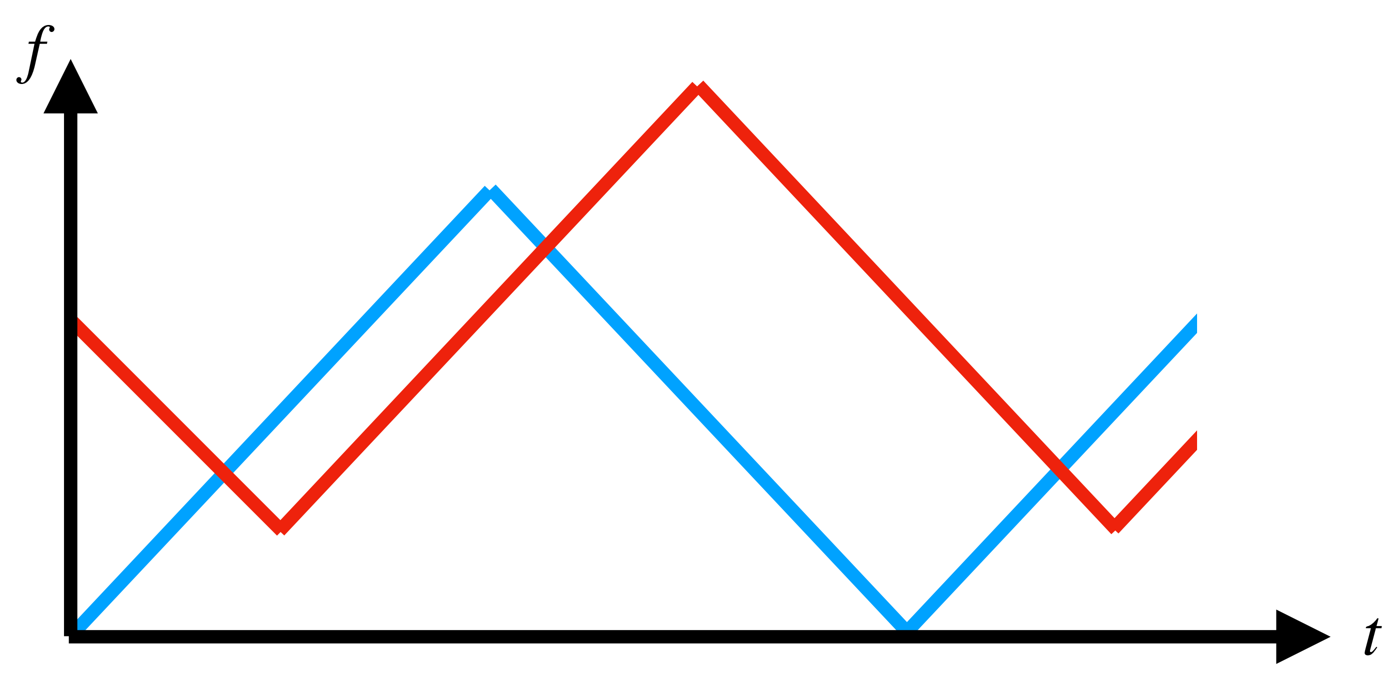
DETECTION SCHEMES



PULSED LIDAR (TOF)

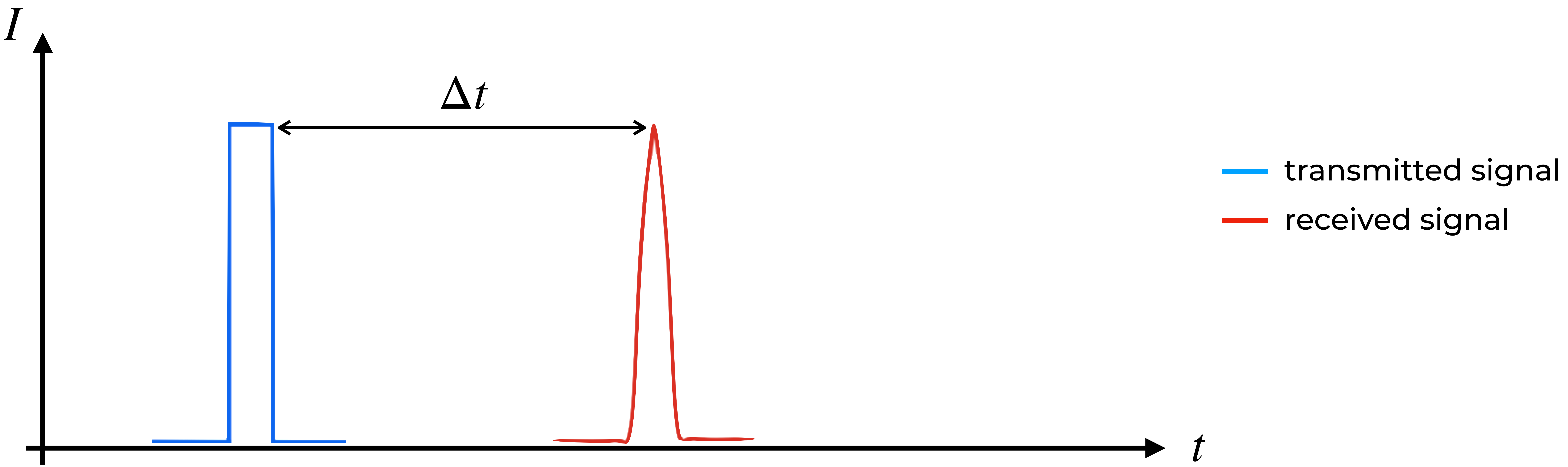


AMCW LIDAR (TOF)



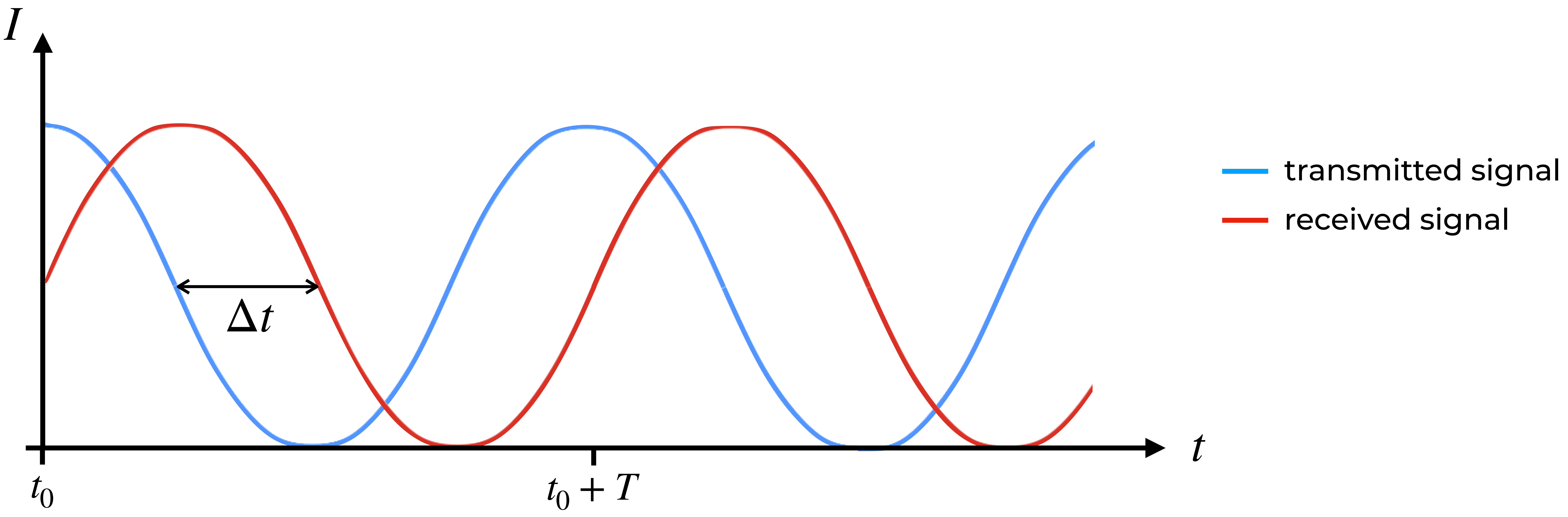
FMCW LIDAR

PULSED LIDAR (TOF)



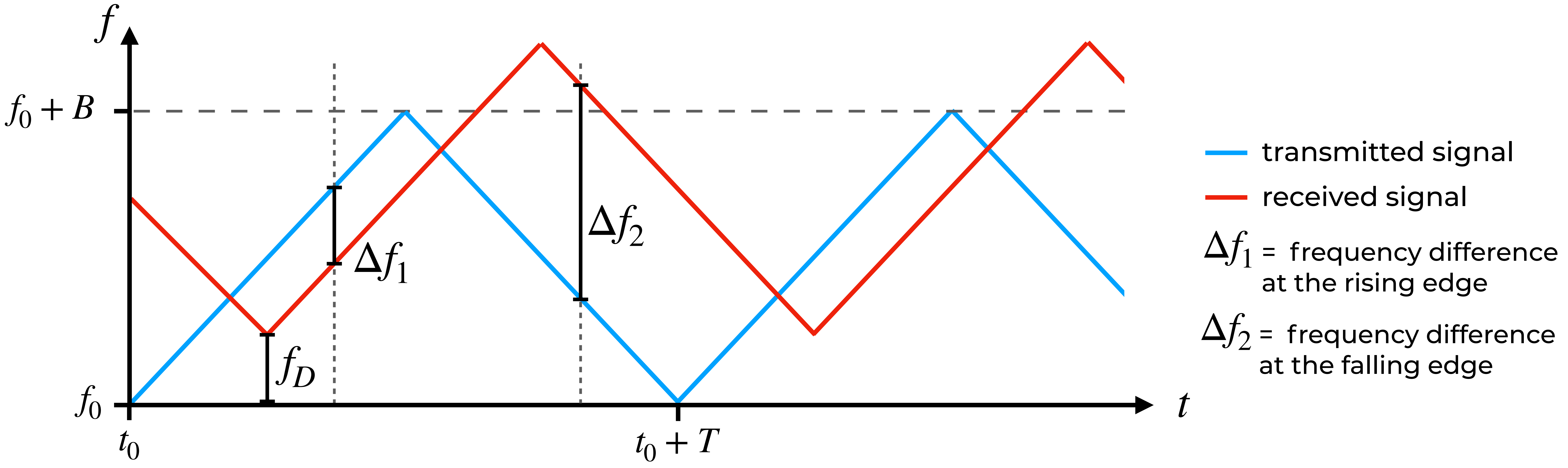
$$R = \frac{c\,\Delta t}{2}$$

AMCW LIDAR (TOF)



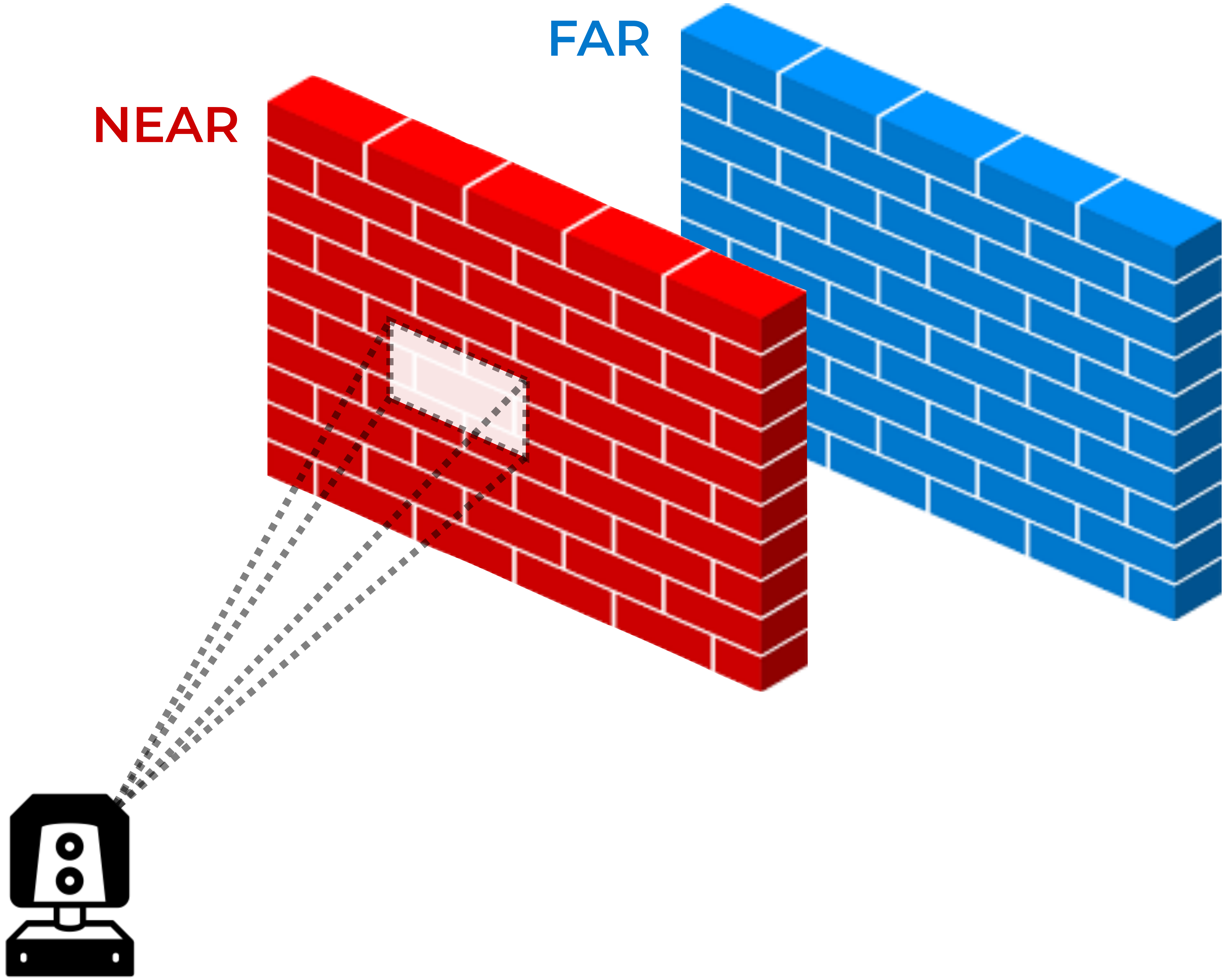
$$\frac{\Delta\varphi}{2\pi} = \frac{\Delta t}{T}, \quad R = \frac{c\ \Delta t}{2} \quad \Longrightarrow \quad R = \frac{c\ \Delta\varphi\ T}{4\pi}$$

FMCW LIDAR



$$R = \frac{c\,T}{4\,B}\left(\Delta f_1 + \Delta f_2\right) \qquad v_r = \frac{c}{4\,f_T}\left(\Delta f_1 - \Delta f_2\right)$$

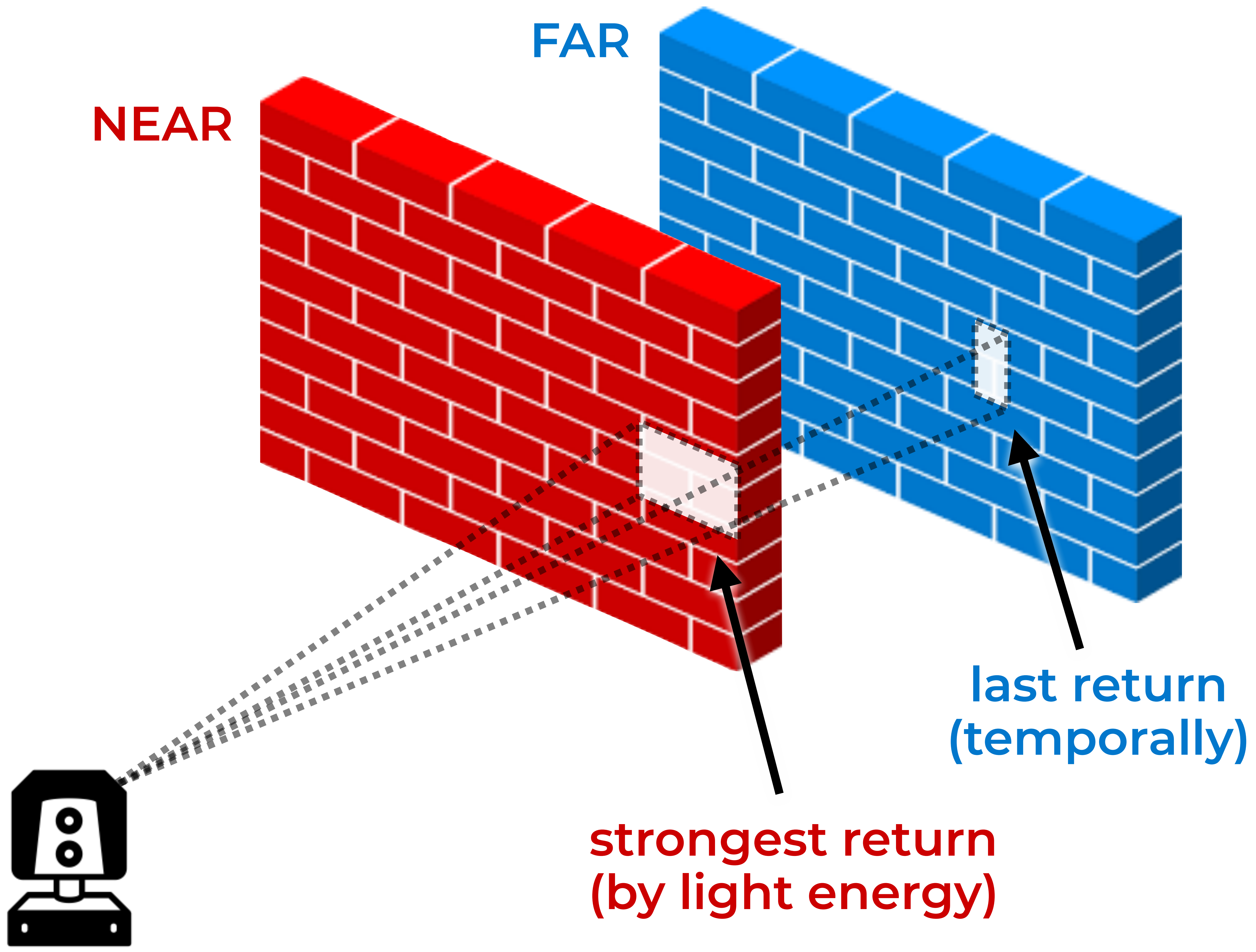
MULTIPLE RETURN MODES



The footprint of the laser beam increases as it gets farther from the LIDAR sensor.

This is known as beam divergence (~3 mRad).

MULTIPLE RETURN MODES



SINGLE RETURN MODE
report the strongest return

DUAL RETURN MODE
report both the strongest and last returns

(if the strongest return is also the last return, report the last and second strongest return)

VELODYNE MODELS

			
	PUCK	**HDL-32**	**ALPHA PRIME**
range (resolution)	100m (± 3cm)	100m (± 2cm)	300m (± 3cm)
scan lines	16	32	128
horizontal / vertical FoV	360° / 30°	360° / 40°	360° / 40°
points per second (single return mode)	~ 300,000	~ 700,000	~ 2,300,000
points per second (dual return mode)	~ 600,000	~ 1,400,000	~ 4,600,000

PROS AND CONS

PROS

- long range (up to 300 m)
- high resolution (~3 cm)

CONS

- expensive ($100 - $10,000)
- affected by weather conditions (rain, fog, snow)
- problems with completely black or very shiny objects