FOR ENERGY EFFICIENT INNOVATIONS

THINK ON.

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Rangefinding and LiDAR
ON Semiconductor Solutions Ecosystem

Public Information

LiDAR concept introduction

Rangefinding and LiDAR definition

LiDAR = A distance measurement system based upon Light which can be used in a wide variety of applications

- Depth perception
- Object detection and avoidance
- Location mapping

Optical rangefinder salvaged from German cruiser Admiral Graf Spee. Source: wikipedia

Several technologies

Radar, Lidar, sonar, ultrasonic, optical …

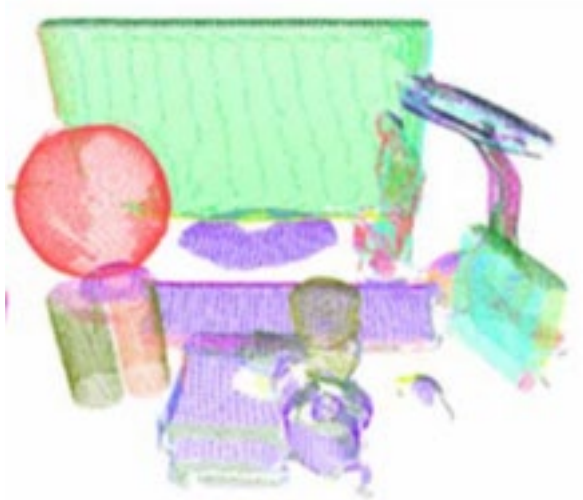
A photo of a range finder at La Corbière
Source: wikipedia

LiDAR target markets :

- Automotive, IoT, industrial, …

Why do we need Depth information in a image ?

- Depth data removes ambiguity
- Helps to distinguish and give meaning to objects within a scene
- Enables automation



Why LiDAR ?

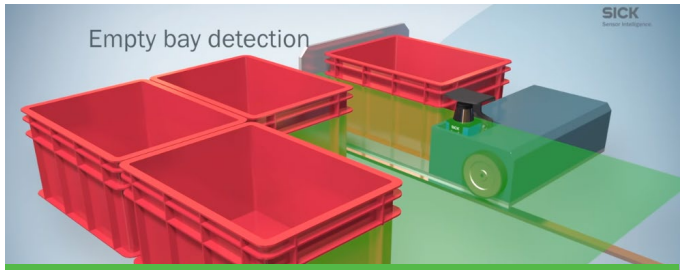
- Configurability
- Good performance at various light conditions and weather
- High data density with low power
- Precise detection of any type of solid object
- Sharp cost decrease

- Adaptable to many use cases/environments
- High accuracy and performance
- Excellent cost-value

IoT, BIS, Industrial, Logistics, …

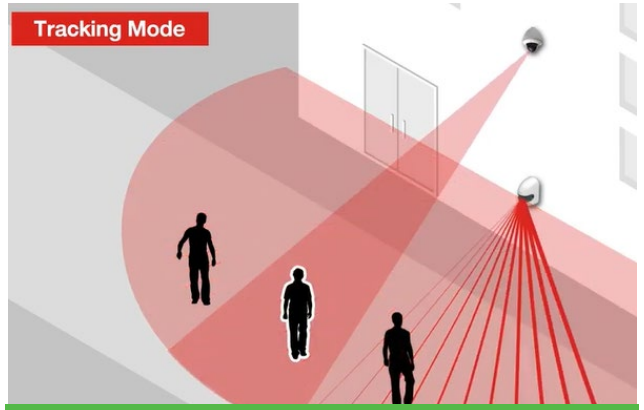
Source: http://home.iitk.ac.in/~blohani/LiDAR_Tutorial/AdvantagesofLiDARtechnology.htm
Source: ON Semicondcutor Intelligent Sensing Division (Sens L)

Examples of Industrial LiDAR Applications



Empty bay detection

*Images courtesy of Sick



People occupancy monitor

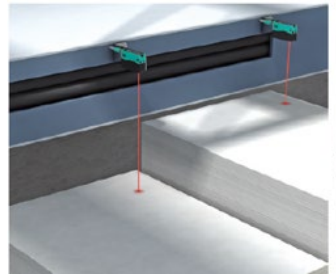
*Images courtesy of Denso Wave

Crop monitoring

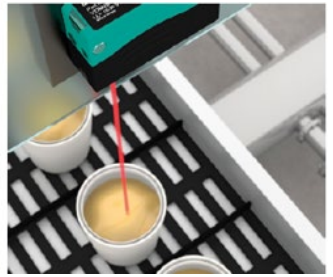
Building Info. Model.

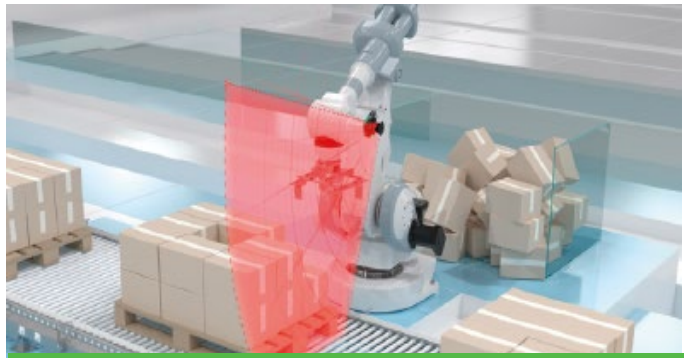
Grain level

Stack height control

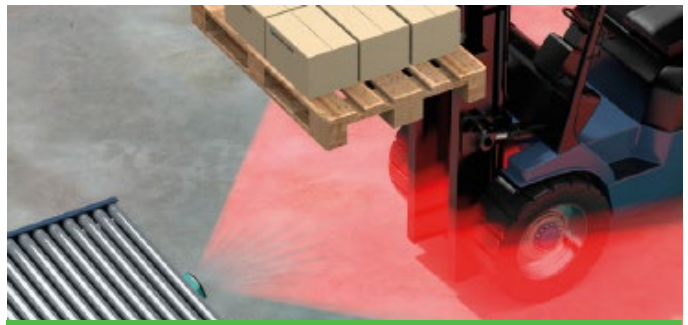


Fill level monitoring





Alignment control



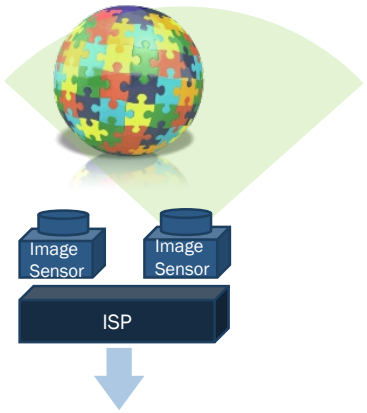
Safety/Proximity sensor

*Images courtesy of Pepperl & Fuchs

Technology variants for High-Resolution Depth Sensing

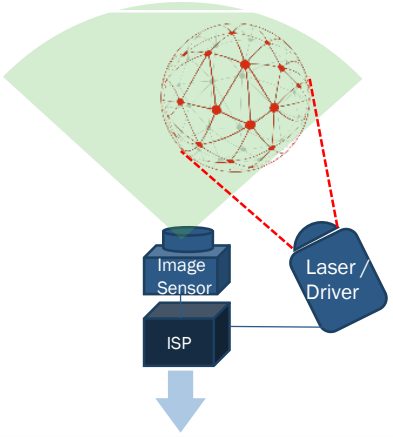
Stereoscopic Vision

Dual camera monitoring Image offset to measure the distance of the target



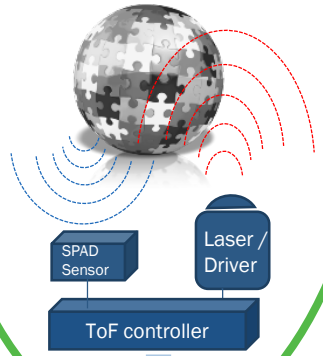
Structured Light

Single camera monitoring distortion from IR light pattern



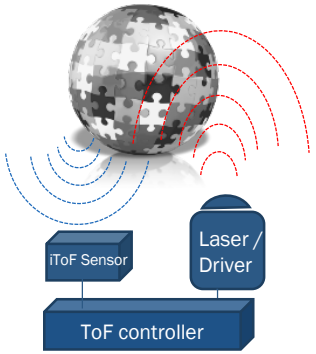
LiDAR (Direct ToF)

Single sensor measuring transit time difference of pulsing light



Time-of-Flight Camera (Indirect ToF)

Single sensor measuring phase difference of IR light to calculate distance



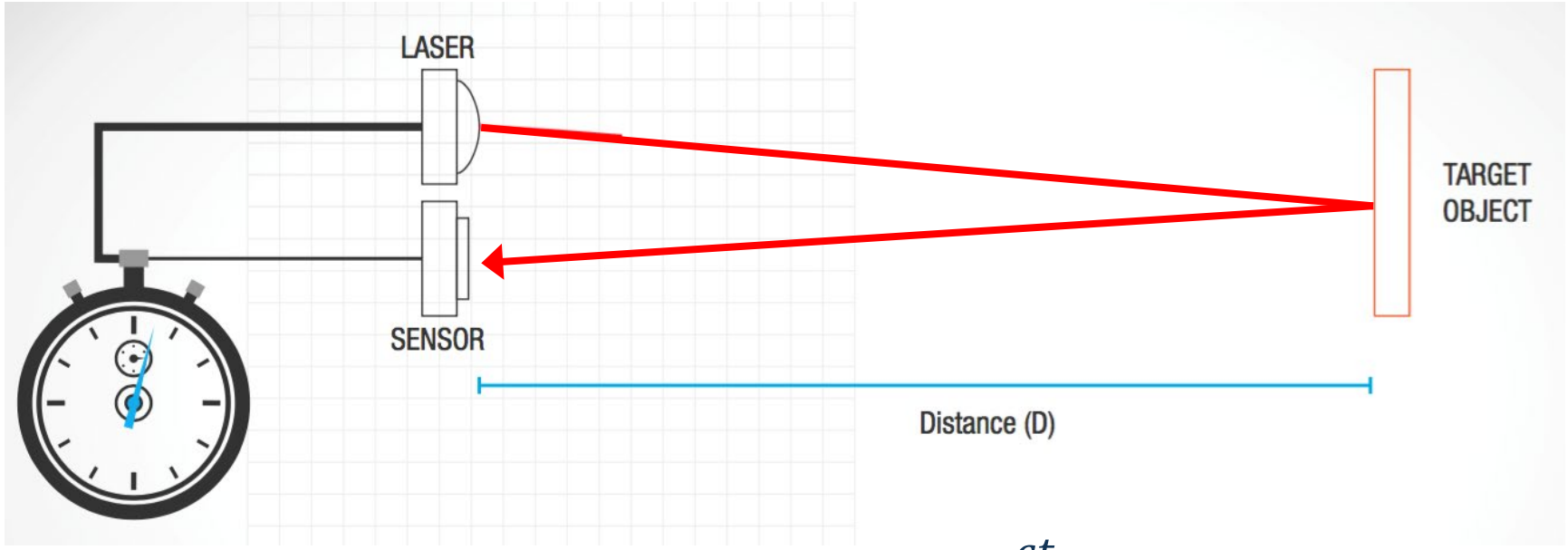
Phase Detection (Pixel-Level)

Single camera measuring pixel level phase difference of ambient light offset to calculate distance

Imaging Analytics Algorithms

Application Software

Direct ToF LiDAR – Simple Concept

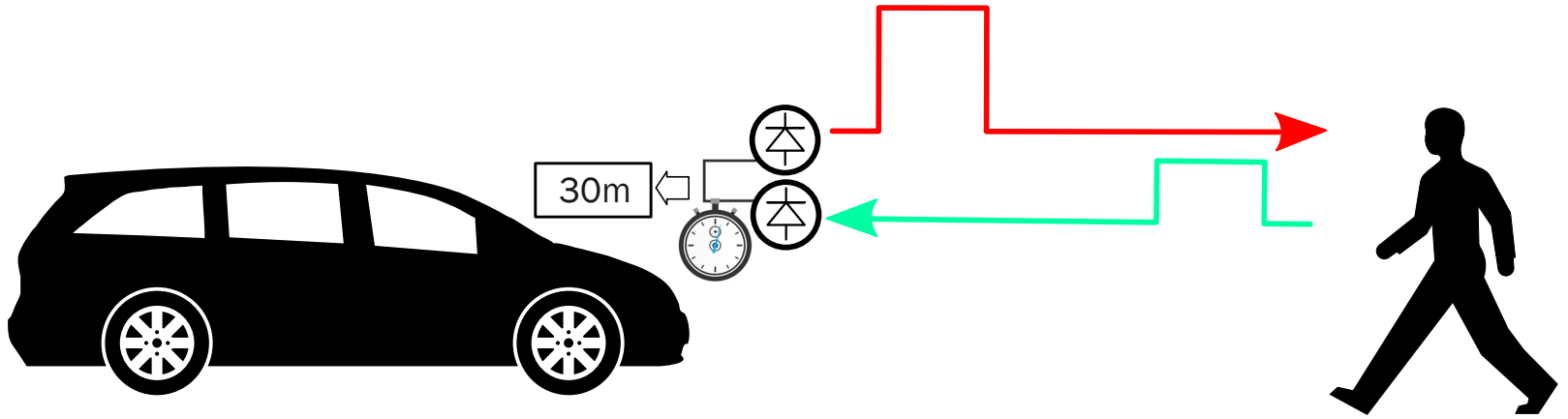


$$D = \frac{ct}{2}$$

… Made challenging by the real world requirements

Direct ToF LiDAR Measurement Techniques

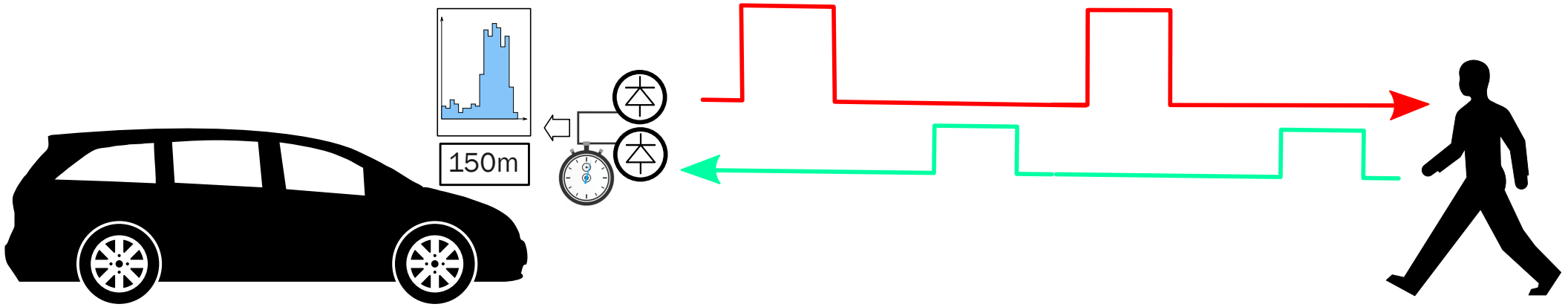
Single Shot laser pulse & photon arrival timestamp for Depth measurement



Multi Shot laser pulses & photon arrival timestamps to calculate **Depth** from histogram

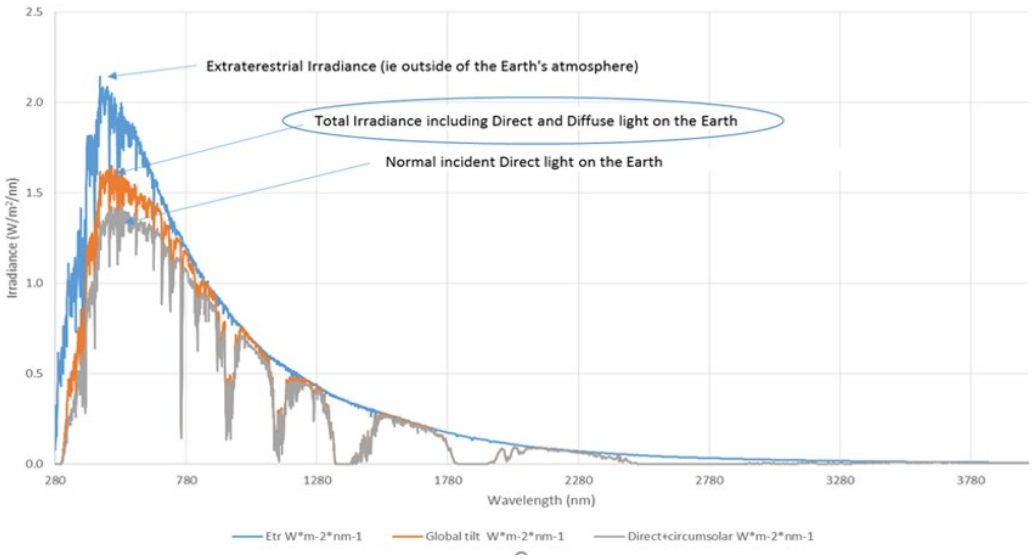
- Photon counting for **Intensity**

Better SNR → Longer Range!



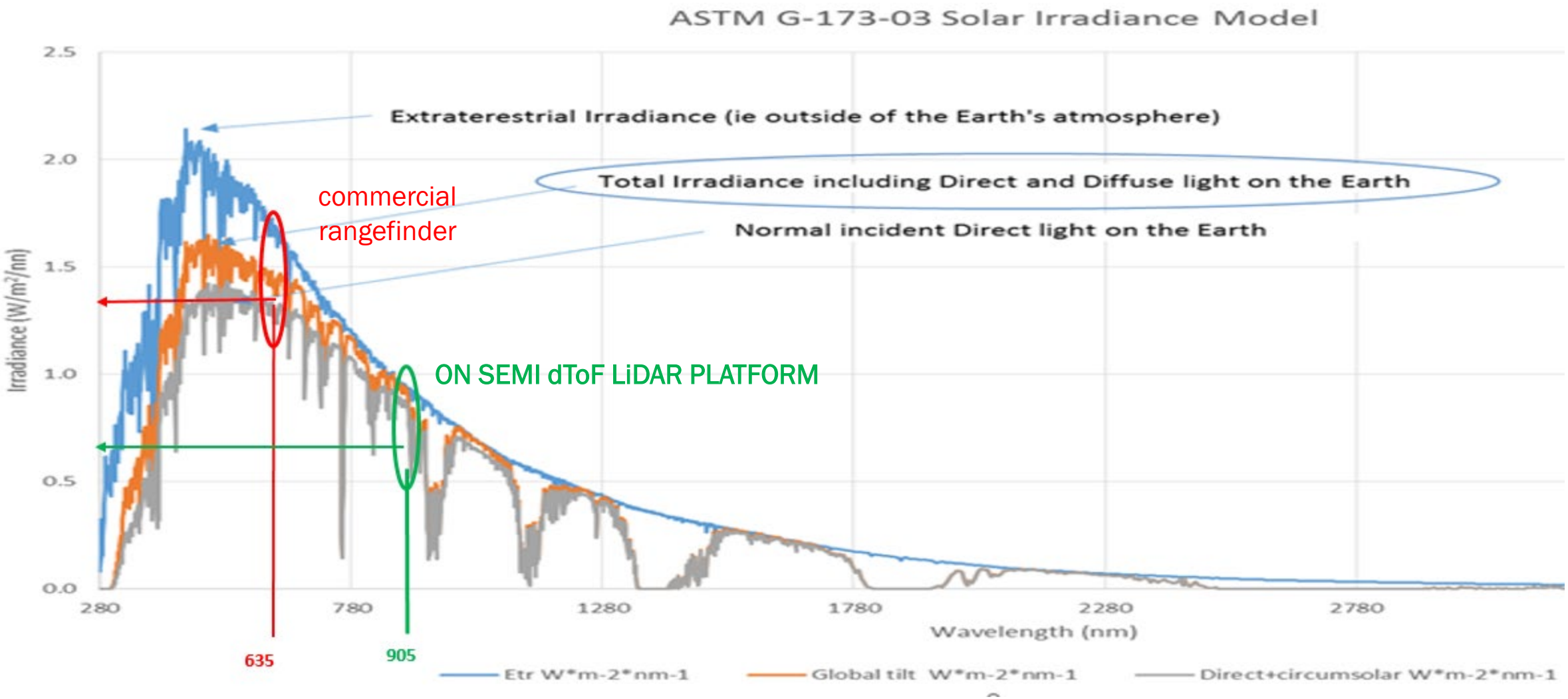
Wavelength Choice

ASTM G173-03 Solar Irradiance Model



Wavelength Range	Visible ~600 nm	Near Infrared ~905 nm	Shortwave Infrared ~1550 nm
Visible beam	Visible	Invisible	Invisible
Eye safety	By design	By design	By design
Emitter/Detector Components	Low cost Silicon detector and cost optimized laser diode		Higher cost III/V materials
Attenuation in water	Lowest	Moderate	Highest
Interference due to sunlight	Higher	Moderate	Lower

Solar Noise Vs Wavelength

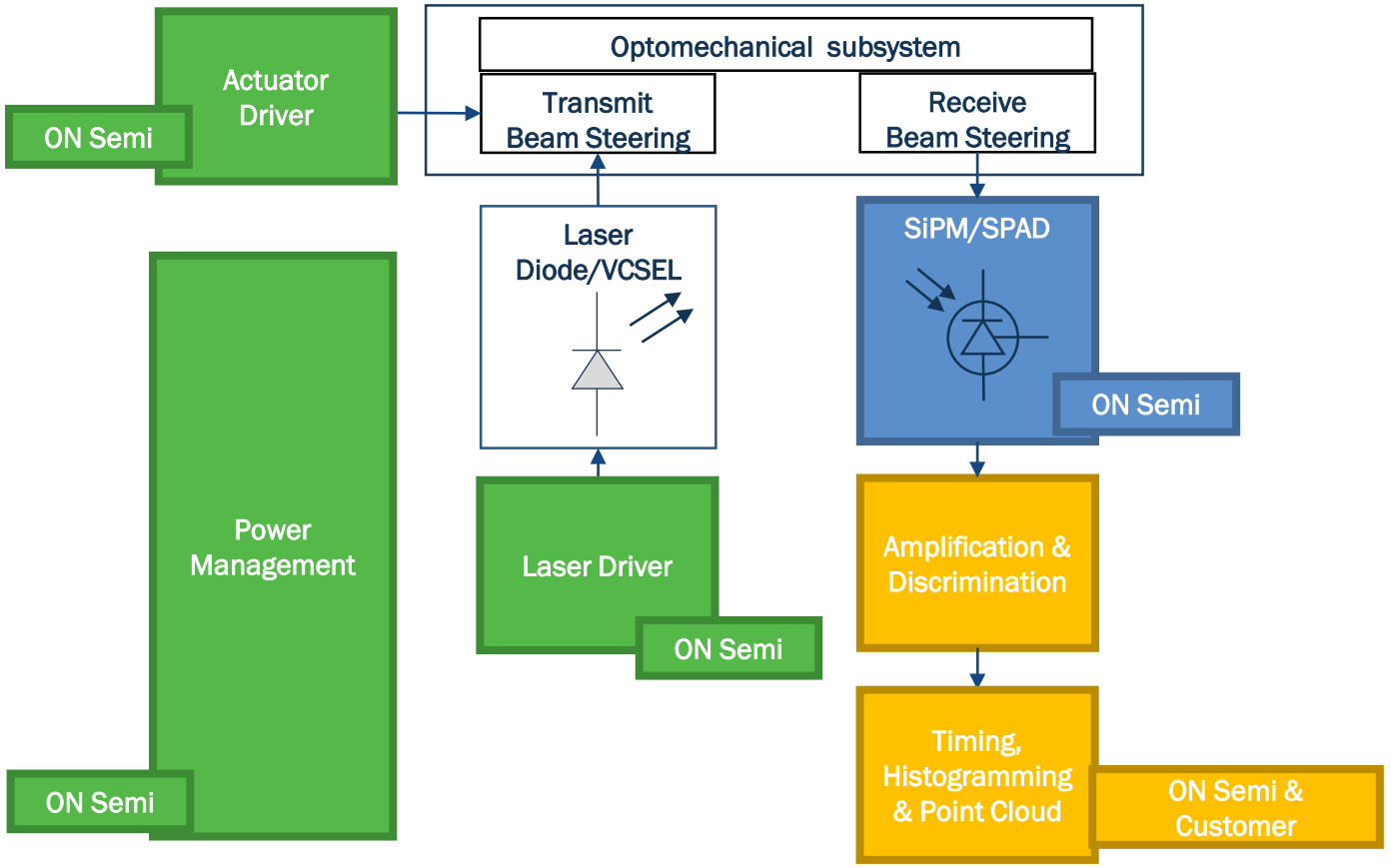


ON Semiconductor LIDAR Products family

LiDAR Functional Block Diagram

Six Major Hardware Functions block on a LiDAR System:

Transmit	• Illumination in NIR spectrum
Receive	• Return photon detection
Beam Steering	• Scanning/Scene Illumination
Optics	• TX and RX focus
Readout	• Signal processing and point cloud
Power and System	• Power management



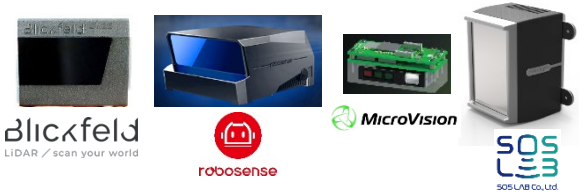
Typical LiDAR System Block Diagram

Key strategic focus for ON Semiconductor is to offer system, sensor, readout and laser driver solutions for all NIR LiDAR architectures

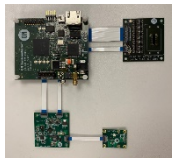
Evolution of Roadmap for Enabling the LiDAR Ecosystem

System Capability

LiDAR Module Products Promoted by ON Semiconductor Partners Program

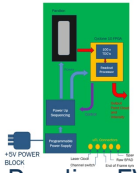


Validated LiDAR Reference Designs for SiPM & SPAD Arrays



16-Channel SiPM LiDAR Ref. Design

SiPM dToF LiDAR Ref. Design



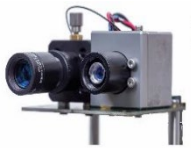
Pandion EVK3 LiDAR Ref. Design

3D and 4Di LiDAR Demos with SiPM & SPAD Arrays

Gen-3 1x16 SiPM Scanning 3D LiDAR

Pandion EVK Flash 4Di LiDAR

Proven Feasibility of dToF LiDAR with SiPMs



Gen-1 SiPM Single Point

Gen-2 SiPM Single Point

ON LiDAR Partners Program

LiDAR Module Designers/Manufacturers

- Knowledgeable in LiDAR design & manufacturing with engagements across markets from industrial to automotive
- Partners with automotive engagements have understanding of qualification and reliability (emerging as "Tier-1")

LiDAR Module Customization Manufacturers

- Established ecosystem manufacturing partner (e.g. for camera modules)
- Able to manufacture LiDAR modules based on a complete reference design

LiDAR Component Suppliers

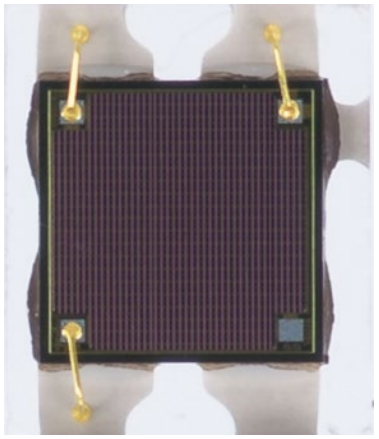
- LiDAR ecosystem component supplier for illumination, beam-steering, signal processing, etc.

Phase 1 | Phase 2 | Phase 3 | Phase 4

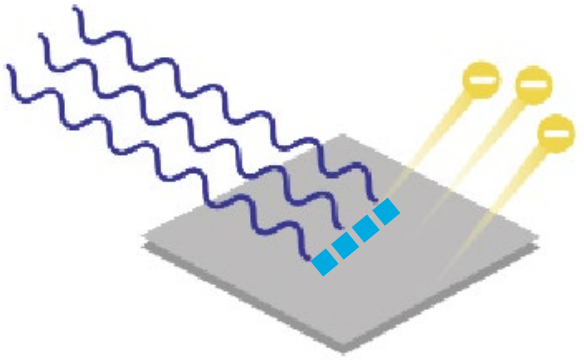
Pre-Study / Proof of Concept | Product Development | Product / Process Development

What is a SPAD/SiPM?

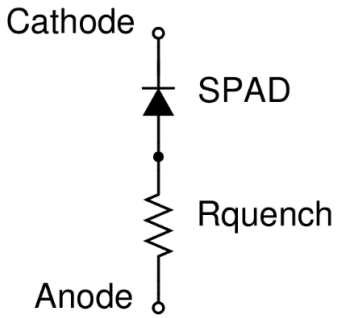
“Single photon sensitivity to identify objects in 3D at long distance”



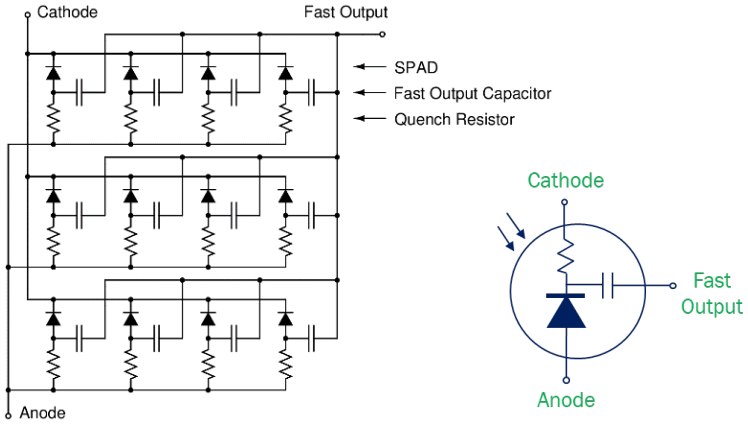
MicroRB-10020-MLP SiPM
(1590 microcell elements)



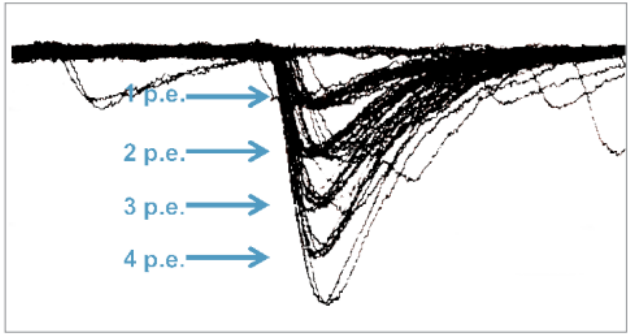
Photons detected by a SPAD
produce a measurable current pulse



SPAD
(Microcell)

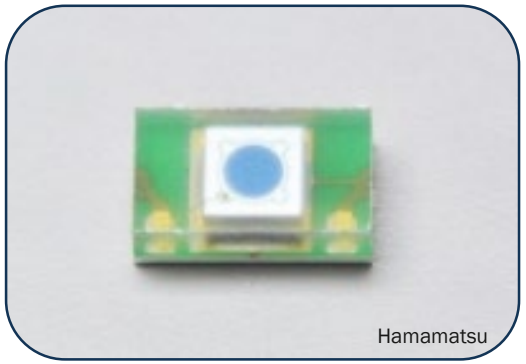


SiPM is a parallel array of microcells



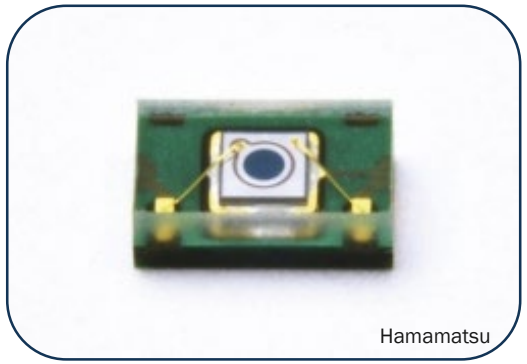
SPAD/SiPM time or count multiple photons
SiPM can measure intensity

Types of Photodetectors for LiDAR



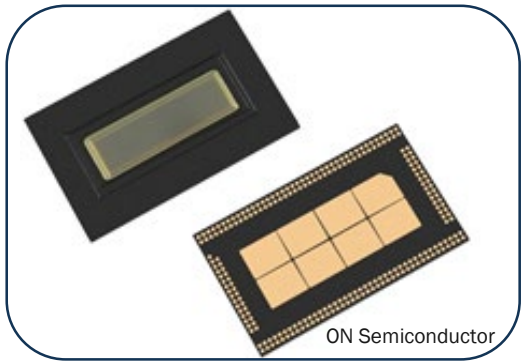
PIN Diodes

- ✓ Low Voltage
- ✓ Good Uniformity
- ✗ No Gain
- !! Linear Mode
- ⇓ Market Adoption



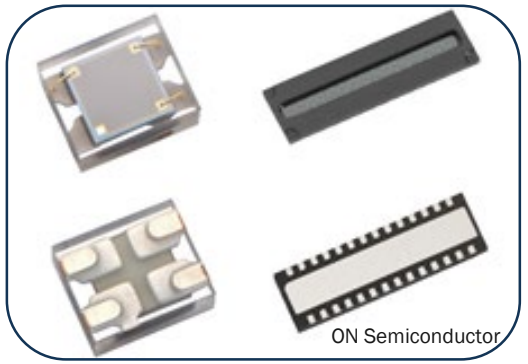
Avalanche Photodiodes & APD Arrays

- ✗ High Voltage
- ✗ Poor Uniformity
- ✓ Moderate Gain (10^2)
- !! Linear Mode
- ⇘ Market Adoption



Single Photon Avalanche Diodes & SPAD Arrays

- ✓ Low Voltage
- ✓ Excellent Uniformity
- ✓ Very High Gain (10^6)
- ✓ Geiger Mode – Single Photon
- ⇗ Market Adoption

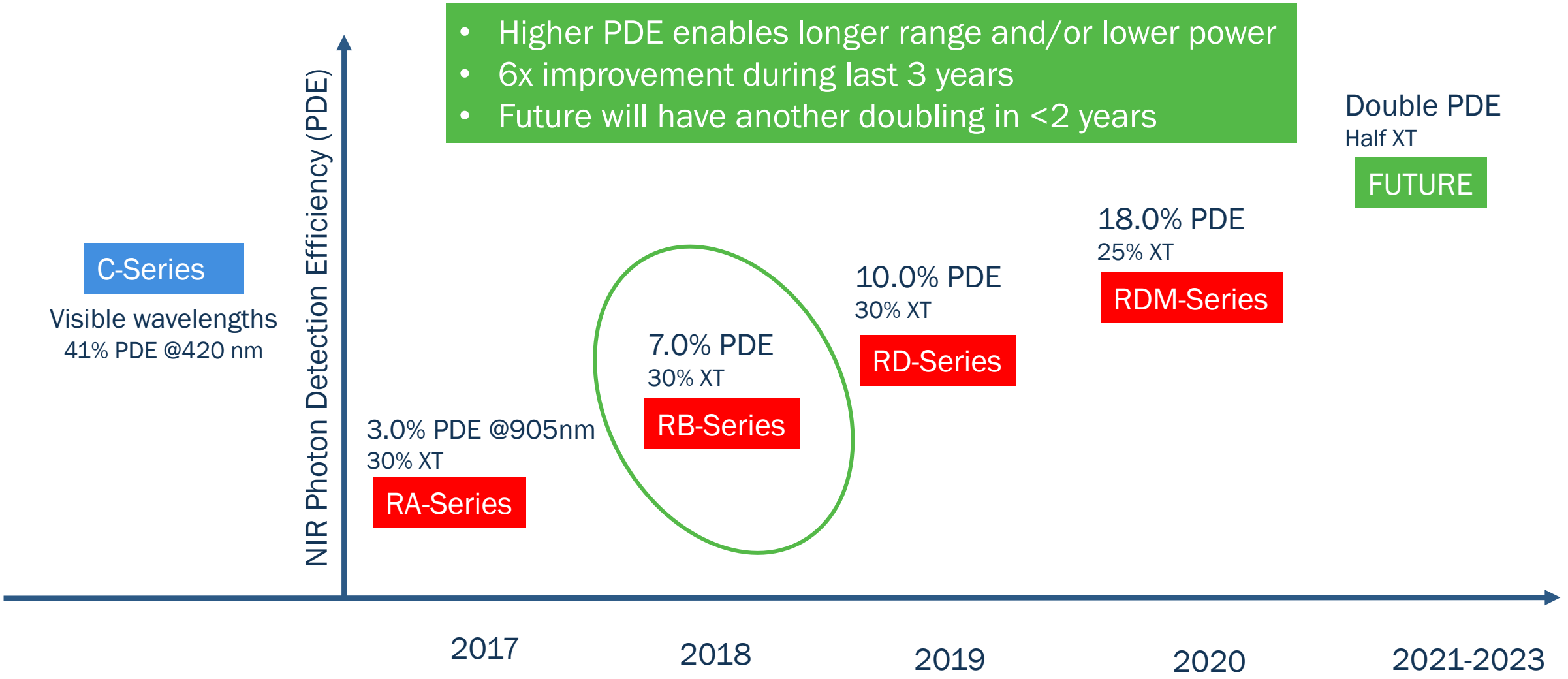


Silicon Photomultipliers & SiPM Arrays

- ✓ Low Voltage
- ✓ Excellent Uniformity
- ✓ Very High Gain (10^6)
- ✓ Geiger Mode – Multi-Photon
- ⇗ Market Adoption

Higher Performance Detector = Better Depth Sensing Performance

ON Semiconductor SiPM Detector Trend



All PDE measurements at 905nm, 22°C room temp;
See datasheets for exact specification

RB-Series SiPM – Single photon sensitive for NIR LiDAR

- Optimized for NIR LiDAR
- High sensitivity → up to 10% PDE @905nm
- Single photon sensitive → Gain 10^6
- Low operating voltage → ~40V bias
- CMOS process → Excellent uniformity
- High bandwidth → < 1 ns rise time
- Features unique SensL Fast output → 2 ns FWHM

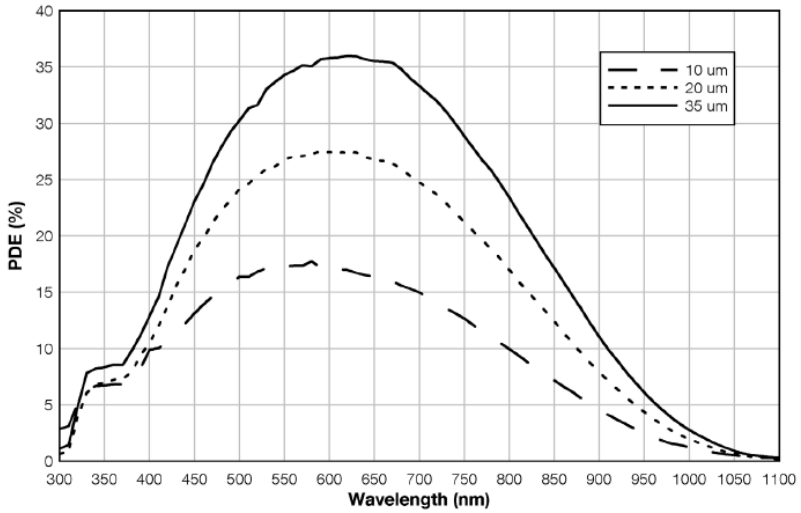
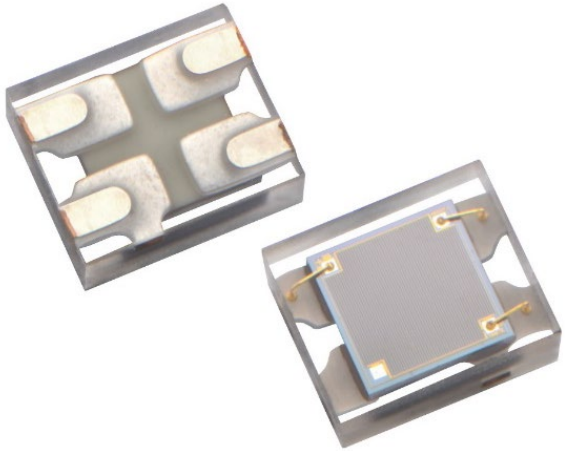
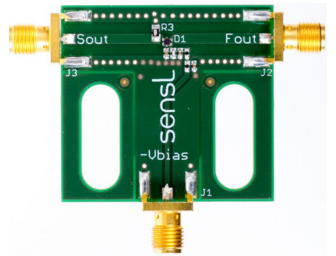


Figure 1. PDE vs. Wavelength
(MICRORB–10010, MICRORB–10020, MICRORB–10035 @ Maximum Overvoltage)



- Reliable robust MLP package
- Operating range of -40°C to 85°C
- Available in 10 um 20 um and 35 um cell size for optimum PDE/DR
- Evaluation boards and reference designs available



ON Semiconductor SiPMs Differentiators ?

Silicon Photomultiplier (SiPMs)

Highly sensitive photodetectors

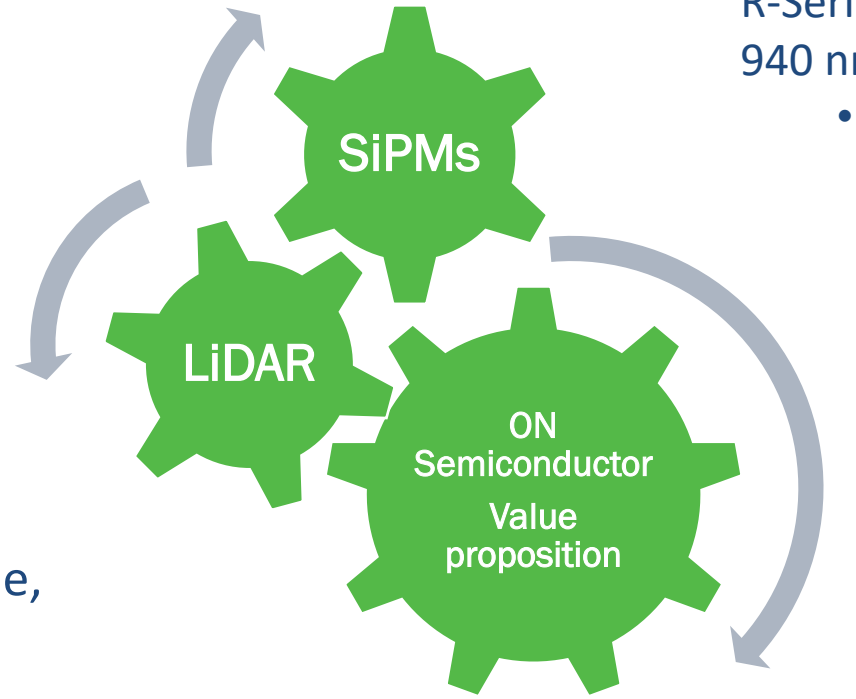
Low noise characteristics

Fast response time (accurate ToF)

High data density

LiDAR

- SiPM based system is simple, reliable and scalable



ON Semiconductor SiPMs

Highly uniform and cost optimized

- suitable for high volume production

R-Series NIR sensors optimized for 850 nm to 940 nm wavelength range

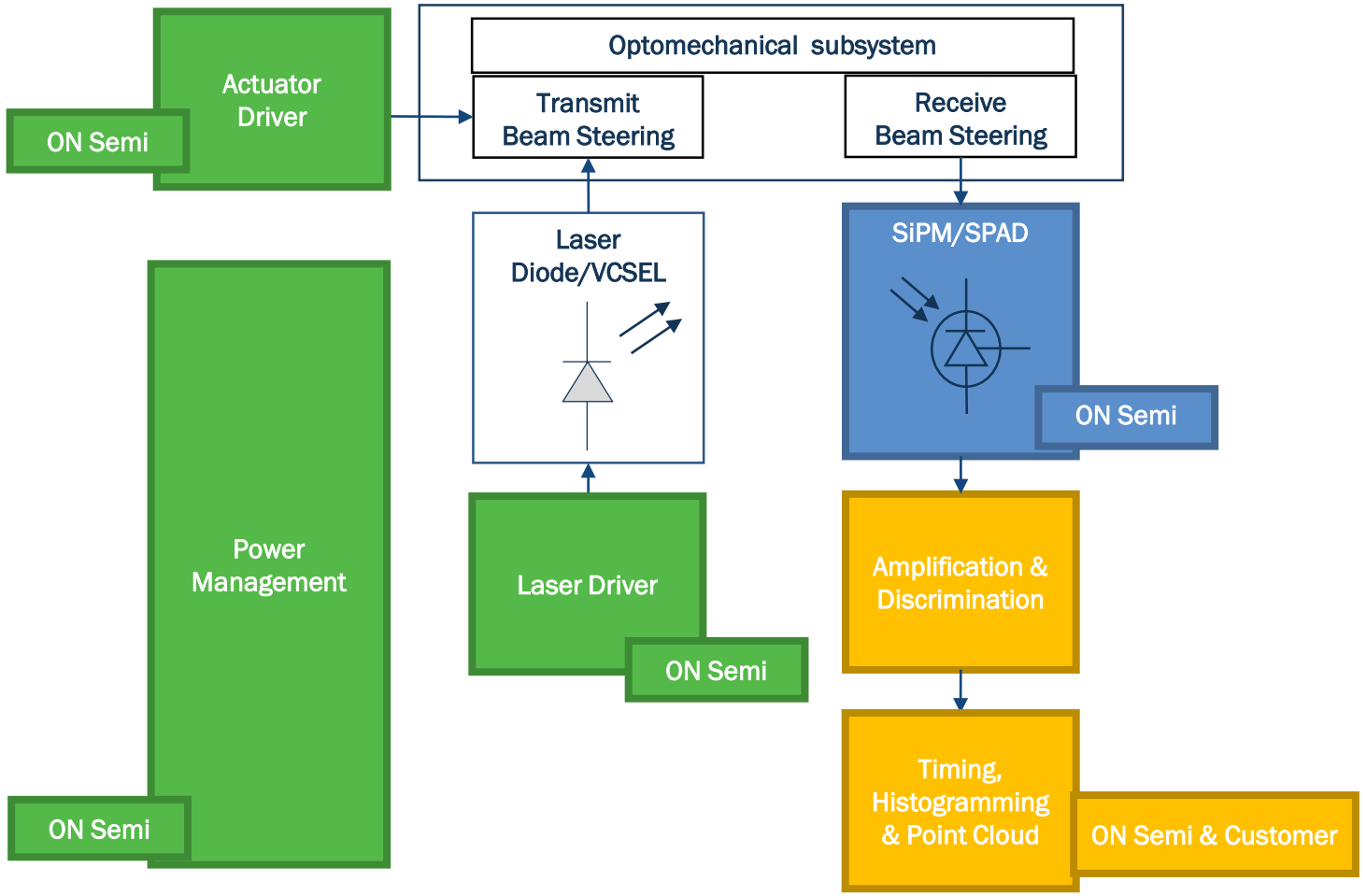
- Design in systems with cost-optimized mass production laser diodes

Source: ON Semicondcutor Intelligent Sensing Division (Sens L)

LiDAR system major functions

Six Major Hardware Functions block on a LiDAR System:

Transmit	• Illumination in NIR spectrum
Receive	• Return photon detection
Beam Steering	• Scanning/Scene Illumination
Optics	• TX and RX focus
Readout	• Signal processing and point cloud
Power and System	• Power management



Typical LiDAR System Block Diagram

SiPM
Direct Time of Flight (dToF)
LiDAR platform

Get your kit*

* www.onsemi.com/support/evaluation-board/seco-rangefinder-gevk

SiMPs dToF LiDAR platform – In a nutshell

Single point range-finding

Plug-and-play

Range 0.1 m – 23 m

Class 1 laser (intrinsic eye-safety)

RB-series NIR SiPM sensor

Cost-optimized system

Mass-deployment ready

All manufacturing files available

System overview

Laser system

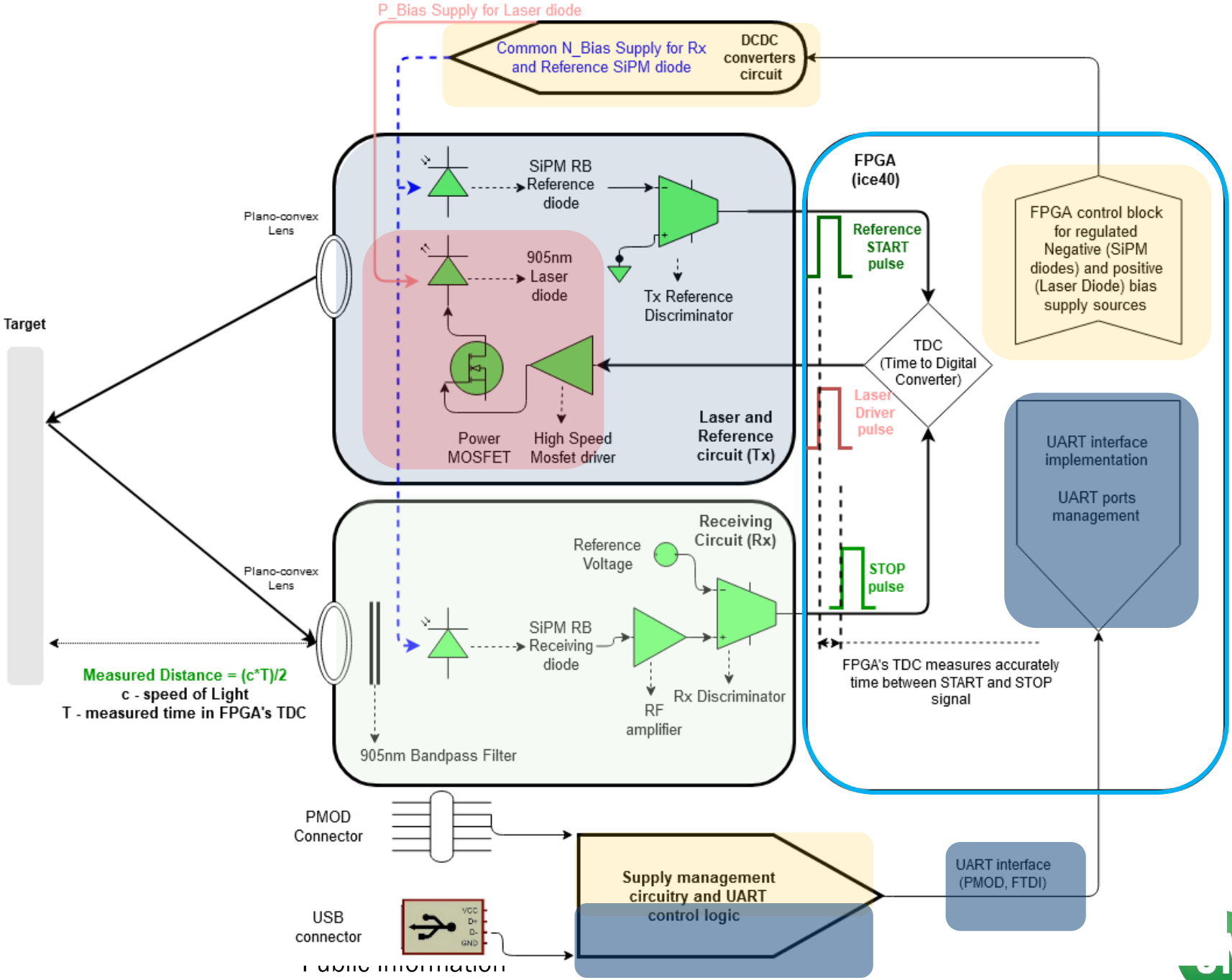
Transmitting circuit (Tx)

Receiving circuit (Rx)

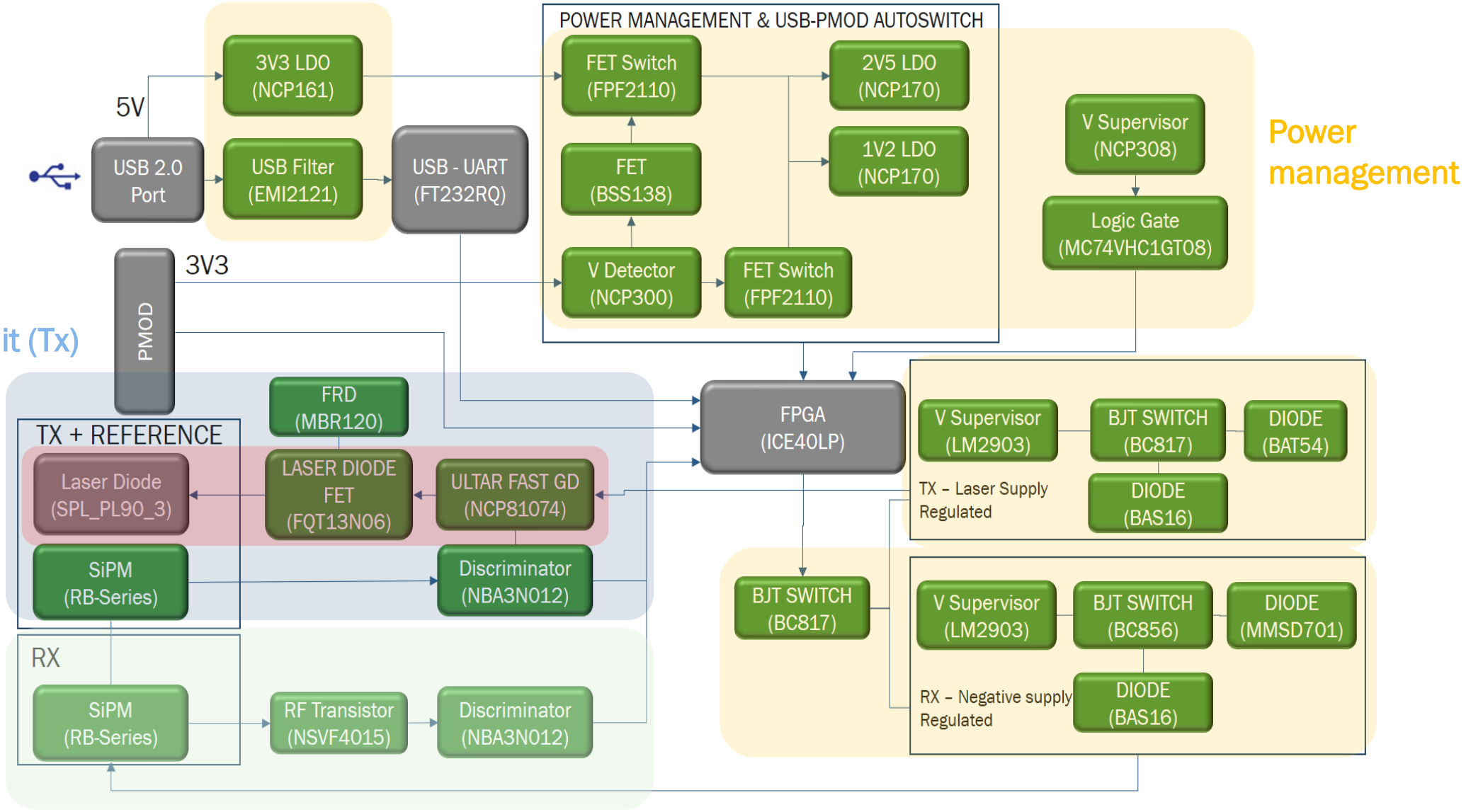
Power management

FPGA

UART communication



Enabling the system solution



Other features

GUI

Out of the box operation – no installation
Adjustable SiPM bias for different use cases
Save and load data

Laser and optics

RB-Series SiPM detector
905nm laser diode transmitter
650-1050nm coated BK7 plano-convex lenses
    Maximizes distance measurement
905±5nm band pass optical filter (FWHM: 30±5nm) for RX
    Highest sensitivity in selected spectrum

Power supply

USB 5V
PMOD 3.3V

Regulations

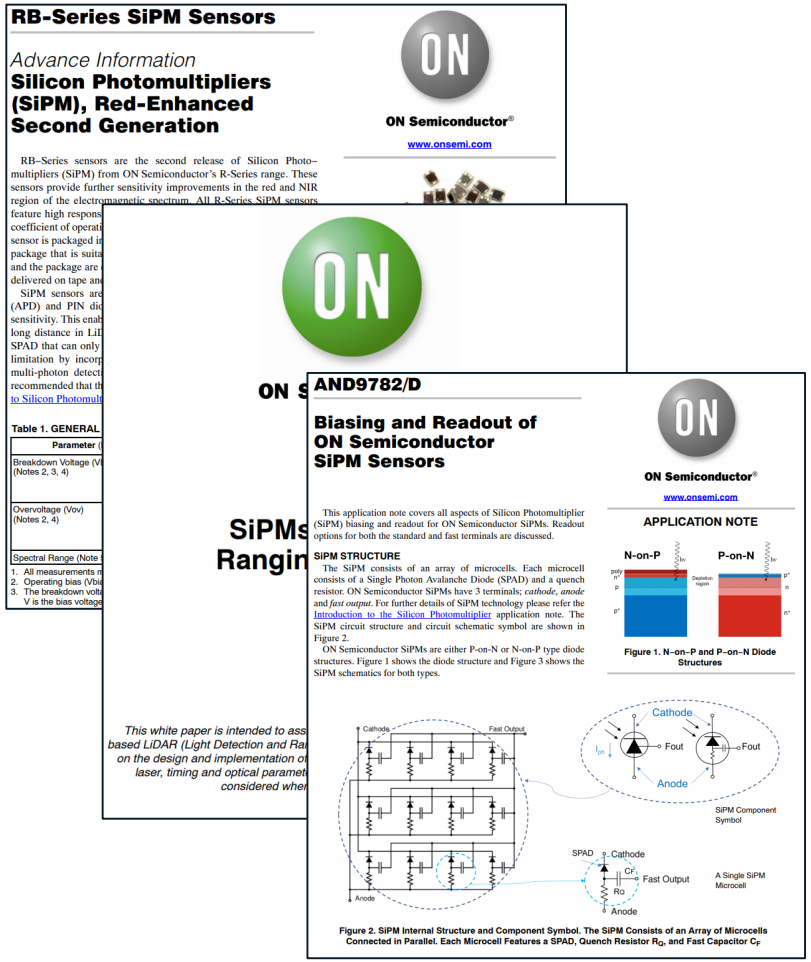
Class 1 laser – eye-safety intrinsic
FDA certified

Time to Digital Conversion (TDC)

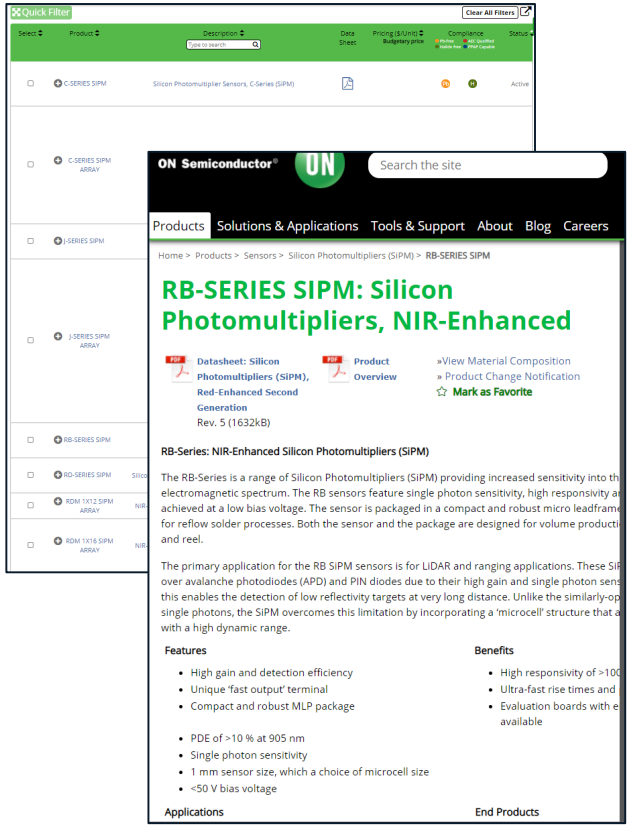
FPGA based (ice3)
~ 85ps bin width
Automatic TDC calibration

Resources

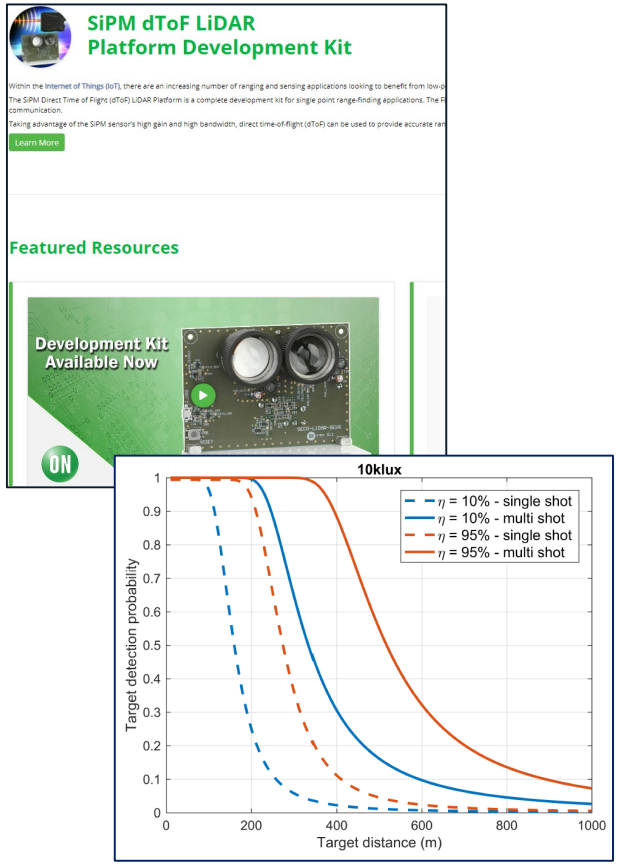
Application notes and papers



SiPMs



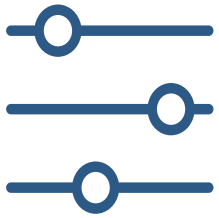
Development kits & LiDAR modeling *



*under request

ON Semiconductor industrial LiDAR unique ecosystem

Focus on your application while we make LiDAR easier for you



System solution expertise

SiPMs leading technology

Development tools and educational resources