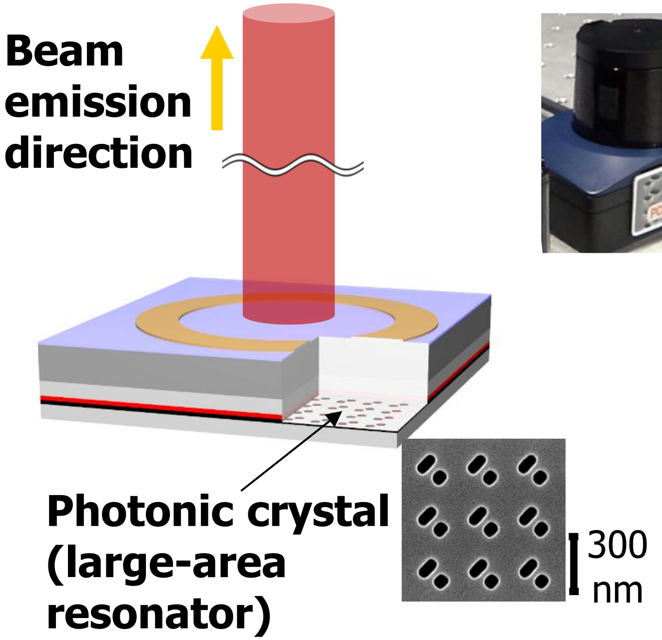
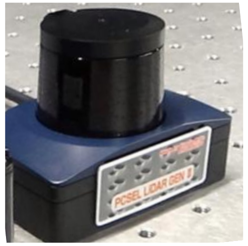
March 2026

「Cross-ministerial Strategic Innovation Promotion Program (SIP) Phase 3 / Construction of smart mobility platform / Development of infrastructure and onboard sensor systems that utilize compact LiDAR technology to understand the actual situations of streets in living areas and busy districts」





Commissionees: Kanazawa University, Kyoto University 金沢大学 京都大学 KYOTO UNIVERSITY

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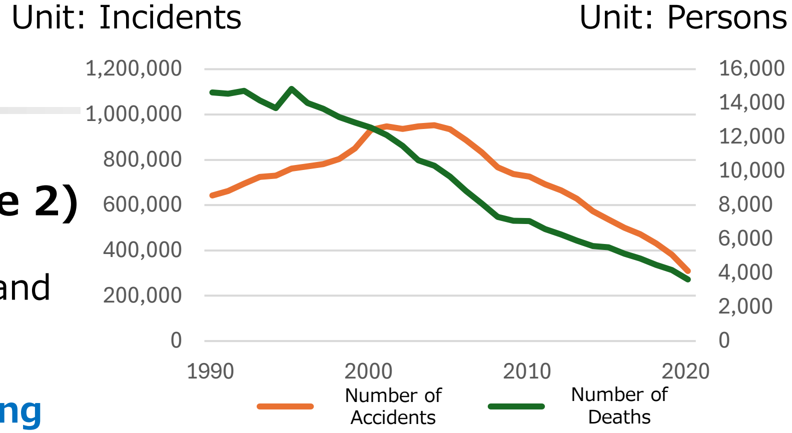
Research Background (p.4~p.5)

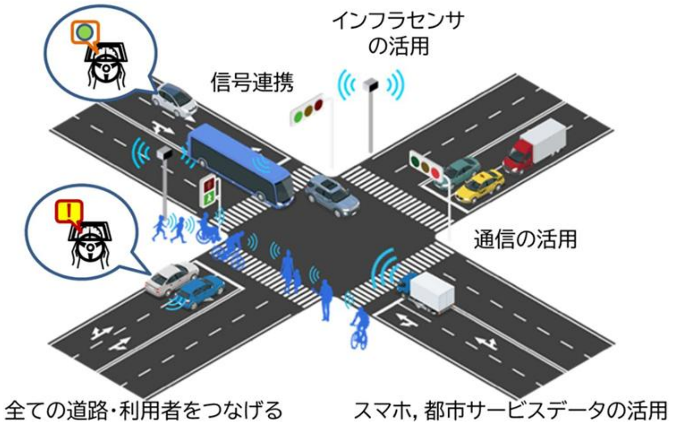
Research Background

- **Exit Strategy for the Social Implementation of SIP Smart Mobility (Task Force 2)**
  - Reduction of casualties from persistently occurring tragic traffic accidents
  - Proposal and implementation of comprehensive infrastructure to realize safe, comfortable, and vibrant cities
- **Importance of Sensing in the Above-Mentioned Exit Strategy**
  - **Comprehensive sensing for micro-mobility to ensure zero missed detections, including vulnerable road users**
  - **Monitoring of traffic participants and traffic flows, and detection of incoming vehicles in narrow street environments**
  - **Infrastructure and on-vehicle sensing applicable to driving assistance and automated driving systems (Such as RoAD to the L4 projects)**
- **Importance of LiDAR-based sensing**
  - Effective from perspectives of privacy and resolution
  - Accurate understanding of actual conditions, including vehicle dimensions
- **Current state of LiDAR**
  - Mostly foreign-made and large in size
    - **Domestic production** is desirable from the perspective of **economic security**

⇒ The realization of a domestic, high-performance (e.g., omission-free), compact, and low-cost LiDAR will widely contribute to building smart mobility, including infrastructure sensing



Trends in the Number of Traffic Accidents and Fatalities
(Source: Prepared based on National Police Agency data)



https://www.road-to-the-l4.go.jp/activity/theme04/pdf/theme04_01.pdf

Taken from the home page of the RoAD to the L4 Project

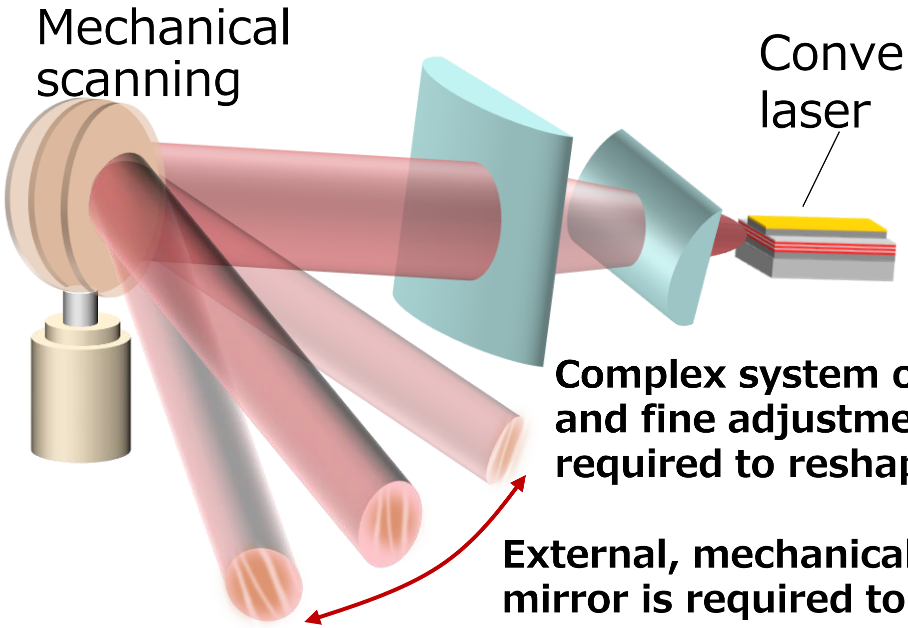
*Light Detection and Ranging

Research Background

Comparison of conventional semiconductor laser and PCSEL* for LiDAR

Conventional laser

<u>Low brightness</u> : Poor beam quality, wide divergence angle
<u>Poor functionality</u> : No native beam scanning



Complex system of lenses and fine adjustments are required to reshape the beam

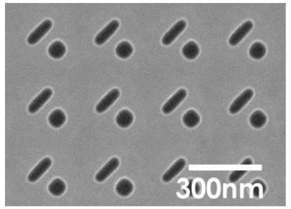
External, mechanically rotating mirror is required to scan the beam

Bulky, costly LiDAR system: Bottleneck

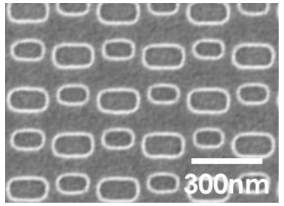
Photonic crystal laser (PCSEL)

<u>High brightness</u> : High beam quality, narrow divergence angle (lens-free)
<u>High functionality</u> : Capable of multi-dot emission and native beam scanning

Double-lattice PC



Dually modulated PC



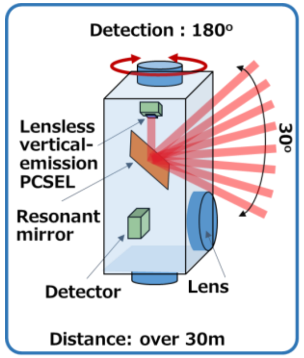
Small, simple, low-cost LiDAR system: Solves the bottleneck

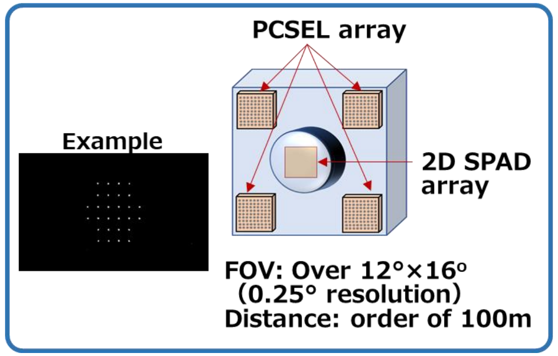
(*PCSEL: <u>P</u>hotonic <u>C</u>rystal <u>S</u>urface <u>E</u>mitting <u>L</u>aser)

Overview of R&D (p.7~p.10)

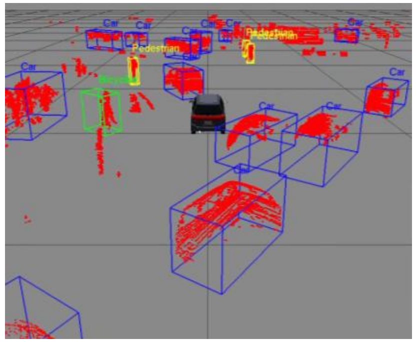
Overview of R&D

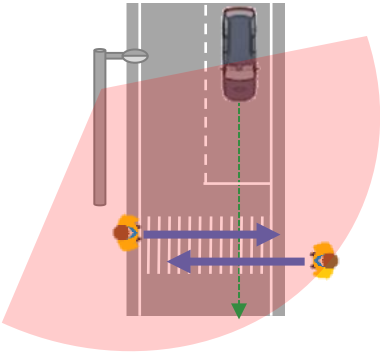
*Photonic Crystal Surface Emitting Laser





- ① **Development of PCSEL*-LiDAR systems (Kyoto Univ.)**
  - Development of card-type PCSEL-LiDAR (Step 1 Additional Item)
    - **Application to micro-mobility with zero missed detections**
  - Development of mechanical wide-FOV PCSEL-LiDAR (Step 1)
    - **Utilization as infrastructure sensors for monitoring pedestrian/traffic flows and detecting incoming vehicles**
    - Use as a sensor for monitoring vehicle blind spots
  - Prototyping & development of all-chip PCSEL-LiDAR system (Step 2)
    - **Applicable as both infrastructure and on-vehicle sensors due to its compact and low-cost design**



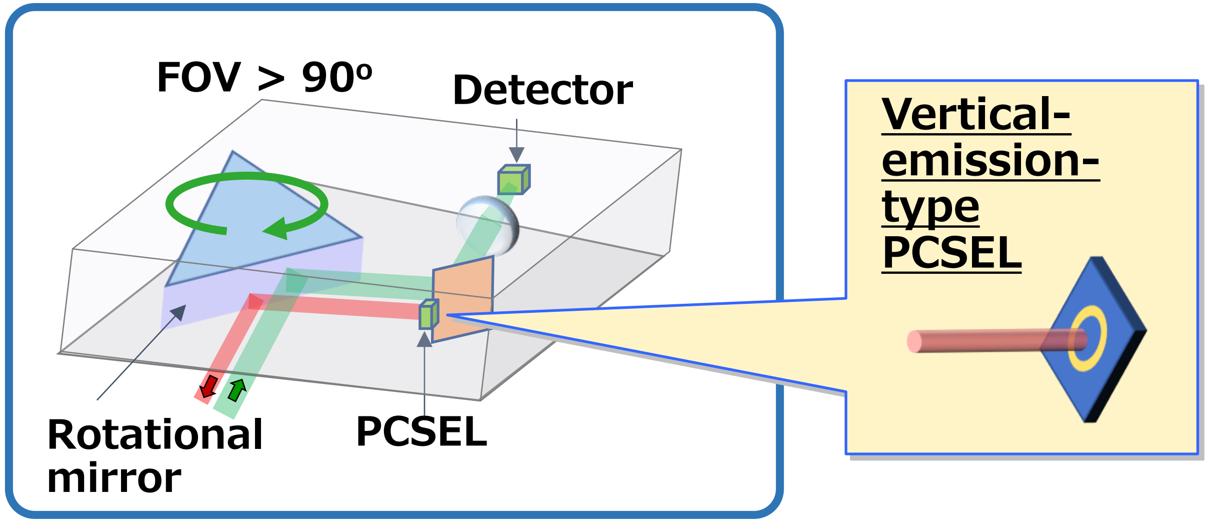


- ② **Development of recognition technology and conducting field-operational test (Kanazawa Univ.)**
  - Development of recognition technology using LiDAR
    - Analysis of point cloud obtained by PCSEL-LiDAR
    - **Development of technology for precise detection of vehicles, pedestrians etc.**
  - Field-operational test (FOT) using LiDAR
    - **Demonstration and verification of use as an infrastructure sensor**
      - Expansion to and collaboration with other projects are under consideration
    - **Demonstration of autonomous driving using PCSEL-LiDAR**
      - Demonstration of L4-equivalent autonomous driving in conjunction with infrastructure sensing

R&D Goals : ①PCSEL-LiDAR Systems

Application to micro-mobility with zero missed detections

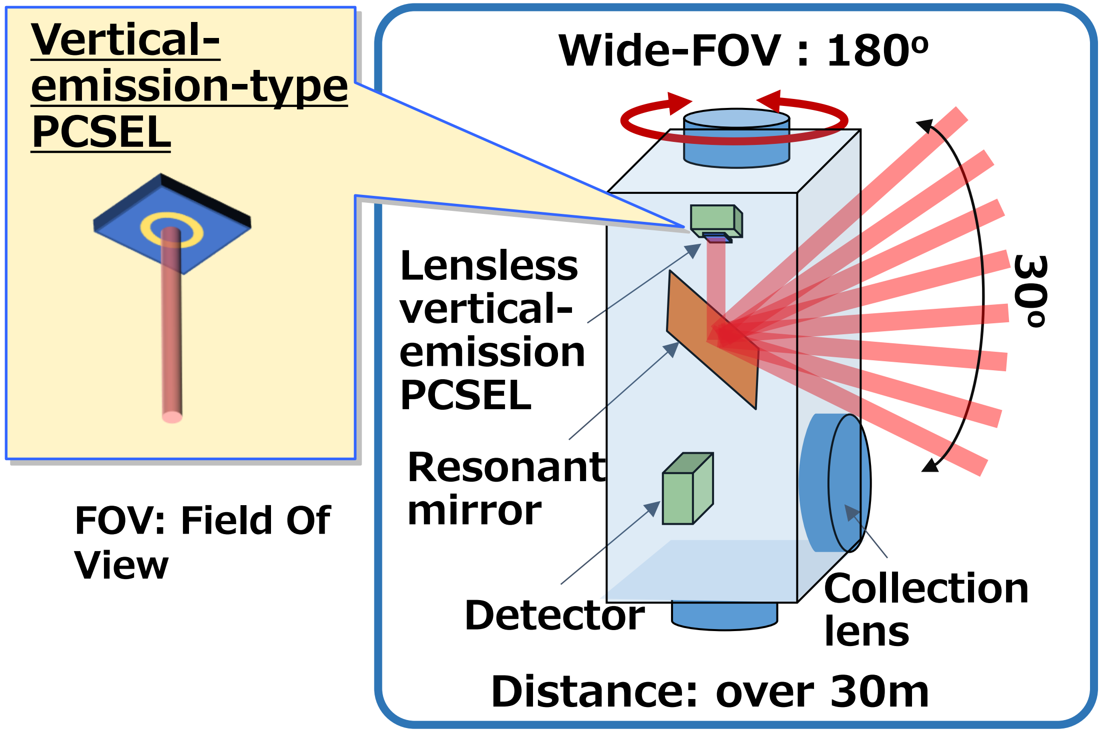
⇒ Ultra-compact card-type PCSEL-LiDAR (Step 1 : Additional item)



Specific Needs:
- Wheelchair-mounted sensing system at Kurume Institute of Technology
- Infrastructure sensor for vehicle detection/monitoring in IBS Consortium

Utilization as an infrastructure sensor for monitoring pedestrian/traffic flows and detecting incoming vehicles

⇒ Mechanical wide-FOV PCSEL-LiDAR (Step 1)



FOV: Field Of View

Specific Needs:
- Pedestrian and traffic flow monitoring in IBS Consortium

R&D Goals : ①PCSEL-LiDAR Systems

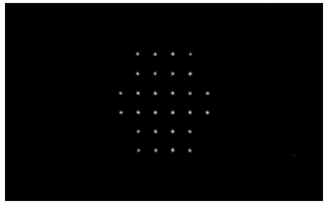
Applicable as both infrastructure and on-vehicle sensors due to its compact and low-cost design

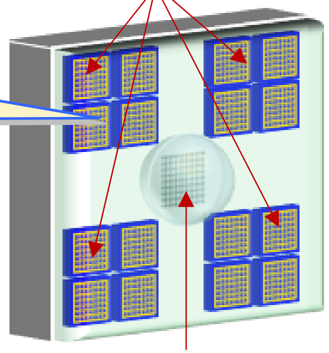
⇒ All-chip PCSEL-LiDAR（Step 2）

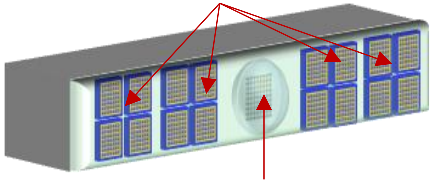
The all-semiconductor chip design enables compact size and low cost

Multi-dot emission PCSEL

Example (video)







The all-chip architecture enables a wide variety of system designs.

PCSEL array :
Over 3,072 dots by multiple chips

2D-SPAD array :
64 × 48 pixel array (3,072 total pixels) (Each pixel comprises a 2 × 2 SPAD array)

SIP Target Specifications:
Field of View (FOV): 12°×16° (0.25° resolution)
Range: 100m class

Note: In the future, a 3 × 3 (or larger) high-sensitivity SPAD array together with increased peak-power-per-PCSEL-spot is expected to enable 200–300 m ranging. Scaling both the SPAD pixel and the number of PCSEL illumination spots further enables a wide FOV (>25° × 100°).

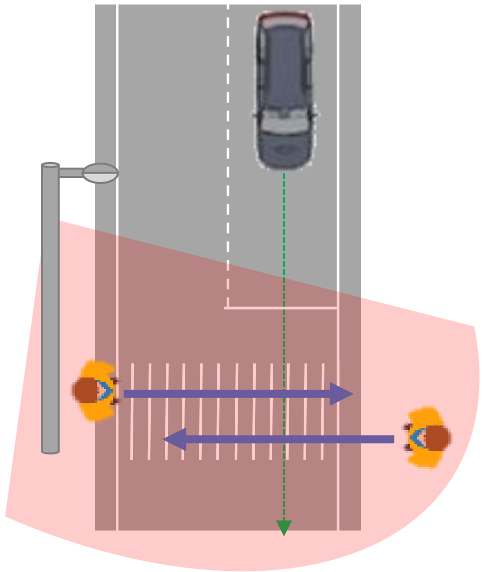
R&D Goal : ② Development of Recognition Technology and Conducting Field-operational Test

Mid-term goal :
Conducting FOT using infrastructure sensing

Development of recognition algorithms using Mechanical Wide-FOV 3D PCSEL-LiDAR, and conducting field operational test

Final goal :
Conducting FOT of level4 equivalent autonomous driving

Development of recognition algorithms using multi PCSEL-LiDAR, and conducting field operational test with cooperating infrastructure and on-board sensors.

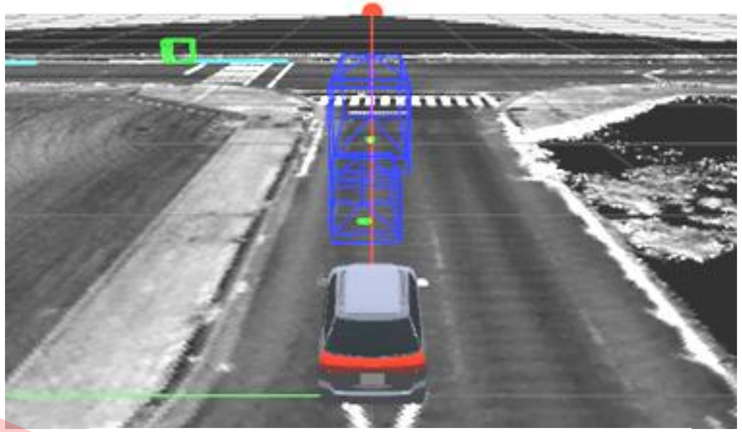


Monitoring crossing pedestrian
(Mechanical Wide-FOV PCSEL-LiDAR)

Cooperating infrastructure and on-board sensors

Monitoring blind spot near vehicle
(Mechanical Wide-FOV PCSEL-LiDAR)

Monitoring in front of vehicle
(All Chips PCSEL-LiDAR)



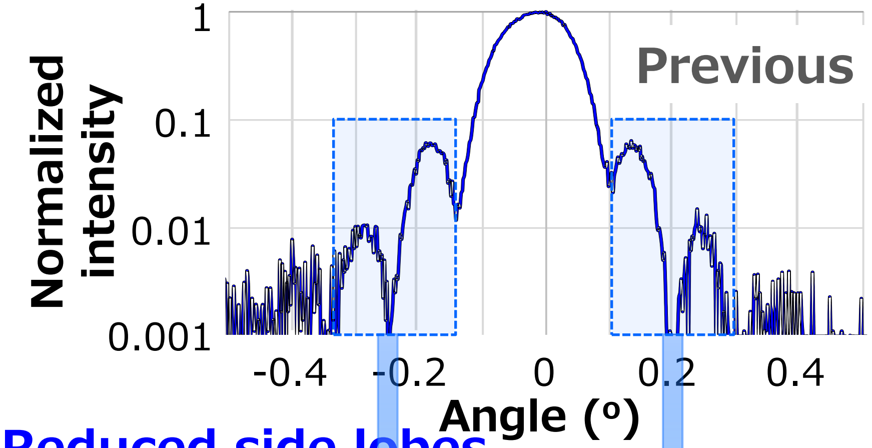
Recognition using on-board sensors

R&D Results (p.12~p.46)

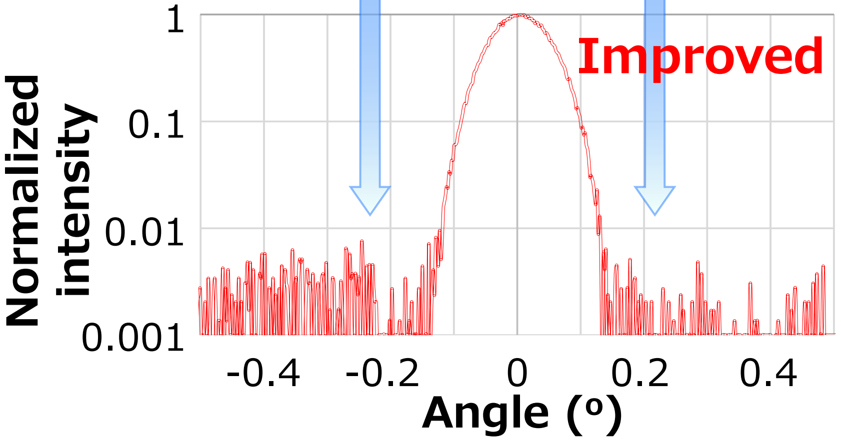
R&D Goal ①
Development of 3D PCSEL-LiDAR system
(Kyoto Univ.)

Advanced Vertical-Emission PCSEL Technology —Realization of an Gaussian Beam—

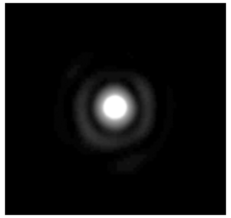
Intensity profile of the emitted beam



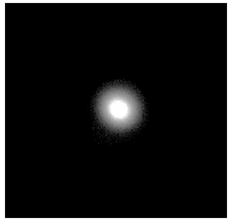
Reduced side lobes



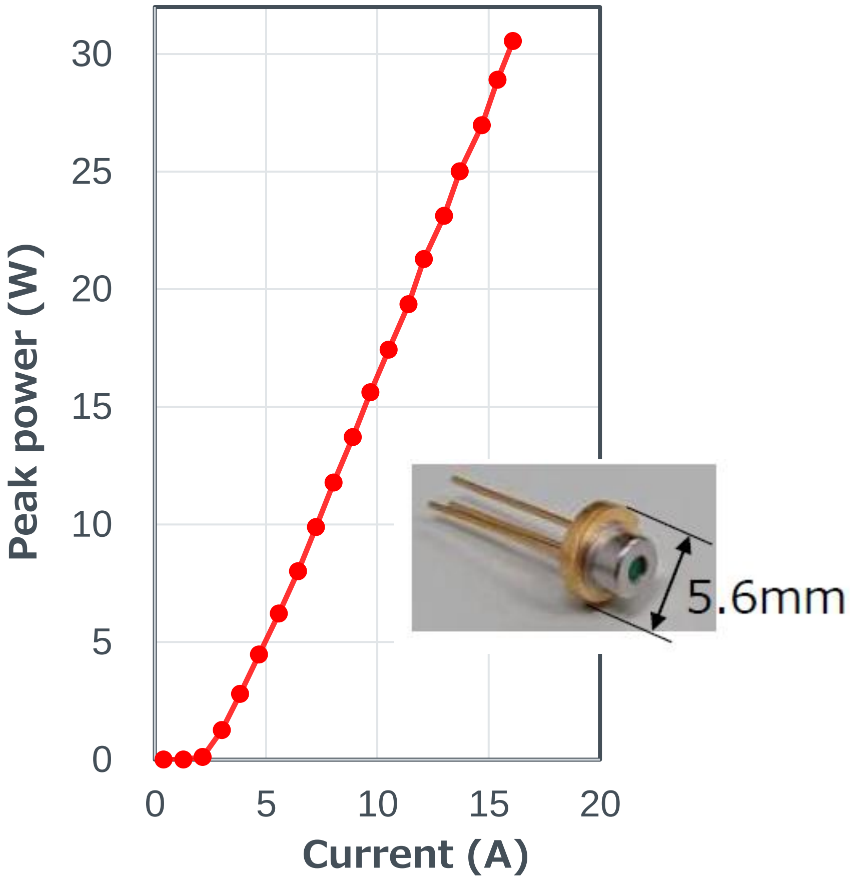
Beam pattern (brightness enhanced)



Beam pattern (brightness enhanced)

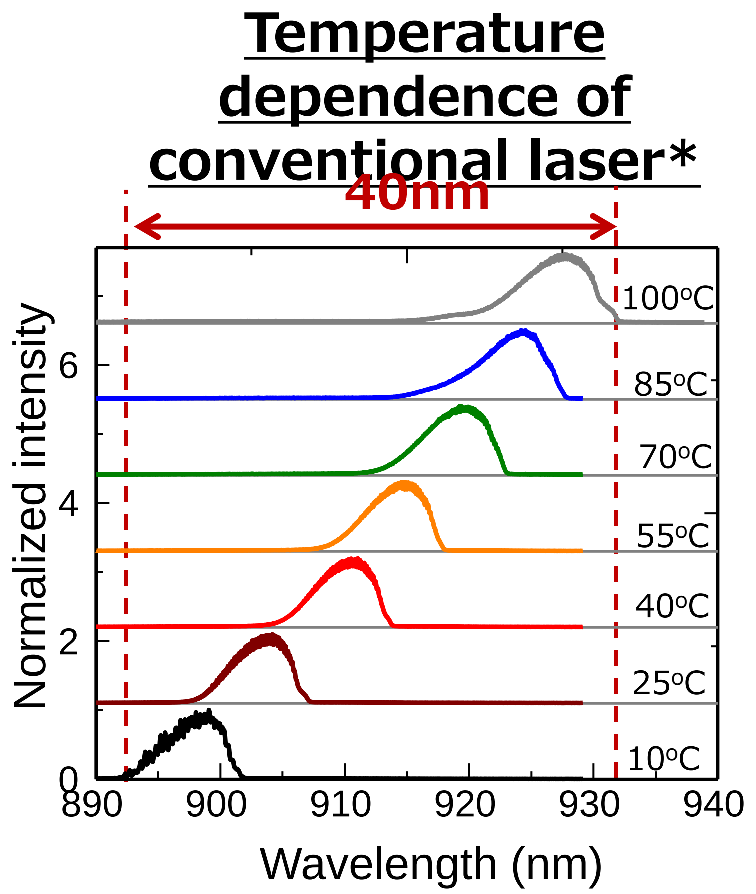


I-L characteristic

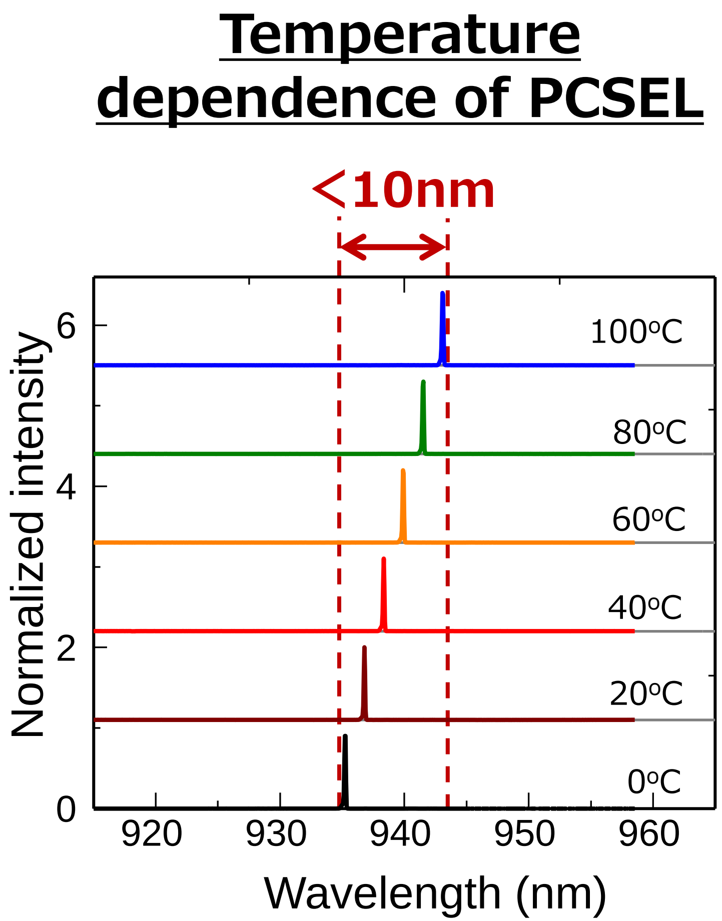


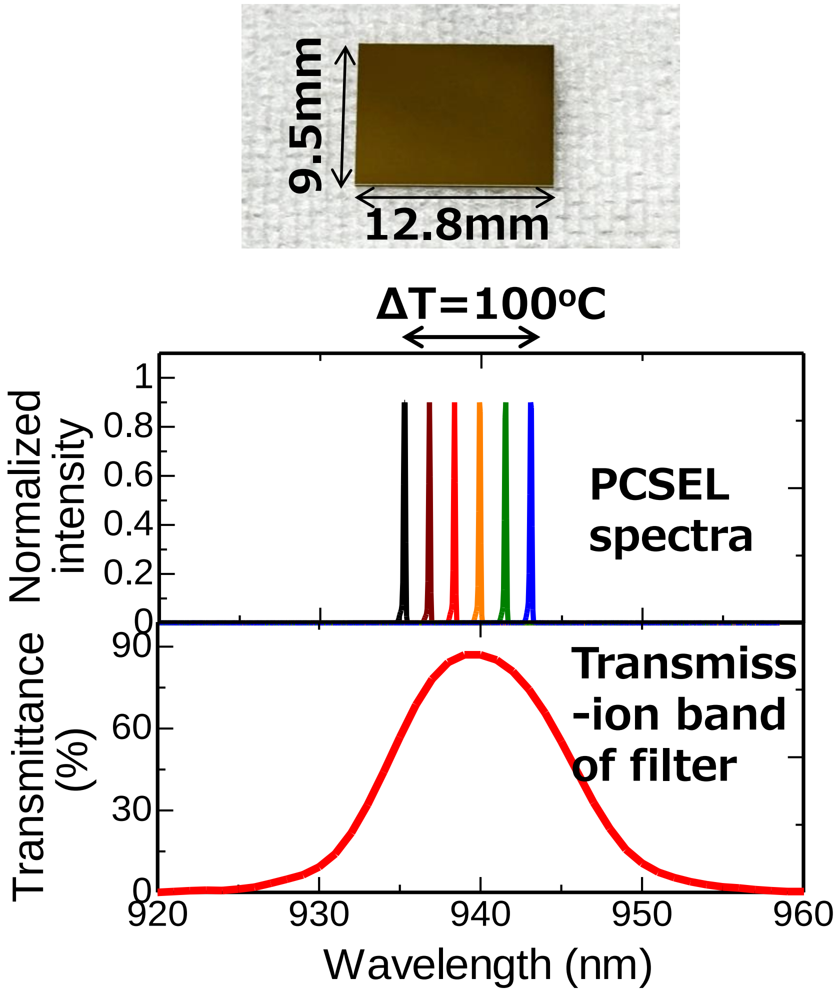
⇒ Essential for suppressing ghost artifacts and preventing missed detections.

Development of Narrow Bandpass Filter



＊Coherent, Inc. semiconductor laser



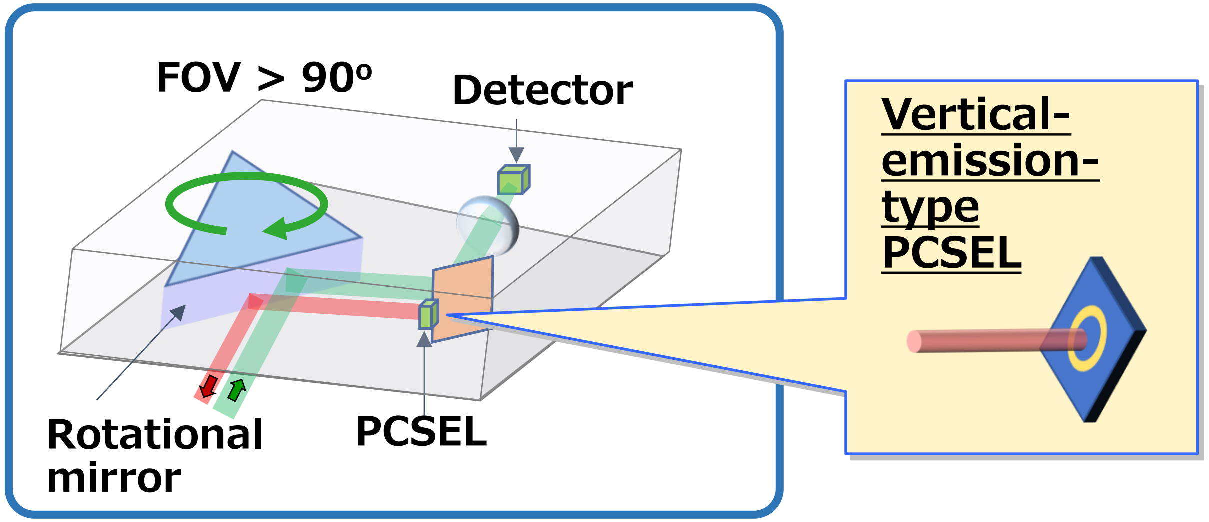


By utilizing a PCSEL, the bandpass filter can be narrowed to less than 1/4

R&D Goals : ①PCSEL-LiDAR Systems

Application to micro-mobility with zero missed detections

⇒ Ultra-compact card-type PCSEL-LiDAR (Step 1 : Additional item)



Specific Needs:
- Wheelchair-mounted sensing system at Kurume Institute of Technology
- Infrastructure sensor for vehicle detection/monitoring in IBS Consortium

Utilization as infrastructure sensors for monitoring pedestrian/traffic flows and detecting incoming vehicles

⇒ Mechanical wide-FOV PCSEL-LiDAR (Step1)

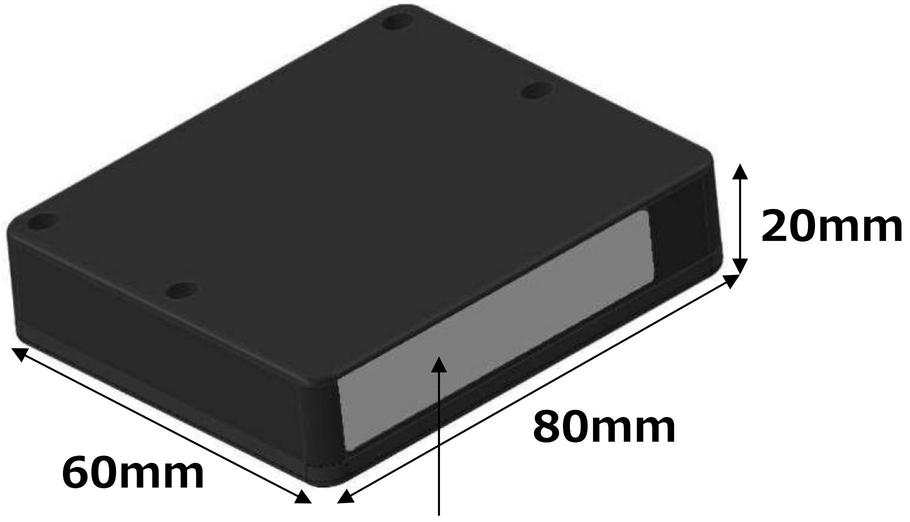
FOV: Field Of View

Specific Needs:
- Pedestrian and traffic flow monitoring in IBS Consortium

Development of Ultra-Compact Card-Type PCSEL-LiDAR (Step 1: Additional Item) − Incorporating Advanced Vertical-Emission PCSEL−

Application : Application to micro-mobility with zero missed detections

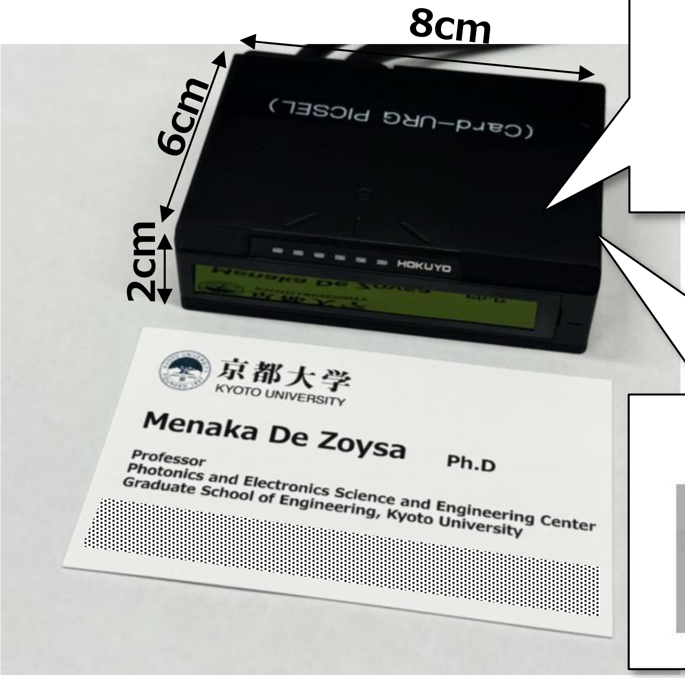
Appearance of the card-type PCSEL-LiDAR



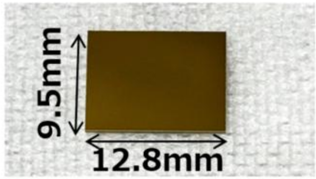
PCSEL-LiDAR Specifications

Parameters	Values
Bandpass filter	1/4th of conventional
Horizontal FOV	90°
Vertical FOV	3 layers（-2°、0°、+1°）
Resolution	0.125°
PCSEL wavelength	940 nm
Distance（R=90%）	10m
Distance accuracy	±4 cm
Scan speed	60 fps
Data points	172.8k per second
Interface	Ethernet 100BASE-TX
Size	20x60x80 mm^3
Supply voltage	10-30V
Power consumption	<2.7W
Operating temperate	-10～+50℃
Shockproof	20G X,Y,Z, 10 times each
Weight	<100 g（excluding cables）

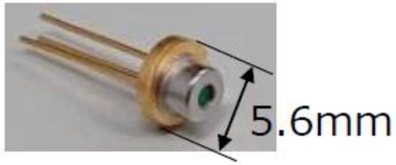
Prototyping Card-type PCSEL-LiDAR and characterization



Narrow bandpass filter

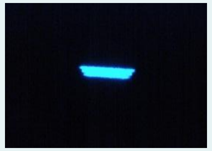


Improved PCSEL



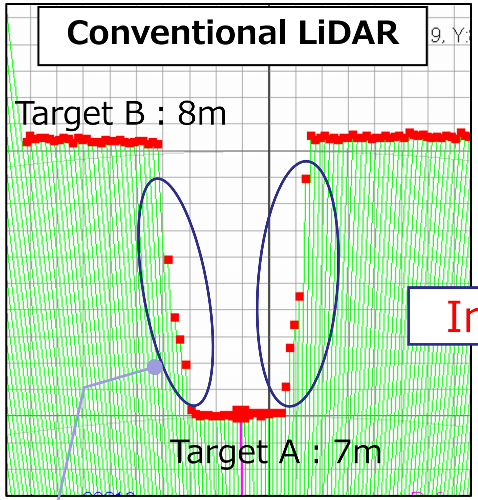
Footprint: Smaller than a business card

Beam evaluation

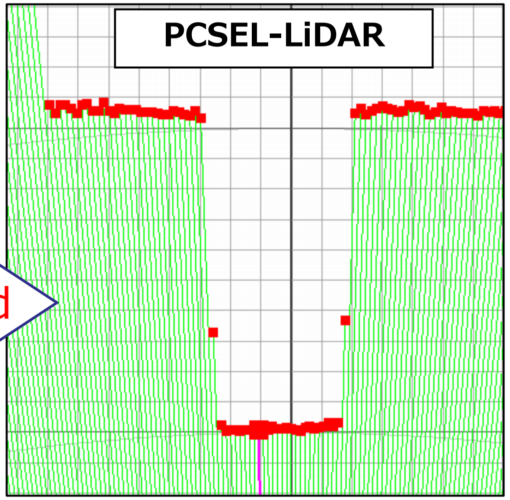
	Beam at 2m distance		
3-stack edge-emitting laser (lens + complex adjustments)		X : 52.0mm Y : 11.6mm	**Even when lenses are used, the beam is horizontally deformed**
New PCSEL ⇒ Gauss beam (Lens-free)		X : 23.2mm Y : 23.2mm	**Perfectly circular beam, very easy to use with Lidar (comment from Hokuyo Automatic)**

Evaluation of False Detections (Ghosts)

Conventional LiDAR: Ghost detections caused by the elongated beam profile
PCSEL-LiDAR: The circular beam profile greatly reduces ghost detection



Improved

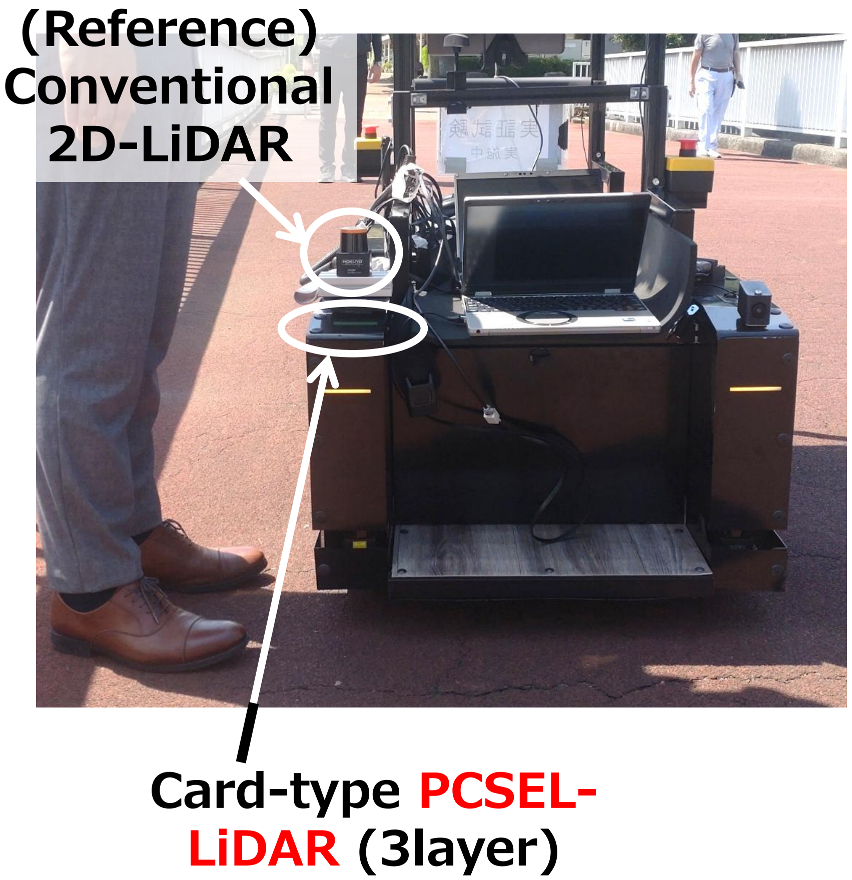


Falsely detected position (ghost)

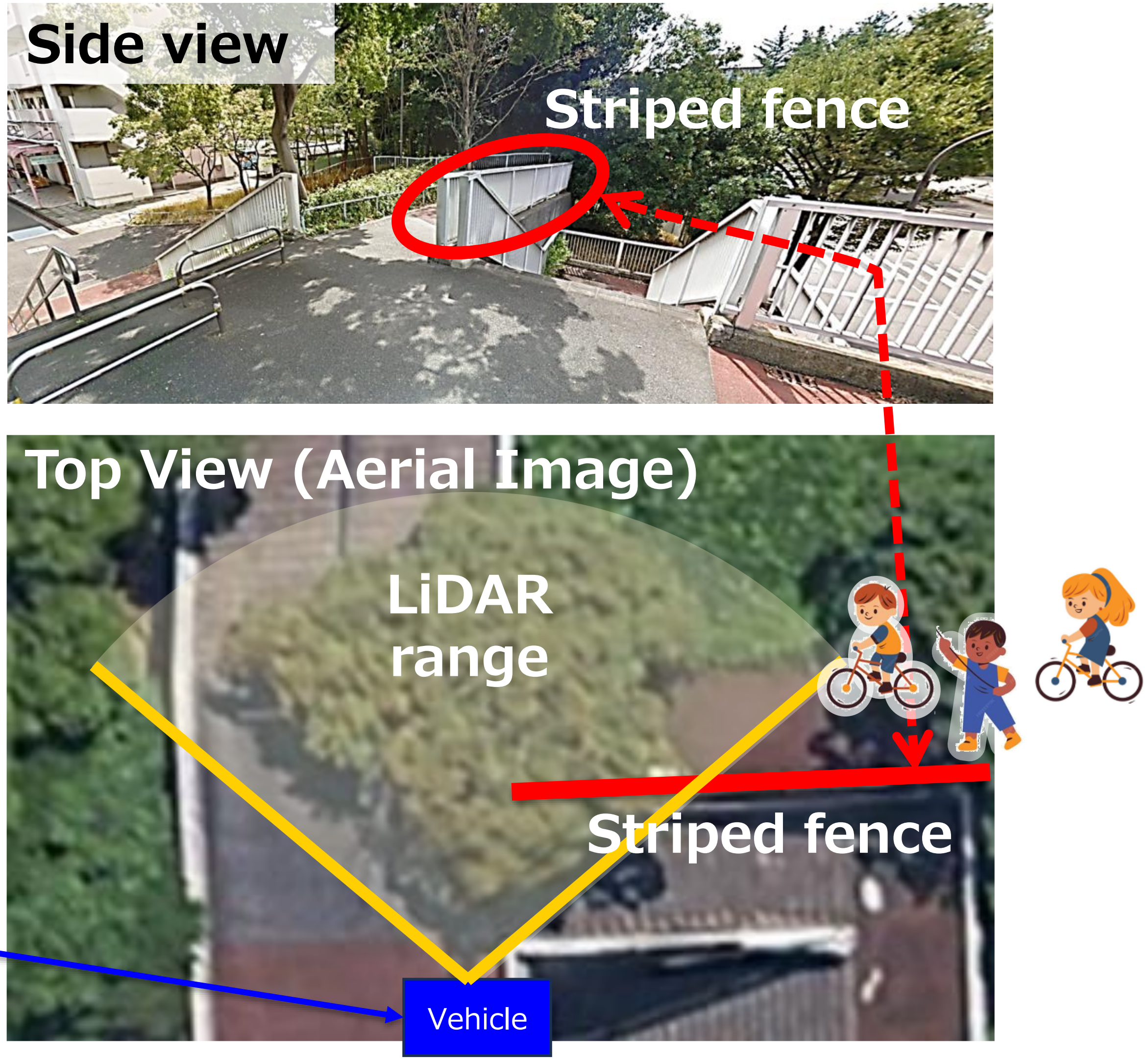
➡ **Greatly improved by PCSELs**

Field Demonstration of the Card-Type PCSEL-LiDAR : Detection of Objects Behind a Fence (Joint experiment with Kurume Institute of Technology)

Autonomous mobility vehicle and LiDAR setup

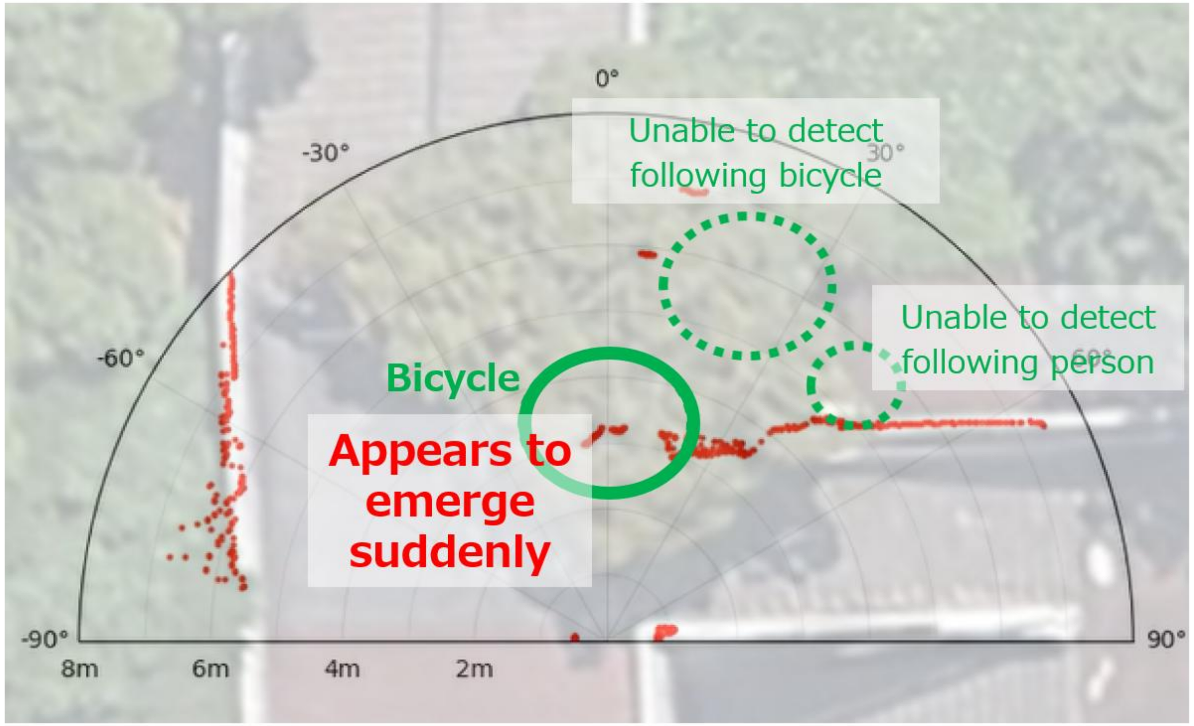


Experimental site



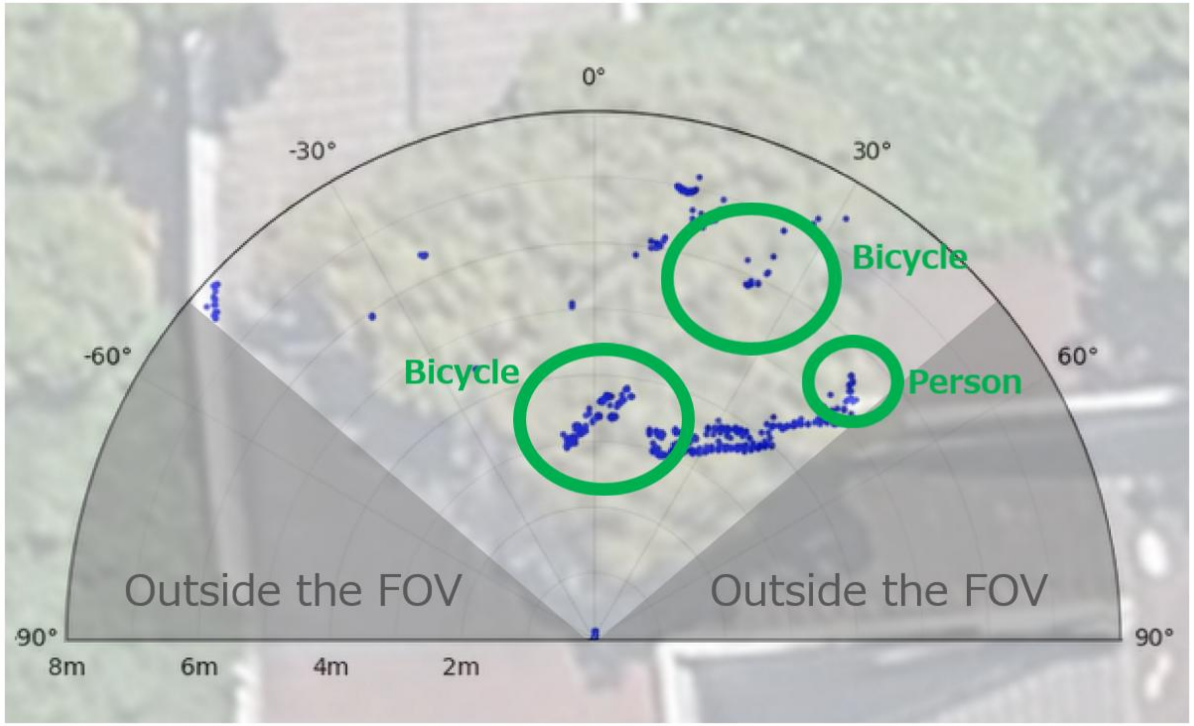
Field Demonstration of the Card-Type PCSEL-LiDAR : Detection of Objects Behind a Fence (Joint experiment with Kurume Institute of Technology)

(Reference) Conventional 2D-LiDAR



Objects behind the fence are not detected, causing them to appear to emerge suddenly from behind the fence, which poses a significant safety risk.

Card type PCSEL-LiDAR (3layer)



The high-quality PCSEL beam enables detection of objects behind the fence, allowing early hazard detection. (The three-layer configuration further provides more detailed object detection.)

Advantages of the Card-Type PCSEL-LiDAR : Feedback from Kurume Institute of Technology

- **Enhanced safety :** The PCSEL-LiDAR can detect children, cyclists, and small mobility vehicles located behind fences, which are blind spots for conventional LiDAR systems. This enables earlier hazard detection and contributes to safer autonomous driving. Furthermore, because wheelchairs and small mobility vehicles have a low eye level, users often feel uncertain about their surroundings. The proposed LiDAR can enhance situational awareness and reduce the psychological burden on users.

- **High-precision environmental perception :** With significantly fewer ghost detections, the PCSEL-LiDAR can accurately recognize narrow gaps and passage widths, enabling smooth, safe, and efficient navigation.
- **Excellent design flexibility and vehicle integration :** Its thin, card-type form factor minimizes design constraints when integrated into vehicles. It can be also retrofitted to existing vehicles without compromising their appearance while adding advanced sensing capabilities.
- **Compact yet high performance :** Despite its compact, thin-profile design, the PCSEL-LiDAR employs a three-layer scanning architecture, enabling accurate perception of both the three-dimensional environment and temporal changes in the surroundings.

Superior performance leads to greater confidence for people with mobility challenges, enabling them to travel to more places with greater confidence and safety

R&D Goals : ①PCSEL-LiDAR Systems

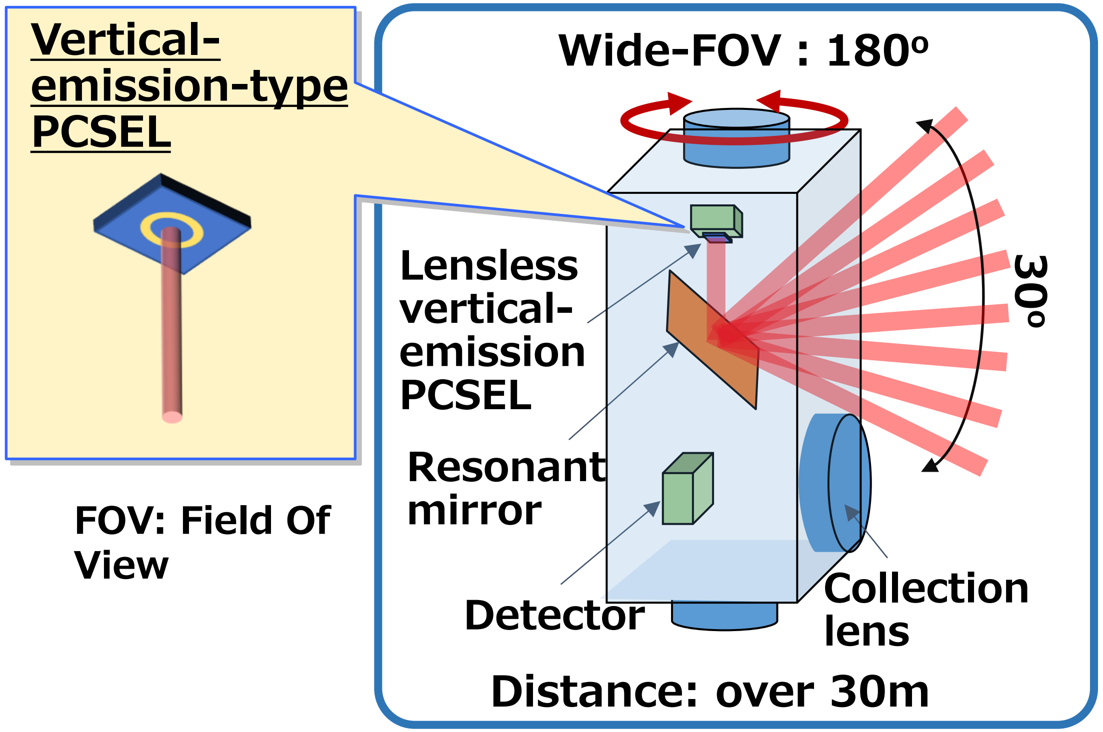
Application to micro-mobility with zero missed detections

⇒ Ultra compact card type PCSEL-LiDAR (Step1 : Additional item)

Specific Needs:
- Wheelchair-mounted sensing system at Kurume Institute of Technology
- Infrastructure sensor for vehicle detection/monitoring in IBS Consortium

Utilization as an infrastructure sensor for monitoring pedestrian/traffic flows and detecting incoming vehicles

⇒ Mechanical wide-FOV PCSEL-LiDAR (Step 1)

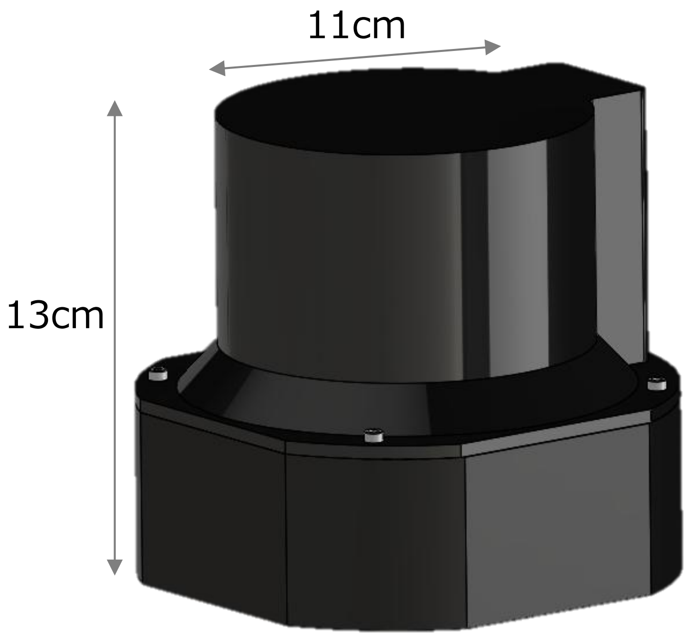


FOV: Field Of View

Specific Needs:
- Pedestrian and traffic flow monitoring in IBS Consortium

Development of Mechanical wide-FOV PCSEL-LiDAR — Finalizing the PCSEL-LiDAR Specifications —

Appearance of STEP1 wide-FOV 3D PCSEL-LiDAR

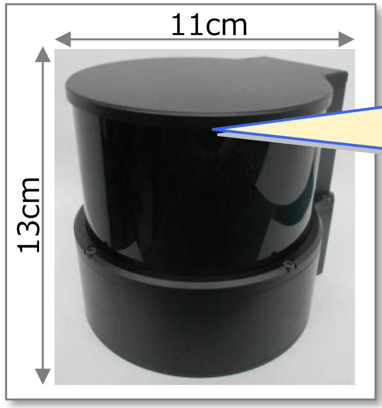


PCSEL-LiDAR Specifications

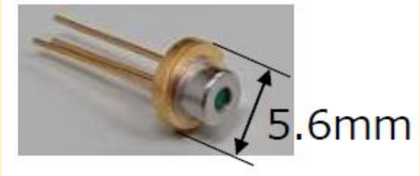
Parameters	Values
Horizontal FOV	180°
Vertical FOV	30°
Distance（R=90%）	30 m
Resolution（H･V）	0.5°(H)･0.6°(V)
PCSEL wavelength	945 nm
Bandpass filleter	40 nm
Distance accuracy	±5 cm
Frame rate	10 fps
Supply voltage	24 V
Interface	Ethernet
Power consumption	20 W
Data amount	500k/s
Size	13(H)×11 (D) cm
Weight	2.3 kg
Operating temperature	-10℃～+50ºC

Prototype Development and Initial Evaluation of Mechanical Wide-FOV PCSEL-LiDAR

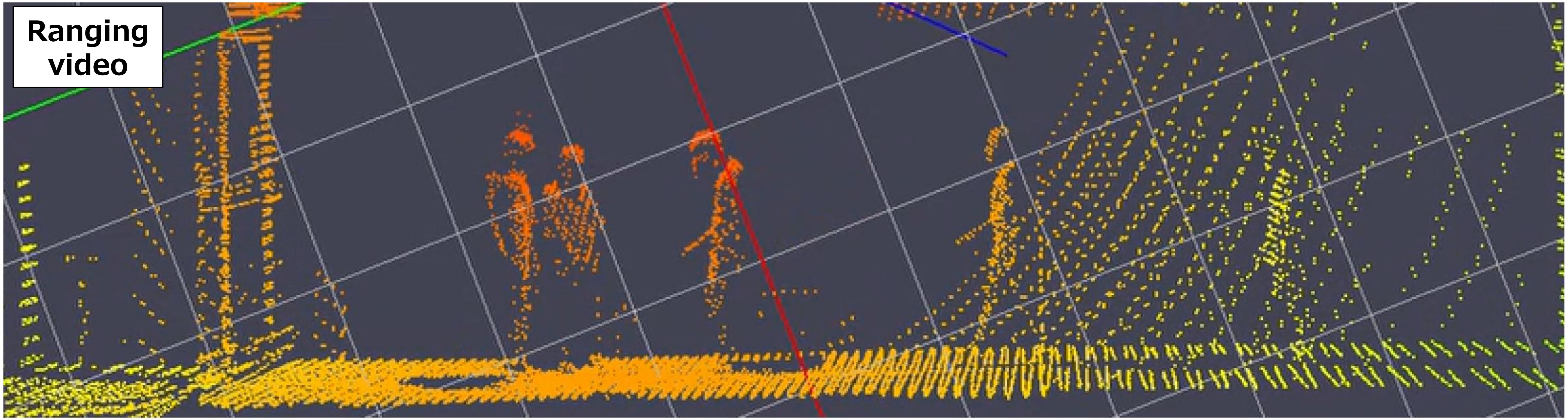
PCSEL-Equipped LiDAR System



Advanced PCSEL



Ranging video



R&D Goals : ①PCSEL-LiDAR Systems

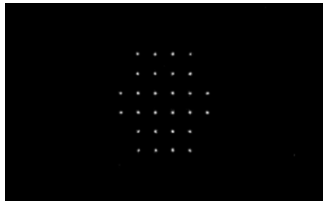
Applicable as both infrastructure and on-vehicle sensors due to its compact and low-cost design

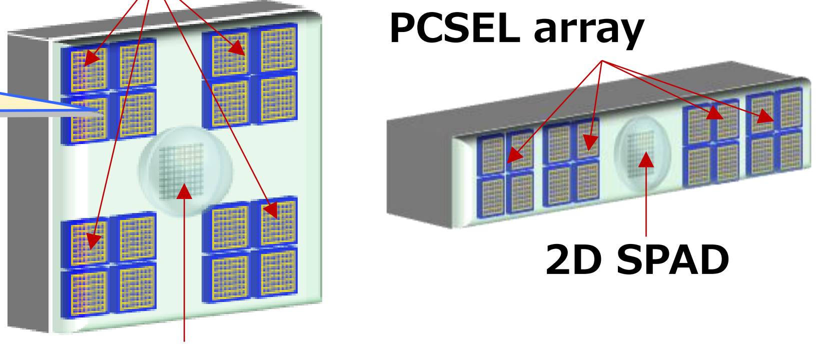
⇒ All-chip PCSEL-LiDAR（Step 2）

The all-semiconductor chip design enables compact size and low cost

Multi-dot emission PCSEL

Example (video)





The all-chip architecture enables a wide variety of system designs.

PCSEL array :
Over 3,072 dots by multiple chips

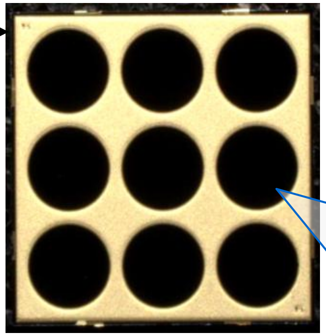
2D-SPAD array :
64 × 48 pixel array (3,072 total pixels)(Each pixel comprises a 2 × 2 SPAD array)

SIP Target Specifications:
Field of View (FOV): 12°×16° (0.25° resolution)
Range: 100m class

Note: In the future, a 3 × 3 (or larger) high-sensitivity SPAD array together with increased peak power per PCSEL spot is expected to enable 200–300 m ranging. Scaling both the SPAD pixel and the number of PCSEL illumination spots further enables a wide FOV (>25° × 100°).

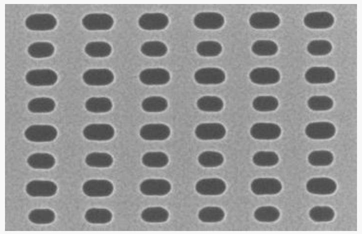
Electronic Beam-Scanning PCSEL and Driver Circuit

A single chip integrates 3 × 3 array of 1-mm PCSELs, generating >400 beam spots in a stripe pattern.

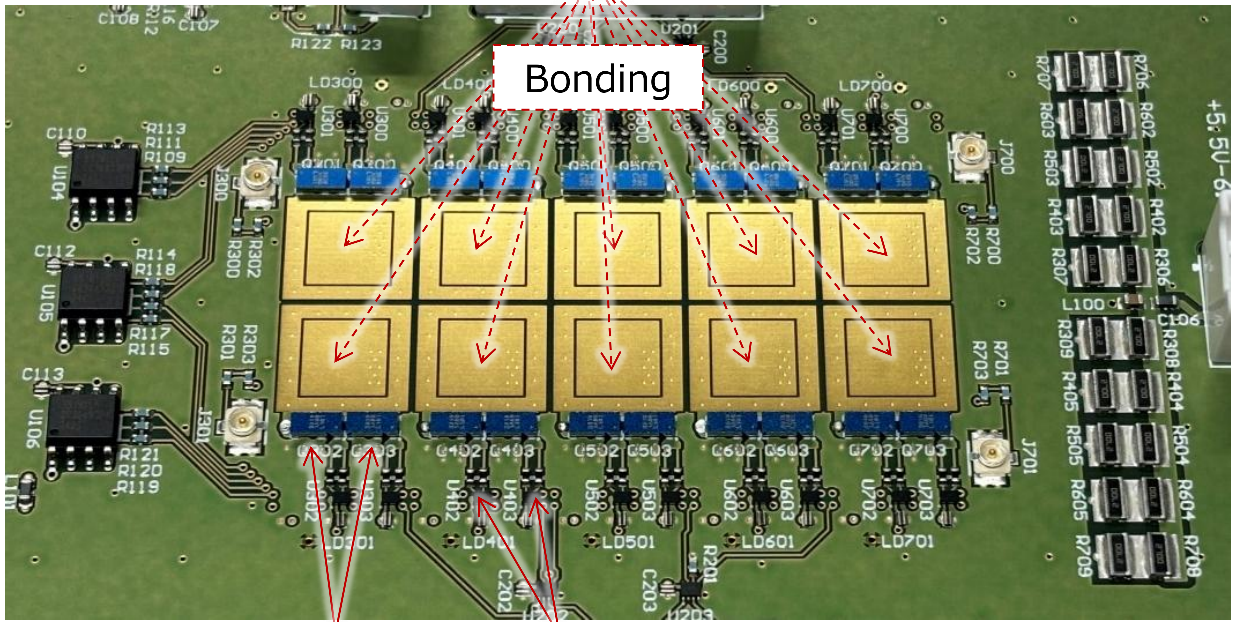


4.5mm

Integrated modulated photonic crystal



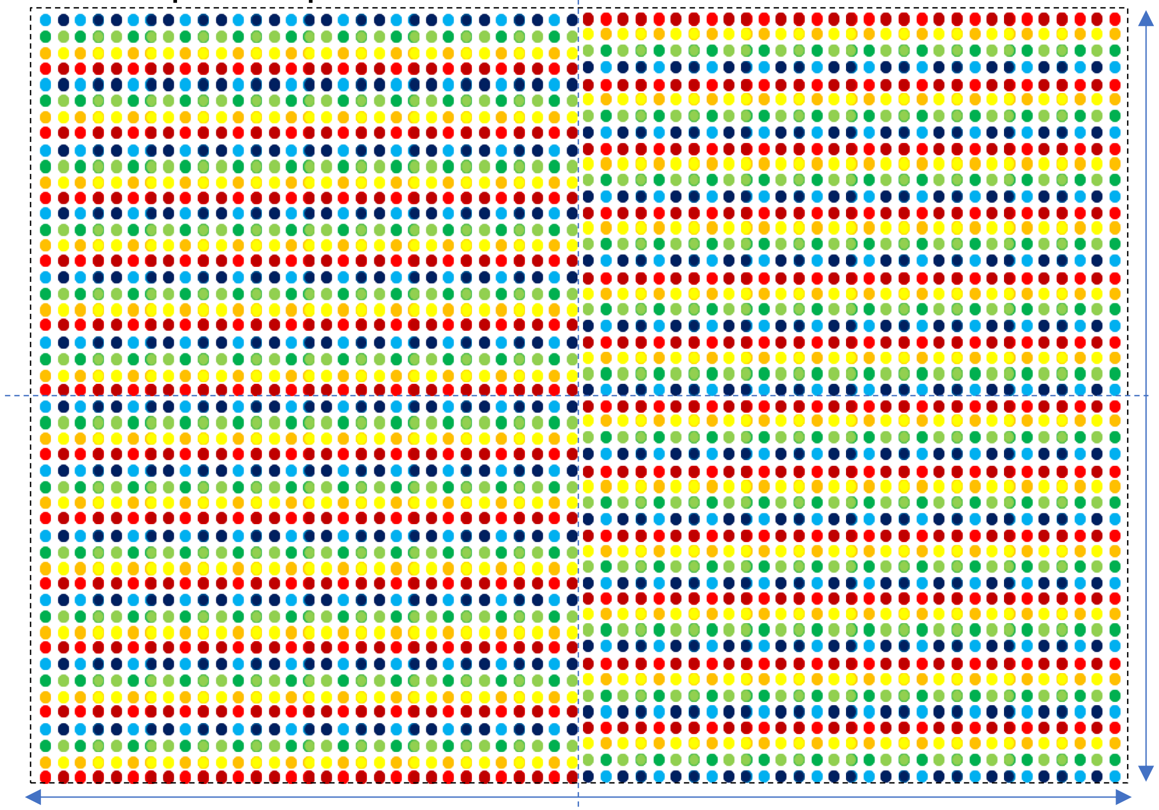
500nm



GaN-FET **Gate driver**

Target Beam Pattern and Beam Steering

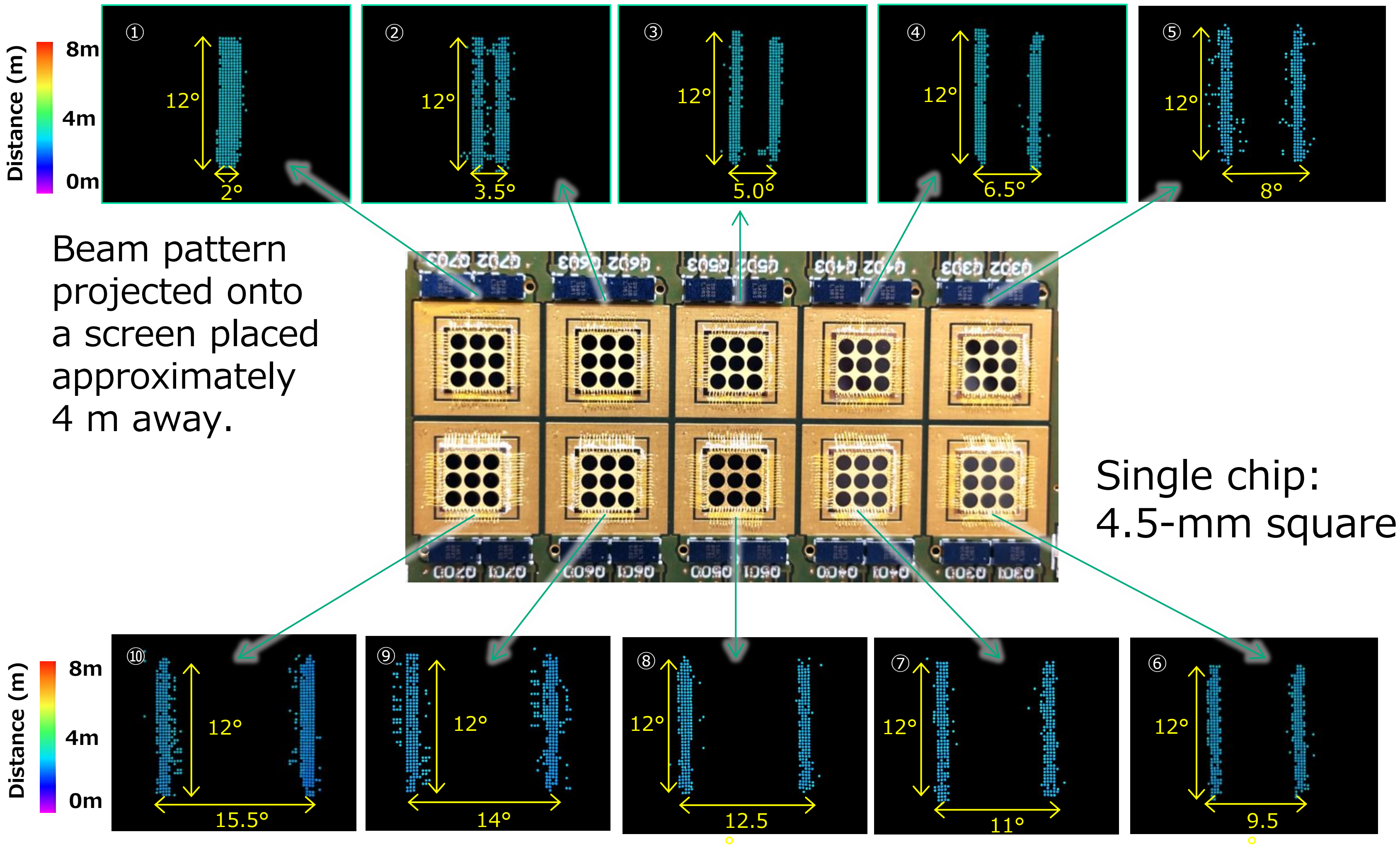
- >400 beam spots emitted in a stripe pattern from a single chip
- Beam steering achieved by electronic switching of multiple chips



12°

16°

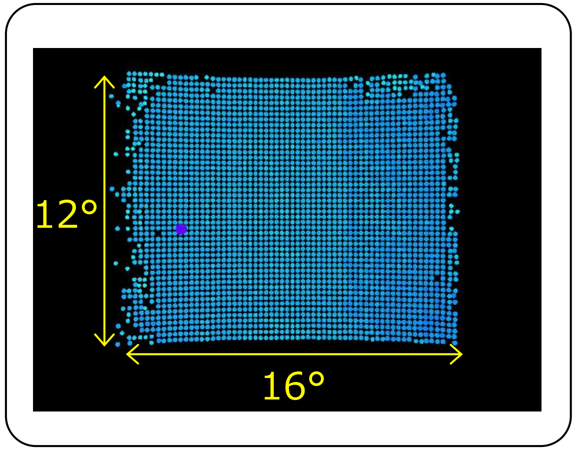
Electronic Beam Steering Enabled by Multi-dot Emission PCSEL Arrays



Beam pattern projected onto a screen placed approximately 4 m away.

Single chip: 4.5-mm square

Electronic beam scanning using PCSEL arrays (Beam scanning : ~1 kHz)

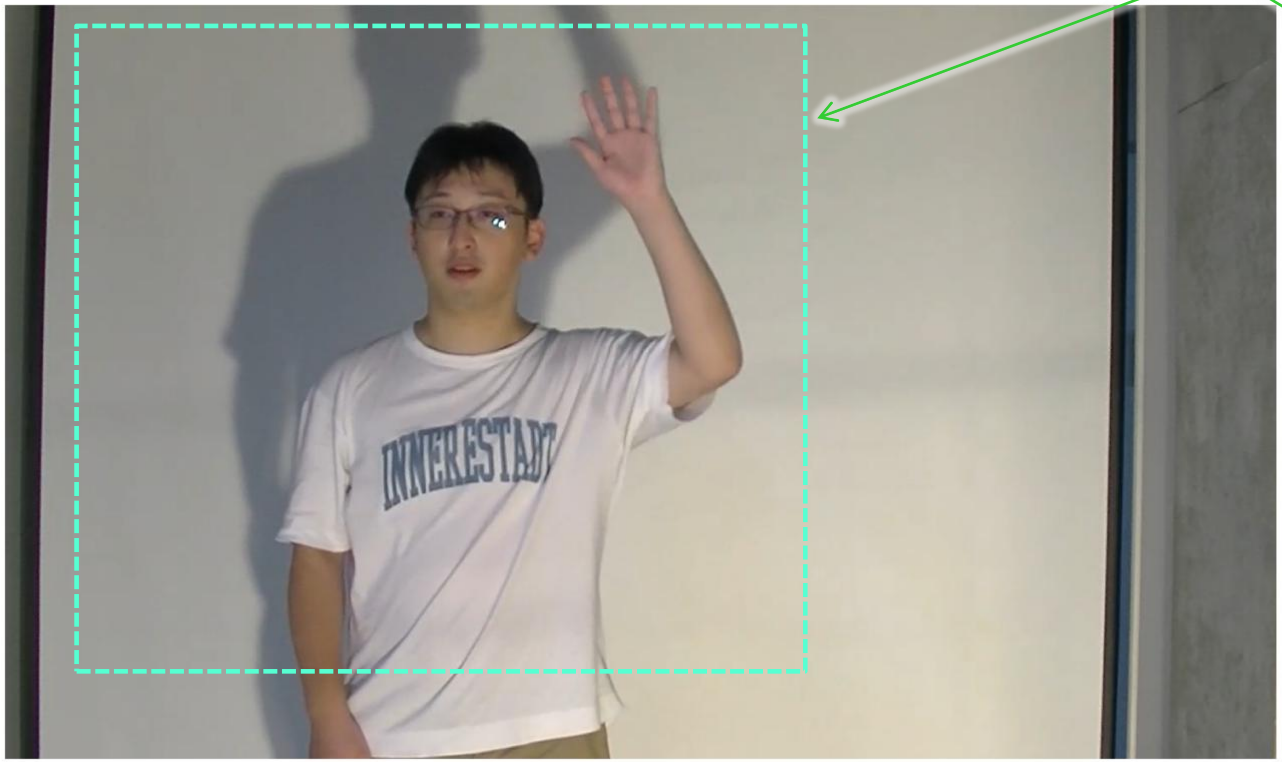


Successfully demonstrated all-chip electronic beam scanning using multi-dot emission PCSELs

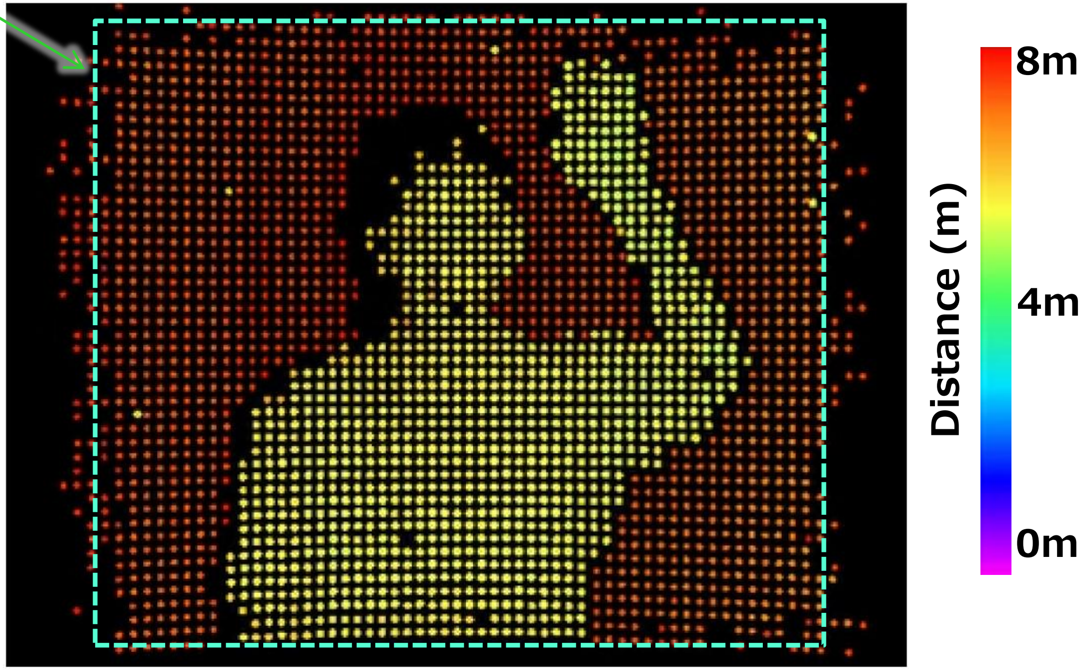
Prototype and Evaluation of All-Chip PCSEL-LiDAR Based on PCSEL Array and SPAD Array

Camera video

FOV



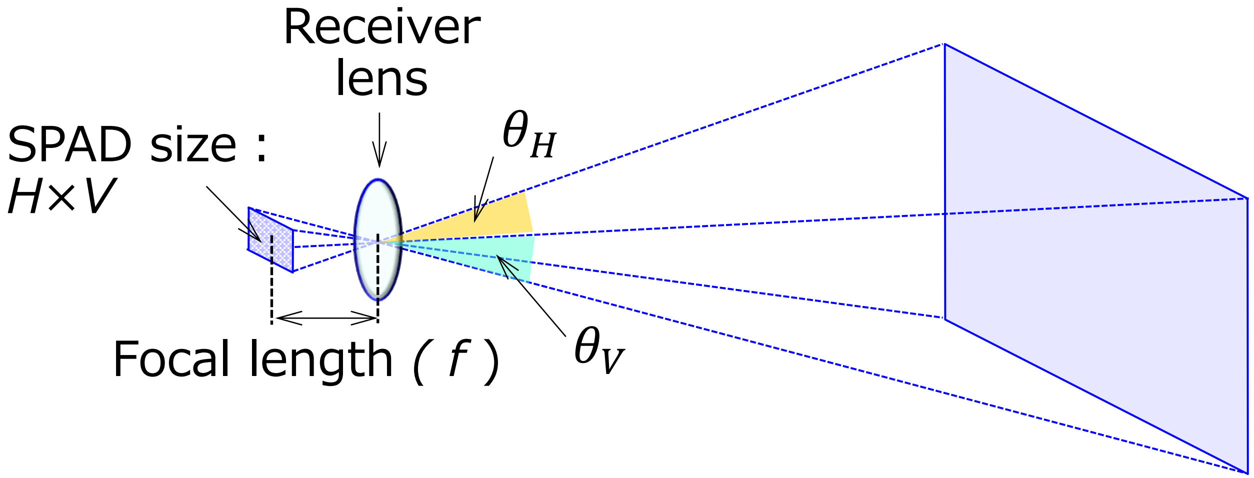
Ranging video



Successfully demonstrated the world's first proof-of-concept of an all-chip PCSEL-LiDAR (Completed 18 months ahead of the project schedule)

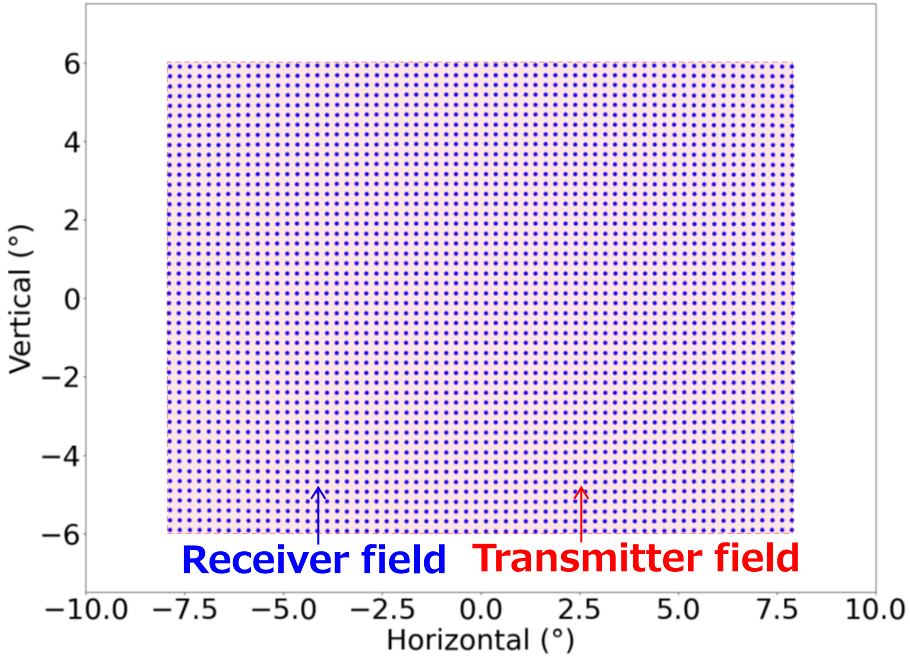
Investigation of Range Extension

Receiver efficiency improvement: Alignment of receiver and transmitter fields



Horizontal: $\theta_H = 2\tan^{-1}\left(\frac{H/2}{f}\right)$ Vertical: $\theta_V = 2\tan^{-1}\left(\frac{V/2}{f}\right)$

Receiver field = Transmitter field =~16°×12°



Receiver efficiency improvement: Higher transmission by anti-reflection-coated lenses + enhancement of the SPAD detection efficiency

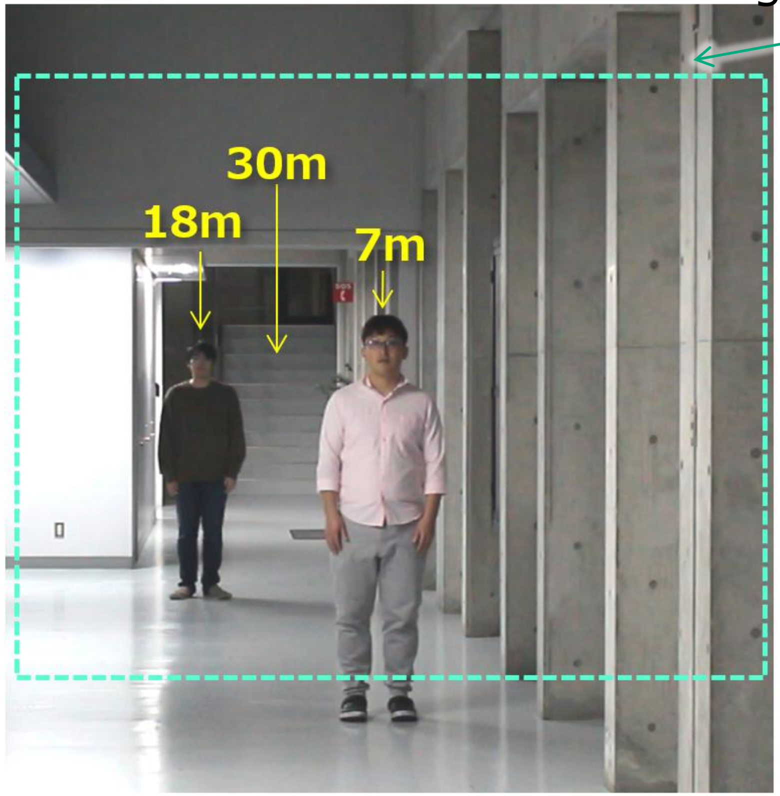
Receiver efficiency × SPAD detection Efficiency: > 12× improvement

⇒ Expected ranging distance: > 3.5× improvement

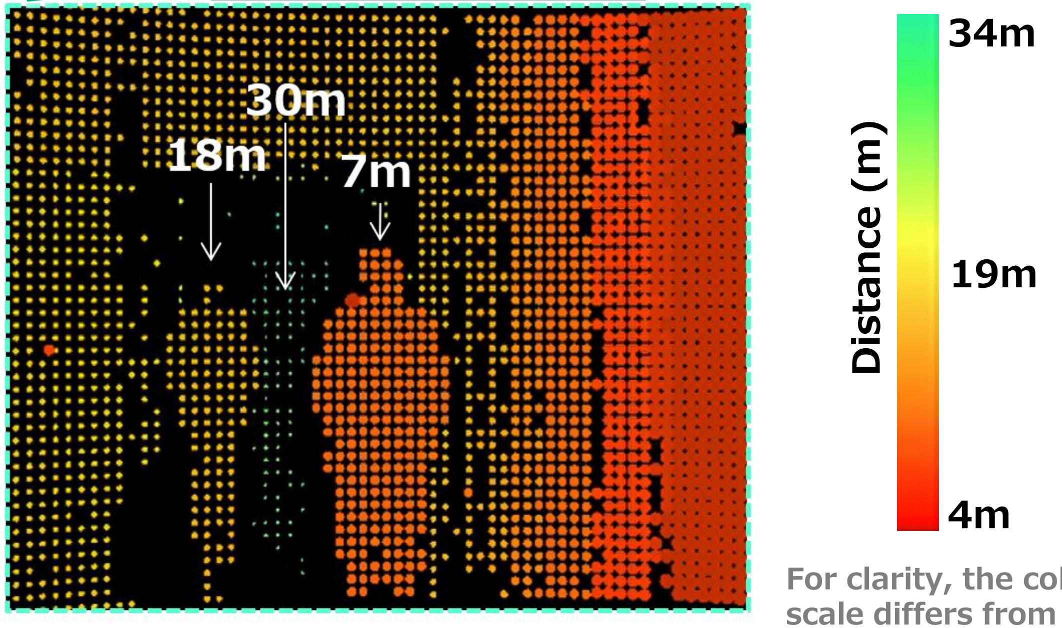
Experimental Evaluation of Ranging Distance Extension

M-PCSEL array scanning range (~16° × 12°)

Camera video



Ranging video



For clarity, the color scale differs from that used on p. 27.
Red: Near, Green: Far

The all-chip PCSEL-LiDAR achieved a range of 30 m (>3.5× improvement)

SIP end target : Expand this POC to 100-m-class (FOV: 12°×16°)

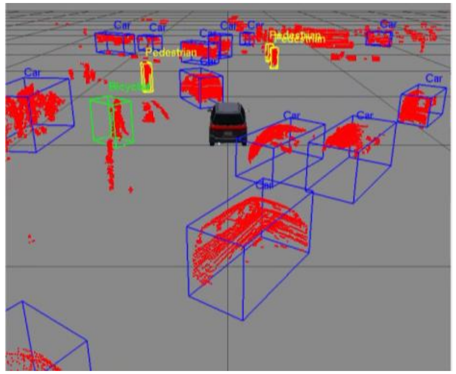
Beyond SIP project : Through collaboration with other programs, higher-output multi-dot PCSELs and more sensitive SPADs will enable FOV>25°×100°, range>200 m

R&D Goal ②
Development of recognition technology and conducting field-operational test (Kanazawa Univ.)

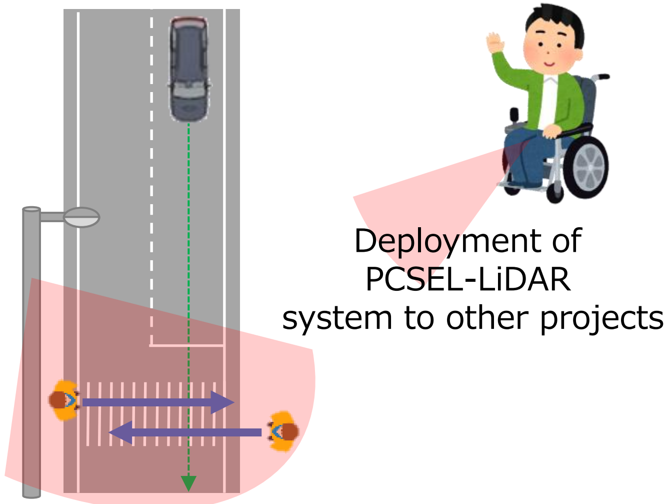
Development of Recognition Technology and Field-operational Test

*SIP Phase 2 (SIP-adus)

- **Achievement of SIP Phase 2 (SIP-adus)***
  - Autonomous driving system
    - R&D of recognition technology using on-board sensors
  - Field-operational test using infrastructure
    - FOTs at Tokyo waterfront area
- **R&D contents in this project**
  - Development of recognition technology using LiDAR
    - Applying LiDAR to infrastructure sensor
      - Monitoring crossing pedestrians, etc.
    - Utilizing LiDAR as onboard sensor
      - Development of recognition technology and sensor evaluation
  - Field-operational test (FOT) using LiDAR
    - Deployment of PCSEL-LiDAR system to other projects
    - Testing of level 4-equivalent autonomous driving with cooperating infrastructure sensors

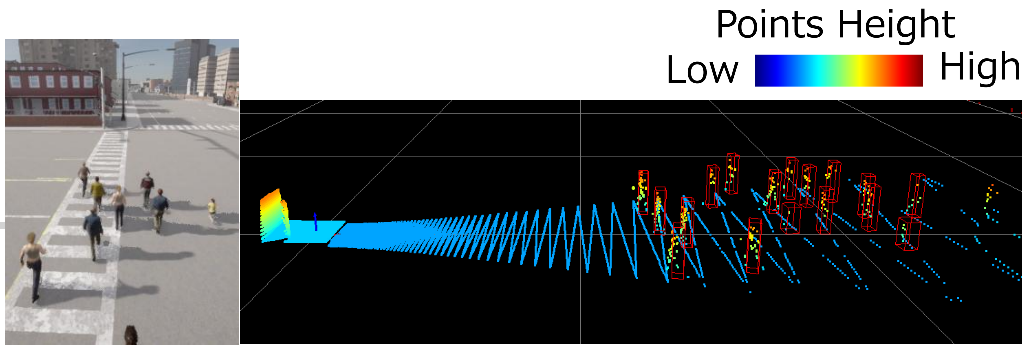


Development of recognition technology using LiDAR



Cooperate with infrastructure sensor and onboard sensor

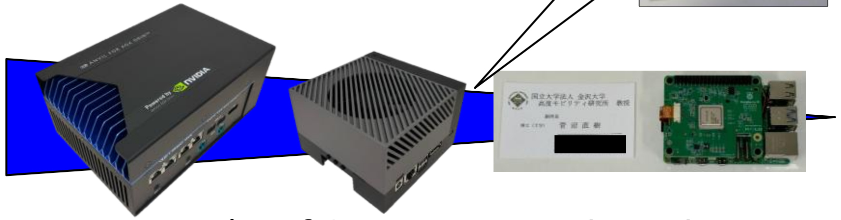
Activities for This Year



Example of sensor data simulating the pedestrian deck around Tsukuba Station
(Left: Camera image, Right: LiDAR point cloud)

- **LiDAR-based recognition technology**
  - Development using deep learning (DNN*)
    - Implementing recognition algorithms processable on compact computing units
    - Developing real-time recognition technology for vehicles within 135 m and pedestrians within 50 m
  - Virtual environment for LiDAR evaluation
    - Construction of a preliminary evaluation environment prior to using the actual Mechanical Wide-FOV PCSEL-LiDAR【Step1】
    - Evaluation within the virtual environment established last year
- **Conducting a field-operational test (FOT) using LiDAR**
  - Field testing of Mechanical Wide-FOV PCSEL-LiDAR as an infrastructure sensor
    - Study on LiDAR installation scenarios for infrastructure sensing
    - Execution of evaluation experiments using the actual device
      - Arrival of the actual device at Kanazawa University in October 2025
  - Acquiring real-world data by driving on public roads
    - In Tokyo, Ishikawa, Hokkaido, etc.
  - Providing test ride opportunities for automated vehicles

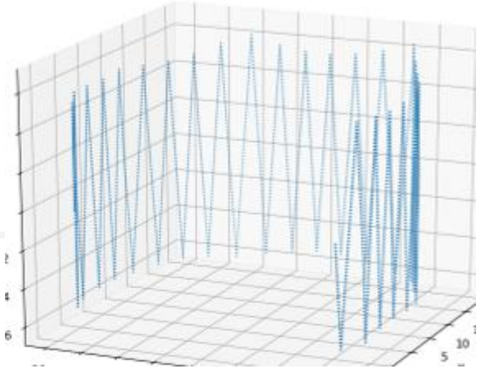
Orin Nano
An ultra-compact, palm-sized computing unit



Examples of Compact computing units
Anvil, Orin, and Raspberry Pi (equipped with AI chip) from left to right

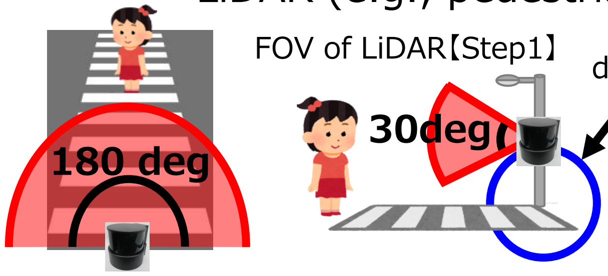
*DNN: Deep Neural Network

Construction of a virtual evaluation environment application to infrastructure sensors (Implemented last year)



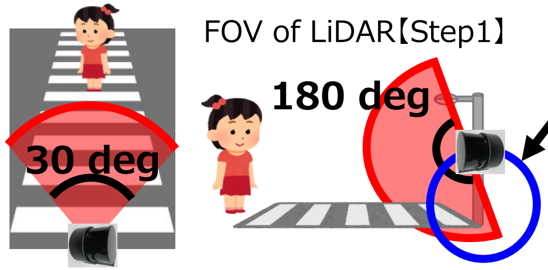
Scanning pattern of the Mechanical Wide-FOV PCSEL-LiDAR modeled in the simulator

- Construction of a sensor model for the Mechanical Wide-FOV PCSEL-LiDAR using the open-source simulator CARLA
  - 3D measurement of wide areas through rotating zigzag laser scanning
- Simulation assuming real-world use cases (UCs) by installing the Mechanical Wide-FOV PCSEL-LiDAR at elevated positions
  - Study on installation methods considering wide-area coverage (e.g., intersections) and detection directly beneath the LiDAR (e.g., pedestrian decks)



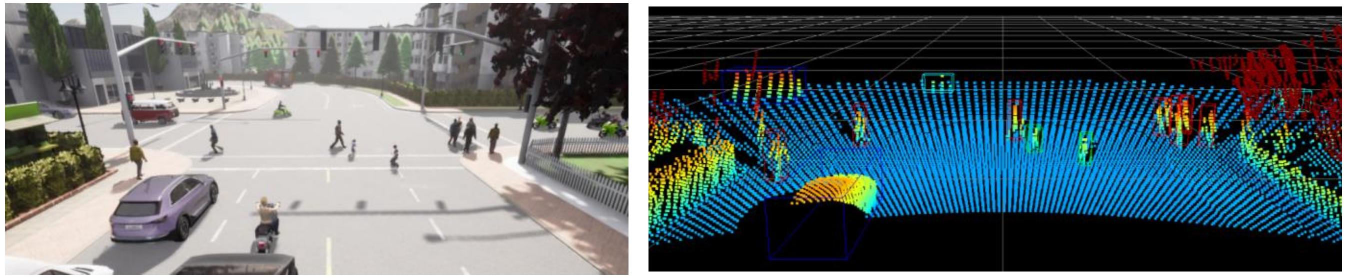
Standard installation (for wide-area monitoring)

Rotated 90 degrees in the roll direction



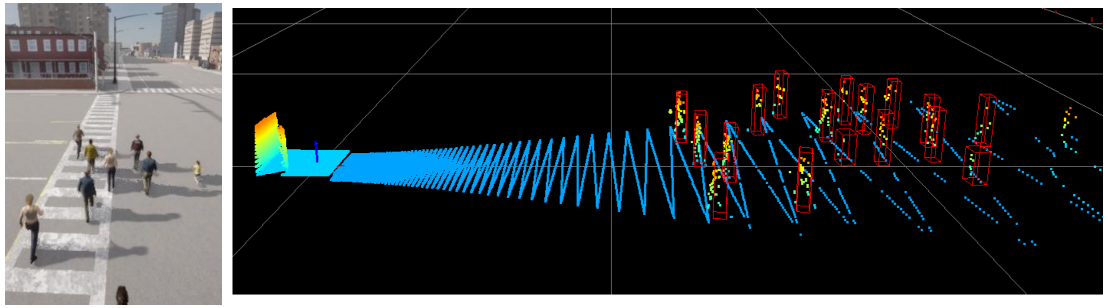
Installation method considering detection directly beneath the LiDAR

  - Generation of massive sensor data for building deep learning-based recognition models
    - Generation of diverse datasets, varying locations, pedestrian densities, and walking patterns (e.g., speeds)
    - Reproduction of point cloud measurement errors (noise) reflecting real-world environments



Example of sensor data using the installation method for wide-area coverage (e.g., intersections)
(Left: Camera image, Right: LiDAR point cloud)

Points Height
Low High



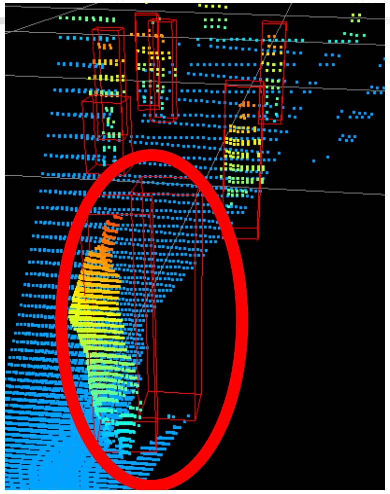
Example of sensor data using the installation method considering detection directly beneath the LiDAR (e.g., pedestrian decks)
(Left: Camera image, Right: LiDAR point cloud)

Comparative evaluation simulating the installation of Mechanical Wide-FOV PCSEL-LiDAR at multiple heights for infrastructure

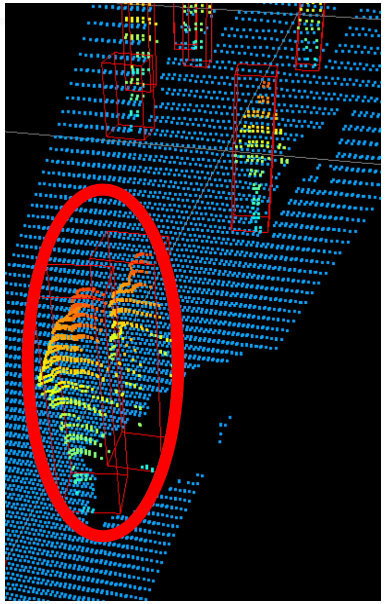
- Pedestrian point clouds observed when installed on traffic signals, street light poles, and traffic sign poles
  - Higher installation positions result in a larger number of observable pedestrians

Number of Observable Pedestrians (LiDAR Point Clouds)			
Total Simulated Pedestrians	Traffic sign pole 2.0m	Street light pole 3.5m	Traffic signal 4.25m
197,208	136,294	149,204	157,303

Traffic sign pole 2.0m

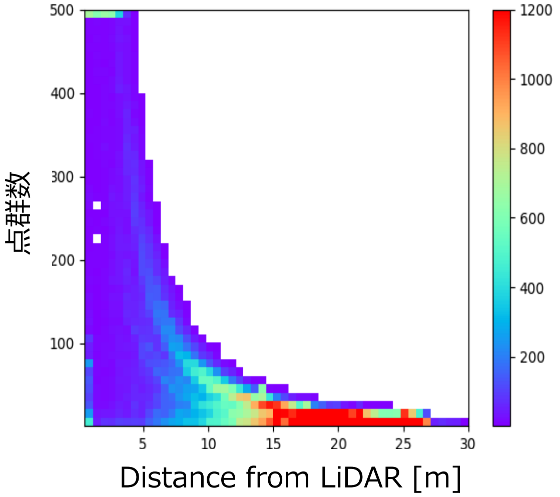


Traffic signal 4.25m

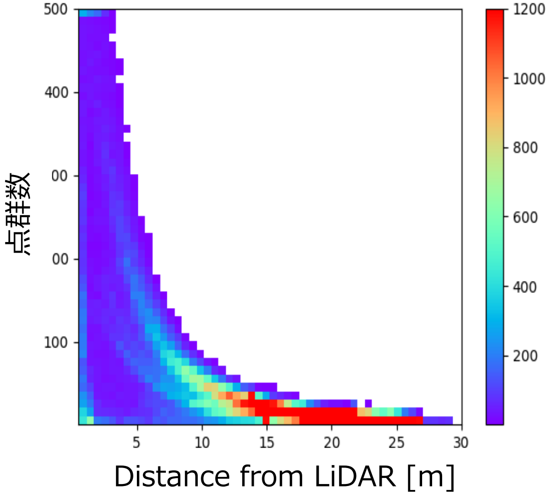


An increase in unobservable pedestrians at lower installation heights

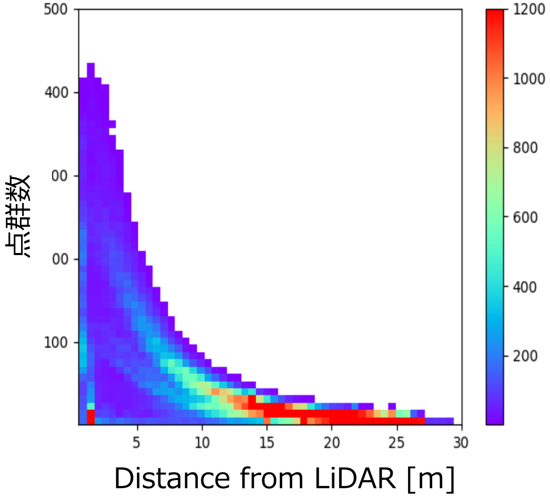
Traffic sign pole 2.0m



Street light pole 3.5m



Traffic signal 4.25m



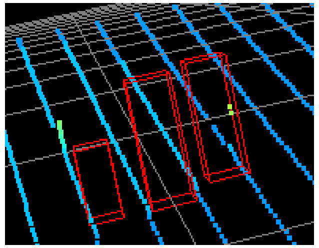
□ : Pedestrian

Points Height

Low High

Study on the Scanning Direction of Mechanical Wide-FOV PCSEL-LiDAR

- Differences in observed point clouds based on scanning direction (Installation height: 3.5 m)
  - Standard installation
    - Observable from 3-5 m away from the LiDAR
  - Installation considering detection directly beneath the LiDAR
    - Observable from 0 m
  - Minimal impact from gaps between layers in both installation methods
    - Note: With the Velodyne VLP-16, pedestrians may fall into the gaps between layers
    - Highly versatile: Can be selectively applied based on use cases (UCs)

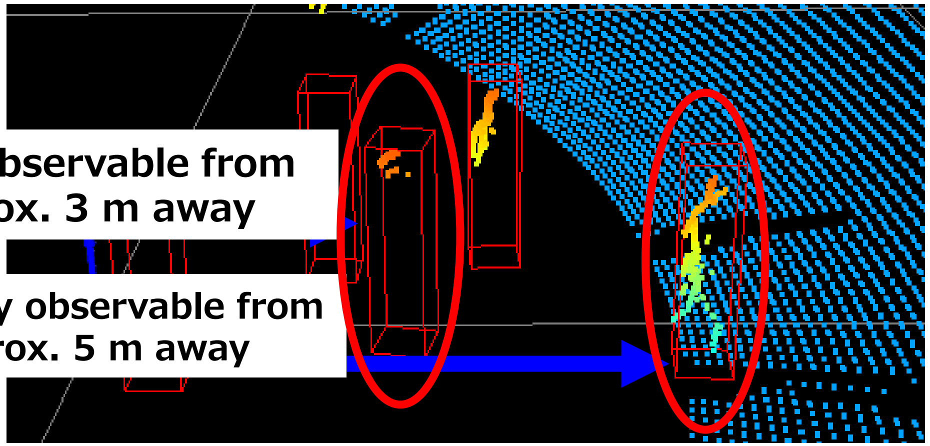


Pedestrian remaining unobservable due to falling into layer gaps (VLP-16)

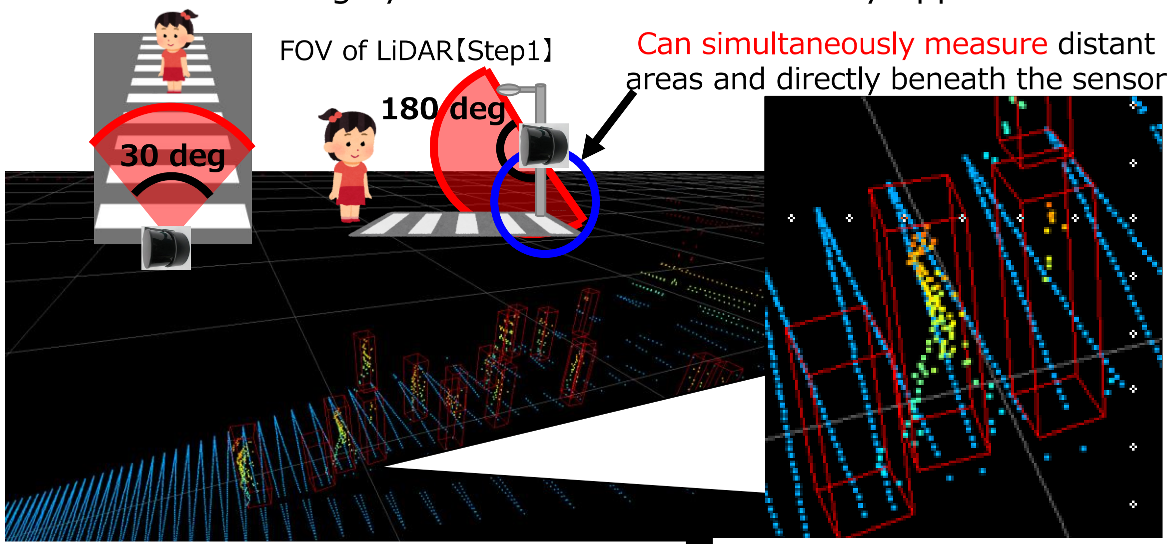
□ : Pedestrian

Points Height

Low — High

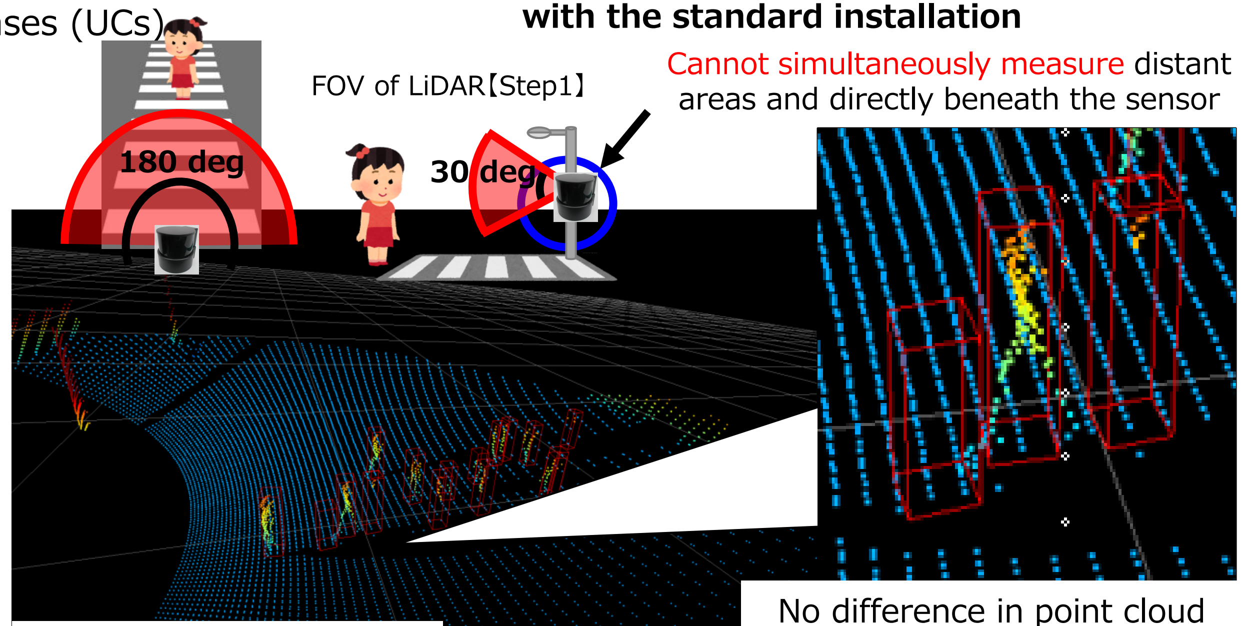


Minimum observable distance for pedestrians with the standard installation



Installation method considering detection directly beneath the LiDAR

No difference in point cloud appearance due to occlusion

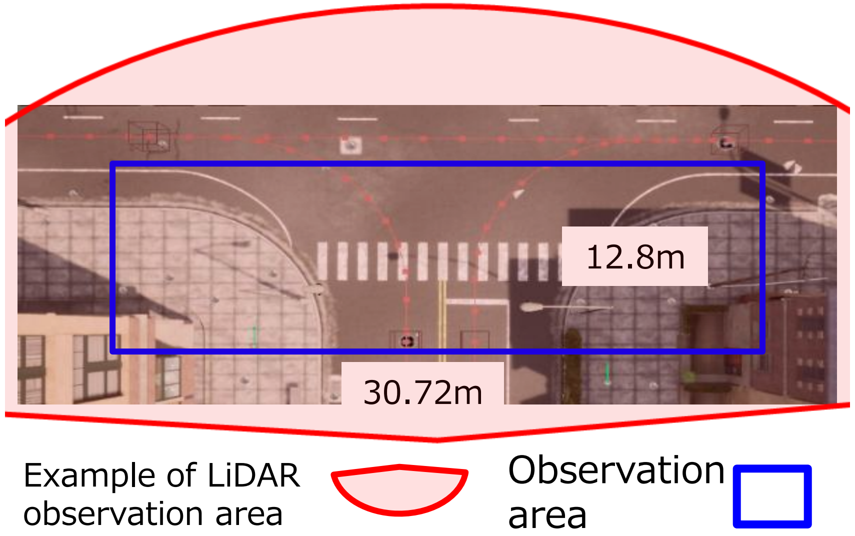


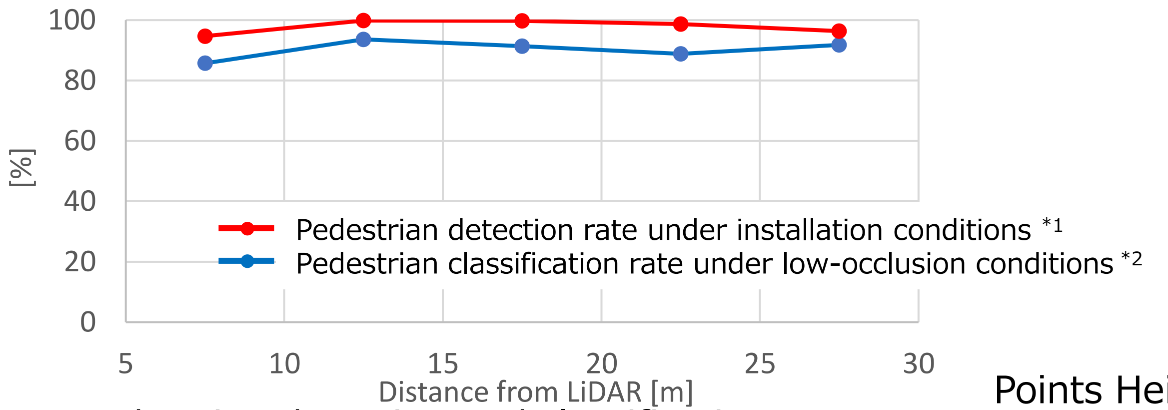
Standard installation

No difference in point cloud appearance due to occlusion

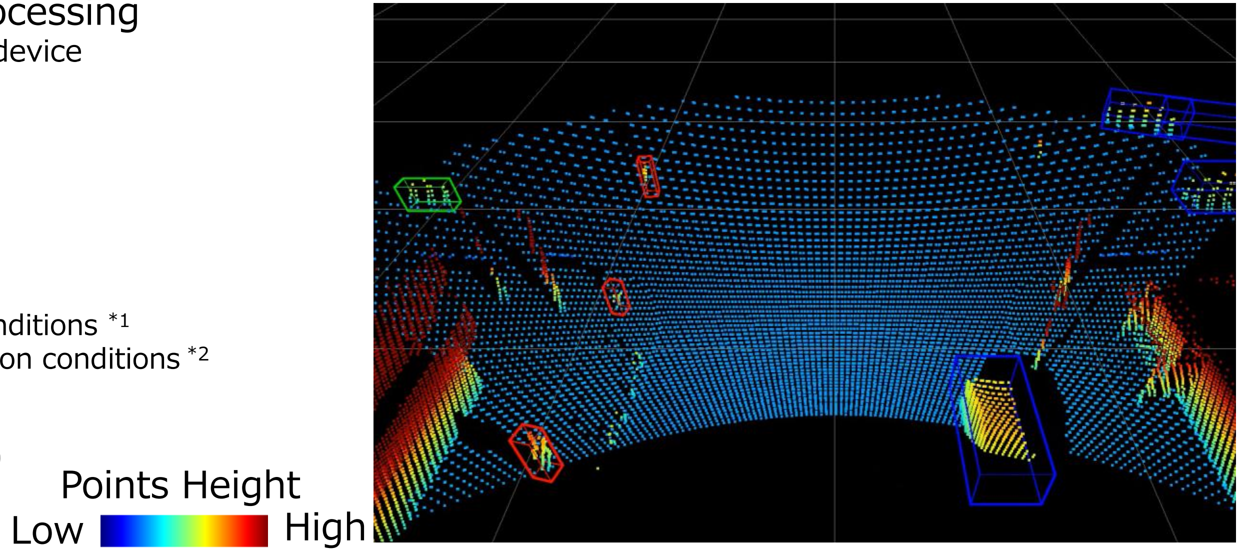
Performance Evaluation of the Developed LiDAR Recognition Model

- Assuming the monitoring of pedestrians at a crosswalk with two lanes in each direction
  - Simulating the installation of a Mechanical Wide-FOV PCSEL-LiDAR at a height of 5 m
  - Development of a model capable of recognizing pedestrians, two-wheelers, and vehicles
- Quantitative evaluation results of pedestrian detection and classification rates
  - Object detection rate*1 evaluation results:
    - Average detection rate: 97.8% (including cases occluded by other objects)
      - Detection rate can be improved by mitigating occlusion through the use of multiple LiDARs
  - Object classification rate*2 evaluation results:
    - Average classification rate: 90.5% (Reference: Vehicles 98.4%, Two-wheelers 90.5%)
      - Evaluated strictly on a single-frame basis without temporal processing
  - Higher accuracy is possible by incorporating temporal processing
    - Effectiveness will be verified through field testing using the actual device





Pedestrian detection and classification rates

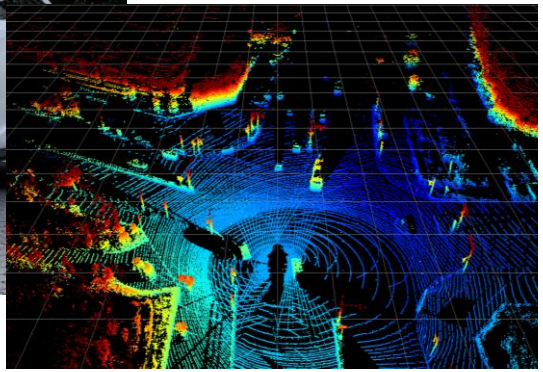


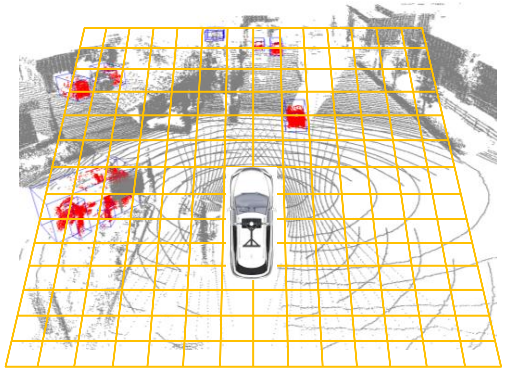
Recognition results of the developed model

※1 To account for noise, objects with 3 or more observed points are defined as true detections.
※2 Objects with correctly estimated classes are defined as true classifications.

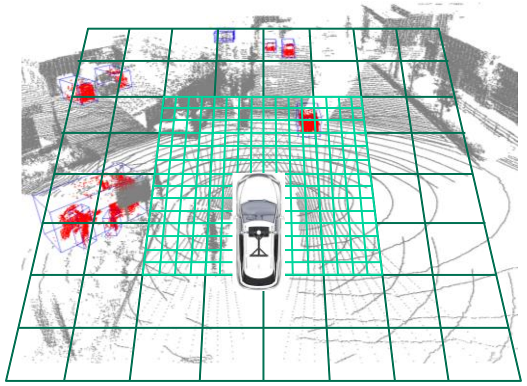
Efforts to Extend the Detection Range of Recognition Models for Applying to Automated Driving

- Preliminary study on recognition using long-range PCSEL-LiDAR for autonomous driving applications
  - Study on a recognition model capable of detecting vehicles within 135 m and pedestrians within 50 m (FY2025)
  - Evaluation using real-world data from an autonomous vehicle at Kanazawa University
    - Preliminary testing with a 128-layer Velodyne LiDAR
    - Evaluated using driving data from Ishikawa, Toyama, Tokyo, and Chiba prefectures
  - Development tailored for implementation on compact computing units
    - Challenge: Expanding detection range increases resource requirements, posing a major hurdle for compact device implementation.
    - **Solution: Custom-developed model that maintains recognition accuracy while suppressing resource consumption.**
    - **Method: Achieved through distance-adaptive optimal processing of point clouds.**





Baseline recognition model

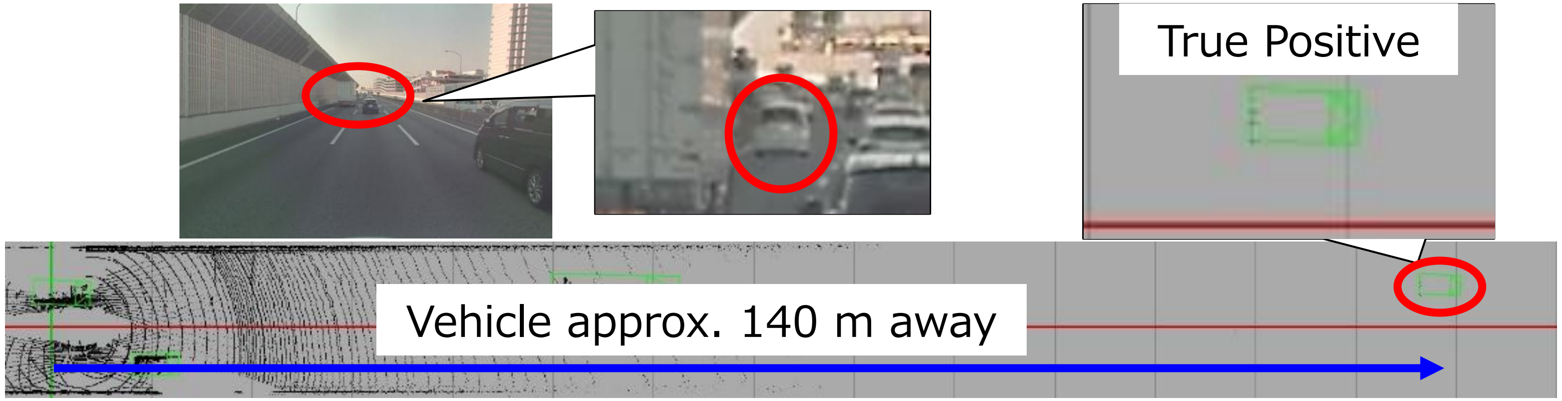


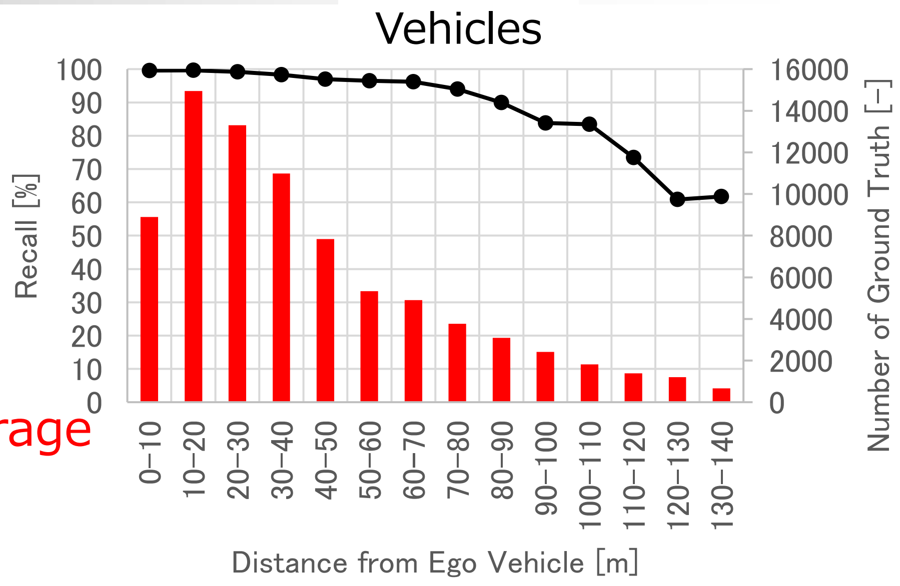
Developed recognition model

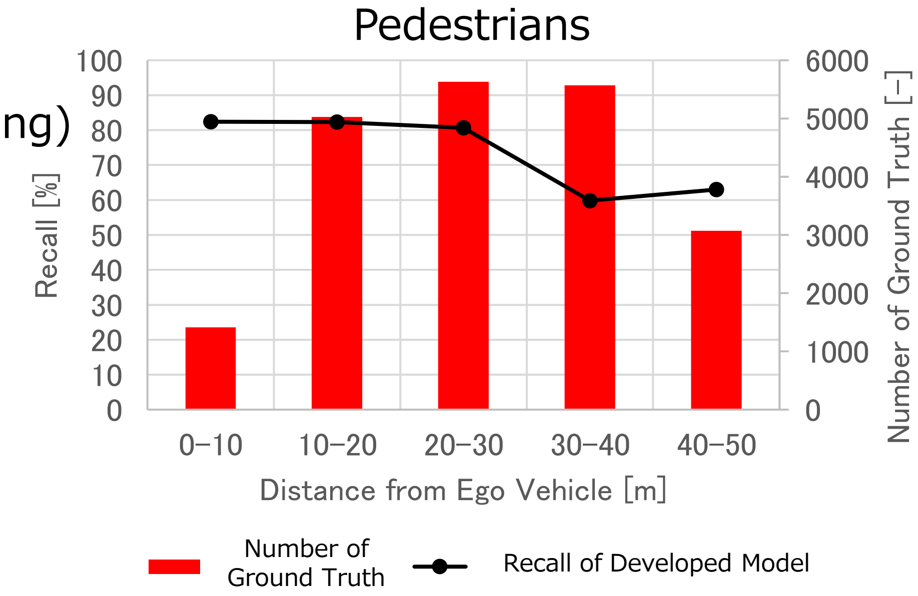
*Recall = True Positive / Ground Truth
(The percentage of actual pedestrians correctly recognized)

Efforts to Extend the Detection Range of Recognition Models for Applying to Automated Driving

- Evaluated strictly on a single-frame basis without temporal processing
  - Vehicles within 135 m (Target: 90%*)
    - Average recognition rate across all distance ranges: 88.12%
  - Pedestrians within 50 m (Target: 55%*)
    - Average recognition rate across all distance ranges: 71.66%
  - Achieved high-speed processing of 83.30 ms/frame on average (compared to 172.57 ms/frame with conventional models)
    - Achieved a lightweight design while maintaining a high recognition rate
    - Analyze issues in specific distance ranges where performance falls below SOTA
    - Investigate further accuracy improvements (temporal processing)

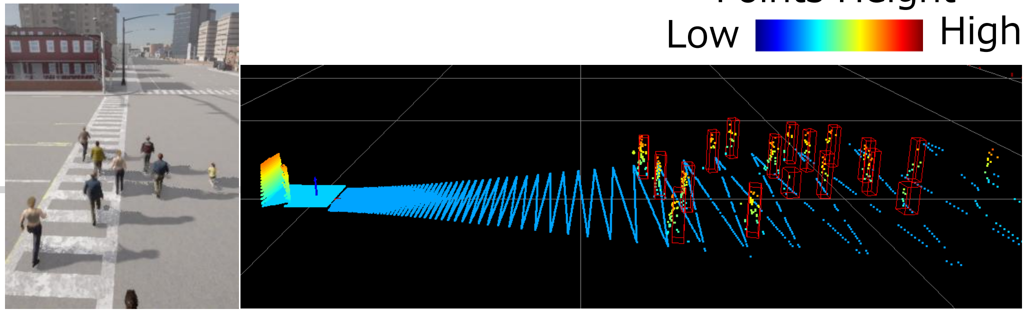






*Recent leading recognition results on standard public datasets. Average values across all distance ranges, including occluded objects.

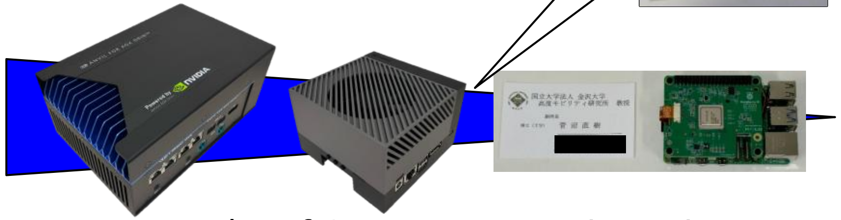
Activities for This Year



Example of sensor data simulating the pedestrian deck around Tsukuba Station
(Left: Camera image, Right: LiDAR point cloud)

- **LiDAR-based recognition technology**
  - Development using deep learning (DNN*)
    - Implementing recognition algorithms processable on compact computing units
    - Developing real-time recognition technology for vehicles within 135 m and pedestrians within 50 m
  - Virtual environment for LiDAR evaluation
    - Construction of a preliminary evaluation environment prior to using the actual Mechanical Wide-FOV PCSEL-LiDAR【Step1】
    - Evaluation within the virtual environment established last year
- **Conducting a field-operational test (FOT) using LiDAR**
  - Field testing of Mechanical Wide-FOV PCSEL-LiDAR as an infrastructure sensor
    - Study on LiDAR installation scenarios for infrastructure sensing
    - Execution of evaluation experiments using the actual device
      - Arrival of the actual device at Kanazawa University in October 2025
  - Acquiring real-world data by driving on public roads
    - In Tokyo, Ishikawa, Hokkaido, etc.
  - Providing test ride opportunities for automated vehicles

<u>Orin Nano</u>
An ultra-compact, palm-sized computing unit



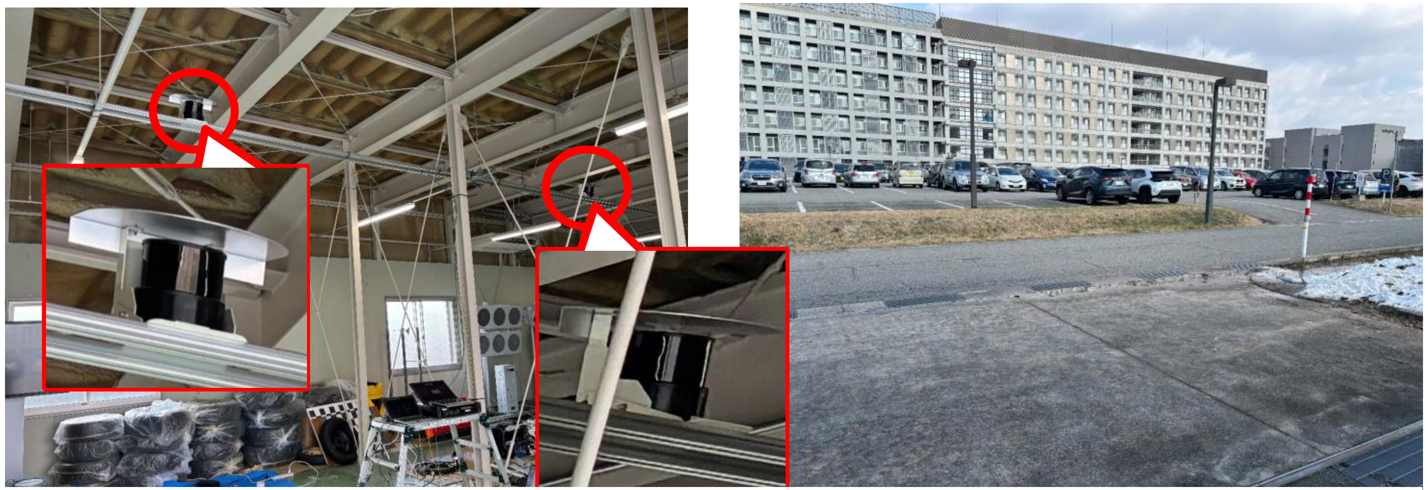
Examples of Compact computing units
Anvil, Orin, and Raspberry Pi (equipped with AI chip) from left to right

*DNN: Deep Neural Network

Field Validation of the Developed Recognition Logic Using the Actual Device

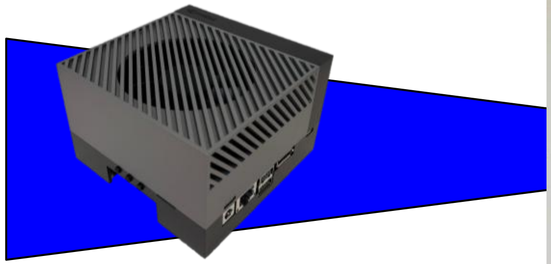
- 【Step 1】Installation of the actual Mechanical Wide-FOV PCSEL-LiDAR
  - The actual device arrived at Kanazawa University in October 2025
  - Commencing road observation experiments simulating infrastructure sensing via indoor installation of the prototype
    - Installation and experimentation at the Kanazawa University garage
    - Experiments using the standard installation method without rotation

Installation conditions	
Hight	3.5m
Tilt	18° downward
Minimum road surface observation distance	5m~
Number of installed units	2 devices
Installation interval	5m



Images of the Kanazawa University garage setup
Left: Two Mechanical Wide-FOV PCSEL-LiDARs installed inside the garage, facing the road
Right: Target road for observation in front of the garage

Compact computing units used for recognition



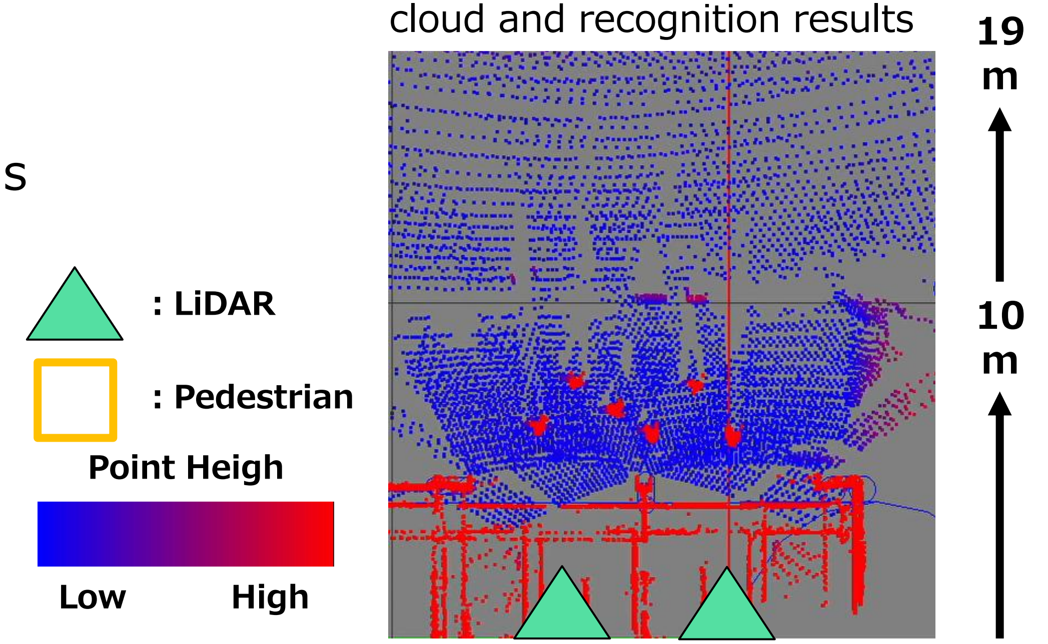
- Orin @NVIDIA
  - Compact Developer Kit
- Footprint equivalent to approx. 2.5 business cards

- Orin Nano @NVIDIA
  - Compact Developer Kit
- Footprint equivalent to approx. 1.8 business cards
- Height: 35mm

Field Validation of the Developed Recognition Logic Using the Actual Device

- Implementation of recognition logic incorporating temporal processing
  - Recognizing vehicles, two-wheelers, and pedestrians
  - **Achieved high-speed processing of 41.26 ms/frame** on average (Orin Nano)
- Evaluation items for the actual Mechanical Wide-FOV PCSEL-LiDAR
  - Impact of weather conditions
    - Evaluating the effects of rain and snow
  - Impact of color
    - Evaluating moving objects with low-reflectivity colors
  - Impact of occlusion
    - Evaluating a 2-unit setup and temporal processing in occluded areas
  - Impact of distance to the target
    - Comparative evaluation with VLP-16 for pedestrians

Top view of Mechanical Wide-FOV LiDAR point cloud and recognition results



Synchronized camera footage

Recognition logic experiment in front of the Kanazawa University garage

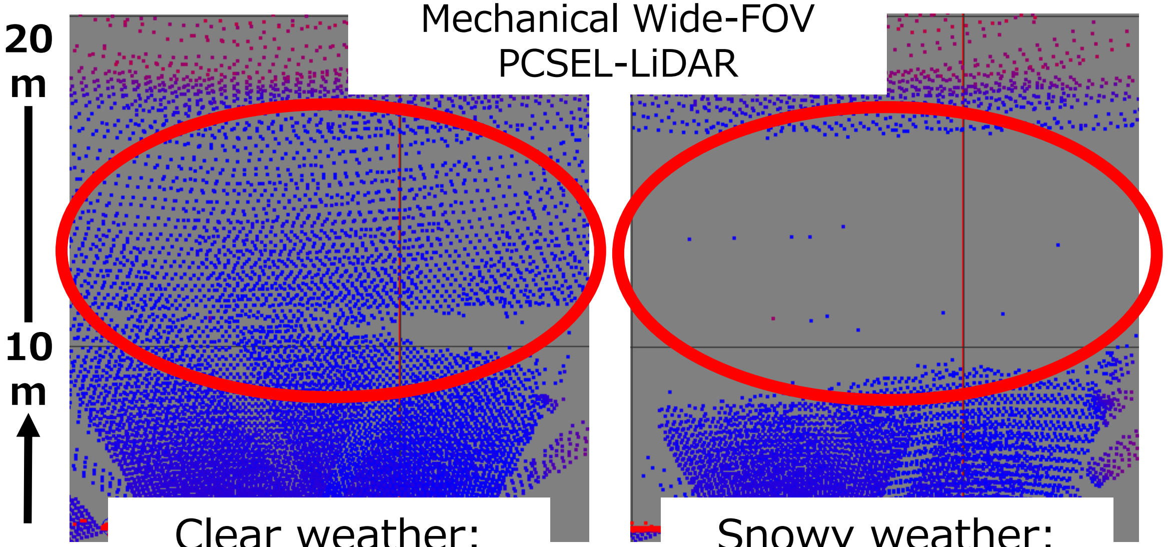
Evaluating the Impact of Weather Conditions Using the Actual Device

Point Heigh
Low High

- Impact of wet snow conditions
  - Observation of the wet road surface at 10 m is difficult
  - Minimal impact on recognition performance
    - Due to the network architecture
      that utilizes temporal processing with previous frames
    - **Pedestrians holding umbrellas can also be recognized without any issues**

Camera footage during wet snow experiments

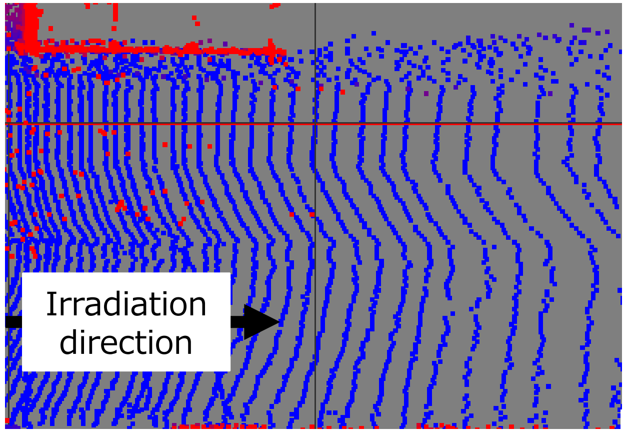
Mechanical Wide-FOV
PCSEL-LiDAR



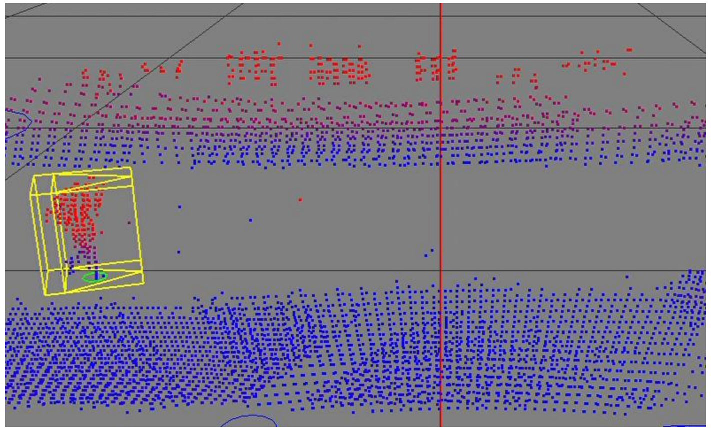
Clear weather:
Dry road surface

Snowy weather:
Wet road surface

VLS128 (Observed from an autonomous vehicle 20 m away)



Observation with VLS128 on the same snowy day

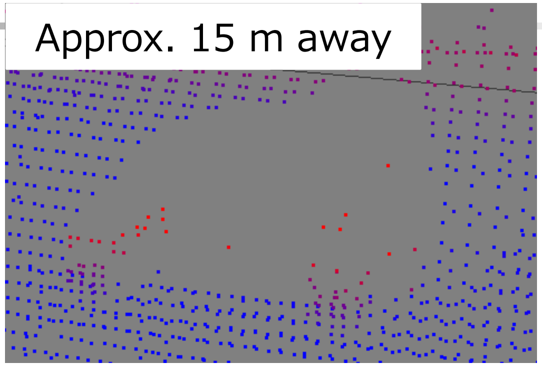


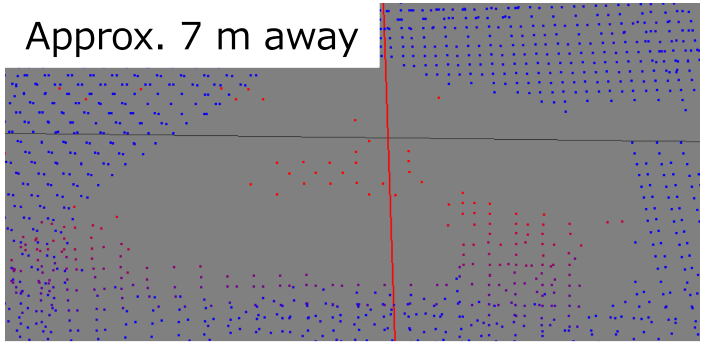
Observation of a pedestrian holding an umbrella on a wet road

Evaluating the Impact of Color Using the Actual Device

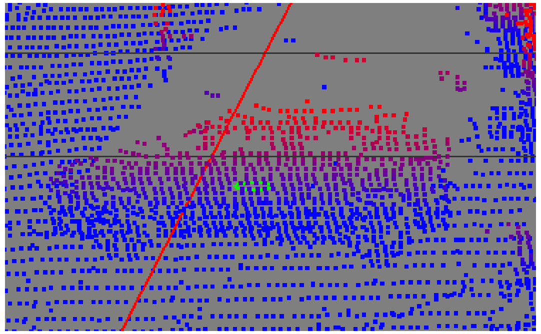
- Impact of low-reflectivity black vehicles:
  - Observation of point clouds is difficult
    - Significant impact on recognition performance
  - **Recognition of black vehicles is extremely difficult**
- Pedestrians wearing black clothing:
  - No impact on recognition

Target black vehicle

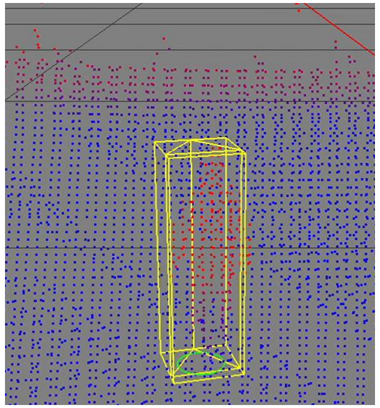




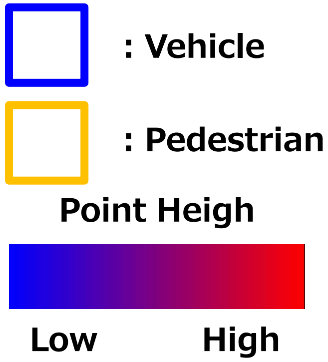
Observation of a black vehicle using Mechanical Wide-FOV PCSEL-LiDAR

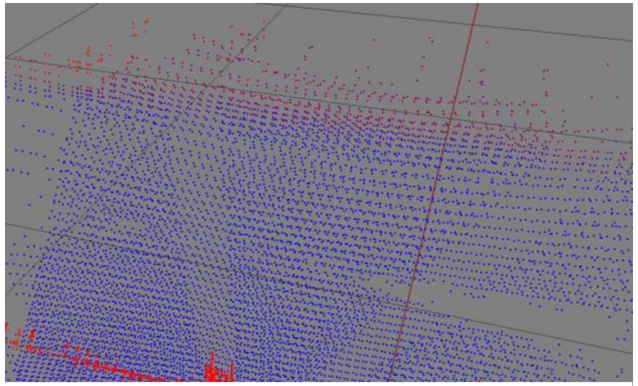


Observation of a black vehicle at 20 m using VLS128



Observation of pedestrians in black clothing (5 m to <20 m)



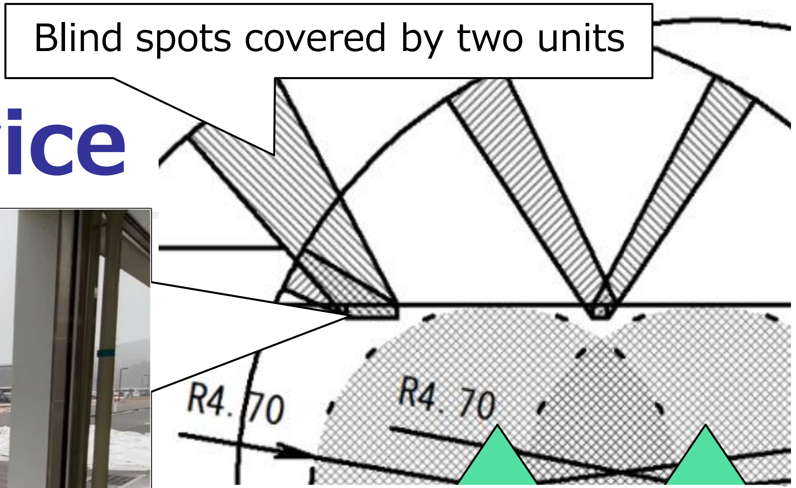


Observation of a white vehicle using Mechanical Wide-FOV PCSEL-LiDAR (no impact on recognition)

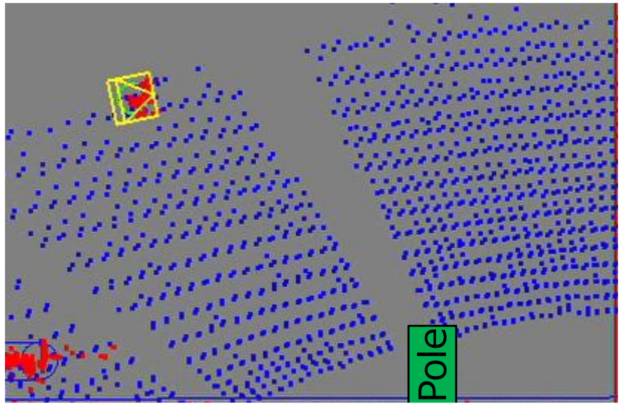
Evaluating the Impact of Occlusion Using the Actual Device

- Impact of occlusion in a 2-unit setup:
  - Blind spots occur due to obstacles such as pillars
  - Blind spots are compensated for by the other LiDAR
    - Continuous and correct recognition is possible
- Impact of occlusion in a single-unit setup:
  - **Handles temporary occlusion through temporal processing**

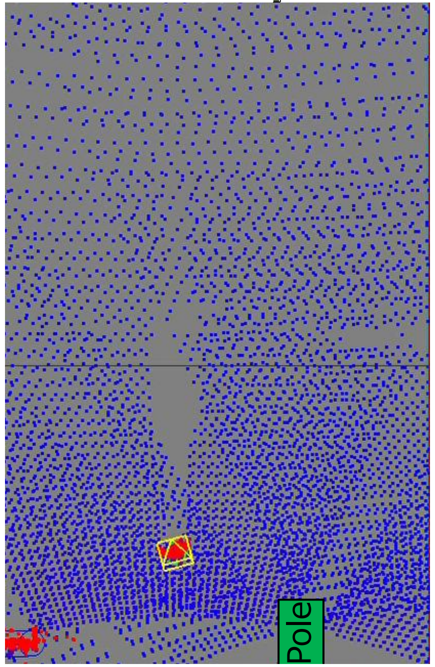
Pillar causing the blind spot



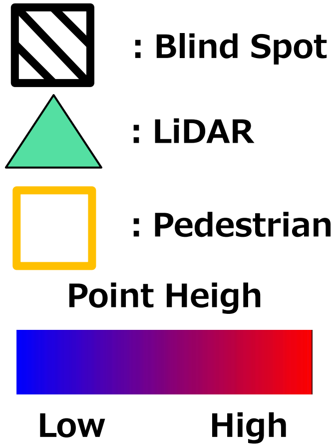
Locations of blind spots in a 2-unit setup



Recognition results in fully occluded areas (Single-unit setup)

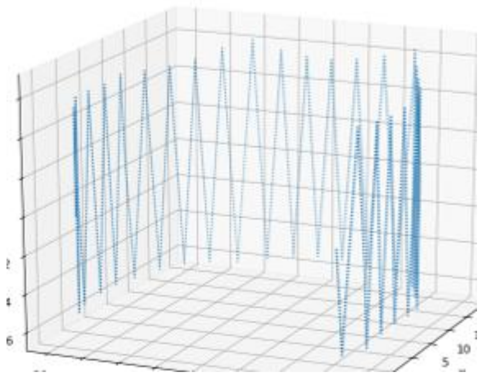


The second unit compensates for occluded areas (2-unit setup)

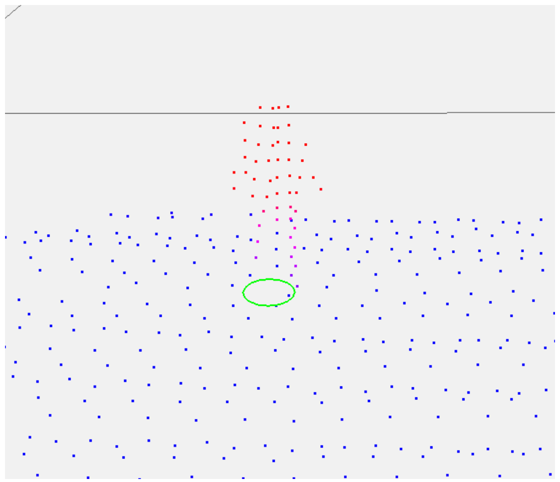


Evaluating the Impact of Observation Distance Using the Actual Device

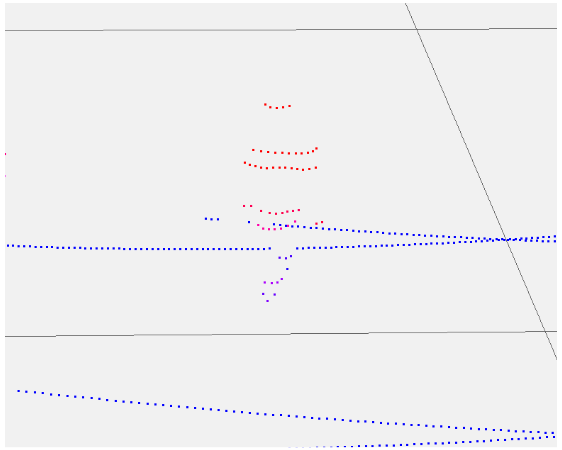
- Comparison of pedestrian observation at approx. 20 m:
  - Mechanical Wide-FOV PCSEL-LiDAR:
    - Even coverage of the full body
    - Facilitates easier recognition
  - VLP-16 (Simulation data):
    - Only 3 to 4 layers can be captured
    - Prone to gaps between layers
  - Advantages of the wedge-shaped scanning method for recognition, despite roughly equal point counts



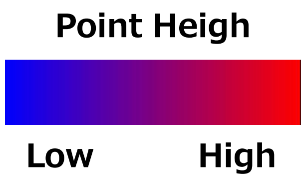
Scanning pattern of the Mechanical Wide-FOV PCSEL-LiDAR modeled in the simulator



Pedestrian at approx. 20 m (Mechanical Wide-FOV PCSEL-LiDAR)



Pedestrian at approx. 20 m (VLP-16, simulation)



Providing Opportunities for Autonomous Vehicle Test Rides

moveez

- Implementation of field tests in collaboration with MoveEz Inc., a robotaxi development company
  - Implementation of robotaxi field tests in Kamishihoro, Hokkaido
    - Summer field test: August to October 2025
    - Winter field test: January 2025
  - **Accelerating social implementation by utilizing LiDAR-based recognition technology developed in SIP**
    - Post-SIP: Considering the adoption of compact, low-cost PCSEL-LiDAR for the domestically produced autonomous driving system (MoveEz)
  - Providing opportunities for autonomous vehicle test rides
    - For stakeholders including the Mayor of Kamishihoro and PD Ishida
- Plans for future test ride opportunities:
  - Continuously providing test ride opportunities and more through MoveEz
    - Advancing the wide-area implementation of autonomous driving in collaboration with relevant organizations

Mr. Takenaka, Mayor of Kamishihoro, and Eric, CEO of MoveEz

MLIT Subsidy for Securing, Maintaining, and Improving Regional Public Transportation (FY2025 Autonomous Driving Social Implementation Promotion Project)

Efforts Toward Social Implementation (p.48~p.50)

Establishment of『Kyoto University PCSEL Research Center』

― The Core Organization for Social Implementation of PCSEL and PCSEL-LiDAR Technologies ―

Before

PCSEL CoE for accelerating development of PCSELs

Kyoto University
(previous organization)

PCSEL R&D Center
(Light & Quantum COE)

- Propose new concepts
- R&D of new technology
- Lend samples (MTA)
- Provide intel

Close collab.

- Various large-scale collaborative R&D projects
- But university is not suited to business ventures
- Growing beyond the bounds of a university

New corporation『Kyoto University PCSEL Research Center』

For the purpose of further accelerating the proliferation and social implementation of PCSELs

Separated from the university, so it also can serve as a business base

An independent bridging corporation, inspired by the style of Fraunhofer/IMEC

- R&D (applications, social implementations)
- Networking, proliferation
- Sample provision
- Equipment lending, tech support
- Personnel training

Can serve in various ways to contribute to the creation of a super-smart society

Measures to prevent outflow of government-sponsored results, ensure Japanese advantage, and contribute to economic security

Enable an ecosystem for mass production

Strengthen collaboration with various companies, construct bridges between companies, serve as a core of national projects, etc.

Supporting Materials

Establishment of『Kyoto University PCSEL Research Center』

— A Bridging Organization for Technology Transfer and Commercialization —

Established: December 2, 2024 (Press release / Website : December 6, 2024)

November 27, 2024

Members of the Kyoto University Press Club
Members of the Kyoto Bureaus of the Four Commercial Broadcasters in Osaka

Invitation to a Press Briefing on the Establishment of the『Kyoto University PCSEL Research Center』

Kyoto University is a world leader in research on Photonic-Crystal Surface-Emitting Lasers (PCSELs). PCSELs are semiconductor lasers based on photonic crystals—artificial crystals consisting of nanoscale periodic structures in which materials with different refractive indices are arranged at intervals comparable to the wavelength of light. They are characterized by their ability to achieve high-output, high-beam-quality operation while offering a wide range of unique functionalities.

PCSEL technology is expected to find applications in numerous fields, including sensing, laser materials processing, optical communications, mobile devices, medicine and life sciences, and space technologies (such as inter-satellite optical communications, spaceborne sensing, and solar sail propulsion). It also has significant potential for advanced applications such as extreme ultraviolet (EUV) light generation and nuclear fusion.

Progress in the Social Implementation of Recognition Technology

- Social implementation initiatives in collaboration with MoveEz Inc. (Robotaxi developer)
  - Robotaxi field tests in Kamishihoro, Hokkaido (Aug. - Oct. 2025)
    - Social implementation of autonomous driving equipped with commercial LiDAR recognition tech
  - Advancing efforts for Level 4 (driverless) certification & service launch
    - Strengthening collaboration with Kamishihoro, Hokkaido (Photo)
  - Accelerating social implementation via SIP-developed LiDAR recognition tech
    - Ongoing promotion of results & implementation through MoveEz Inc.

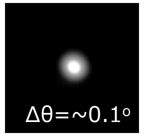
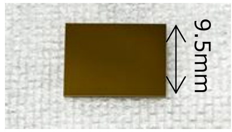
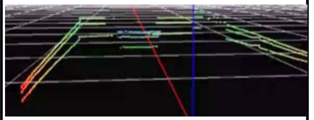
moveez

Kanazawa Univ. certified venture:
Established in May 2024
based on SIP research results

Robotaxi field test with autonomous driving at a max speed of 60 km/h in Kamishihoro, Hokkaido

Level of Achievement (p.52~p.54)

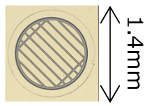
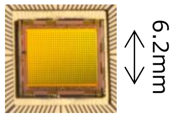
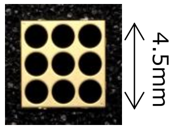
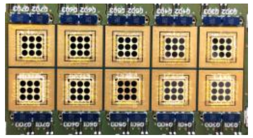
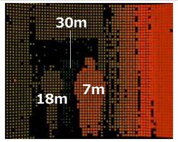
FY2024 R&D Achievement Status (Kyoto University)

Implemented Items			Status of Development Items	Illustration	Completion Rate·Timeline
Development of PCSEL-LiDAR systems	**·Advancement of PCSEL Technology** **·Card-Type PCSEL-LiDAR** **·Development of Mechanical Wide-FOV PCSEL-LiDAR** **(Step 1) (Kyoto University)**	Advancement of vertical-emission-type PCSEL	Completed: Vertical-emission-type PCSEL with ideal Gaussian beam Remaining: None		●
		Design·fabrication of narrow-bandpass filter	Completed: Design and prototyping of narrow bandpass filter (1/4 narrower than typical ones) leveraging PCSEL characteristics Remaining: None		●
		Determining specifications for card-type PCSEL-LiDAR	Completed: Specification of FOV, range, resolution, weight, power consumption, operating temperature range, etc. Remaining: None		●
		Prototyping of card-type PCSEL-LiDAR	Completed: Transmitter optics, receiver optics, electronics, packaging, and related components, and development of a prototype incorporating the advanced PCSEL Remaining: None.	 8×6×2cm	●
		Evaluation of card-type PCSEL-LiDAR	Completed: Fundamental evaluation and field demonstration of the card-type PCSEL-LiDAR Remaining: None		●
		Determining specifications for mechanical wide-FOV PCSEL-LiDAR	Completed: Finalization of FOV, ranging distance, angular resolution, weight, power consumption, operating temperature range, and other key parameters Remaining: None		●
		Prototyping mechanical wide-FOV PCSEL-LiDAR	Completed: Transmitter optics, receiver optics, mirror system, scanning mechanism, electronics, and other key components, along with initial assembly and preliminary evaluation of the first prototype Remaining: None	 H13cm Φ11cm	●

Continued on the next page

FY2024 R&D Achievement Status (Kyoto University)

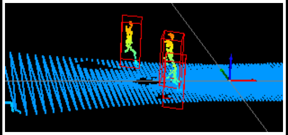
Continued from the previous page

Implemented Items			Status of Development Items	Illustration	Completion Rate·Timeline
Development of PCSEL-LiDAR systems	**·Development of an All-Chip PCSEL-LiDAR (Step 2) (Kyoto University)**	Fabrication and characterization of a single multi-dot emission PCSEL	Completed: Design, fabrication, and evaluation of a single PCSEL device Remaining: None		●
		Procurement and initial evaluation of a 2D SPAD Array	Completed: 2D SPAD array procurement and initial evaluation, including simultaneous measurements Remaining: None (Further performance enhancements will continue)		●
		Development of the PCSEL array (Ahead of schedule)	Completed: Design and prototype development of the PCSEL array, as well as assembly and initial evaluation of the PCSEL array Remaining: None (Further performance enhancements will continue)		●
		Electronic beam steering by PCSEL arrays (Ahead of schedule)	Completed: Design and first prototype of the driver circuit, as well as implementation and initial evaluation of multiple PCSEL arrays Remaining: None (Further performance enhancement and miniaturization will continue)		●
		Initial proof-of-concept (PoC) of an all-chip PCSEL-LiDAR (Ahead of Schedule)	Completed: Initial proof-of-concept (PoC) of an all-chip PCSEL-LiDAR using electronic beam steering with multiple PCSEL arrays and a 2D SPAD array Remaining: None (Continue toward longer-range operation)		●
		Demonstration of extended ranging for all-chip PCSEL-LiDAR (Ahead of Schedule)	Completed: Improved SPAD detection efficiency and enhanced receiver efficiency by matching receiver to transmitter. Remaining: None (Continue toward longer-range operation)		●

Future Plans (Kyoto University)

- Deploy the mechanical wide-FOV PCSEL-LiDAR to other consortia and projects to promote cross-project collaboration and achieve feedback.
- Increase optical output power through the development of a high-current driver of all-chip PCSEL-LiDAR. ⇒ Longer-range and fully integrated module.

FY2025 R&D Achievement Status (Kanazawa University)

Implemented Items			Status of Development Items	Illustration	Completion Rate･Timeline
Development of infrastructure and onboard sensor systems that utilize compact LiDAR technology to understand the actual situations of streets in living areas and busy districts	**Development of recognition technology using LiDAR**	Development of recognition algorithms for compact computing devices	Completed : Implementation of temporal processing & deployment on compact computing devices Remaining : None		●
	Implementation of demonstration using LiDAR	Field tests using Mechanical Wide-FOV PCSEL-LiDAR	Completed : Field testing & feedback using Mechanical Wide-FOV PCSEL-LiDAR Remaining : None		●
		Preparing for field tests using PCSEL-LiDAR as on-board sensors	Completed : Conducted sensor data acquisition testsfor recognition evaluation using existing LiDAR in Kanazawa city, Ishikawa prefecture, and thecoastal Areas of Tokyo Remaining : None（Planned to continue in the next FY）		●

Research Dissemination (p.56~p.59)

Dissemination

International conferences (plenaries, key notes, invited talks)

- S. Noda, “**[Plenary]** Recent Progress and Future Prospects of Photonic-crystal Surface emitting Lasers(PCSELs)”, Photon 2026, 2026/9/1-4.(To be presented)
- S. Noda, “**[Legend]** Progress in the photonic-crystal surface-emitting laser (PCSEL)”, The 30th International Semiconductor Laser Conference ISLC2026, 2026/6/14-17. (To be presented)
- S. Noda,“ **[Tutorial]** Photonic-Crystal Surface-Emitting Lasers (PCSELs): From Fundamentals to the State of the Art”, Laser Science to Photonic Applications CLEO2026, 2026/5/17-21.
- S. Noda,“ **[Invited]** Photonic-Crystal Surface-Emitting Lasers as Solutions for Space and Earth”, OPIC LSSE, 2026/4/24.
- S. Noda,“ **[Plenary]** Progress of Photonic-Crystal : from Fundamentals to Social Implementation”, OPIC PS-02, 2026/4/22.
- T. Inoue, R. Morita, S. Ishimura, S. Noda, ”**[Invited]** High-power Photonic-crystal surface-emitting lasers for long-distance free-space optical communications”, OPIC ICNNQ, 2026/4/22.
- S. Noda, “**[Invited]** Dynamic and Static Properties of Photonic-Crystal Surface-Emitting Lasers (PCSELs)”, The future of optical networking and communications OFC2026, 2026/3/15-19.
- M. De Zoysa, “**[Invited]** Compact LiDAR systems based on Photonic crystal lasers”, International Symposia on Creation of Advanced Photonic and Electronic Devices and Advanced Quantum Technology for Future, 2026/3/11.
- S. Noda, “**[Invited]** Progress of Photonic-Crystal Surface-Emitting“, International Workshop on PCSELs 2025 / The 14th International Symposium on Photonic and Electromagnetic Crystal Structures (PECS XIV), 2025/11/10.
- M. De Zoysa, K. Ishizaki, T. Inoue, M. Yoshida, S. Noda, “**[Invited]** Compact LiDAR Technology - Based on Photonic Crystal Lasers -”, ITS world congress 2025, 2025/8/27.

Dissemination

International conferences (plenaries, key notes, invited talks)

- S. Noda, "**[Invited]** Recent progress in photonic-crystal surface-emitting lasers (PCSELs)", ICNS-15, 2025/7/6-11.
- S. Noda, "**[Invited]** Recent progresses in GaN photonic-crystal surface-emitting lasers (PCSELs)", International Workshop on Advanced InAlGaN Laser Diodes (iWILD), 2025/7/3-4.
- S. Noda, "**[Invited]** Recent progress in photonic-crystal surface-emitting lasers", Conference on Lasers and Electro-Optics (CLEO) CLEO/Europe-EQEC2025, 2025/6/23-27.
- T. Inoue, M. Yoshida, and S. Noda, "**[Invited]** Manipulation of light propagation in photonic crystals via non-Hermitian photonic band engineering", The 15th International Conference on Metamaterials, Photonic Crystals and Plasmonics (META 2025), 2025/6/24.
- S. Noda, "**[Tutorial talk]** High-brightness and high-functionality photonic-crystal surface-emitting lasers (PCSELs)", Conference on Lasers and Electro-Optics (CLEO), 2025/5/4-9.
- T. Inoue, R. Morita, M. De Zoysa, and S. Noda, "**[Invited]** Photonic-crystal surface-emitting lasers for short-pulse and high-speed applications", Conference on Lasers and Electro-Optics (CLEO), 2025/5/5.
- S. Noda, "**[Keynote]** Progress of photonic-crystal surface-emitting lasers (PCSELs)", SPIE Optics + Optoelectronics, 2025/4/7-10.
- S. Noda, "**[Plenary]** High-power semiconductor lasers based on Hermitian and non-Hermitian control in photonic crystals", Deutsche Physikalische Gesellschaft (DPG Spring meeting), 2025/3/16-21.
- S. Noda, "**[Tutorial]** Photonic-crystal surface-emitting lasers", The IEEE Photonics Conference (IPC) 2024, 2024/11/10-14.
- S. Noda, "**[Keynote]** Resent progress of photonic-crystal surface-emitting lasers", International Workshop on PCSELs 2024, 2024/11/7-8.

Dissemination

International conferences (plenaries, key notes, invited talks)

- S. Noda, “**[Plenary]** High-power, high-beam-quality, high-functionality photonic-crystal surface-emitting lasers－For paradigm shift towards realizing smart society”, Advanced Solid State Lasers Conference (ASSL) 2024, 2024/10/20-24.
- K. Aoki, S. Noda, et al., “**[Invited]** High-power CW/pulsed operations of 1.55-μm-wavelength photonic-crystal surface-emitting lasers”, IEEE 29th International Semiconductor Laser Conference (ISLC 2024), 2024/9/29-10/2.
- S. Noda, “**[Invited]** High-brightness scalable continuous-wave single-mode photonic-crystal laser (PCSEL)”, The 16th Pacific Rim Conference on Lasers and Electro-Optics (CLEO-PR 2024), 2024/8/9.
- S. Noda, “**[Invited]** Ultra-large area coherent lasing action through Hermitian/non-Hermitian control in photonic crystals”, The 14th Conference on Metamaterials, Photonic Crystals and Plasmonics (META 2024), 2024/7/17.
- S. Noda, “**[Tutorial]** Photonic-crystal surface-emitting lasers - Tutorial”, The 29th Opto-Electronics and Communications Conference (OECC 2024), 2024/7/3.
- S. Noda, “**[Invited]** Photonic-crystal surface-emitting lasers (PCSELs) for paradigm shift towards smart society (Society 5.0)”, IEICE Distinguished Lecturer’s Webinar, 2024/6/25.
- T. Inoue, S. Noda, et al., “**[Invited]** Temporal control of photonic-crystal surface-emitting lasers”, Compound Semiconductor Week (CSW) 2024, 2024/6/5.
- M. Yoshida, S. Noda, et al., “**[Invited]** Kilowatt-class high-peak-power pulsed operation of large-area photonic-crystal surface-emitting lasers”, The Conference on Lasers and Electro-Optics (CLEO) 2024, 2024/5/7.
- S. Noda, “**[Invited]** A new light source: Photonic-crystal surface-emitting laser (PCSEL) - On the numerous possibilities for realizing a smart society -”, The Optics and Photonics International Congress (OPIC) 2024/ BFSS, 2024/4/24.
- T. Inoue, S. Noda, et al., “**[Invited]** Short-pulse high-power photonic-crystal surface-emitting lasers”, The Optics and Photonics International Congress (OPIC) 2024/ ALPS, 2024/4/23.

Dissemination

Seminars and Tutorials (Domestic)

- Susumu Noda, **[Invited]** Recent Progress and Applications of Photonic-Crystal Surface-Emitting Lasers (PCSELs), OPIC Seminar LE-4: Semiconductor Lasers and Their Applications, Apr. 23, 2026.
- Susumu Noda, **[Plenary]** Progress of Photonic Crystals: From Fundamentals to Social Implementation – Looking Back on My 37 Years of Research, 44th Electronic Materials Symposium (EMS-44), Oct. 15, 2025.
- Susumu Noda, **[Invited]** Building a Smart Society with Photonic Crystals, EXPO 2025 Czech–Japan Conference: Photonics, Space, and Lasers – Designing the Future Society: Vision toward 2040, Sept. 9–11, 2025.
- Menaka De Zoysa and Susumu Noda, **[Invited]** Photonic-Crystal Surface-Emitting Lasers and Their Applications to LiDAR Sensing, Open Seminar of Light & Laser Kansai 2024, July 17, 2024.
- Susumu Noda, **[Invited]** Next-Generation Light Source Technology: Photonic-Crystal Surface-Emitting Lasers (PCSELs) – Toward the Advancement of Smart Mobility and Smart Manufacturing, Tektronix Innovation Forum 2024, July 11, 2024.
- Susumu Noda, **[Tutorial]** Photonic-Crystal Surface-Emitting Lasers: From Fundamentals to the Latest Developments, IEICE Technical Committee on Laser and Quantum Electronics (LQE), May 28, 2024.
- Susumu Noda, **[Invited]** Advances in Photonic-Crystal Surface-Emitting Laser Technology Toward the Realization of Society 5.0, 27th KEC Techno Forum, Jan. 16, 2024.

Roadmap・Management Framework (p.61~p.62)

(p.61~p.62)

R&D Items & Roadmap

Collaboration with other projects

Results of SIP Phase 2

Infrastructure co-ordination demonstration

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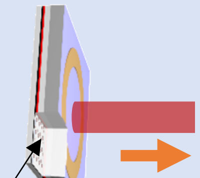
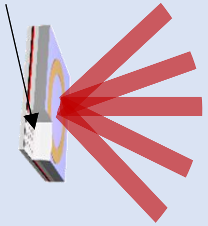




Photonic crystal laser (PCSEL)

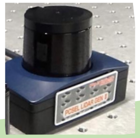
京都大学 KYOTO UNIVERSITY PCSEL-COE

Field-operational test (FOT) by Kanazawa University

② Development of recognition technology and conducting field-operational test

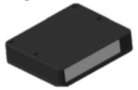
Evaluation of applicability of PCSEL-based 2D LiDAR (SIP Phase 2)

Evaluation of applicability of 2D PCSEL-LIDAR



PCSEL-based 2D LiDAR

Additional item: Prototyping of 2D card-type PCSEL-LiDAR for inter-project collaboration scheduled for end of December 2024



② A. Development of recognition technology

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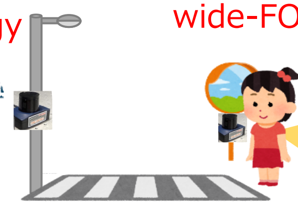

② B. Field-operational test (FOT) of infrastructure sensing

① STEP-1. Development of wide-FOV 3D PCSEL-LiDAR

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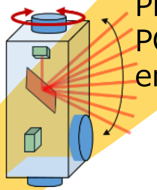
Operation test of wide-FOV 3D PCSEL-LiDAR

Test of wide-FOV 3D PCSEL-LiDAR prototype



Prototyping of wide-FOV 3D PCSEL-LiDAR: Scheduled for end of September 2025

② B. Field-operational test (FOT) of on-board sensor

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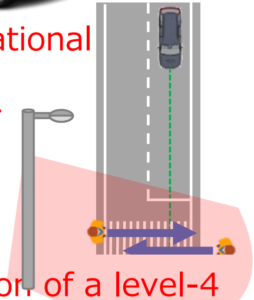

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② B. Conduction of a level-4 equivalent demonstration that co-ordinates infrastructure and on-board sensing

Operation test of non-mechanical 3D PCSEL-LiDAR prototype

Kyoto University & Ecosystem + Hokuyo Automatic

① Development of 3D PCSEL-LiDAR system

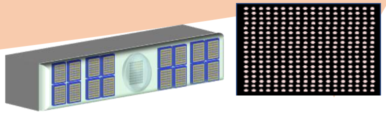
Design of light source for 3D PCSEL-LiDAR

Fabrication of light source for 3D PCSEL-LiDAR

Accelerate implementation of PCSEL/SPAD LiDAR in a separated configuration

Prototyping of non-mechanical 3D PCSEL-LiDAR

①STEP-2: Development of non-mechanical 3D PCSEL-LiDAR



(First, start with PCSEL/SPAD in a separated configuration)

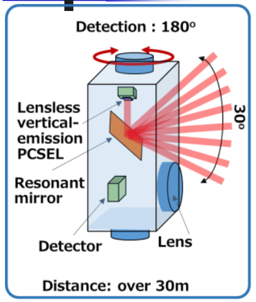
京都大学 KYOTO UNIVERSITY PCSEL-COE

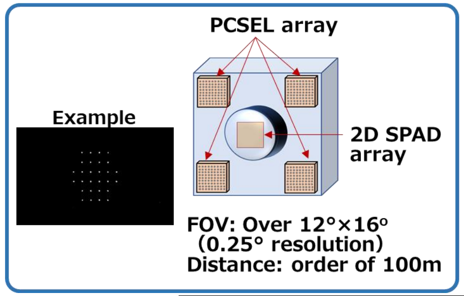
Development of 3D PCSEL-LiDAR for innovation of smart mobility

SIP Phase 3

Year 1	Year 2	Year 3	Year 4	Year 5

Implementation Structure





Instructions & Discussion

NEDO

Head of R&D
- Affiliation: Kanazawa University Advanced Mobility Research Institute
- Title: Vice-director, Professor
- Name: Naoki Suganuma

Commissioning

Kyoto University
(① Development of 3D PCSEL-LiDAR system) Susumu Noda, Menaka De Zoysa, and others

PCSEL-LiDAR development

Feedback from demonstration

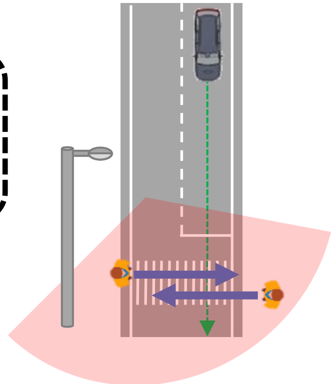
Kanazawa University
(② Development of recognition technology and conducting Field-operational test) Naoki Suganuma, Keisuke Yoneda, and others

Recommissioning

Hokuyo Automatic
Construction and basic evaluation of LiDAR system Naohiro Shimaji and others

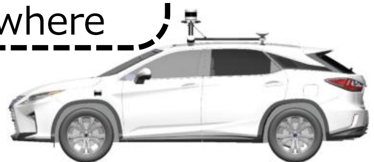
Collaboration

Fraunhofer (International collaborator)
PCSEL-COE ecosystem



Proof-of-concept demonstrations

<Demonstration sites>
- Tokyo waterfront area (Odaiba)
  Kanazawa City, Ishikawa Prefecture
- Abashiri City, Hokkaido, and elsewhere



This report partially includes the results of Cross-ministerial Strategic Innovation Promotion Program (SIP) 3rd Phase, Development of Smart Mobility Platform” promoted by Council for Science, Technology and Innovation, Cabinet Office. （Project Management Agency : New Energy and Industrial Technology Development Organization (NEDO) (Project Code JPNP23023)).