

Keynote Speech
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Visible Light Communication and Optical Wireless Communication

VLCA chair

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The profile of the speaker

- The speaker was born in Tokyo in 1946 and obtained Ph.D. degree from Keio University 1974. He was Professor and is now Professor emeritus of the University. He studied CDMA, OFDM, Mobile Communication technology and Optical Wireless Communication (OWC) and Visible Light Communication (VLC). VLC field was proposed by him in the late 1990s. He is now the chairman of Visible Light Communication Association (VLCA). He was awarded as an IEEE fellow in 2006 and an IEICE fellow in 2001.

1. Wavelength from short to long waves

- **Visible Light**

- ✓ Blue: 435nm-480nm
- ✓ Green: 500nm-560nm
- ✓ Red: 610nm-750nm

- **Infrared Light**

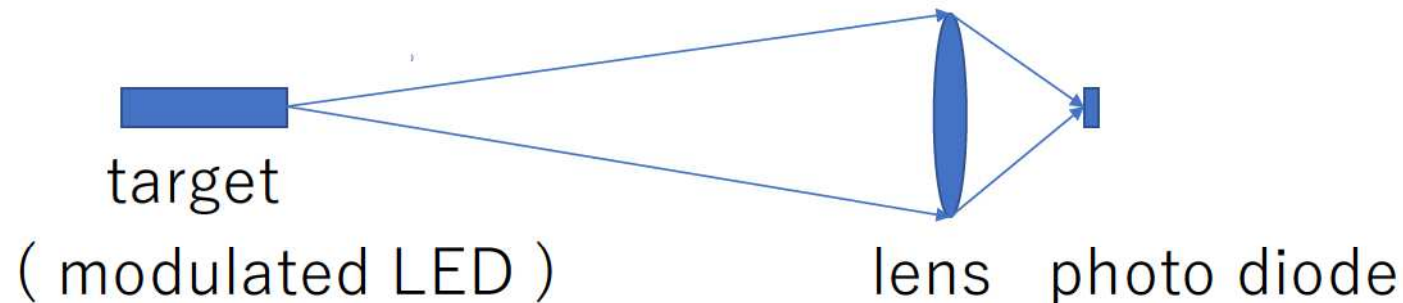
- ✓ IR-A: 800nm-1400nm
- ✓ IR-B: 1.4um-3um
 - 1.55um: laser for fiber communication
- ✓ IR-C: 3um-1mm

- **Millimeter Radio Wave: 1mm-10mm**

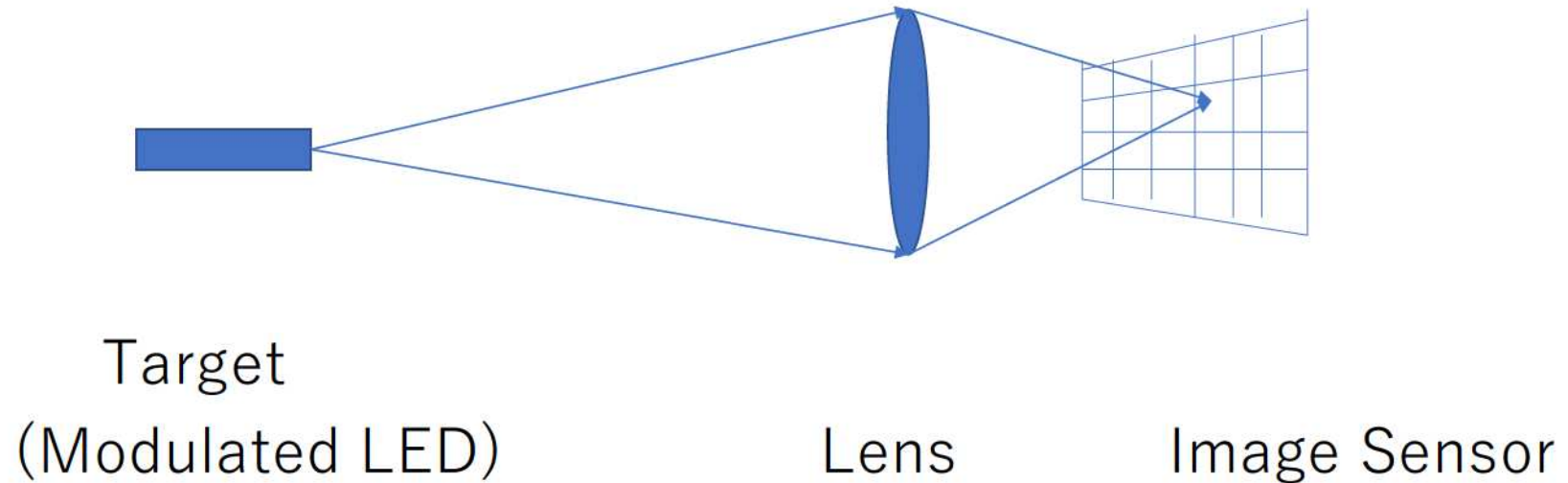
2. Two Types of Visible Light Communication

2.1 Single photo diode detection type (SPD)

This is the simplest VLC type using single photo diode detector and a lens. Mechanical tracking is required for receiving a moving target.

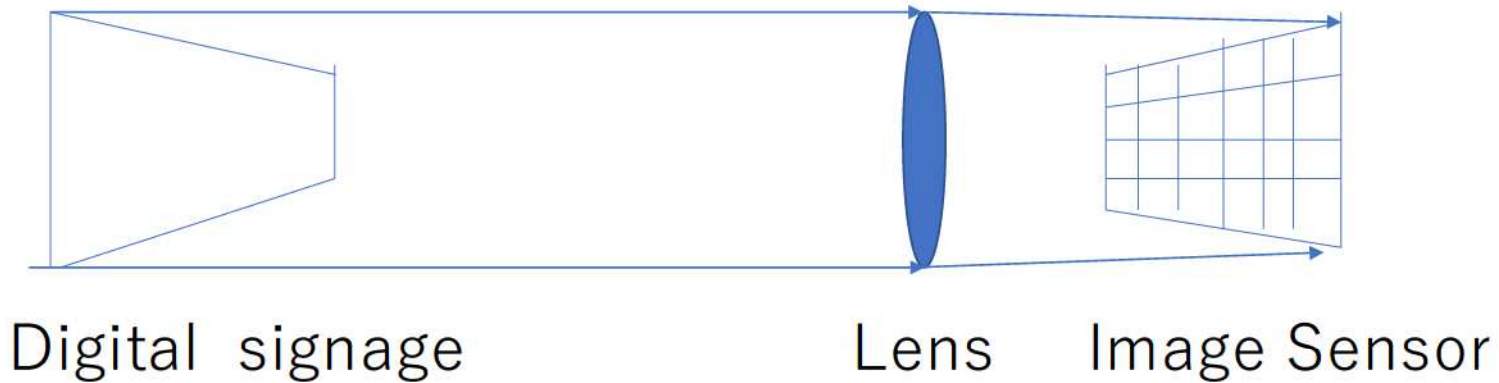


2.2 Image sensor detection type(ISD)



Several moving targets can be simultaneously detected without a mechanical tracking system. Detected data speed is limited by image sensor's frame rate.

2.2.1 Rolling shuttering image sensor detection type



Rolling shuttering method can extend the detected speed limited by the frame rate.

2.2.2 Rolling shuttering or Global shuttering

Future shuttering methods in image sensors may belong to Global shuttering not Rolling shuttering. Because moving pictures taken by Rolling shuttering image sensor include some picture distortion at higher frame rates.

Global shuttering can not extend the data speed limit as Rolling shuttering method does. However, new TV systems adopt higher frame rates as 120fps. One of Sony smartphone camera products adopts 1kfps. Higher frame rates mean higher data rate in image sensor detection type(ISD).

3. Applications of Visible Light Communication

3.1 Navigation system for blind people

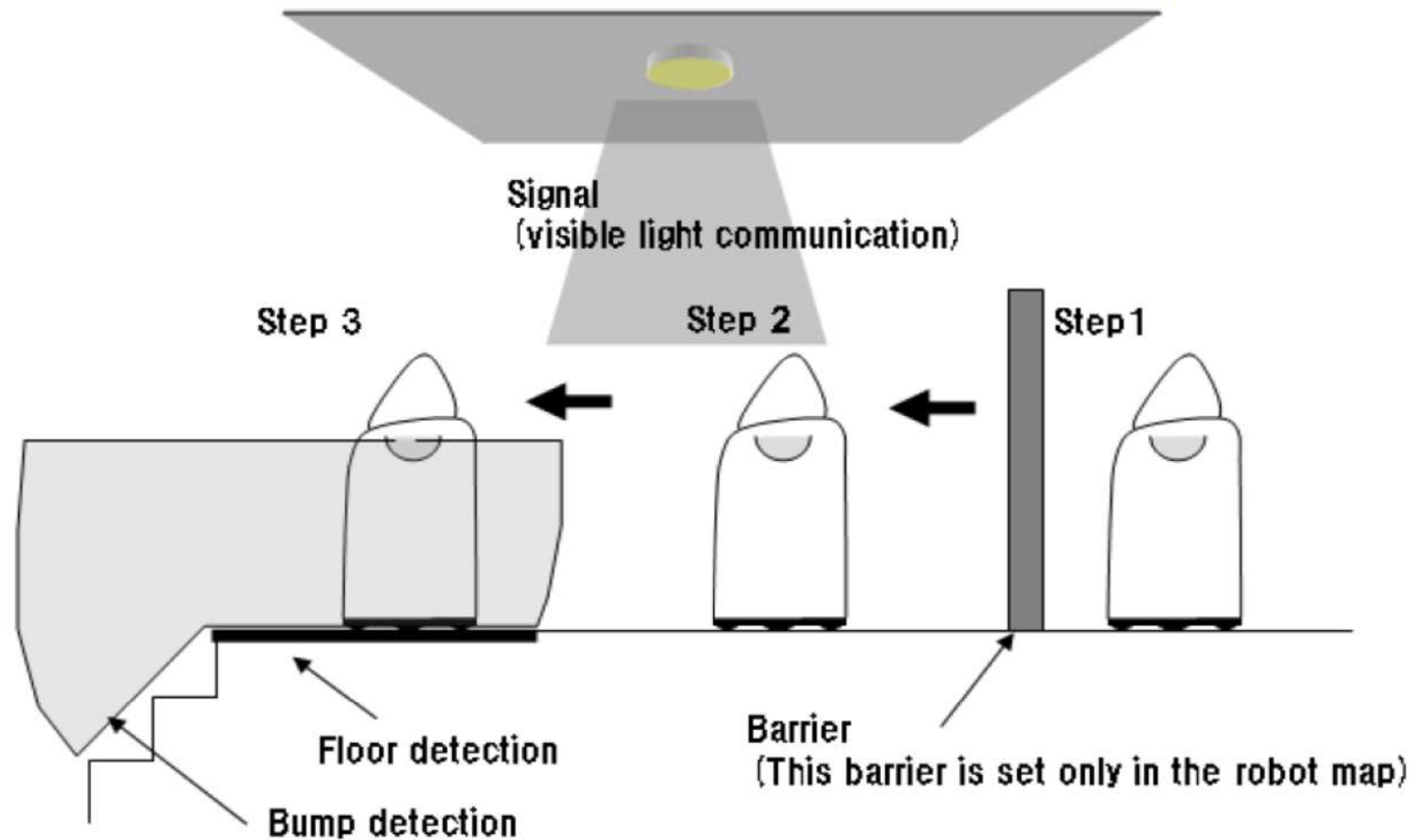
80 % among blind people can recognize directions of light in spite of their disability of recognizing images.





VLC detector with Magnetic field sensor. Audio guide is given by its headphone. Panasonic and Keio Univ. experiment system.

3.2. Visible Light Communication System for Enhanced Control of Autonomous Delivery Robots in a Hospital



The robot stops just before the stairs receiving warning signal from VLC ceiling lights.
Panasonic's product

Stairs



3.3 Underwater Visible Light Communication in an aquarium



Underwater communication methods

1. Supersonics: Long distance. Low data rate. Low security
2. Radio wave: Short distance. Very low data rate. Low security
3. Visible light: Short distance, High data rate, High security. VLC may be suitable for autonomous underwater vehicles (AUV).

4. Optical Wireless Communication

- 4.1 Typical near infrared laser system : Canobeam
Distance:100m-1000m Automatic tracking
Eye safe problem: less than 1.4um laser



4.2 An LED system without eye safe problem



BUILDING OUT A NETWORK

A NEW ERA IN HIGHSPEED WIRELESS COMMUNICATIONS!

2016 ProtoType Image

SPEEDY: No Radio Regs
EASY: Short Set-up Time
FLEXIBLE: No Radio Interference

ENERGY SAVING

The LED BACKHAUL SYSTEM

500Mbps over 100m Distance

A 30 minute HD VIDEO can be transferred in just 1 minute

The Optimization Company

5G backhaul systems require not only high data rate, but also small transmission delay less than 1ms.

- If 8K moving picture is transmitted within 1msec transmission delay, non compressed moving picture transmission at more than 1k fps whose bandwidth is more than 1Tbps is needed!
- Any radio waves are not able to transmit such huge data speed, Optical Wireless Communication is able to do so.

1550nm laser OWC system developed by NICT may be a powerful candidate for 5G backhaul wireless system

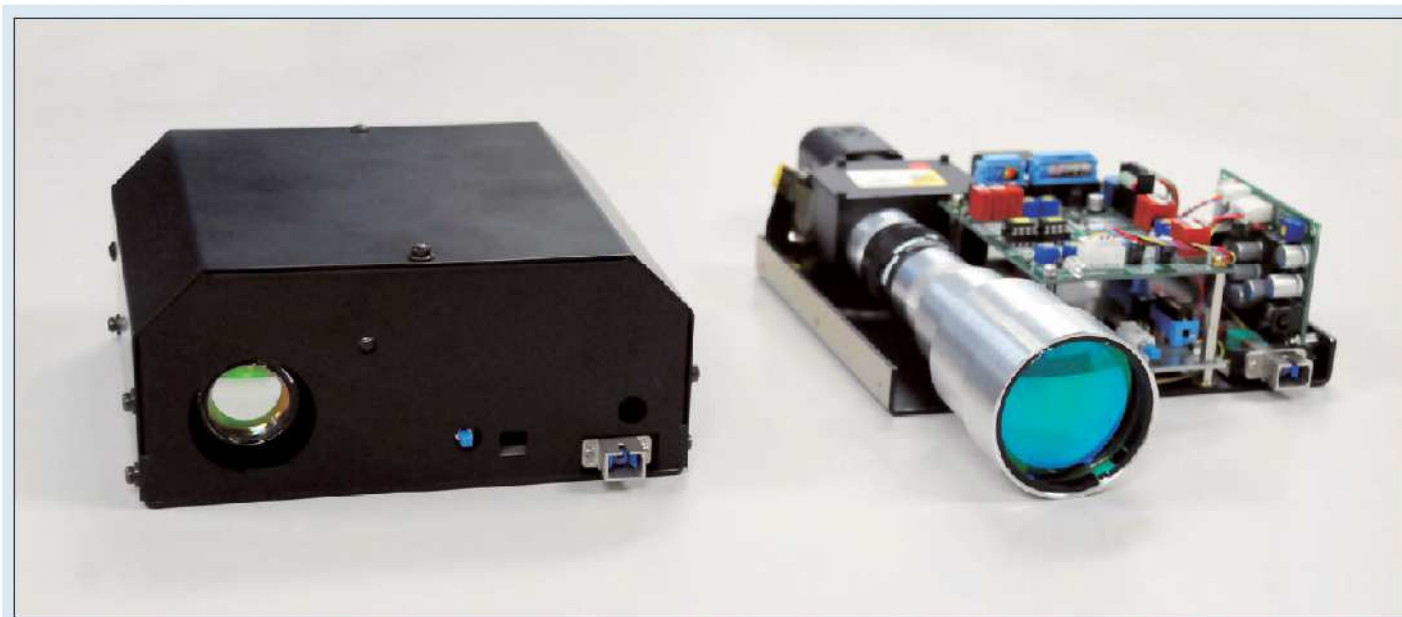


Fig. 1 ● Free space optical communication terminal (left) and the same system with a large telescope attached for long-range communications (right)

Yoshinori Arimoto, "Developing a New Free-space Optical Communication Terminal that Realizes High-Speed Broadband Communications", National Institute of Information and Communications Technology, No. 392, May 2010.

Tracking, fiber amplifier, eye safe,
1.28Tbps, multi-channel, and 210m distance

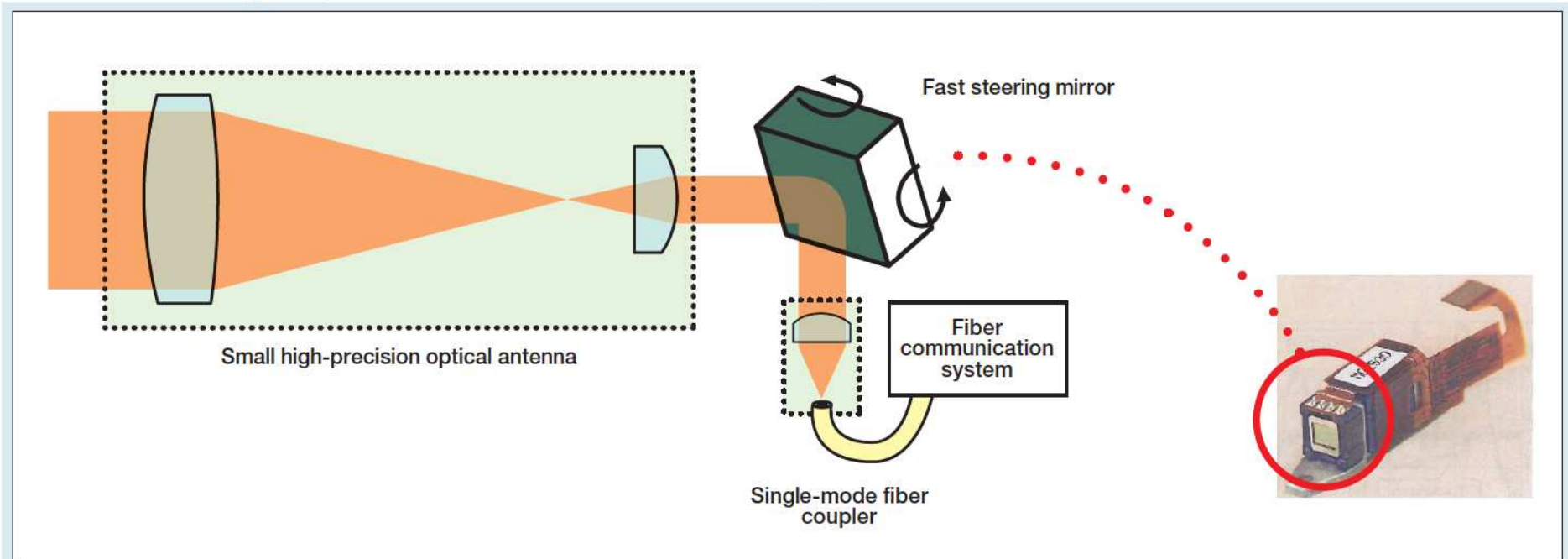


Fig. 3 ● Operating principle of the terminal

Free-space laser beam will be converted to a small collimated beam and then stabilized in its direction by the fast steering mirror so that the beam focus exactly matches the center of the single mode fiber aperture.

Yoshinori Arimoto, "Developing a New Free-space Optical Communication Terminal that Realizes High-Speed Broadband Communications", National Institute of Information and Communications Technology, No. 392, May 2010.

Loopback experiment by NICT

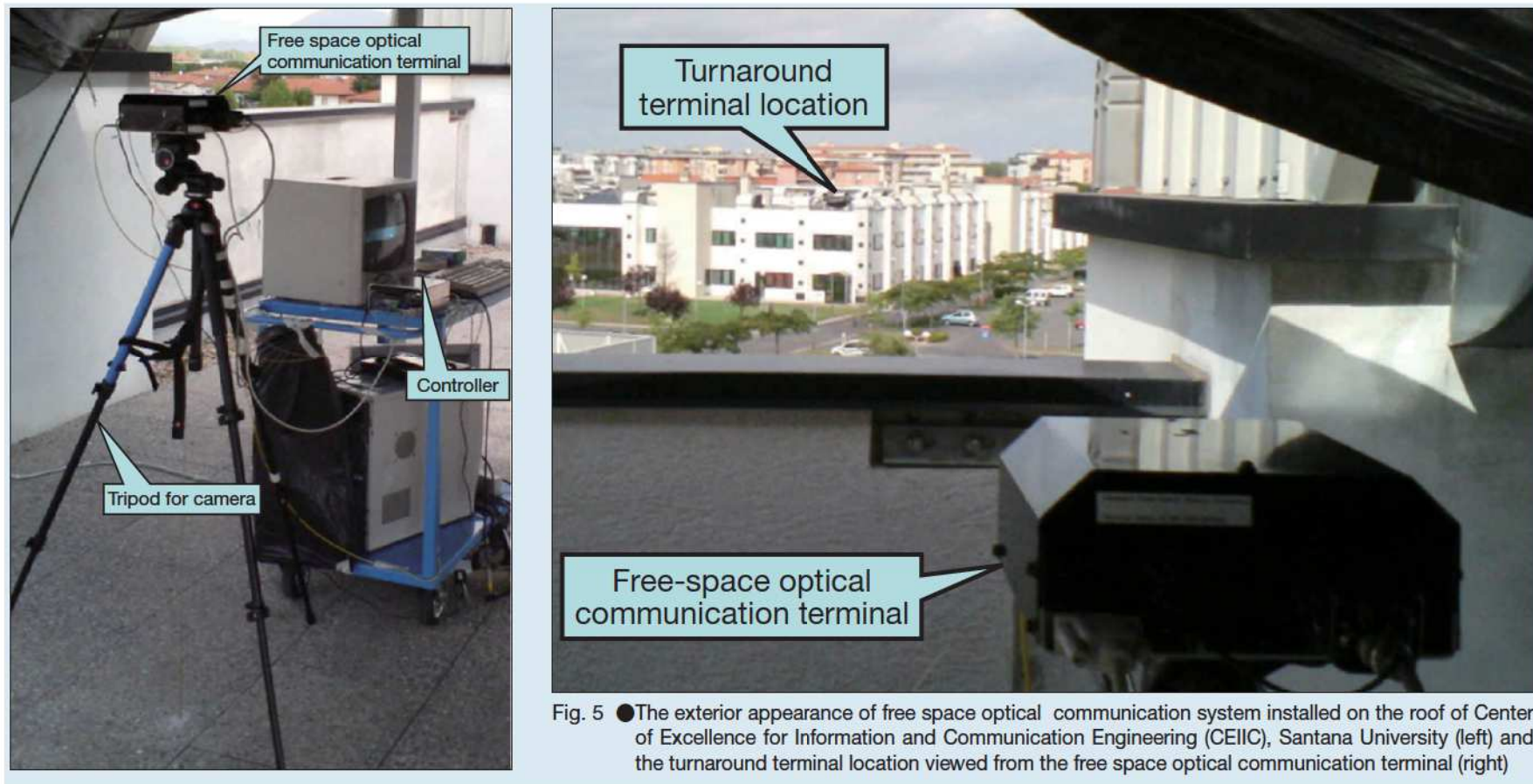


Fig. 5 ● The exterior appearance of free space optical communication system installed on the roof of Center of Excellence for Information and Communication Engineering (CEIC), Santana University (left) and the turnaround terminal location viewed from the free space optical communication terminal (right)

Yoshinori Arimoto, "Developing a New Free-space Optical Communication Terminal that Realizes High-Speed Broadband Communications", National Institute of Information and Communications Technology, No. 392, May 2010.

Eye-safe Laser OWC for 5G front-haul system

- Cost reduction using 10G Ethernet optical components



10GBase-ER SFP+ module (10Gbps, 40km, 1.55um)

Market price 194,000 JPY (1,800 USD)



10Gbps 1.55um Laser (TOSA)



10Gbps PD+TIA (ROSA)

Remote driving



Remote driving

- Remote driving is a kind of feedback system. The driver in a room at Ohmae laboratory in Keio University controls a car watching a TV screen which shows the front of the scene to check whether the track is correct. Its feedback loop's delay time is about 200ms. Because of such large delay time due to the picture compression and the poor sense of reality, its speed is limited at 8km/hour. Very slow.

5. Hybrid OWC and millimeter wave system

	Fog	Heavy Rain
OWC	X	○
Millimeter	○	X
Hybrid System	○	○

Propagation loss : Both systems have complementarity.

	Fog	Rain (100mm/H)	Snow	Typhoon
Laser	X	○ 18dB/Km	X 20dB/km	○ 40dB/km
Millimeter	○	X 34dB/km	○ 5-8dB/km	X 65dB/km

Masayasu Hata, et.al., "Complementary Properties of Laser-beam and Millimetric-wave Propagations", IEICE Technical Report, Vol. 86, No. 312, AP86-132, pp. 31-35, Jan. 1987.

Acknowledgements

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