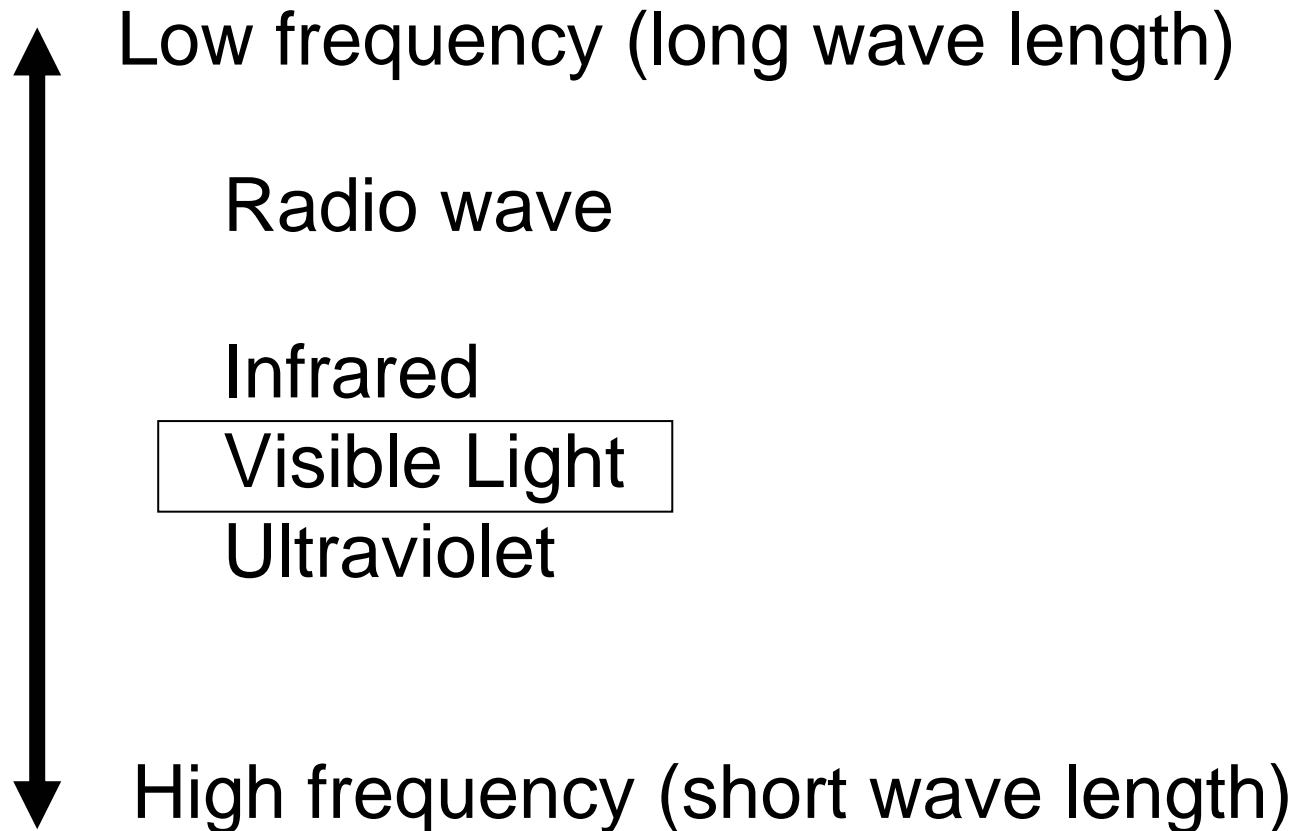


2007 October 25

# Visible Light Communications

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Keio University  
Visible Light Communication Consortium

# 1 Waves for Wireless Communications



## 2 New Light Source LED



Traffic signal



LED tail lamp

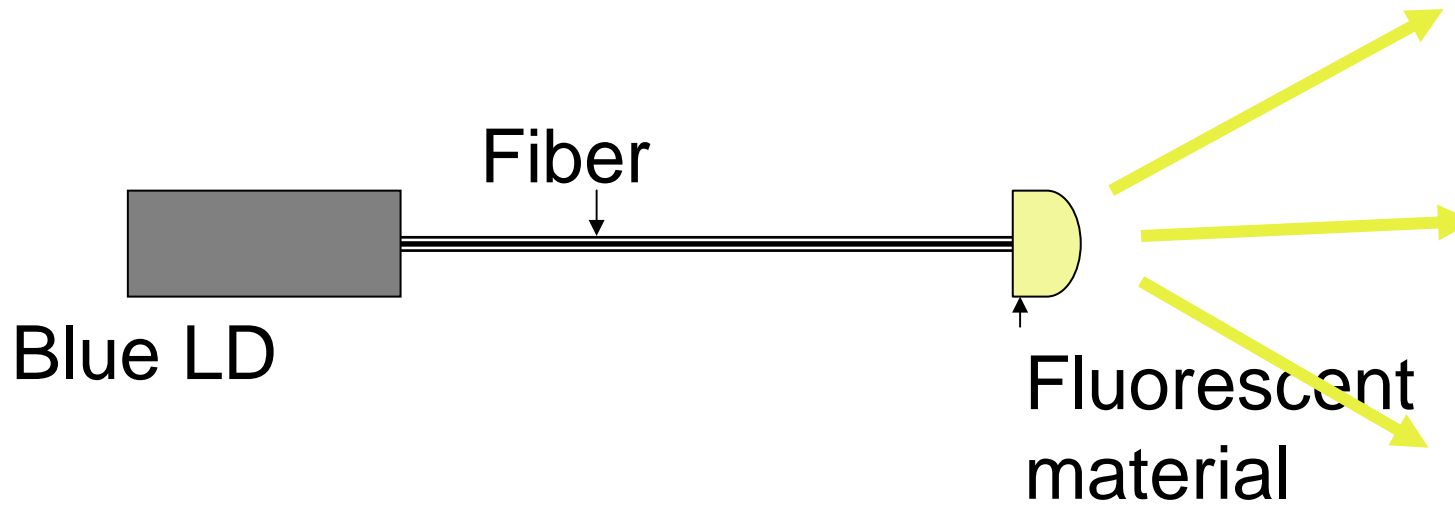


LED spot light modulated by position data

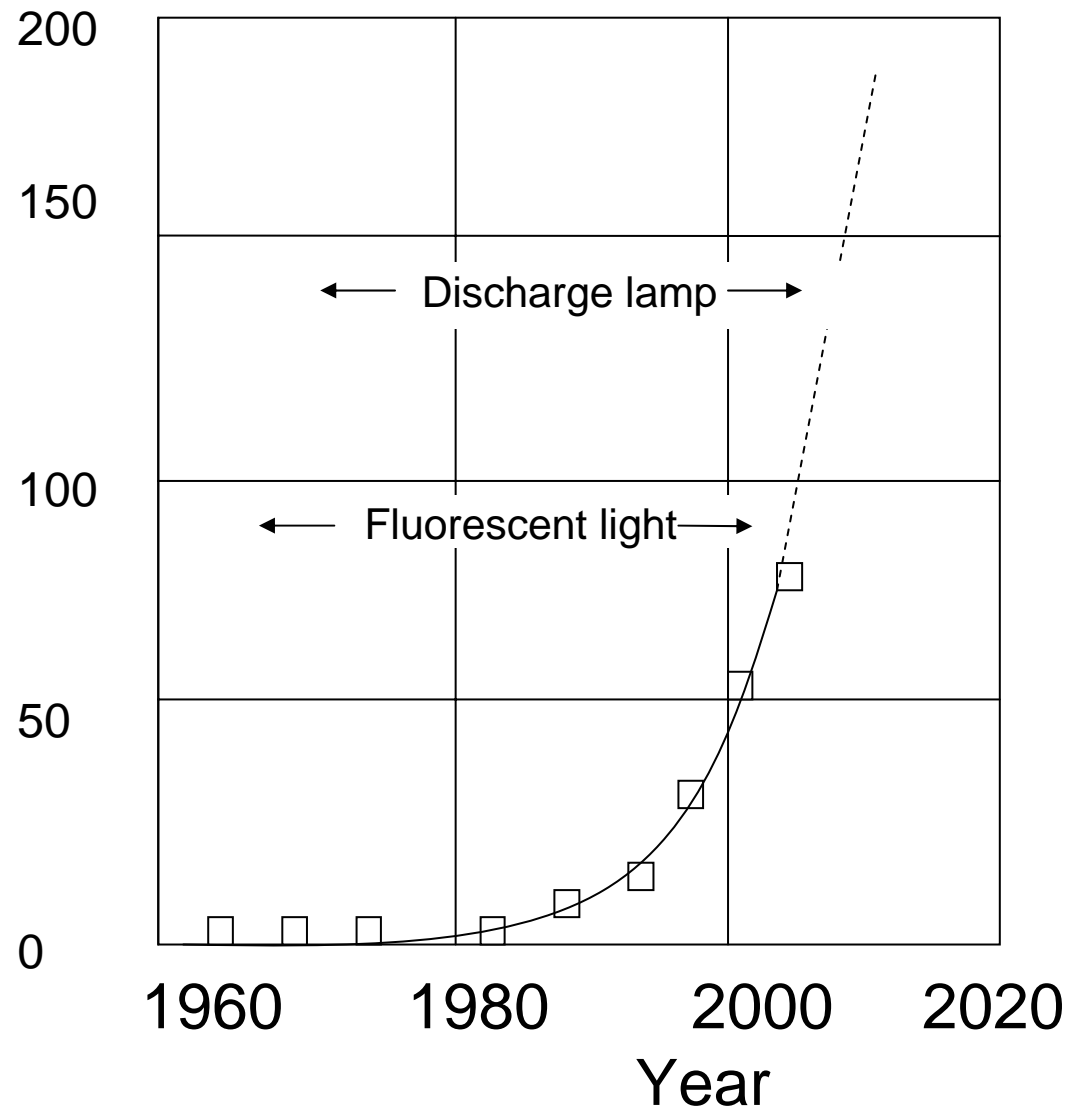
LED spot light modulated by music



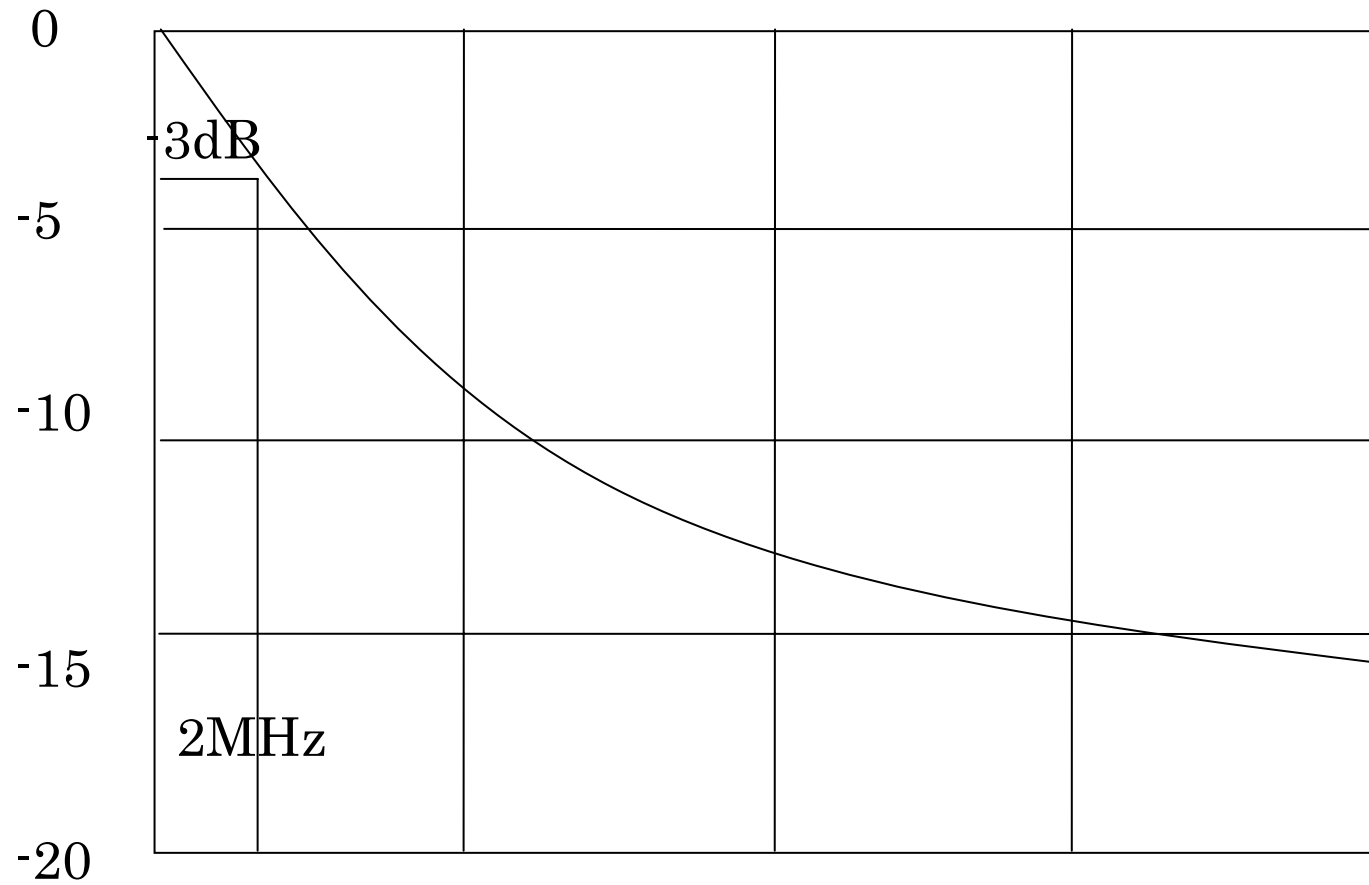
# New white light source using LD (Laser Diode)

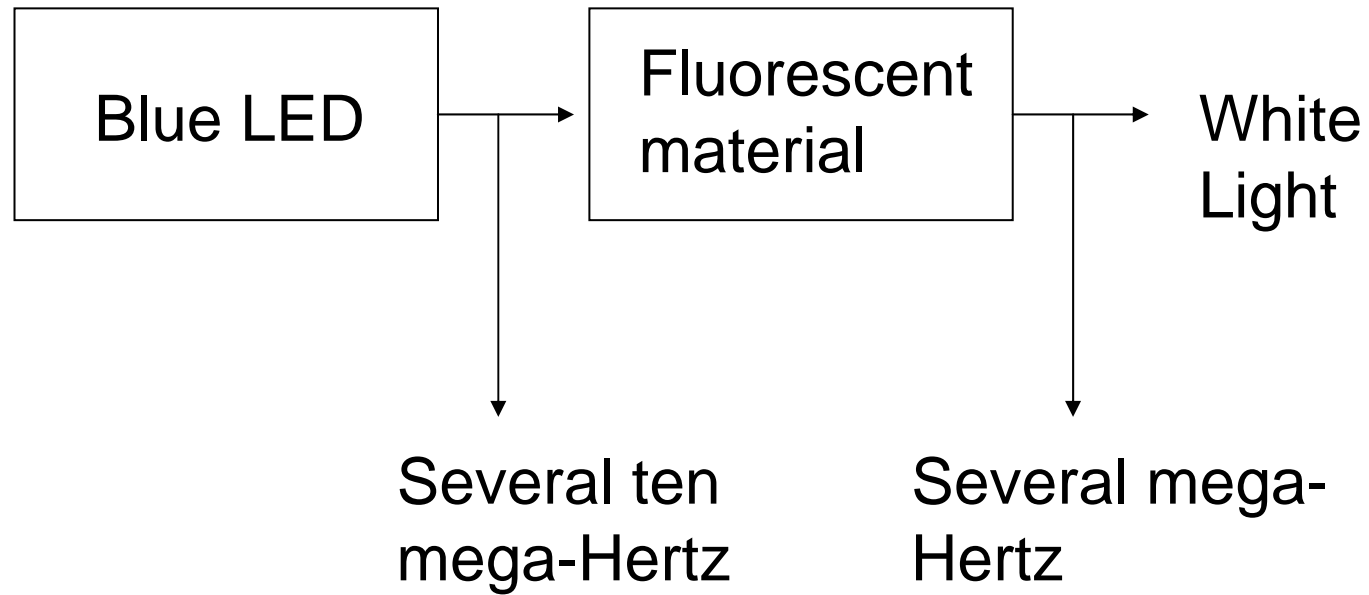


# Luminous Efficiency (lm/w) in LED



# Normalized Magnitude Response of White LED (dB)





## Mechanism of white LED response



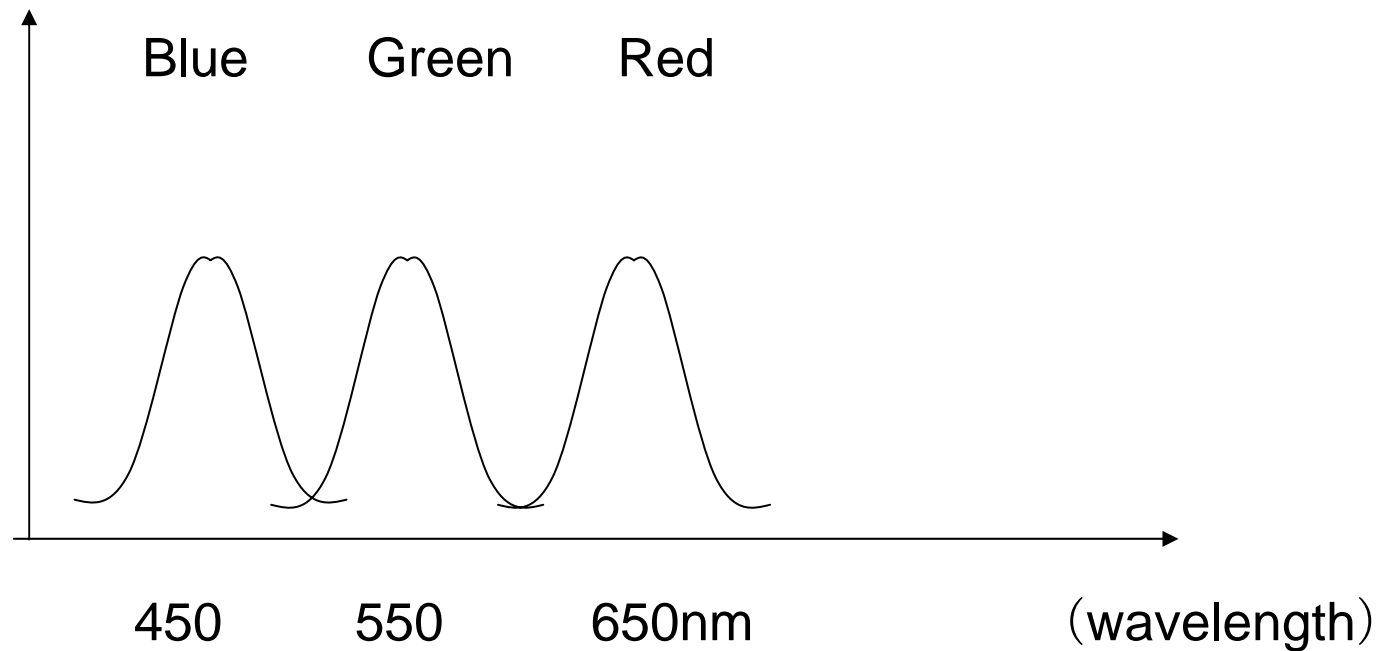
Two mechanisms for illuminating white

(1) White LED using fluorescent material

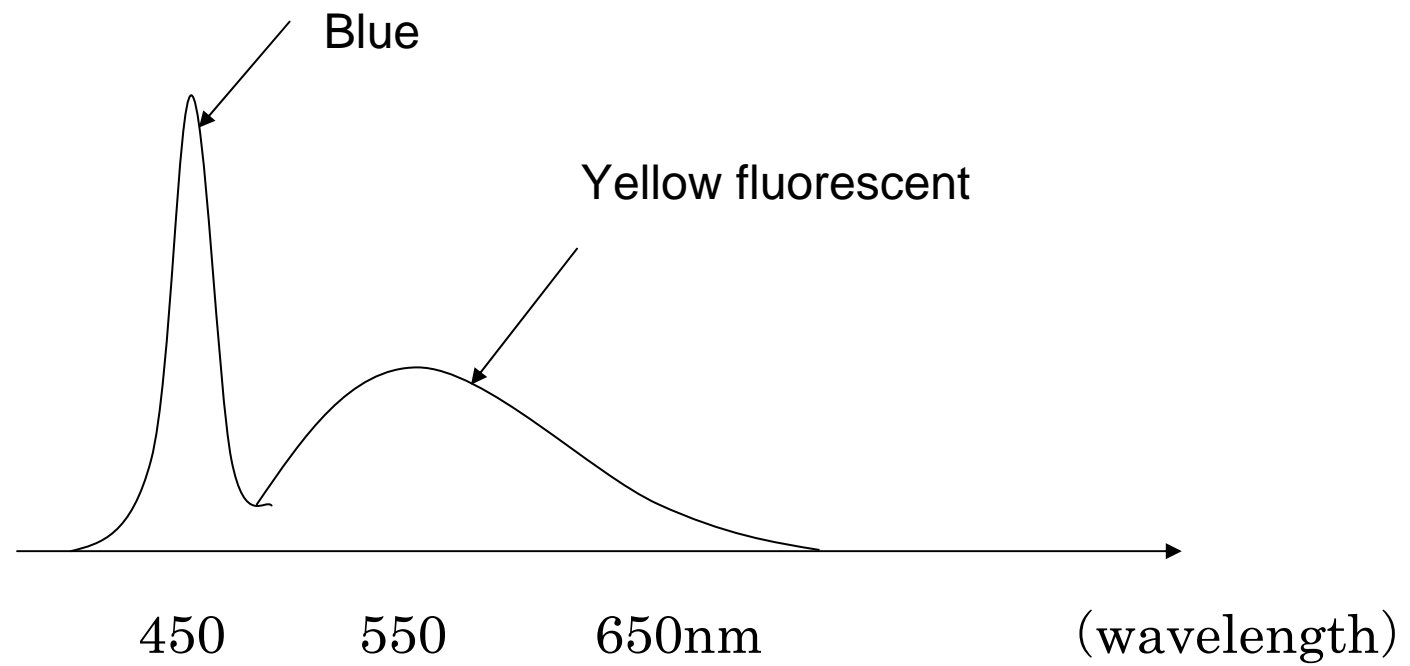
(2) Mixed three colors (RGB)

## Three Colors = White

Three color LED has good frequency response and can change its color. However, it needs three LED electrodes.

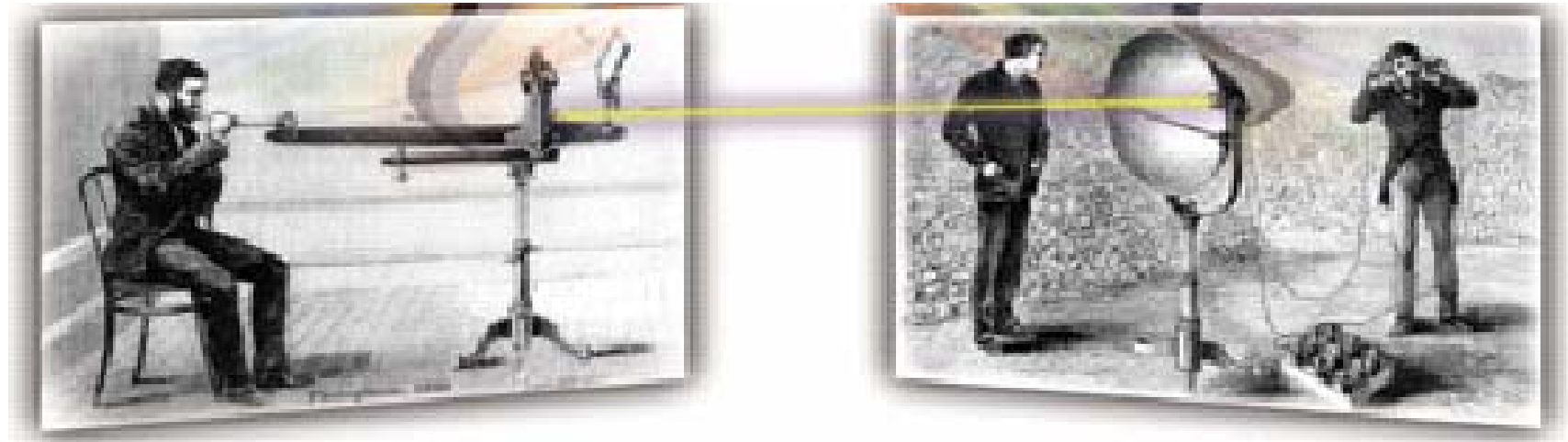


# White LED of fluorescent material driven by blue LED



### 3 . History of Visible Light Communications

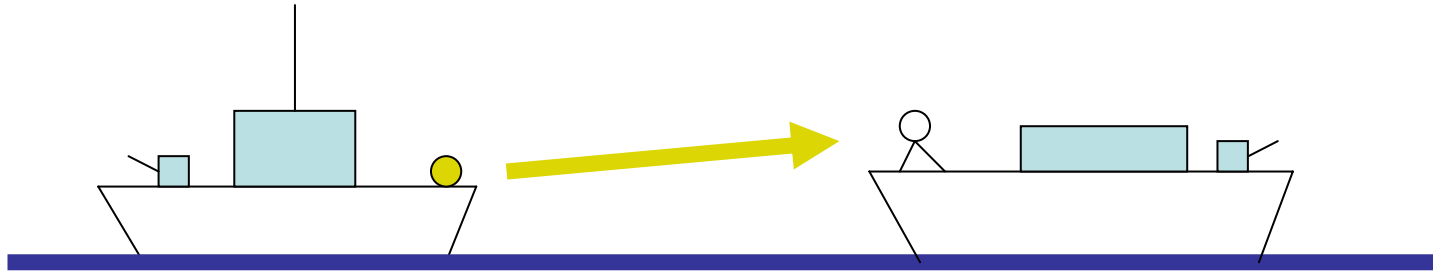
#### Photophone by Graham Bell in 1880



The first experiment of Visible Light Communications was done by Graham Bell whose system was called Photophone. He loved the idea.

This picture is from the website of Bell Laboratories whose experiment showed 200m distance voice communication.

## Morse coded light



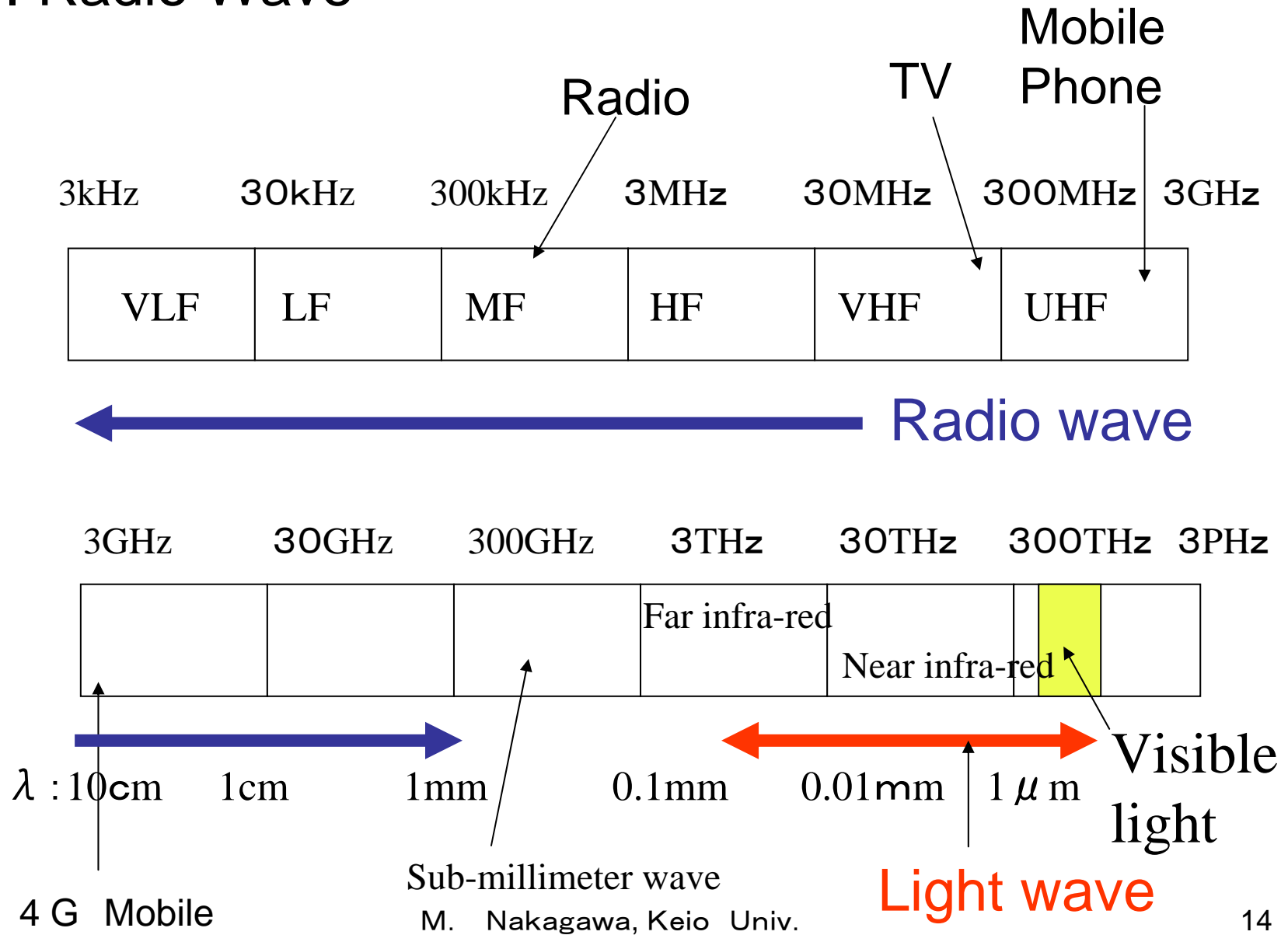
Radio can be eavesdropped by hostile warships or airplanes. Light can be hardly done.

Security: No eavesdrop

Positioning : To find the position of the group ship

Multi-function: Search light and communication both

# 4. Radio Wave



## Telephone Wired Communications



Every-house

receiving and transmitting

## Mobile Wireless Communications



Everywhere receiving and  
transmitting

## Ubiquitous Communications

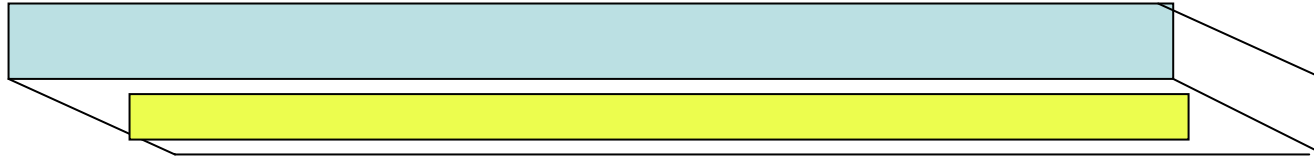
Talking object, Pin point  
communication

Mobile communications uses radio wave, which propagates everywhere.

However, it propagates too much for ubiquitous communications.




## 5. Fluorescent light and LED



Fluorescent light can also transmit information.

## LED as a ubiquitous device

LED (Light Emitting Diode) will become a ubiquitous device.



Pilot lamp  
Traffic signal  
Back light for liquid crystal  
LED screen  
Tail lamp for car  
Room light for car  
Headlight for car  
Corridor light in building  
Room light in building  
Future

## 6. Infrastructure

Mono-functional infrastructure

Multi-functional infrastructure

Road is a typical multi-functional one.

Telephone network is also multi-functional.

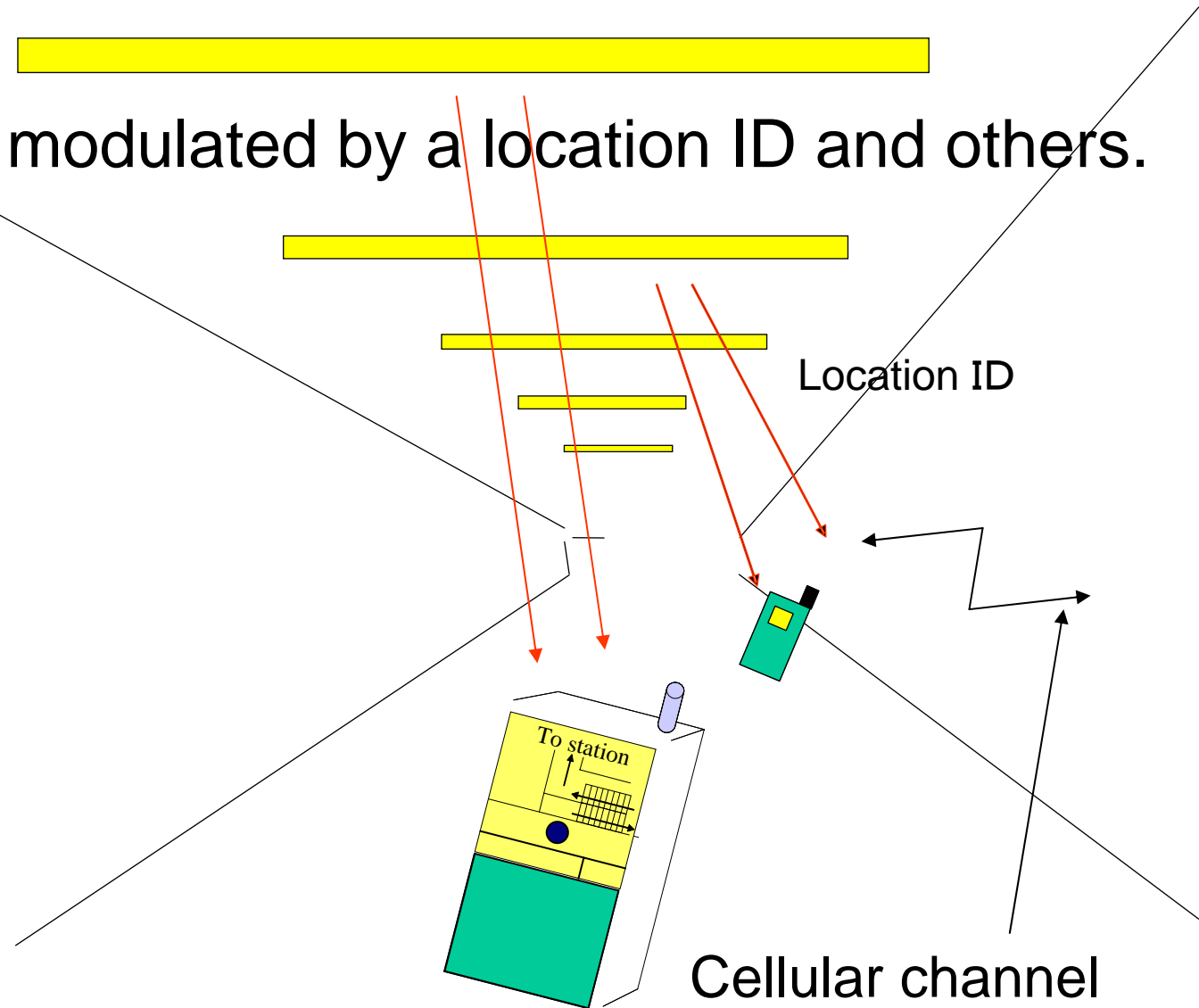
Most of infrastructures are multi-functional.

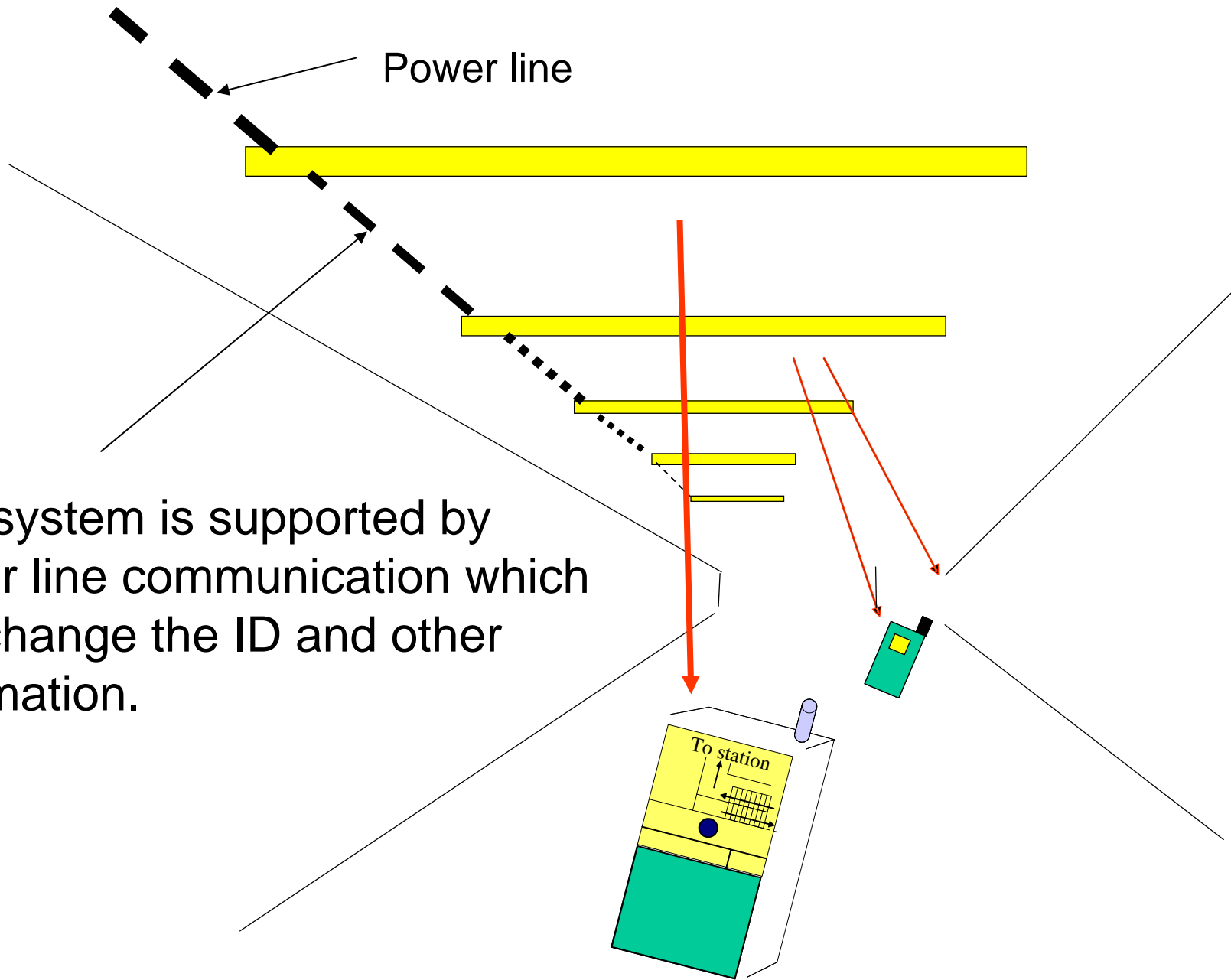
Lighting is now a mono-functional infrastructure.

It will become multi-functional.

## 7. Visible Light Communications for Positioning

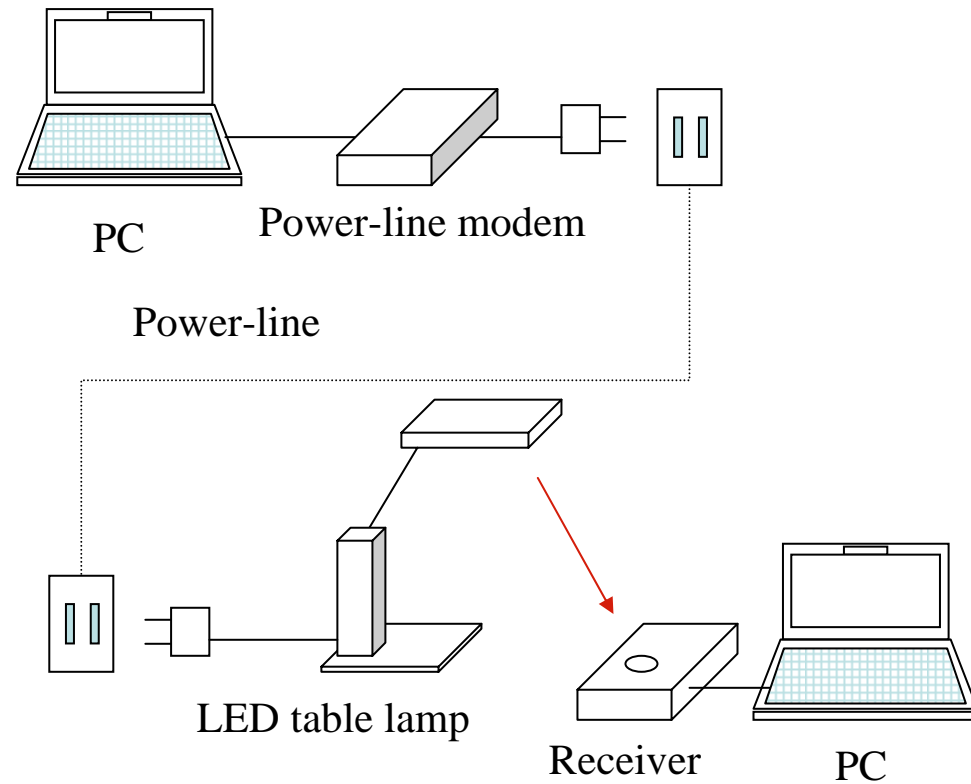
LED light is modulated by a location ID and others.





This system is supported by power line communication which can change the ID and other information.

# Visible Light Communications + Power Line Communications



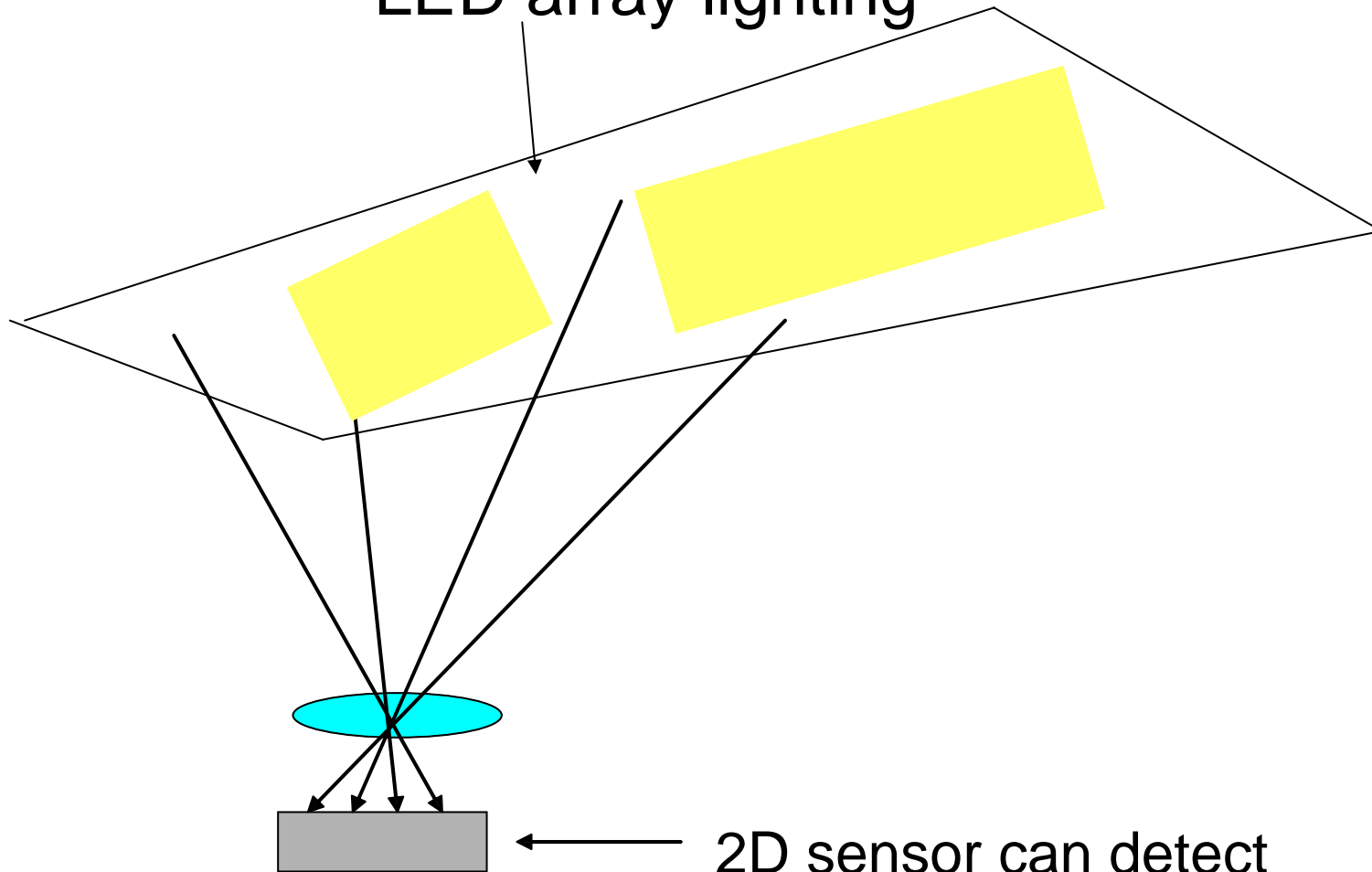
"Integrated System of White LED Visible-Light Communication and Power-Line Communication", T. Komine and M. Nakagawa, IEEE Trans. on Consumer Electronics, vol. 49, no. 1, pp.71-79, Feb. 2003.

2002年 慶応義塾大学中川研

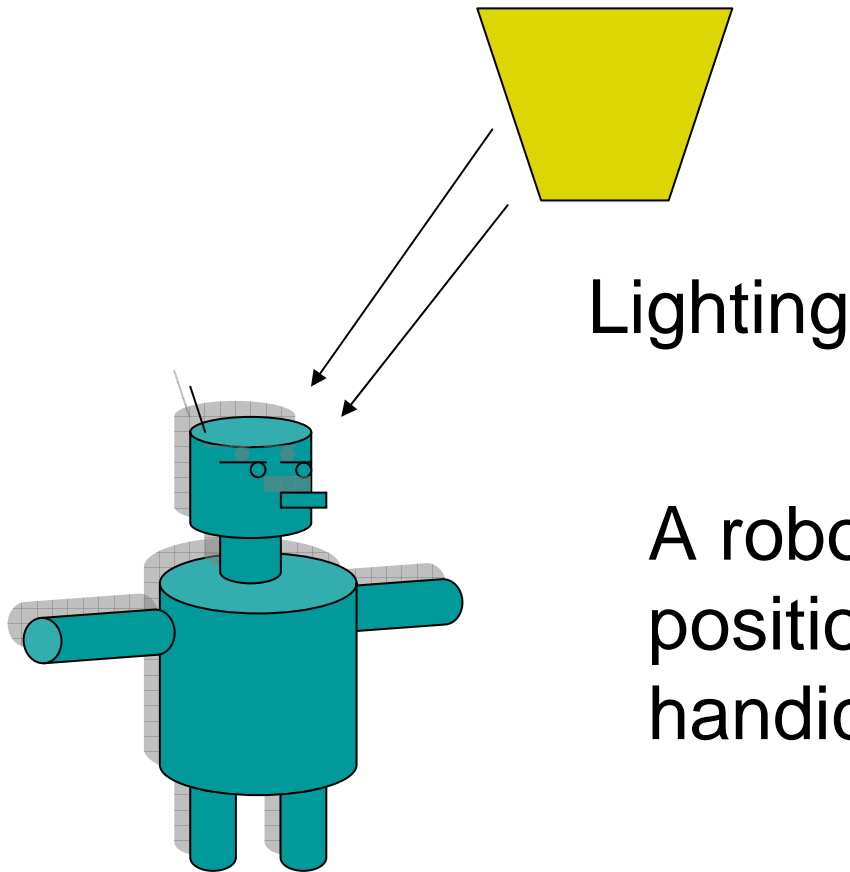
M. Nakagawa, Keio Univ.

# Exact Positioning

LED array lighting



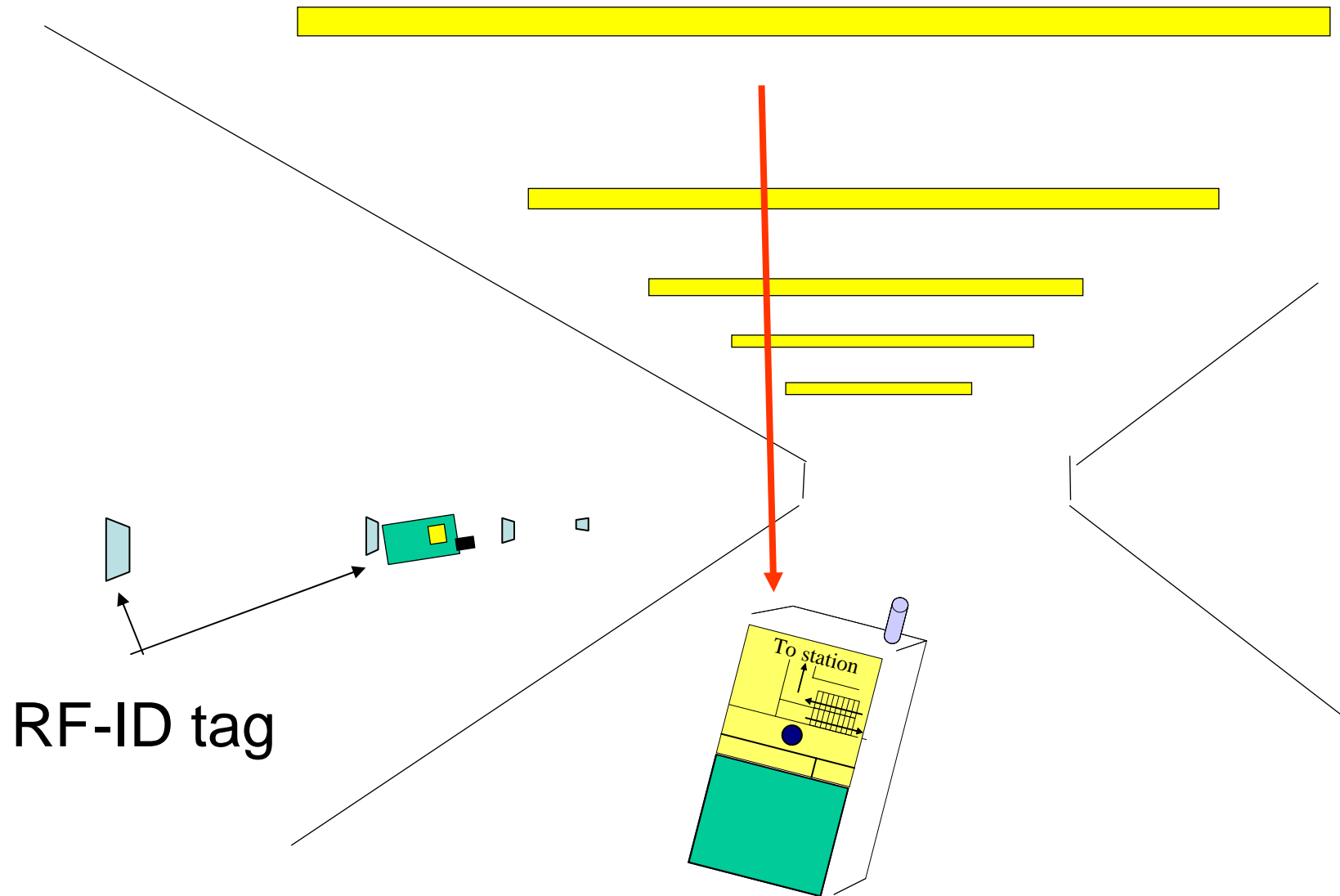
2D sensor can detect exact position in mm.



A robot needs its exact position as well as a handicapped person.



# 8. Competitors



## Comparison-1: Visible Light ID and RF-ID without battery

	VL-ID	RF-ID	Long distance RF-ID
Position exactness	○ ( The light is exact )	○ (Be close to the tag )	×
(Interference)			
License	○ (No license)	○ (No license)	×
Terminal size	○ (Small )	○ (Small )	×
Multi-user	○	×	○
Easy to find	○	×	×

## Comparison-2 Visible Light ID and RF-ID without battery

	VL-ID	RF-ID	long distance RF-ID
Design	○	×	×
Maintenance	○	×	×
		(Touchable from any pedestrian)	
Content changeable	○ (PLC)	×	×
Visual defect person and Handicapped person	○ (not need to be close)	×	×

## 9. Demonstration and Practical Use



## Demonstration

(1) Finding position  
from lighting:

Keio University, NEC,  
and Matsushita  
Denko



LED spot light  
modulated by ID  
data

Mobile terminal test set





Photo diode without lens

WEB Site →





## (2) Traffic signal



The red signal transmits traffic information. Nippon signal and Nagoya Institute Technology





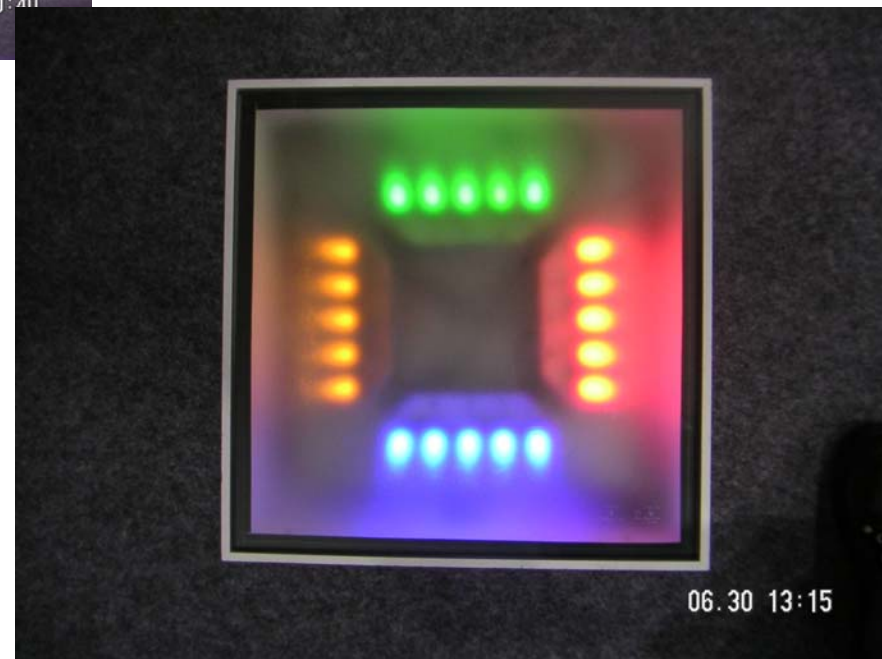
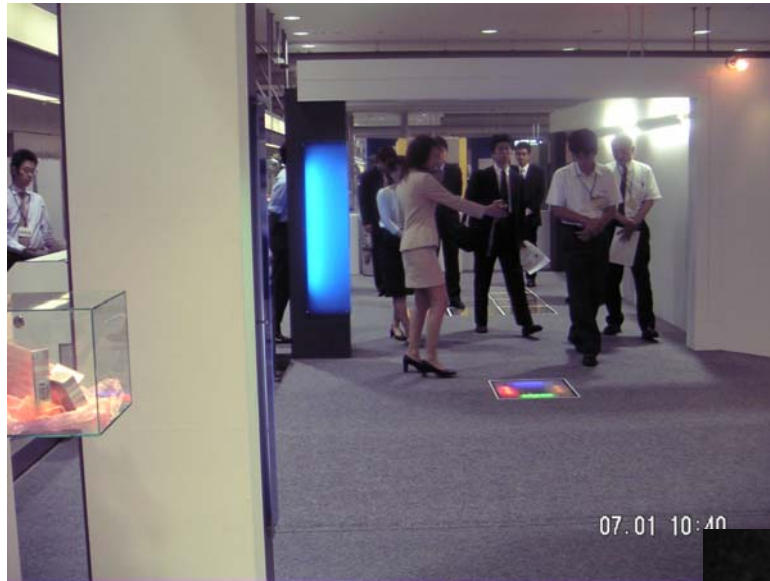
### (3) Kansai airport experiment for visual defect people conducted by Prof. Makino of Niigata University

Most of visual defect people can find the direction of light.

VLC can transmit voice to them.



## (4) Floor lighting for VLC Keio University



# Practical use at Risuhpea in Panasonic



LED Visible Light Transmitter :  
Clear design

M. Nakagawa, Keio Univ.





LED Visible Light Transmitter :with clear design

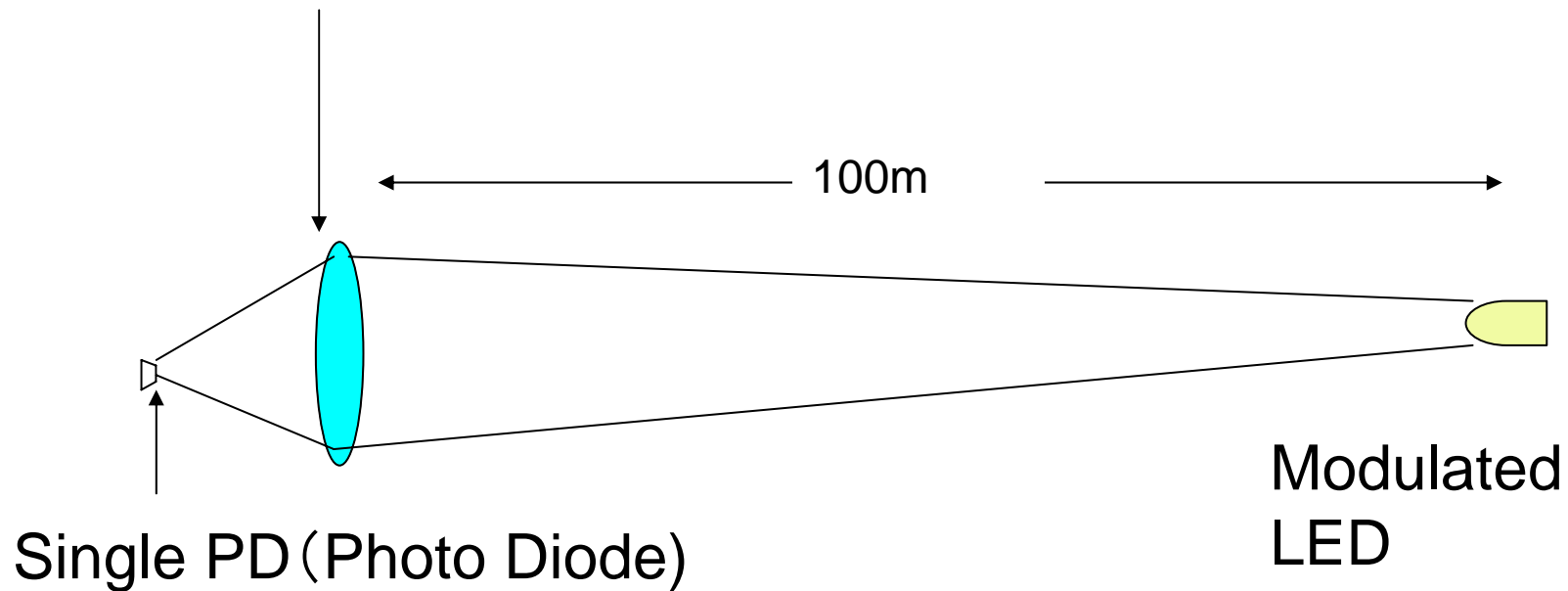
M. Nakagawa, Keio Univ.

## 10 Image Sensor Communication

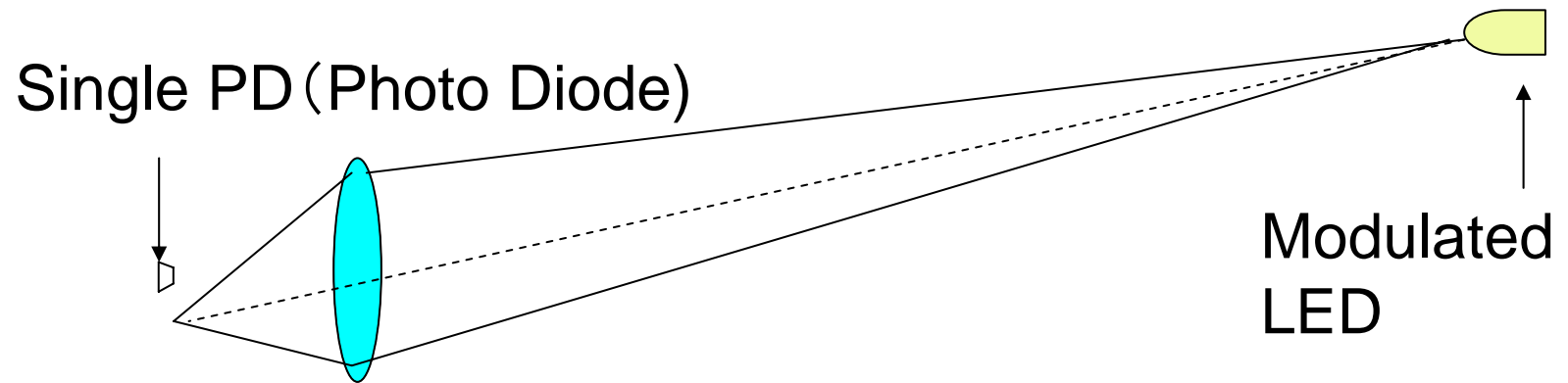


Photo diode without lens is a simple and economical detection method. However, its communication distance is limited short due to background lights.

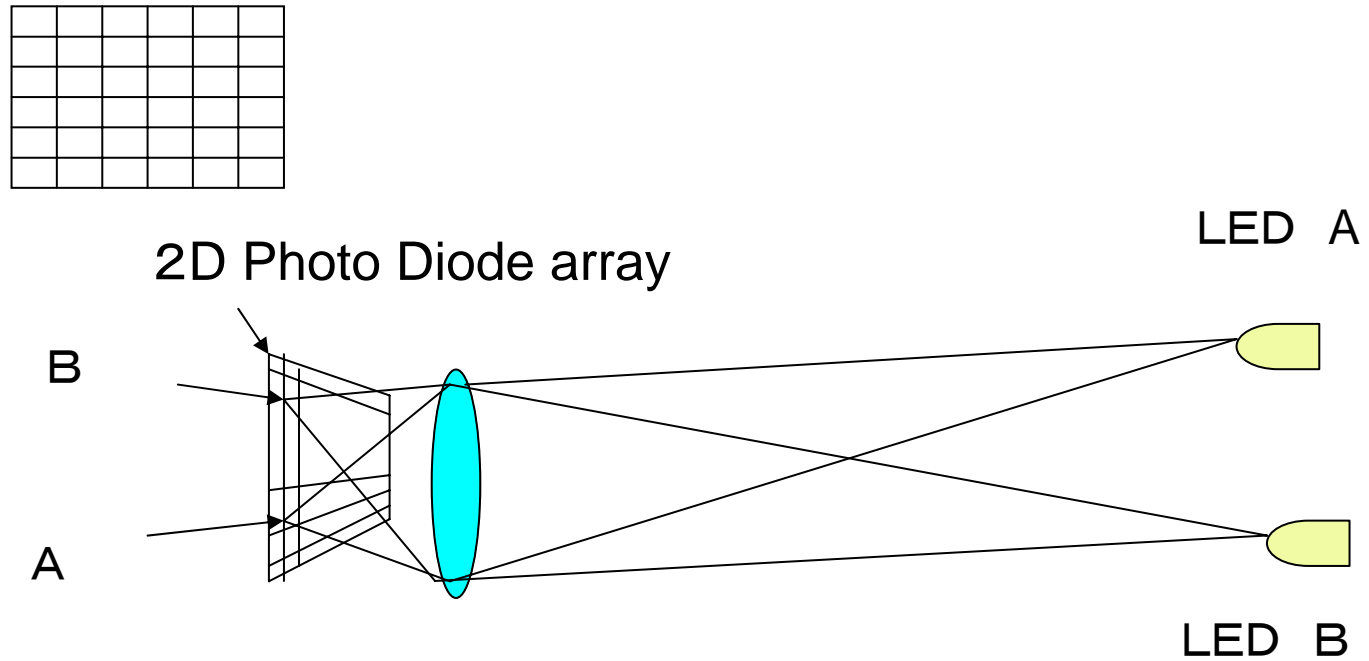
Lens is a powerful tool for long distance communication.



Lens makes possible to receive the far modulated LED light in front of the single PD.

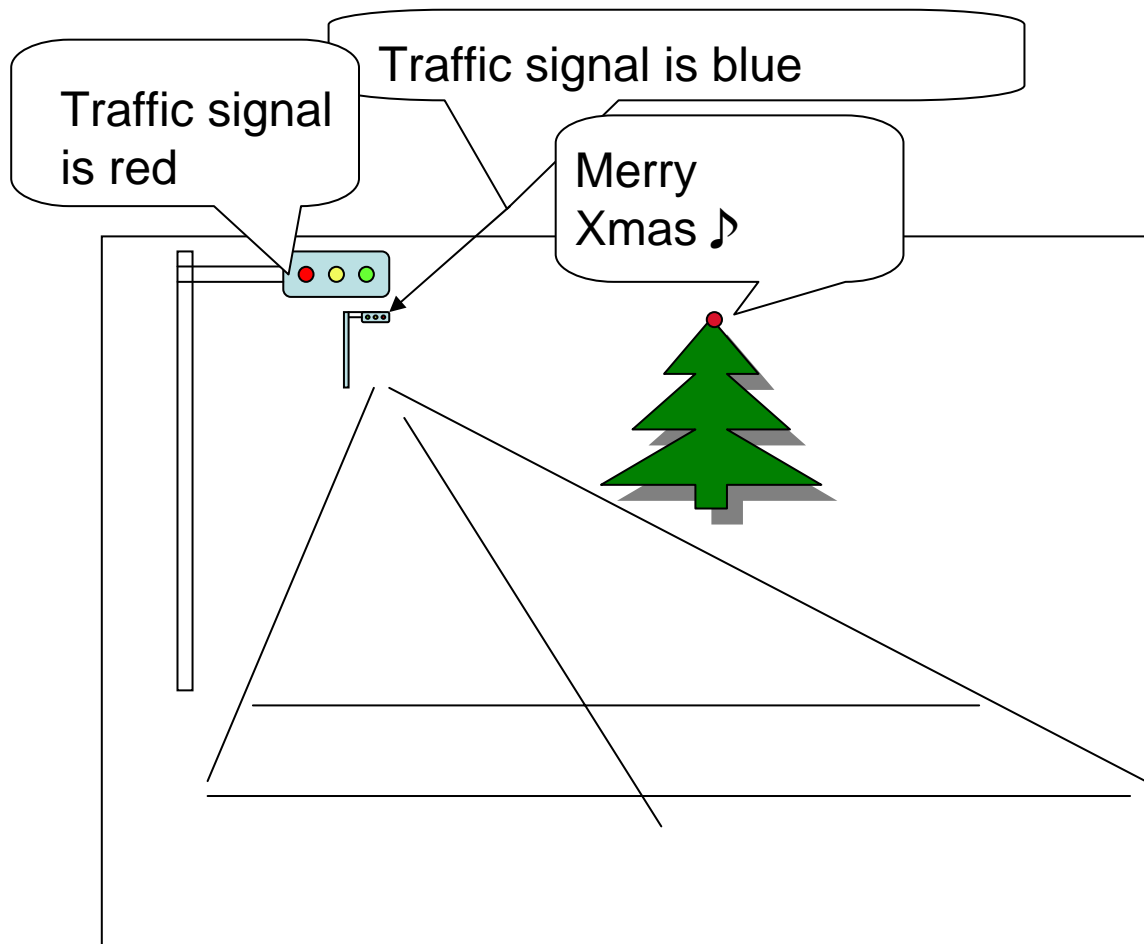


The modulated LED not in front of the single PD can not be detected.

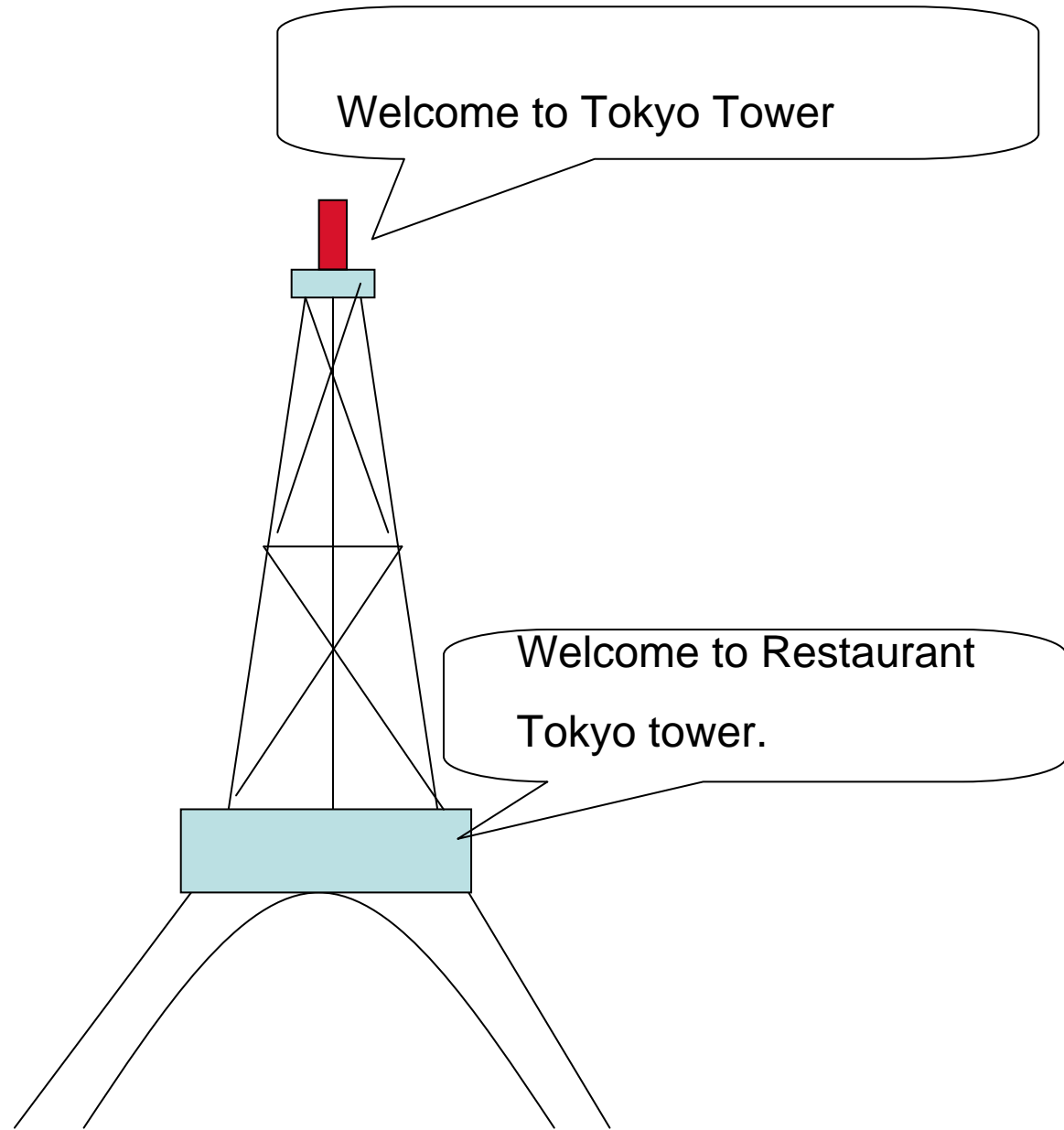


The 2D-PD array can detect the both modulated LED A and B.





Many LED data are simultaneously detected.





Two modulated LED lights, each has 0.5 w  
input power data rate 60bps



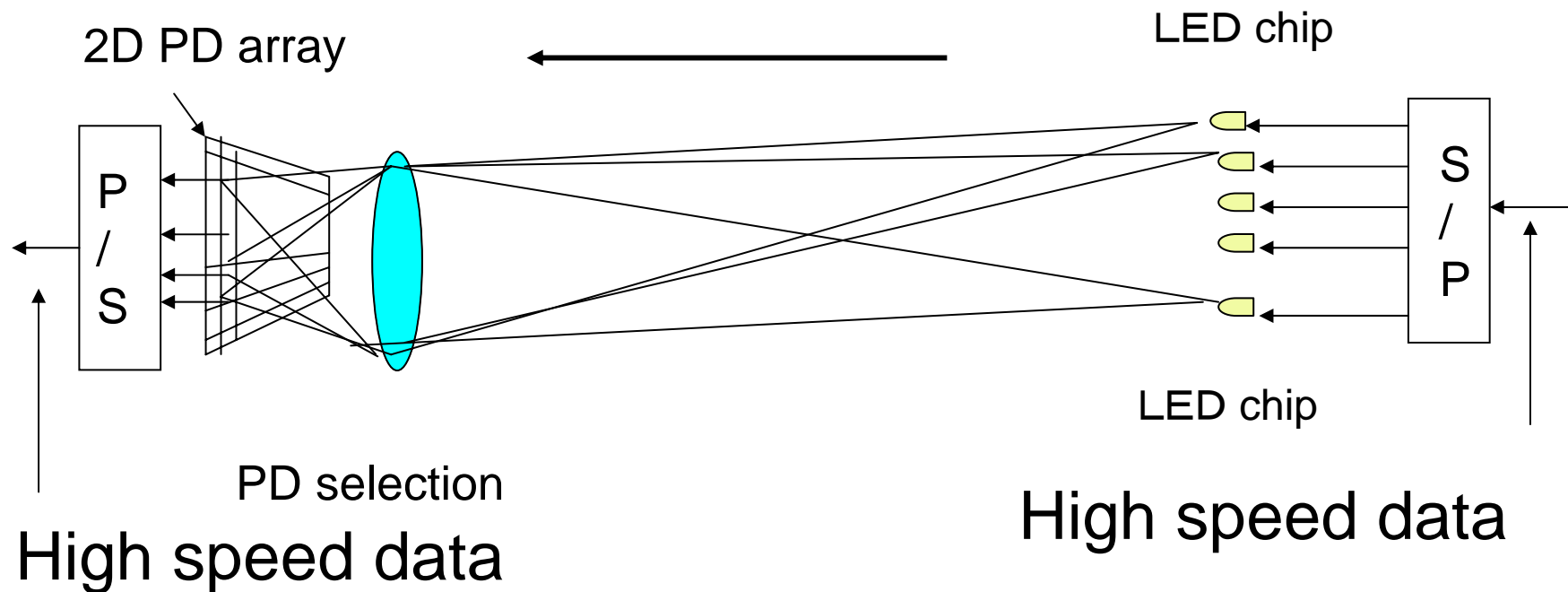
Image  
sensor  
(Video  
camera)

The two modulated light sources can be detected at 200m far point with image sensor detector.



Video camera detects the two ID signals transmitted by the two LED lights 200m away in the presence of many fluorescent lamps. A daytime outdoor 1km experiment was also successful.(CASIO and Keio University)

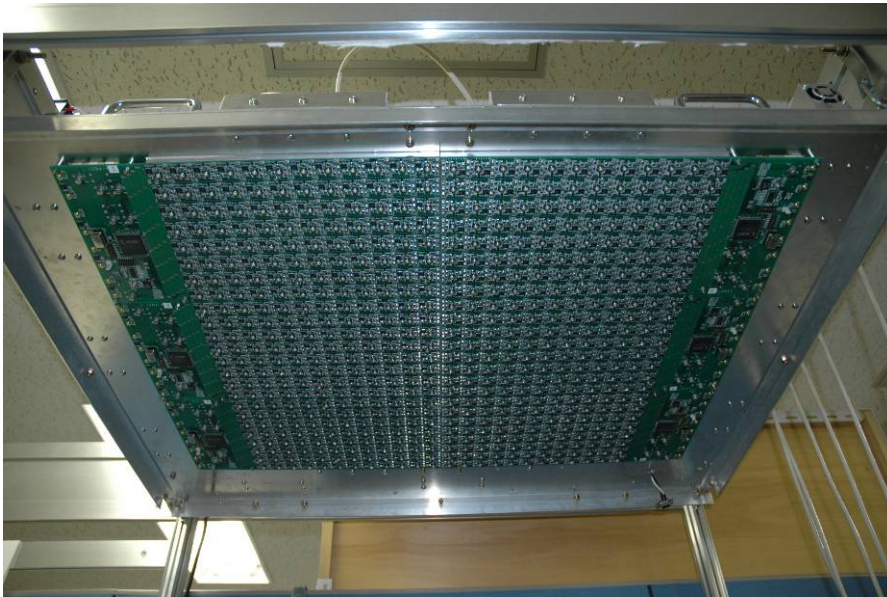
# Parallel Transmission for High Speed Data



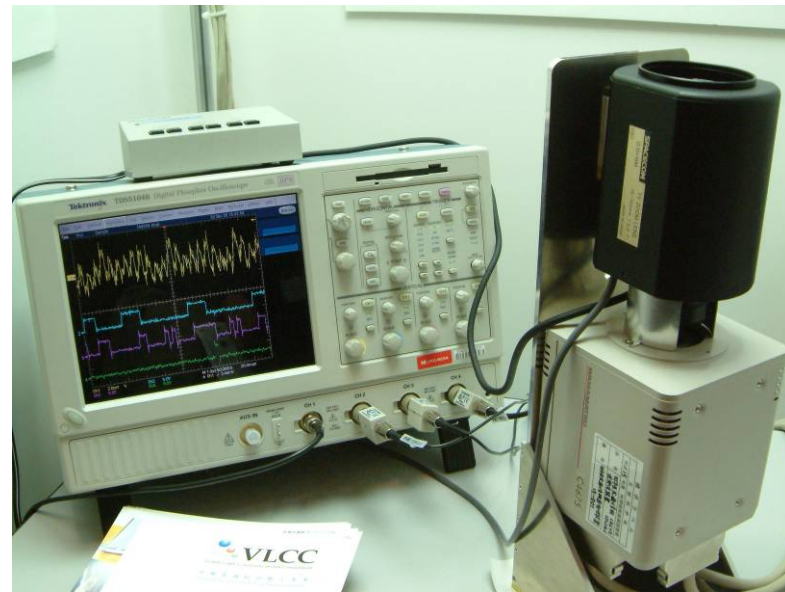
Although LED chips have limited frequency response, the multi-LED chip lighting gives high speed transmission in its parallel transmission and detection.



# High Speed Data for 1Gbps



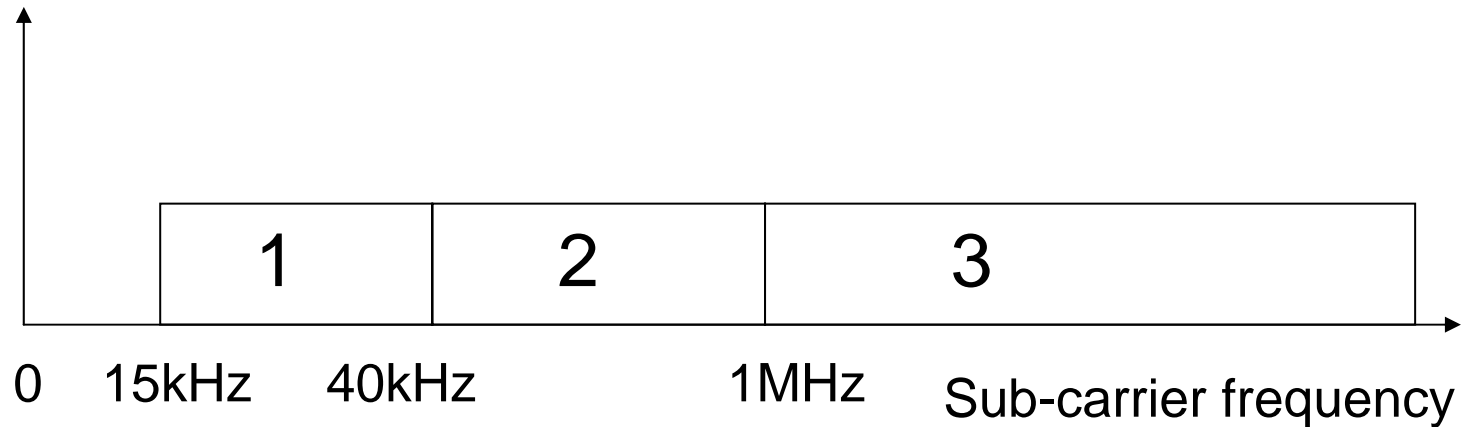
TX: 576 white LED array (each LED chip has 1W input and 5Mbps data)



RX: 256 PD array receiver

# 11 Standardization

## cp-1221 in JEITA

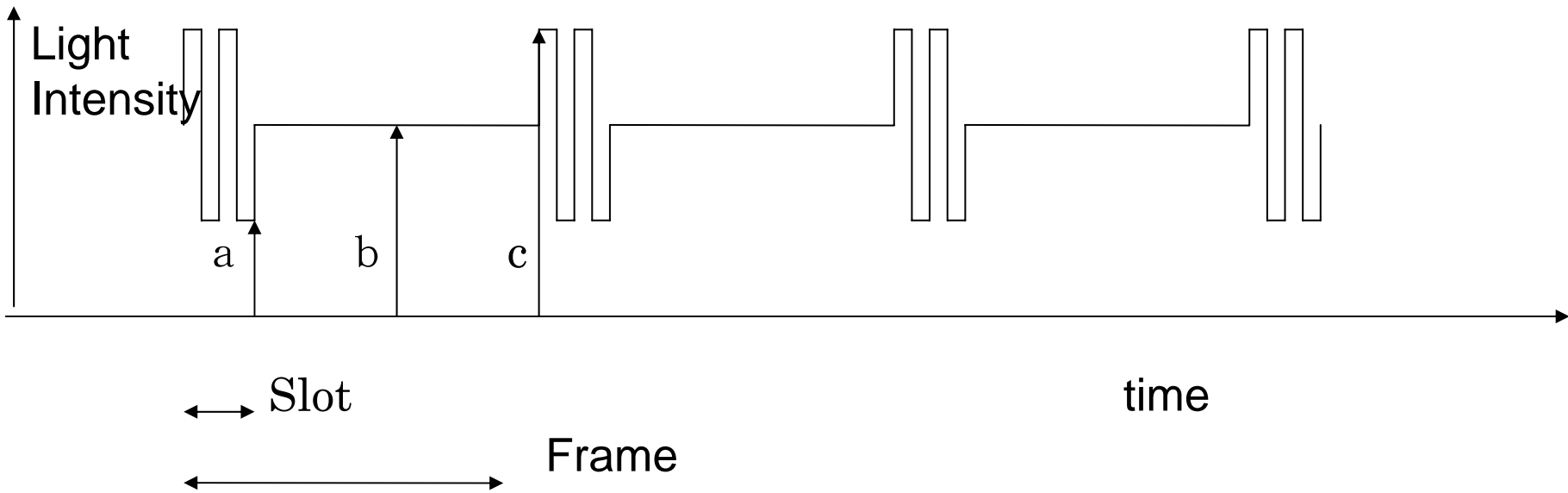


The band 1 from 15kHz to 40kHz is recommended for low speed transmission and the band 3 more than 1MHz is recommended for middle and high speed transmission.

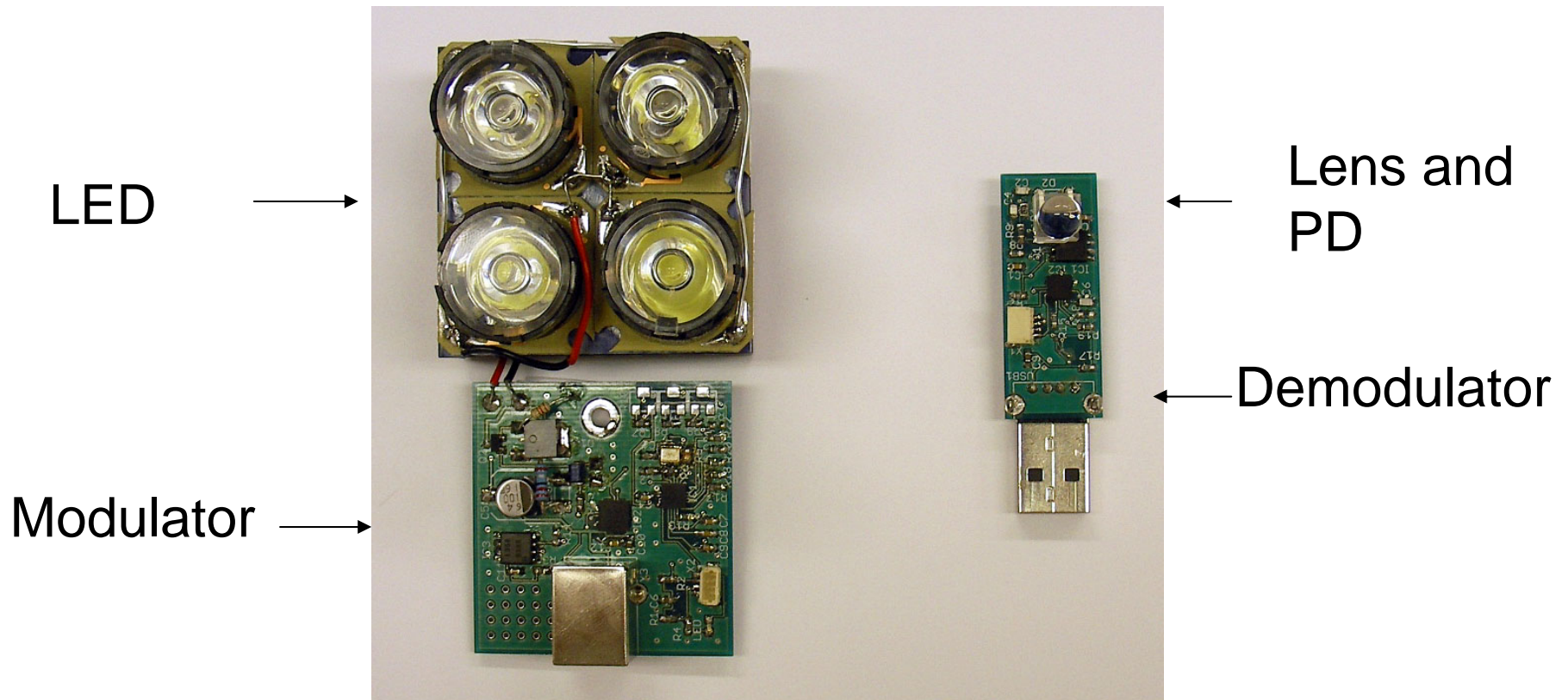


# cp-1222 4PPM modulation

Data	0 0	0 1	1 0	1 1
4PPM	1 0 0 0	0 1 0 0	0 0 1 0	0 0 0 1



Sub-carrier frequency: 28.8kHz, Data rate: 4.8kbits



Visible Light ID kit based on cp-1221, cp-1222

## 12. Conclusions

Infrastructure is important to realize ubiquitous communications.

Lighting will become a multi-functional infrastructure whose second function is visible light communication.

VLC does not ruin the room design and landscape.

VLC is easy for handicapper people.

Image sensor communication is for long distance VLC.