Potentials of deploying a VLC technology in the market

Shinichiro Haruyama
Graduate School of System Design and Management
Keio University

August 2, 2016
VLC Seminar
Chulalongkorn University
Bangkok, Thailand

Contents

1. Visible light communication

Why visible light communication is becoming one of the hot topics of personal-area network communication?

Because:

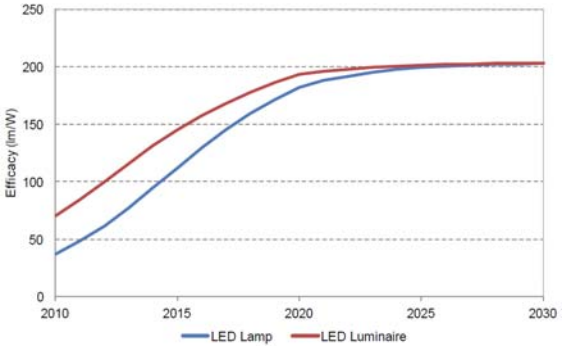
- White LEDs have been widely used
- Visible light communication technology is an enabler of new services

Why white LEDs have been widely used?

Because:

- LED lights have higher luminous efficacy than other light sources.
- LED lights have long lifetime.
- The price of LED lights is dropping due to mass production effect.

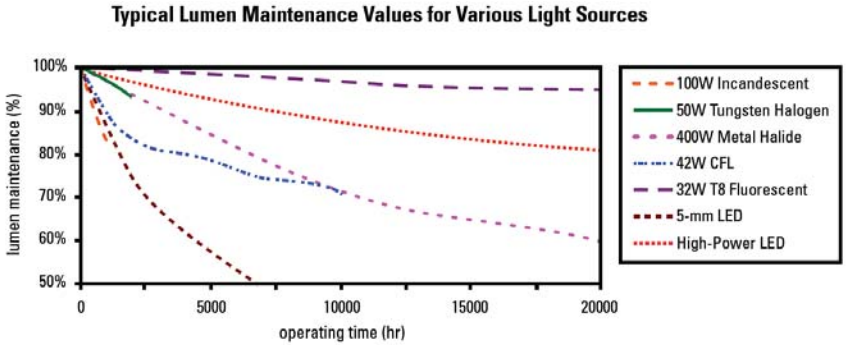
LED lights have higher luminous efficacy



Source: US Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Program, "Energy Savings Potential of Solid-State Lighting in General Illumination Applications", January 2012

Currently the luminous efficacy of LED lamps and luminaires is around 100 lm/W (lumens per Watt), and expected to reach 200 lm/W around 2025, which is much higher than incandescent lamps (around 20 lm/W) and fluorescent lights (around 100 lm/W).

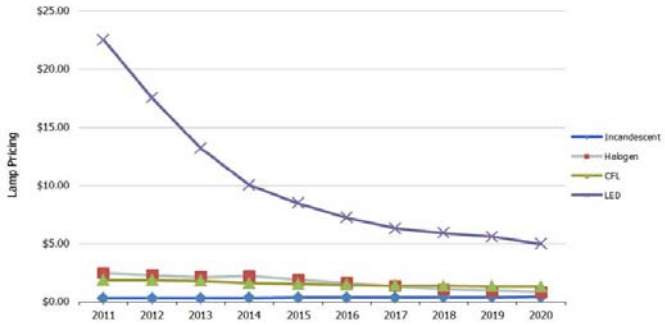
LED lights have long lifetime



Source: Adapted from Bullough, JD. 2003. *Lighting Answers: LED Lighting Systems.* Troy, NY. National Lighting Product Information Program, Lighting Research Center, Rensselaer Polytechnic Institute.

LED lamps typically have a lifetime of 40,000 hours, which is 40 times longer than incandescent lamps.

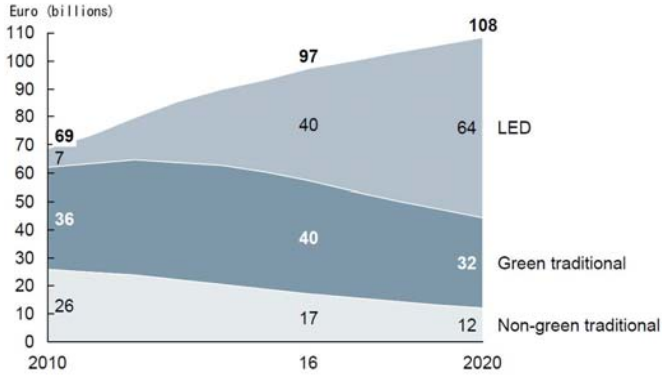
Price of LED lights is dropping due to mass production effect



Source: Philip Smallwood, "Global 60W Replacement Lamp Market", LED Lighting Evolution Conference, Boston, Massachusetts, USA, June 2012

The price of a 60 Watt LED light is expected to drop to US $5 in 2020.

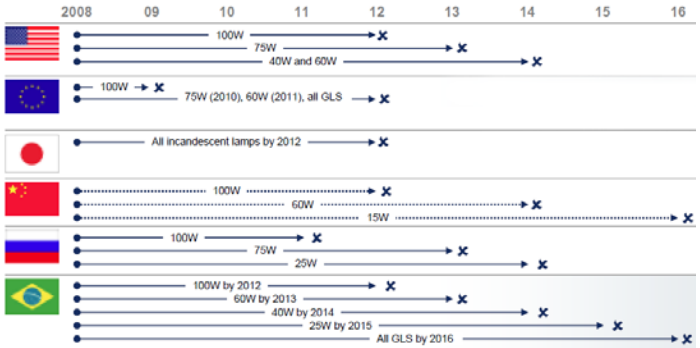
As a result, LED lights are gaining a larger share



Source: McKinsey & Company, "Lighting the way: Perspectives on the global lighting market", 2nd Edition, August 2012

The share of LED lights will become 64 percent of the global lighting product market in 2020.

Governments in many countries are starting to ban inefficient lighting technologies



Source: McKinsey & Company, "Lighting the way: Perspectives on the global lighting market", 2nd Edition, August 2012

Countries such as USA, EU, Japan, China, Russia, and Brazil started to ban 100 Watt incandescent lamps by the end of 2012, and they will ban many of incandescent lamps by 2016.

There is one more reason why visible light communication is becoming one of the hot topics of personal-area network communication:

Because:

- Visible light communication technology is an enabler of new services

  There are unique characteristics of VLC which enables many useful VLC applications and services.

Characteristics of Visible Light Communication:

A. LED lights will be used everywhere

B. Easy detection of the direction of a VLC transmitter

C. Visible light communication signal is not affected by electro-magnetic noise

A: LED lights will be used everywhere

Many light sources such as electric lights, automobile head/rear lamps, traffic lights, indicator lamps, etc. are now being replaced by LED lights. If LED lights can transmit data in addition to emitting visible lights, they can be used as pervasive communication equipments.

B: Easy detection of the direction of a VLC transmitter

If an image sensor is used, the direction of a VLC transmitter can be detected accurately.

C: Visible light communication signal is not affected by electro-magnetic noise

Electro-magnetic noise prevents high-quality communication for radio-based wireless communication, but VLC

Contents

Types of Transmitter Devices

-Visible light LED



LED light LED traffic light Car headlight

LED light intensity is modulated by controlling its current.

Types of Receiver devices

-PIN photo diode 

-high speed reception up to 1Gbps

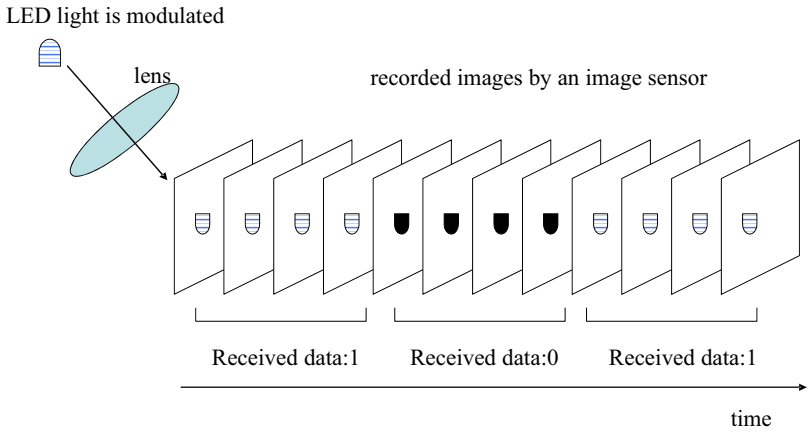
-Avalanche photo diode 

-more sensitive reception than PIN photo diode

-Image sensor 

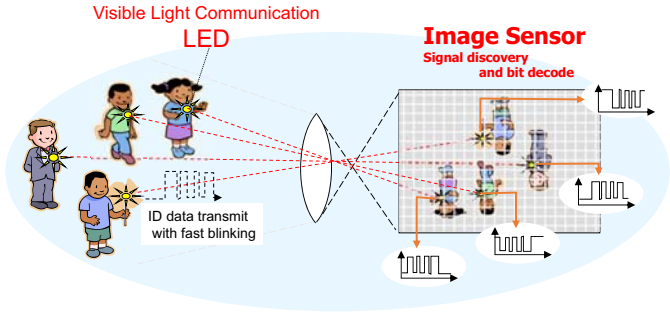
-simultaneous image acquisition and data reception

Image sensor communication



Camera (receiver) continuously takes images of a scene with an LED light and a receiver detects the optical intensity at a pixel where the LED light is focused on.

Image sensor communication(continued)



Even if multiple visible light sources send data simultaneously, an image sensor is able to receive and demodulate all the data simultaneously without any interference between them.

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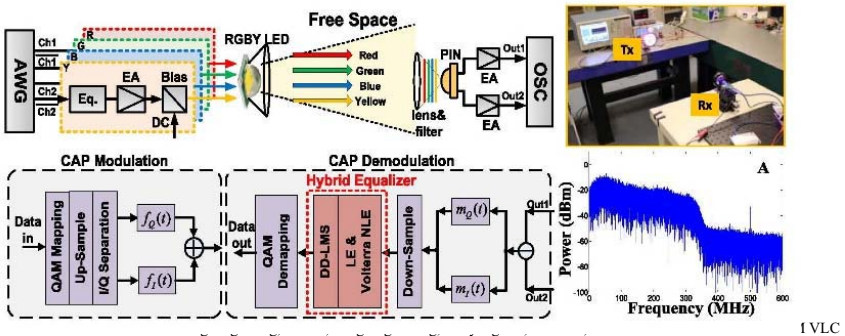
Applications of VLC

- Application examples using photo diode
- Application examples using image sensor

- Application examples using photo diode

Using a photo diode as a receiver, it is possible to have high-speed data transmission using VLC. Some research results show that the speed can be several Giga bits per second.

Example of multi Giga bits per second transmission using VLC



1 VLC System Employing High-Order CAP Modulation and Hybrid Post Equalizer", IEEE Photonics Journal (Volume:7 , Issue: 6 , 2015) (affiliation: Fudan University)

Wang et al. achieved 8 Gbps using 4 wavelengths of visible light at a distance of 1 meter.

- Application examples using image sensor

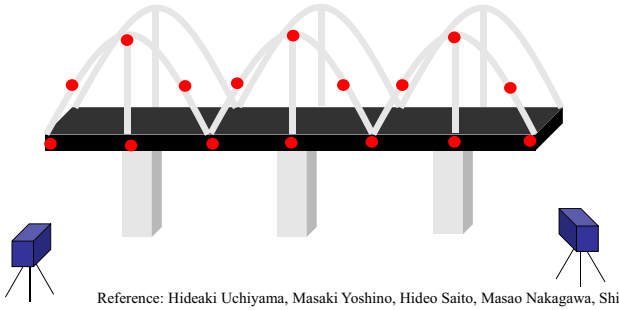
A unique thing about visible light communication is that it can not only receive data, but also detect an accurate direction of incoming light when an image sensor is used as a receiver.
This makes it possible to calculate a very accurate position, that can be used for various applications such as advertisement, augmented reality, survey, etc.

- Application examples using image sensor

① Three dimensional position measuring system using VLC
② Accurate position detection for robot control
③ Lighthouse communication using VLC
④ Application of VLC to Intelligent Transport System
⑤ Drone Monitoring
⑥ Image Sensor Communication using Smartphone camera and color coding
⑦ Image Sensor Communication using Smartphone camera and digital signage

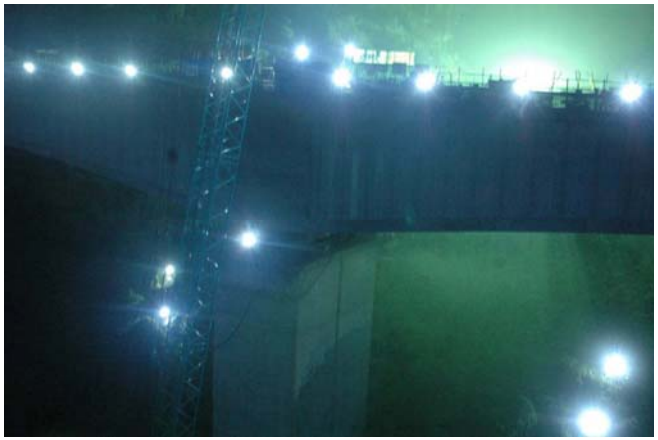
① Three dimensional position measuring system using visible light communication

Keio University and Sumitomo Mitsui Construction Co., Ltd. Developed a new technology for measuring three dimensional position of objects. Objects can be measured by receiving and detecting the direction of visible light signal with an image sensor.



Reference: Hideaki Uchiyama, Masaki Yoshino, Hideo Saito, Masao Nakagawa, Shinichiro Haruyama, Takao Kakehashi, Naoki Nagamoto, "Photogrammetric System using Visible Light Communication", 34th Annual Conference of the IEEE Industrial Electronics Society, Orlando, Florida, USA, November 2008

Example of three dimensional position measuring system using visible light communication



LED lights attached to a highway bridge under construction in Japan

When an object in located in the 40 meter by 40 meter area, this technology is able to measure three-dimensional position of the object in several millimeter accuracy.

Movie of LED lights attached to a bridge

Three-dimensional positions of LEDs attached to a bridge are unknown, while three-dimensional positions of LEDs attached to the ground are pre-measured and known.

Movie of LED lights attached to a bridge at night

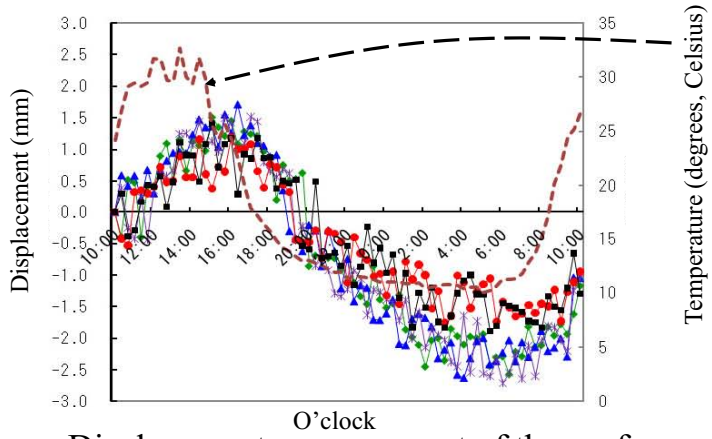
Each LED light transmits unique ID number

Another example of three dimensional position measuring system using visible light communication

The technology is applied to measure the displacement which is caused by the increase of temperature of the aluminum dome roof due to the sunshine in the daytime. 12 LED lightings were attached to the roof. We were able to do automatic measurement of every 20 minutes for 24 hours and confirm the displacement of several millimeters.

Reference: Mikami, Kakehashi, Nagamoto, Nakagome, Taketomi, "Three dimensional position measurement system using visible light communication ", Reports of Technical Research and Development Center of Sumitomo Mitsui Construction Co., Ltd, No.9, pp. 79 – 84, October 2011

Another example of three dimensional position measuring system using visible light communication



Displacement measurement of the roof

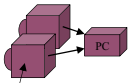
② Accurate position detection for robot control

Keio University and NEC developed a new robot control system with a very accurate position detection.

LED lighting with a transmitter
Position data is transmitted from visible light LEDs

A robot with two image sensors calculates its three-dimensional position in real time.

High resolution image sensor detects accurate direction of incoming light sources

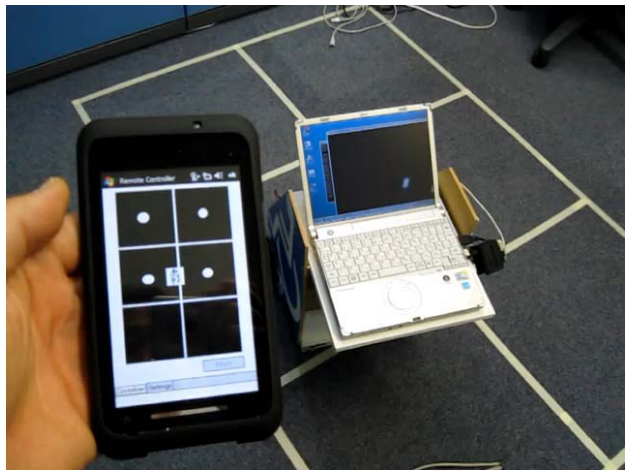


PC calculates three-dimensional position

High speed image sensor demodulates data sent from LED lightings

Reference: Toshiya Tanaka, Shinichiro Haruyama, "New Position Detection Method using Image Sensor and Visible Light LEDs", The 2009 2nd International Conference on Machine Vision (ICMV 2009), Dubai/United Arab Emirates, December 2009

Accurate position detection of a transmitter or a receiver



A user sends a destination position from a smartphone to a robot and a robot autonomously moves to the destination position by measuring its own three-dimensional position using data from LED lights.

③ Lighthouse communication by Visible Light Communication

Maritime Safety Agency Research Center of the Japan Coast Guard requested VLCA (Visible Light Communications Association) to do research about visible light communication using lighthouse or buoy lights, and VLCA member companies (Casio Computer Co., Ltd., NEC, and Toshiba) did the experiments.

Lighthouse communication using visible light communication

LED light in a photograph image

LED light for a buoy

LED light attached to a buoy

Received image and data

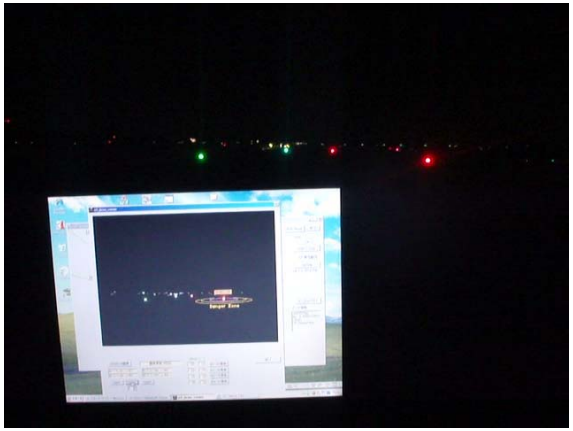
1300 kilo bits per second
2780 frames of pictures per second

Casio Computer Co., Ltd.

The purpose of this project is to develop a new technology that enables the visible light communication using visible light from lighthouses and buoys. An image sensor of a camera on a boat demodulates the incoming data from lighthouses and buoys and displays its content on a display monitor.

Lighthouse visible light communication

Use of AR(Augmented Reality) to show the visible light message in a real picture

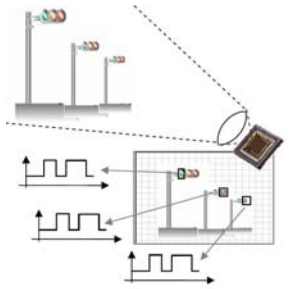


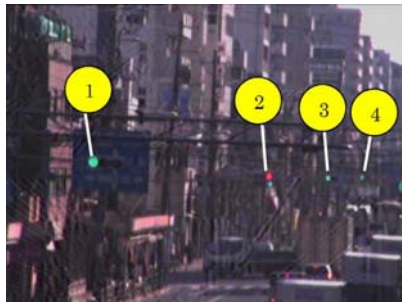
Experiment in 2014

④ Application of VLC to ITS (Intelligent Transport System)

System with LED traffic light transmitter and image sensor receiver

by VLCA (Visible Light Communications Association, Japan) and
The Japan Traffic Management Technology Association



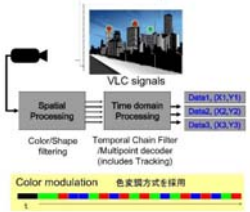


VLCA (Visible Light Communications Association), March 2010

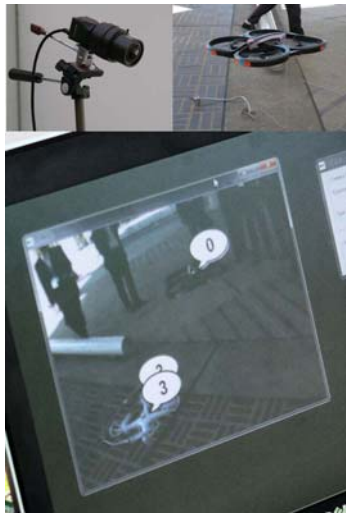
Data from multiple LED traffic lights are received by an image sensor receiver.

⑤ Drone Monitoring

Casio Computer Co., Ltd. proposed a drone monitoring system in 2015. Each drone is equipped with an LED that transmits a unique ID. A camera is able to distinguish multiple drones as shown in the photo on the right. The system uses color modulation and demodulation as shown below. The system is able to distinguish up to 50 different drones.



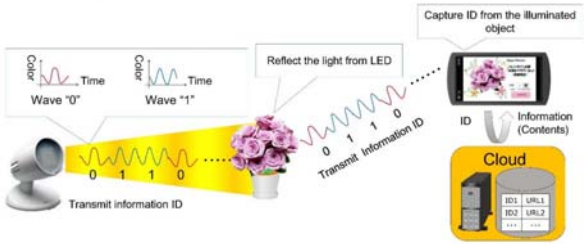
Drawing from a poster of Casio Computer Co., Ltd. at ICEVLC on October 26, 2015, Keio University, Japan.



Prototype demonstration at ICEVLC on October 26, 2015, Keio University, Japan.
Photo from Nikkei Technology Online, October 29, 2015

⑥ Image Sensor Communication using Smartphone camera and color coding

Fujitsu Laboratories Ltd. has developed technology to embed ID information in light, which is cast on the identified object, and recover the ID in the reflection cast back from it using image processing technology. The technology uses color coding and a smartphone camera receives the color code and decodes it. Even though the data rate is slow (about 10 bits per second) due to the limitation of a frame rate of a smartphone, human does not notice the flickering of light from an LED.



Drawing from Fujitsu at ICEVLC on October 26, 2015, Keio University, Japan

Fujitsu Laboratories Ltd.'s technology using color code

Reference: Kuraki, Kato, Tanaka, "Technology for LED Lighting with Embedded Information on Objects", Fujitsu Scientific & Technical Journal, Vol. 66, No. 5, pp. 88-93, September 2015

⑥ Image Sensor Communication using Smartphone camera and color coding (continued)

Fujitsu Laboratories Ltd.'s technology is especially useful for projection mapping technology, because modulation of the intensity of individual pixel of a display can be recognized by an image sensor.

Photo from Nikkei Technology Online, October 29, 2015

Demonstration of the prototype

⑦ Image Sensor Communication using Smartphone camera and digital signage (continued)

Panasonic Corporation announced a new image sensor communication using rolling shutter data reception technology. The technology is able to receive kilo bits of data per second using a conventional smartphone camera with rolling shutter mechanism.

Photo from Nikkei Technology Online, October 29, 2015

Prototype demonstration at ICEVLC in October, 2015

Reference:
Hideki Aoyama, Mitsuaki Oshima, "Line Scan Sampling for Visible Light Communication: Theory and Practice", IEEE International Conference on Communications 2015 (ICC 2015), 6682-6687, London, UK, 9 Jun. 2015
Hideki Aoyama, Mitsuaki Oshima, "Visible Light Communication Using a Conventional Image Sensor", 12th Annual IEEE Consumer Communications and Networking Conference (CCNC 2015), 109-114, Las Vegas, USA, 10 Jan. 2015

⑦ Image Sensor Communication using Smartphone camera and digital signage

The service using this technology will be offered by Panasonic at Tokyo Big Sight. The service will be offered in April 2016.

Drawing from Panasonic, 2015

Digital signage planned at Tokyo Big Sight that transmits data to smartphones.

Contents

Market Opportunities

There are following market opportunities of VLC, where customers may want its unique capabilities which are not available now:

- Last Mile Connectivity
- Alternative Solution To Overburdened Rf Technology For Outdoor and Indoor Networking
- Wireless communication in noisy electromacnetic environment
- indoor positioning and monitoring
- Indoor navigation
- Advertisement
- Underwater communication

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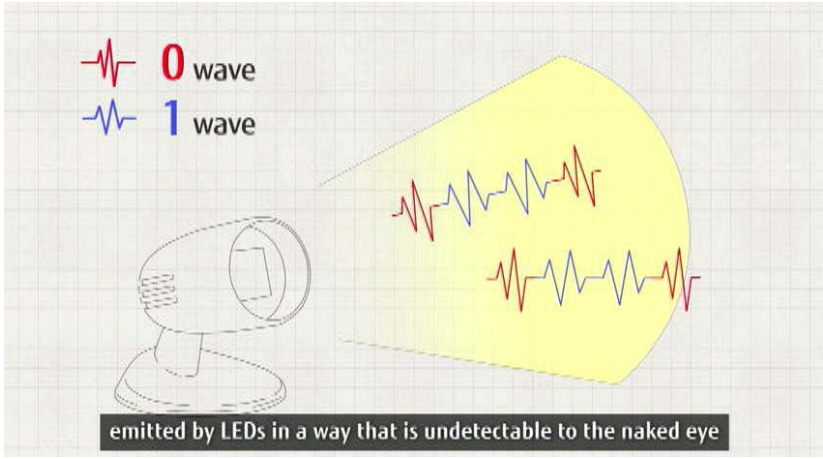
Panasonic

Panasonic's visible light communication technology uses a smartphone to receive visible light ID from digital signage or LED. This technology is useful in crowded area where it can be difficult to access IDs

Fujitsu



Fujitsu Laboratories developed a technology that modulates the color of light emitted by LED lights in such a way as to be undetectable to the human eye.

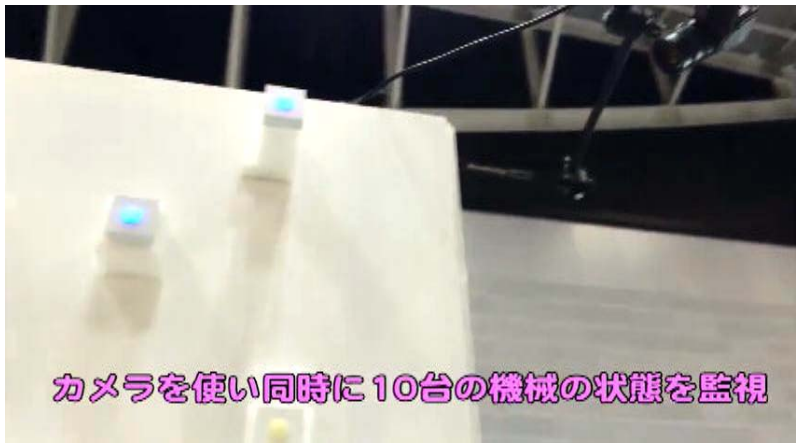
Phillips Lighting

Philips Lighting is using indoor-positioning technology for Carrefour grocery stores using visible light communications. The positioning accuracy is 30 centimeters. The technology can also detect the orientation of a smartphone.

Acuity/Bytelight

Acuity's Indoor Positioning using Bytelight VLC technology

CASIO



CASIO's visible light communication technology enables the monitoring of sensors in plant facilities using a security camera.

Sangikyo

Sangikyo an LED backhaul system that has a data rate of 600 Mbps at a distance of 50 meters, and 250 Mbps at a distance of 200 meters. It uses Fraunhofer (Germany) 's technology.

Outstanding Technology Corp.

Outstanding Technology Corp. has a visible light LAN system that is able to transmit data at a data rate of 20Mbps. This system is useful in the environment where there is a lot of electromagnetic noise such as factories, data centers, and power plants, etc.

Contents

Visible light communication standard proposals

- IEEE802.15.7r1 Optical Camera Communication
- IEC TC-100 Visible Light Beacon System for Multimedia Applications

- IEEE802.15.7r1 Optical Camera Communication

IEEE 802.15 has formed a Study Group in 2014 to draft a Project Authorization Request (PAR) for an amendment to IEEE 802.15.7-2011 implementing Optical Camera Communications (OCC) enabling scalable data rate, positioning/localization, and message broadcasting, etc. using things like the flash, display and image sensor as the transmitting and receiving devices.

Slide of Bob Heile, Chair, IEEE 802.15

- IEC TC-100 Visible Light Beacon System for Multimedia Applications

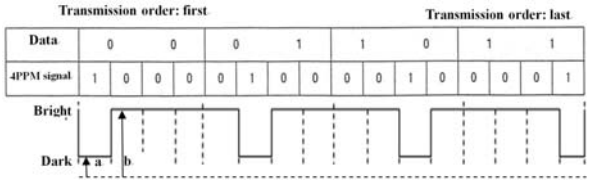
In June 2014, the new proposal was approved in order to start its discussion as IEC PT 62943, and experts from several countries are now discussing about its technical details.

Many of JEITA CP-1223 features were included in the IEC PT 62943.

IEC PT 62943
Visible Light Beacon System for Multimedia Applications

Physical layer

Optical wavelength:
380~780 nm.
Data rate:
4.8 kb/s with its tolerance of data rate shall be no more than 0.5%
Transmission system:
Inverted 4 Pulse Position Modulation (I-4PPM)



IEC PT 62943

Visible Light Beacon System for Multimedia Applications

There are some prototypes based on the proposed method:

Prototype 1: February 2012

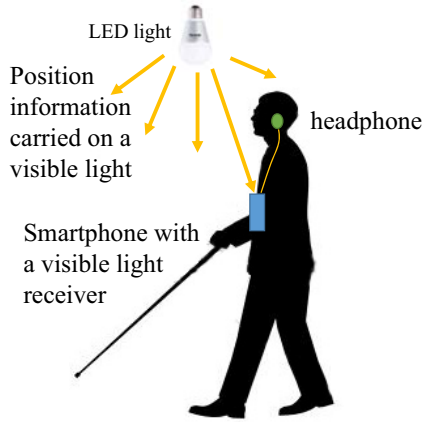
Visible Light Beacon System for indoor navigation for the visually impaired

Prototype 2: April 2013

Visible Light Beacon System for smartphone users indoor

Prototype 1: February 2012

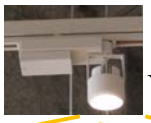
Visible Light Beacon System for indoor navigation for the visually impaired



Visible Light Beacon System detects the position of the visually impaired and sends audio sound of navigation information to him/her.

Prototype 2: April 2013

Visible Light Beacon System for smartphone users indoor



Visible light transmitter

Navigation for users

Management of customer flows

Location-dependent game

Visible Light Beacon System sends ID and a smartphone provides multimedia information to a user.

Conclusion

Thanks to the widespread use of LEDs, There are many market opportunities of VLC.

Especially, image sensor communication may be widely used in the near future for such applications as indoor positioning, advertisement, augmented reality.