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Abstract: [Visible Light Communication using Arrayed PD / Image Sensor]

Purpose: [Contribution to IEEE 802.15 TG7]

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Visible Light Communication using Image Sensor

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Consideration to ambient light noise

- In the place where people live, there exists a lot of artificial and/or nature strong ambient light.

The correspondence to these light noise determines the area width of the applicable field of VLC.

a) Indoor fluorescent lamp

- Strong light noise is caused by a fluorescent lamp around the level of 100/120Hz and 30kHz-500kHz.
- When this frequency band is avoided, the band of 1kHz-30kHz or more than 1MHz will be used with the sub carrier modulation.
- It is not particularly easy for the white LED to modulate at high speed in bands of more than 1MHz, and the frequency division for the sub carrier in each source of light is more difficult.
- We must research the methods to assign appropriate sub carrier frequency to each source of light in various ways.

b) Outdoor sunlight

- We may consider the sunlight noise to be a constant light (DC). Single Photo Diode cannot receive the light signal when it is saturated by the sunlight .
- This can be happened by the surrounding background light even if the sun doesn't enter into FOV (Field Of View) of Single PD directly.

- It might be possible to avoid these above problems by limiting the use case in the case of Single PD.
- It is possible to solve the problems by using image sensor as a receiver device.

Image Sensor : Spatial Separation Capability

Using PD

Noise Power = 1

Data signal Power = 1

20 degree Device FOV

PD

Signal : Noise = 1:1
Everything is accumulated.

SNR deteriorates because the noise ratio increases when Device FOV is getting larger.

Ex) Same device FOV 20 degree

- Robustness to Ambient Light noise.
- No interference even when the Multi Point light sources are received.

Using IS

Noise Power = 1

Data signal Power = 1

20 degree Device FOV

Image sensor

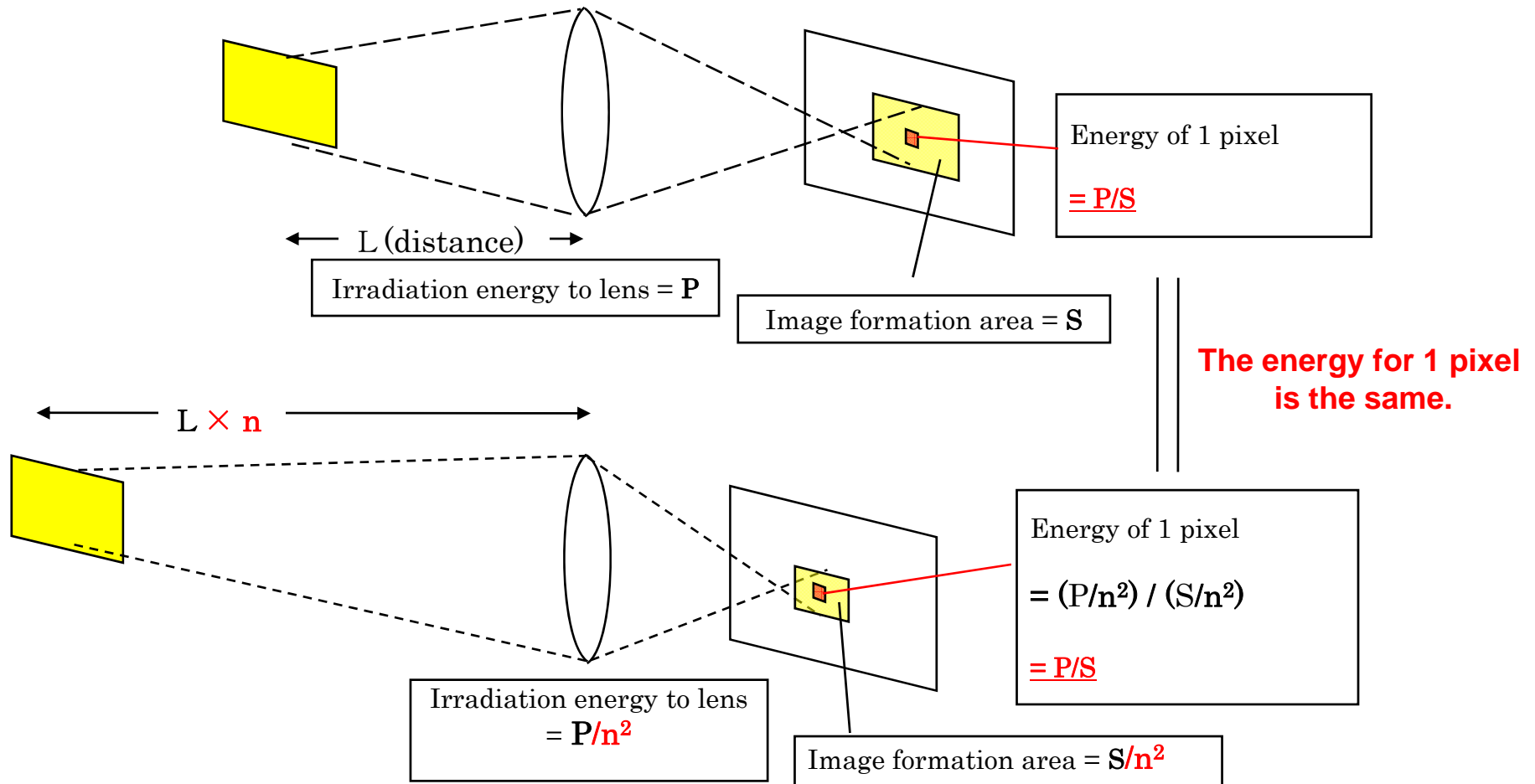
Selected element of array (Pixel in image sensor)

Signal : Noise = 1:0
The noise is excluded by the spatial separation.
Device FOV doesn't affects SNR directly.
(Not Device FOV but Element FOV of array decides SNR.)

*1 An appropriate array element can be properly selected.
*2 Array and optical system have a sufficient resolution capability.

Brightness – Distance Invariable Characteristics

- "Brightness doesn't depend on the distance" is a fundamental law in optics.



“PDC” and “ISC” – Two methods of VLC

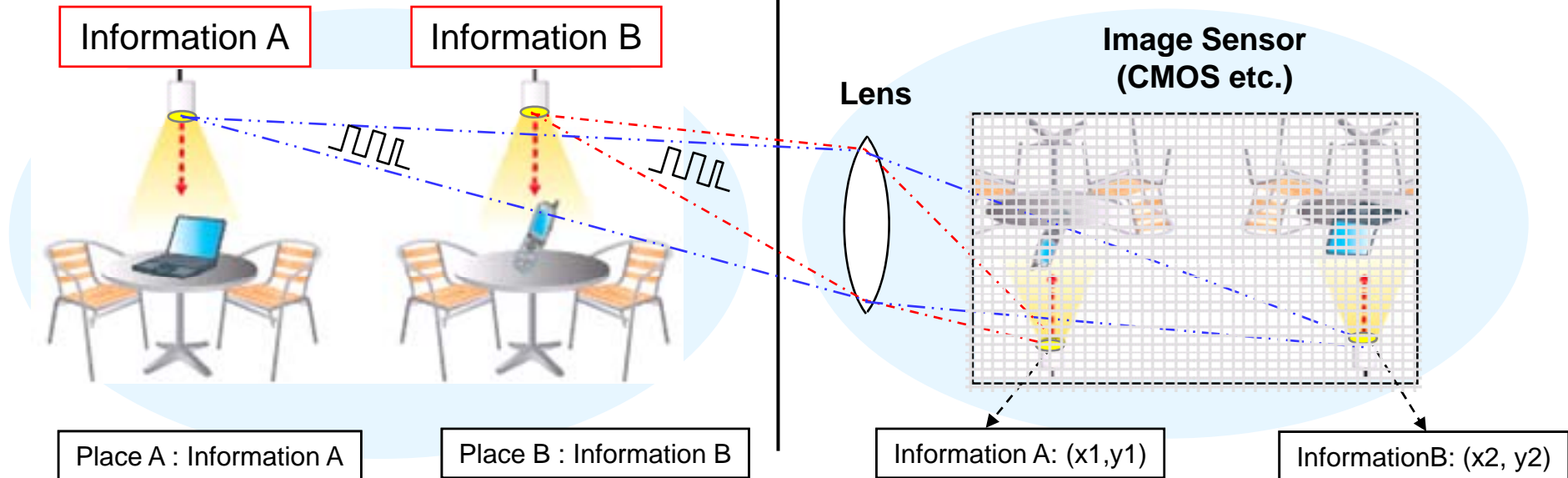


Single PD Communication

Image Sensor Communication (ISC)

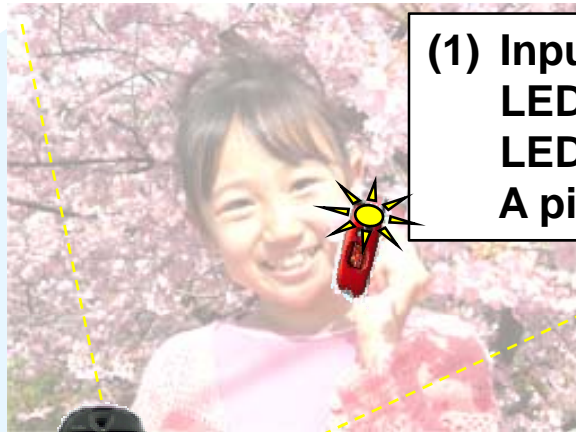


Sending and Receiving	Pt-Pt, Pt-mPt	mPt-Pt
Robustness	Poor	Strong (Spatial Separation Capability)
Communication Distance	~ 10 m	~ 100 m (distance – brightness invariable characteristics)
Positional grasp	Yes	Yes
Data Rate	~ tens of Mbps	~ tens of kbps

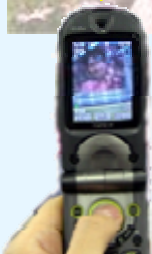


Balloon Photo (Expand to enjoy the photograph)

- Flash LED with a data, the mobile phone takes a picture with the data.
- Provide a new way to enjoy the photograph by using ISC.



(1) Input a message into LED and turn on its LED , then pose. A picture will be taken!



**(2)Take a photo!
What did you input?**

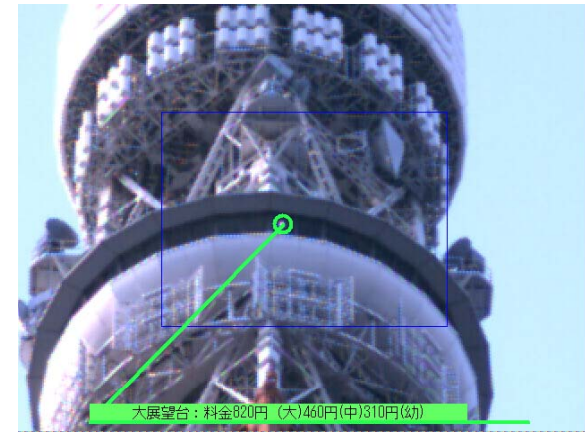


ISC in vehicle

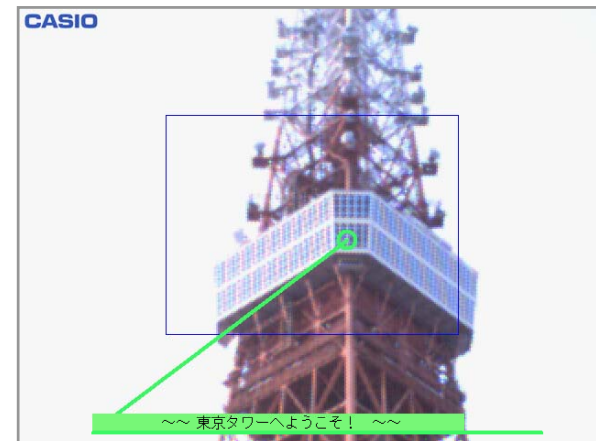
ISC camera can be used for “vehicle to vehicle communication” and “traffic signal to vehicle” .

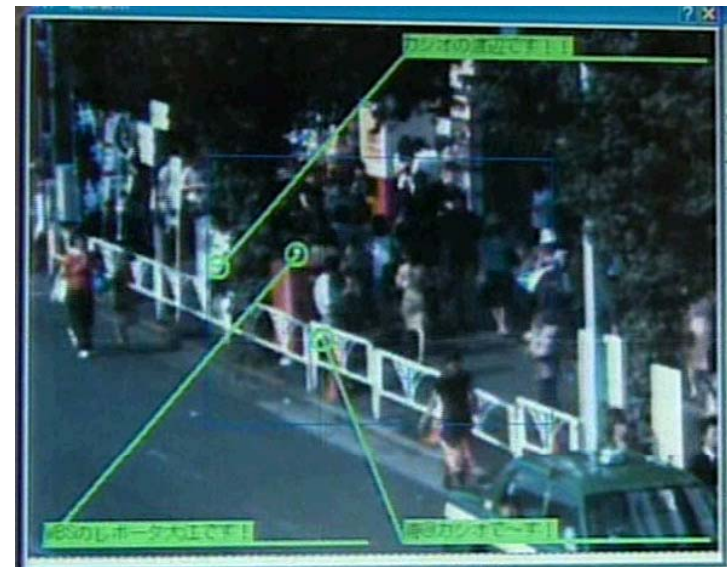
The following pictures show that a running car receives the information data from the traffic signal.
(2006 VLCC/Nippon signal/ CASIO From the NHK TV coverage)





From TV program (2006)





From TV program (2006)

Conclusion

- It is important to include Image Sensor (Arrayed PD) in the standardization discussion of VLC in the following points.
 - Because it is a quite new technological concept, it improves Distinct Identity of VLC.
 - Image Sensor can get Broad Market Potential with a technical feasibility.
 - This is not an implement issue, but the basic technology issue.

- There are two types of the receiver device; Single PD and Image Sensor as follows;
 - Single PD: A Single PD can be used in the limited use case by using accumulated technology and know-how.
 - Image Sensor: A low-speed application can be examined at first, and then it may lead to the best use case in a new field.