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Abstract: [A consideration of light source of VLC is described in this document. Especially mobile to mobile (infra-less) application is mentioned. Some regulation for the LED and LD and issues of the application are also presented.]

Purpose: [Contribution to IEEE 802.15 SG-VLC]

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Light Source Consideration for VLC

2008. 09

Samsung Electronics

Contents

- ❖ VLC Applications & Infrastructure
- ❖ Infraless VLC Applications
- ❖ Considerations of Infraless VLC
- ❖ Light Source for VLC
- ❖ LED vs. Laser Diode
- ❖ Visible RCLED
- ❖ Visible VCSEL
- ❖ Visible LD
- ❖ High-Speed Visible Source
- ❖ RED LD Modulation Test
- ❖ High-Speed VLC
- ❖ LD as a light source for VLC
- ❖ Safety Regulation
- ❖ Consideration about LD Safety
- ❖ How to make LD eye-safe
- ❖ Summary

VLC Applications & Infrastructure

- ❖ **An indispensable element of the VLC / VLC applications: LED infrastructure**
 - Mobile to Infra. applications

Infraless VLC Applications



* Mobile to Mobile

* Mobile to Fixed

- ❖ Visible remote control
- ❖ Large display, Electric photo frame
- ❖ Cradle
- ❖ Kiosk, Optical hot-spot
- ❖ Secure point-to-point data communication
- ❖ Vehicle to vehicle

Considerations of Infraless VLC

❖ Independent from illumination

- Light source: LED (White LED, RCLED), Laser Diode, etc

- Rx / TX

 - ◆ RX : depends on TX component (PD, Image sensor, etc)

- Power saving/control for mobile device

- Mobility

- Compete with other technique

Light Source for VLC

- ❖ **LED (Light Emitting Diode)**
- ❖ **RC (Resonant Cavity) LED**
- ❖ **OLED (Organic light-emitting diodes)**
- ❖ **Laser Diode**
(Light Amplification by Stimulated Emission of Radiation)
- ❖ **VCSEL (vertical-cavity surface-emitting laser)**
 - a type of semiconductor laser diode with laser beam emission perpendicular from the top surface

LED vs. Laser Diode

	LED	Laser Diode
Light	Spontaneous emission	Stimulated emission
Output power	Low	High
Directional	Worse directed beam / No direction	Better directed beam / direction exist
Spectrum Width	Broad spectra ~ 40 nm	Narrow spectra < 0.01 nm
Response time	Slow	Fast
	Incoherent	Coherent
Price	Low	High
Driving Circuit / Easy to handle	Relatively Simple / Easy	Complicated / Not easy

Visible RCLED

Type	Wavelength	Year	Status
Blue RCLED	460 nm	2000	Research
Green RCLED	507 nm 525 nm	2008 2006	Research
Green SQW-LED	495 nm	2005	250 Mb/s Prototype
Red RCLED	660 nm	1998	250 Mb/s Product

Visible VCSEL

Type	Wavelength	Year	Status
Blue VCSEL	448 nm	2005	Research
Blue VCSEL	462 nm	2008	Research
Green VCSEL	502 nm	2004	Research
Red VCSEL	660 nm		> 3GHz automotive, laser mouse, laser printer, position sensor...

Visible LD

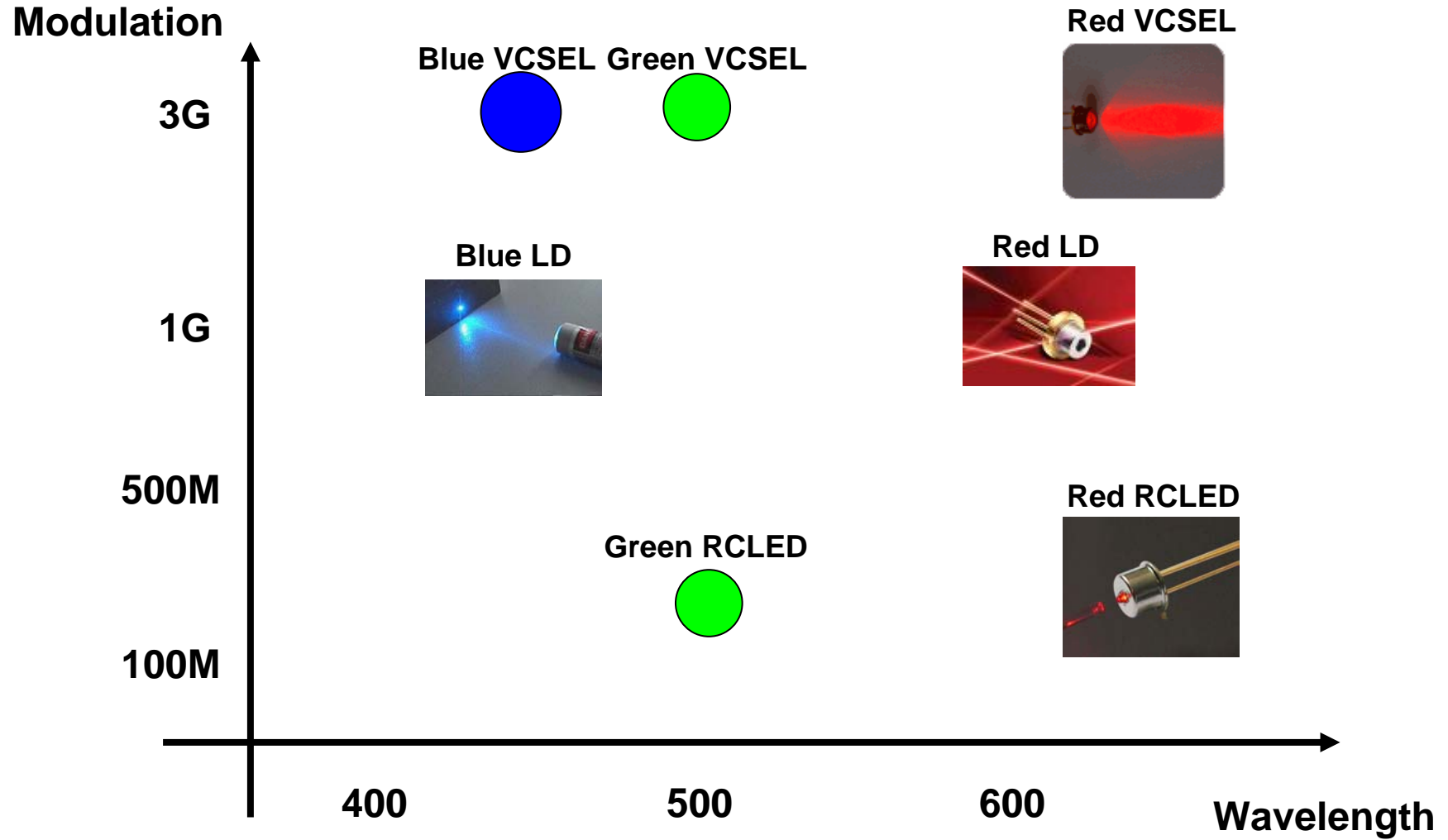
- ❖ **Nichia : Blue LD on sale.
> 1GHz**

- ❖ **eGismos :
: Red, Blue LD on sale
> 1GHz**

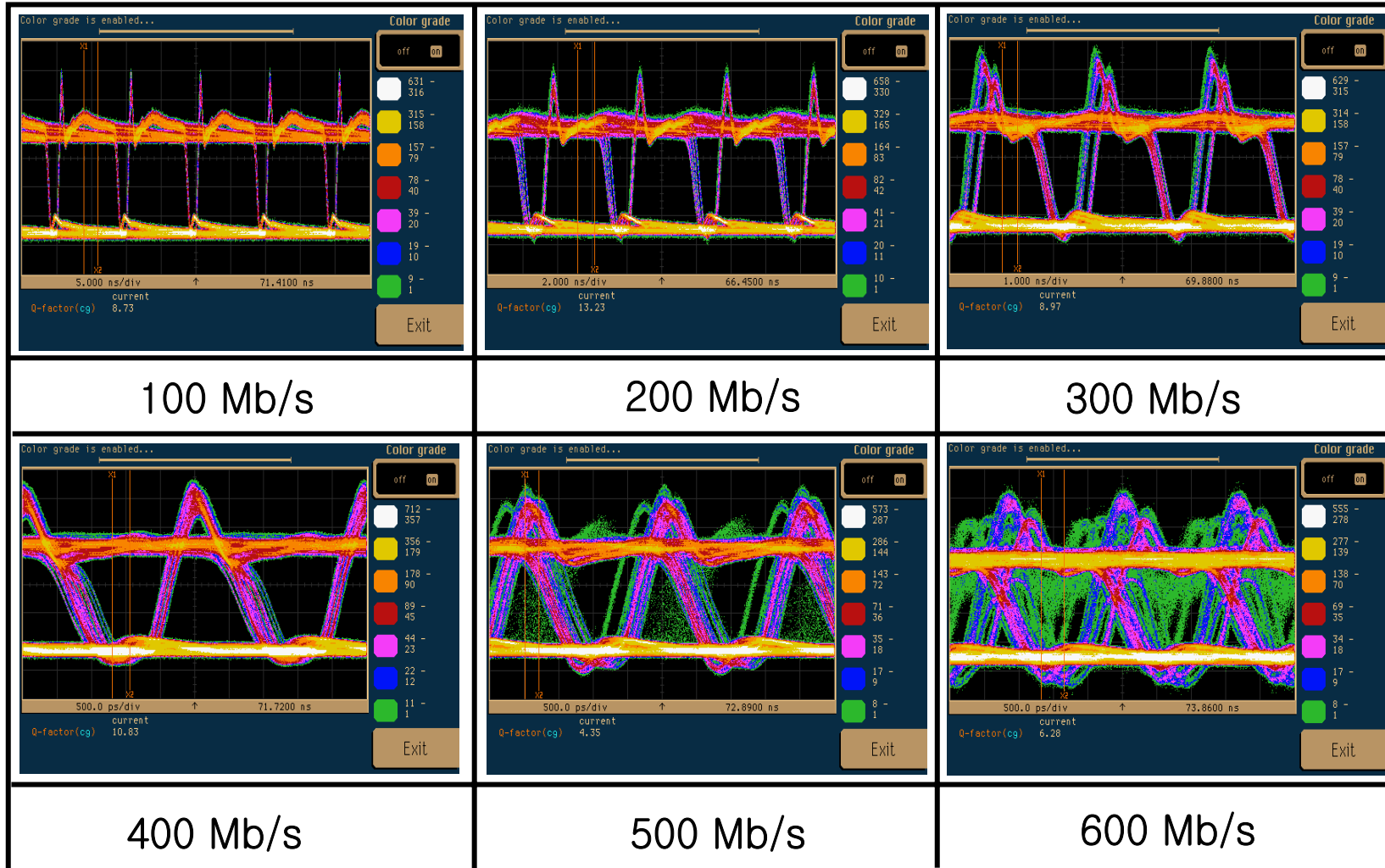
- ❖ **Hitachi :**

- ❖ **Sanyo :**

High-Speed Visible Source



RED LD Modulation Test



High-Speed VLC

❖ Some method for high-speed VLC

- 15-08-0265-03: Dr. O'Brien (July 2008)
 - ◆ Equalization
 - ◆ Complex modulation
 - ◆ MIMO

- 15-08-0430-1: Dr. Kwon (July 2008)
 - ◆ Different approach is required for illumination function.
 - ◆ Brightness control: Modulation Depth Control or DC control
 - High speed data transmission possible. (additional PWM signal may not be required.)

■ ?

LD as a light source for VLC

❖ Advantage

- High speed modulation
- Beam shaping
- Directional

❖ Drawback

- Safety
- Cost
- Align (divergence)

*** Lasers: light is directional, monochromatic and coherent in phase.**

* Source: <http://www.math.ubc.ca/~cass/courses/m309-04a/laser.pdf>

Safety Regulation (1/4)

- ❖ **Existing LD/LED safety standards**
 - **IEC 60825: Safety of Laser Products**
 - **IEC 62471: Photo biological safety of lamps & lamp systems**
 - **CIE: Standard S 009/E:2002 :Photo biological Safety of Lamp & Lamp systems**
 - **ANSI Z136.1: American National Standard for Safe Use of Lasers**
 - **ANSI/IESNA: RP-27.1-96: Recommended Practice for Photo biological Safety for Lamp & Lamp Systems**

Safety Regulation (2/4)

❖ Existing LD/LED safety standards

■ Title 21 CFR CH 1, Part 1040 :

- ◆ Title 21 is the portion of the Code of Federal Regulations that governs food and drugs within the United States for the Food and Drug Administration (FDA), the Drug Enforcement Administration (DEA), and the Office of National Drug Control Policy (ONDCP).
 - Chapter I — Food and Drug Administration
 - Chapter II — Drug Enforcement Administration
 - Chapter III — Office of National Drug Control Policy

- ◆ **The 1000 series covers radiation emitting device (e.g. lasers, cell phones) requirements enforced by CDRH.**
 - The Center for Devices and Radiological Health (CDRH) is the branch of the United States Food and Drug Administration responsible for the premarket approval of all medical devices, as well as overseeing the manufacturing, performance and safety of these devices. The CDRH also oversees the radiation safety performance of non-medical devices which emit certain types of electromagnetic radiation, such as cellular phones and microwave ovens.

Safety Regulation (3/4)

❖ Solid state lighting standards in US

■ Safety, Installation, and Other Requirements

* UL Standards (Underwriters Laboratories)

8750	Outline of Investigation for Light-Emitting Diode (LED) Light Sources for Use in Lighting Products • Will specify the minimum safety requirements for SSL components, including LEDs and LED arrays, power supplies, and control circuitry.
1598	Luminaires • Specifies the minimum safety requirements for luminaires. The requirements in this document may be referenced in other documents such as UL 8750 or separately used as part of the requirements for SSL products.
1012	Power Units Other Than Class 2 • Specifies the minimum safety requirements for power supplies other than Class 2 (as defined in NFPA 70-2005).
1310	Class 2 Power Units • Specifies the minimum safety requirements for Class 2 power supplies (as defined in NFPA 70-2005).
1574	Track Lighting Systems • Specifies the minimum safety requirements for track lighting systems.
2108	Low Voltage Lighting Systems • Species the minimum safety requirements for low-voltage lighting systems.
60950-1	Information Technology Equipment – Safety – Part 1: General Requirements • Species the minimum safety requirements for electronic hardware.

Safety Regulation (4/4)

❖ Solid state lighting standards in US

■ Safety, Installation, and Other Requirements

NFPA Requirements (National fire Protection Association)

70-2005	National Electrical Code <ul style="list-style-type: none">• Most SSL products must be installed in accordance with the National Electrical Code.
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FCC Requirements (Federal Communications Commission)

47 CFR Part 15	Radio Frequency Devices <ul style="list-style-type: none">• Specifies FCC requirements for maximum allowable unintended radio-frequency emissions from electronic components, including SSL power supplies and electronic drivers.
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Source:

U.S. Department of Energy

Energy Efficiency and Renewable Energy (Solid-State Lighting)

<http://www.eere.energy.gov/>

Consideration about LD Safety

❖ Not the only Power

- Power
- Transmitter beam size
- Divergence
- Wavelength
- Pulse duration
- Installation location

* AEL (Accessible Emission Limit): The maximum accessible emission permitted within a particular class

* MPE (Maximum Permissible Exposure): Level of laser radiation to which, under normal circumstances, persons may be exposed without suffering adverse effects

* Source: IEC 60825-1

How to make LD eye-safe

- ❖ Low power ?
- ❖ Control divergence of light (spread out) ?
- ❖ Remove the coherent property (diffuser) ?
- ◆ **“Eye-Safe Laser Diodes for Ultra Fast IrDA (UFIR)”**, KAWANISHI HIDENORI, SHIMONAKA ATSUSHI, HIRAMATSU TAKUMA, MORIMOTO NAOYUKI,
 - Quote: “Eye-safe laser diodes have been developed by introducing an optical diffusion part in the light path of the output beam of laser diodes”
- ◆ **“Eye safe laser transmitter”** US patent 453806, Raymond V. Wick
 - Quote: “The diffuser outputs a diverging beam of substantially incoherent radiation to a collimator that provides a collimated output beam that can be used in laser communications, laser rangefinders and other laser field devices in an “eyesafe” mode.
- ◆ **Diffuser (*)**
 - Any device that diffuses or spreads out or scatters light in some manner
 - Optical diffusers use different methods to diffuse light and can include ground glass (glass whose surface has been ground to produce a flat but rough (matte) finish) diffusers, teflon diffusers, holographic diffusers, opal glass diffusers, and greyed glass diffusers.

Source: <http://www.wikipedia.org>

■ Laser projection display.

What is LPD?



LPD is a projection display technology that uses 3 lasers coupled with scanning mirrors to produce full color, high resolution images

LPD Product Concepts



PDA's

- PowerPoint
- Spreadsheets
- Full motion video



Cell Phones

- Streaming video
- High res photos
- Live sports



Video iPods

- Full length movies
- Live TV
- Home videos

Source: http://www.sid.org/chapters/ne/sid_ne_jan2007_wittenberg.pdf

Summary

- ❖ **VLC Applications and Infrastructure**
 - Infraless VLC applications
 - Consideration

- ❖ **Various Light Source for VLC**
 - LD, LED, RCLED

- ❖ **LD as a light source for VLC**

- ❖ **Safety Regulation**

- ❖ **Consideration about LD Safety**
 - Power / Transmitter beam size / Divergence ...

Thank you