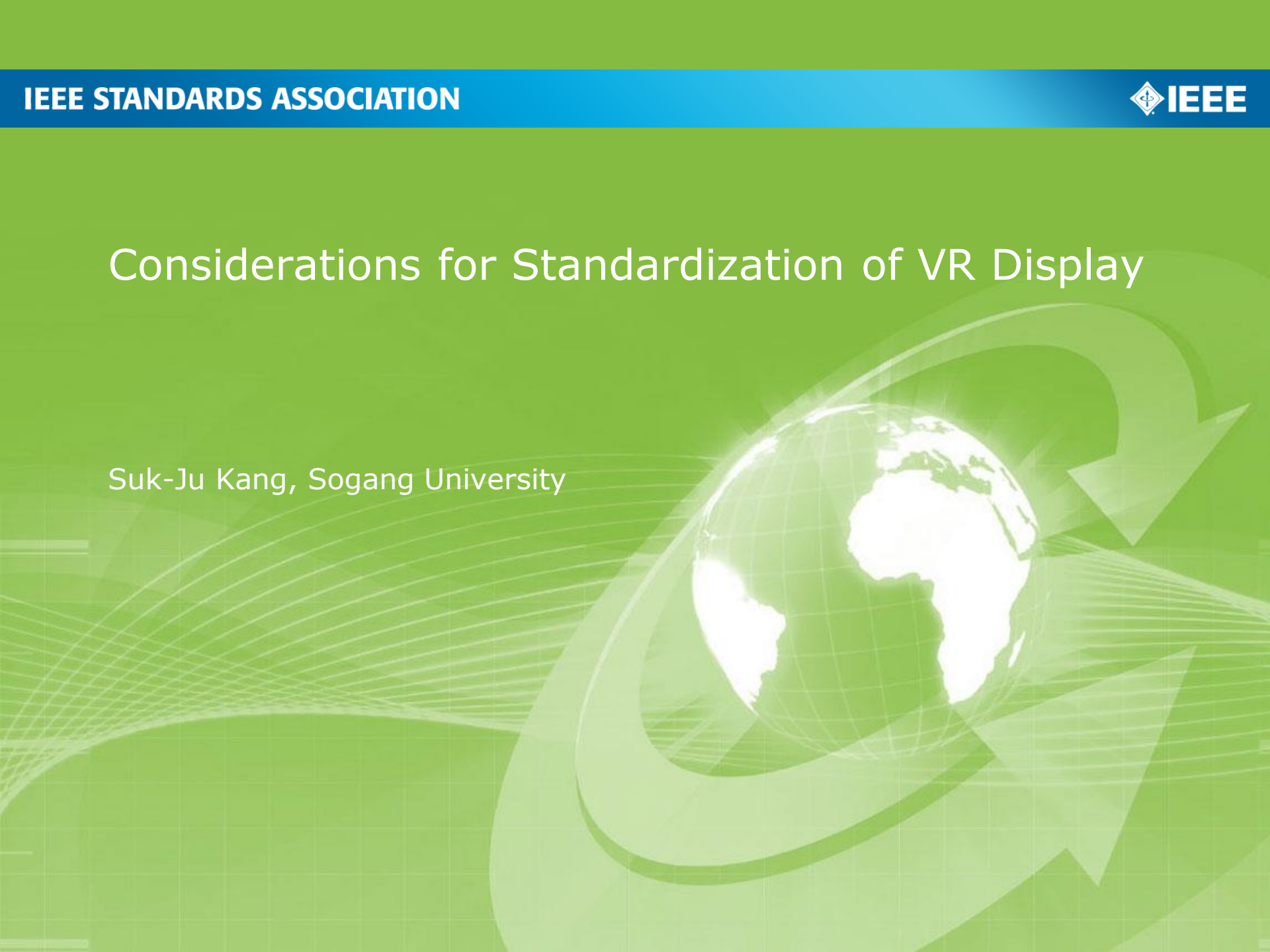


# Considerations for Standardization of VR Display

Suk-Ju Kang, Sogang University



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**IEEE P3333.3**  
**HMD Based 3D Content Motion Sickness Reducing Technology**  
**[Dong Il Seo and dillon@volercreative.com]**

**Considerations for Standardization of VR Display**

**Date:** 2017-07-10

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# Outline

- ✓ Introduction
- ✓ Considerations in VR Displays
  - Part I: Display Resolution
  - Part II: Chromatic Aberration and Correction
  - Part III: Display Technology Trend in VR
- ✓ Conclusion

# Introduction

- ✓ Challenge of Virtual Reality
  - Users feel gaps on their sense between the reality and virtual reality because of a motion-to-photon latency
  - This causes dizziness and motion sickness to user
- ✓ Motion-to-photon latency must be measured and compensated!

## Problems from latency of HMD



Blurring

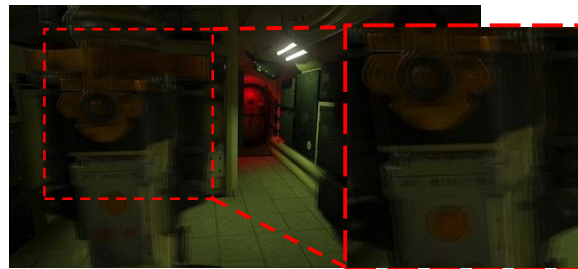
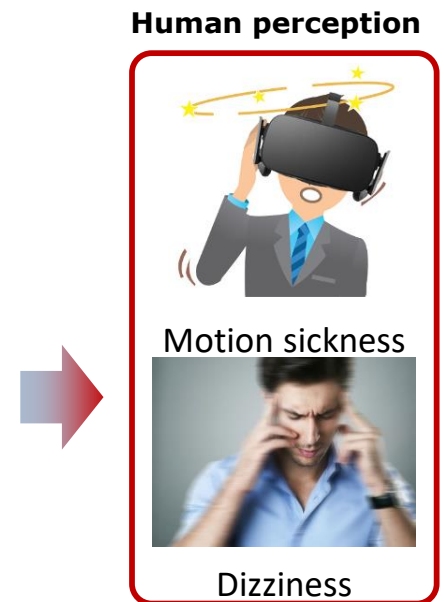
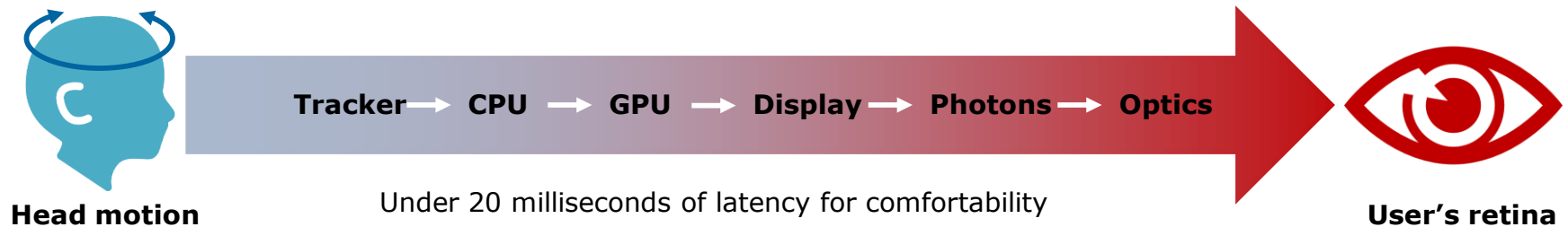


Image judder



# Introduction

- ✓ Motion-to-Photon Latency
  - Motion-to-Photon latency is the time needed for a user movement to be fully reflected on a display screen
  - Low motion-to-photon ( $< 20$  ms) latency is a prerequisite to convince user's mind that user is in another place
  - A high motion-to-photon latency makes a poor virtual reality experience



# Introduction

- ✓ We have to consider several factors in VR displays
  - Display Resolution
  - Chromatic Aberration and Correction



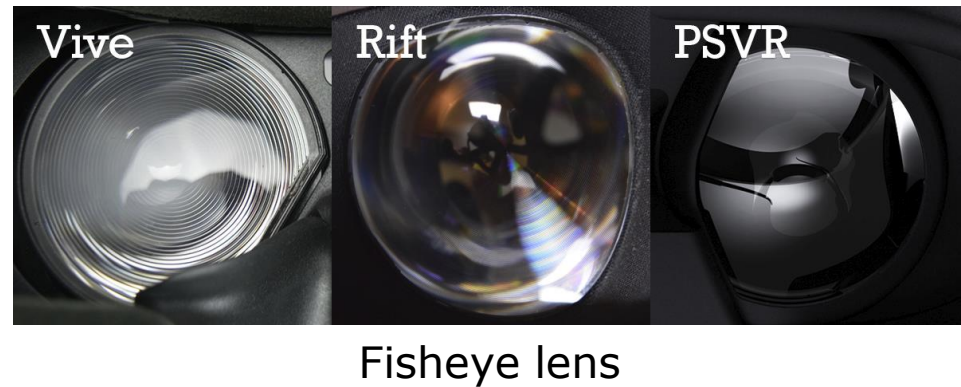
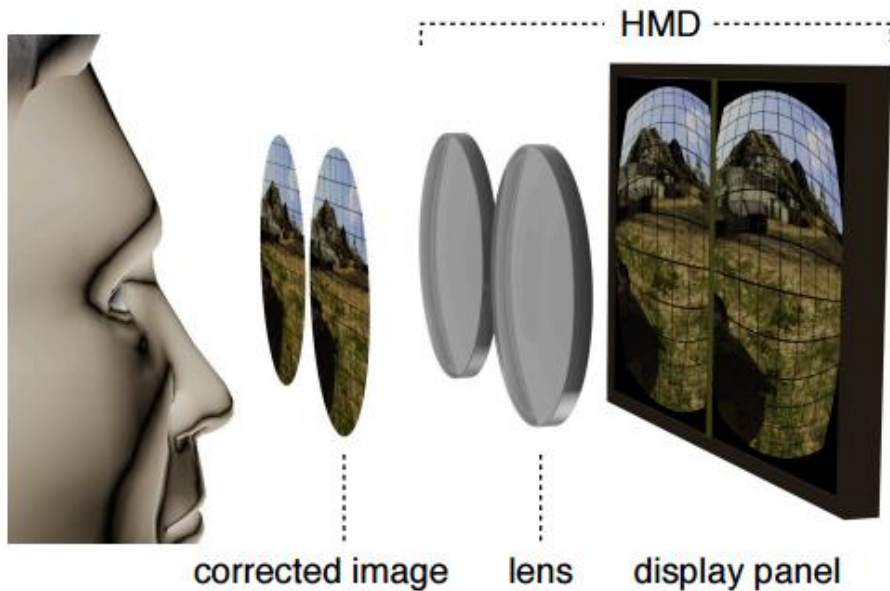
# CONSIDERATIONS IN VR DISPLAYS

## PART I: DISPLAY RESOLUTION



# Display Resolution

- ✓ Chromatic Aberration
  - General HW structure in HMDs
    - Display panel
    - Fisheye lens
    - Perceptual image



# Display Resolution

- ✓ Pixels per inch (PPI)
  - Measurement of the pixel density (resolution) of an electronic image device such as a monitor or television display
  - A  $100 \times 100$  pixel image printed in a 1 inch square has a resolution of 100 pixels per inch

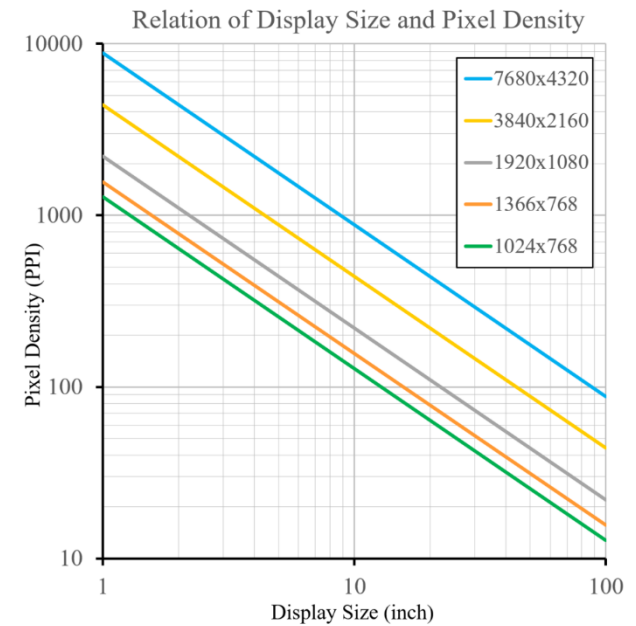
$$d_p = \sqrt{w_p^2 + h_p^2} \quad \rightarrow \quad PPI = \frac{d_p}{d_i}$$

$d_p$  is diagonal resolution in pixels

$w_p$  is width resolution in pixels

$h_p$  is height resolution in pixels

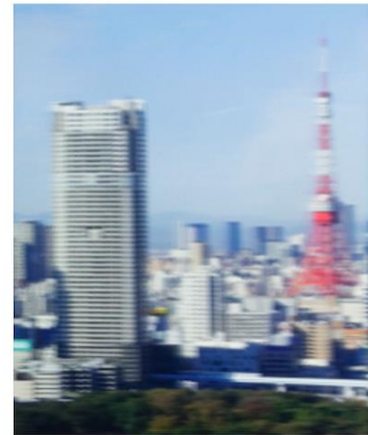
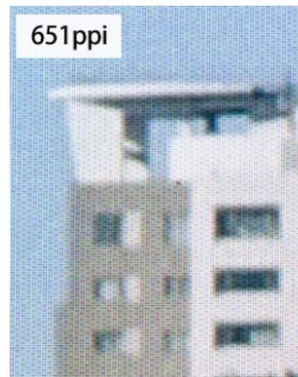
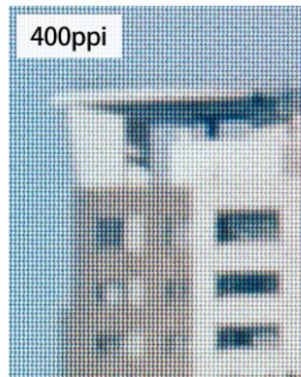
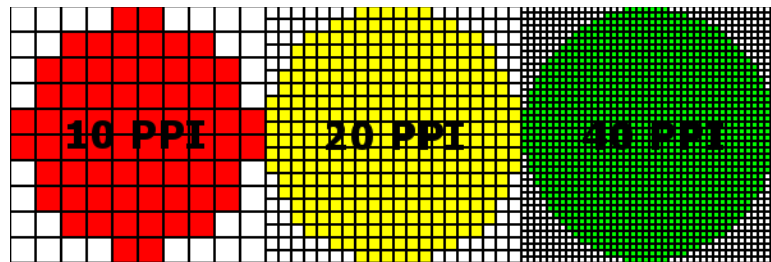
$d_i$  is diagonal size in inches (this is the number advertised as the size of the display).



# Display Resolution

✓ JDI

- New displays will be 3.42-inch low temperature polysilicon (LTPS) TFT LCD specifically designed for virtual reality (VR) head mount displays



(a) Smartphone display



(b) VR display

# Display Resolution

LCD/LED TV



LG OLED TV

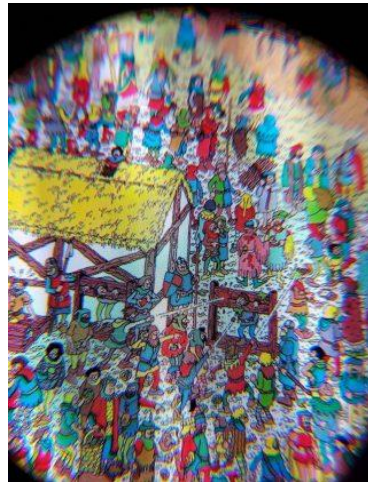


\*Response time (GTG: Gray to Gray) : LCD/LED TV 5ms  
OLED TV 0.005ms

# Display Resolution

- ✓ Samsung
  - A new display targeting use in VR headsets packs 2,024 x 2,200 pixels into a 3.5" form-factor, delivering an impressive 858 PPI (Nearly twice the 460 PPI of the Rift and the Vive)
  - The display is also capable of a 90Hz refresh rate and 100 nits brightness

Previous VR display



New VR display



## CONSIDERATIONS IN VR DISPLAYS

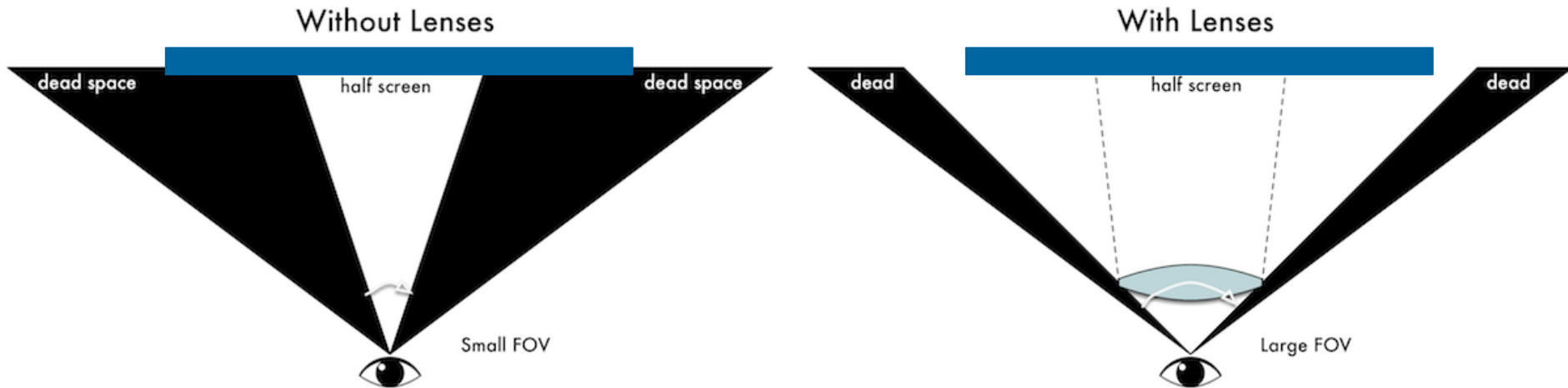
# PART II: CHROMATIC ABERRATION AND CORRECTION

# Chromatic Aberration and Correction

## ✓ Chromatic Aberration

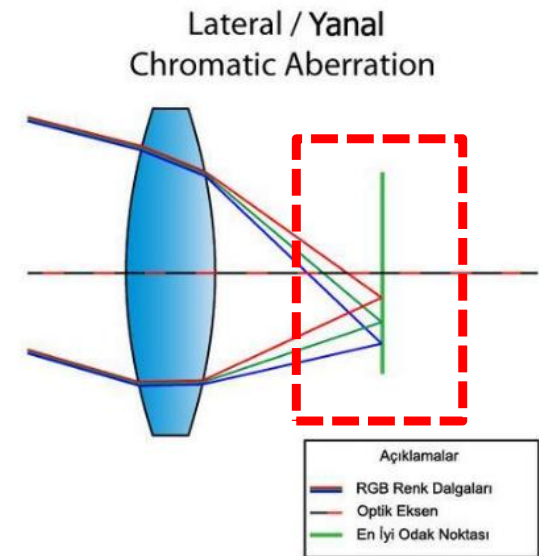
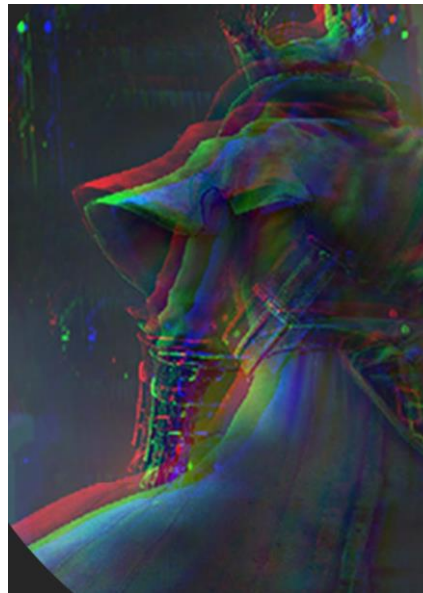
### – Fisheye lens

- The Fisheye lens gives users a wide viewing angle
- Normal HMDs provide a FOV(Field Of View) of over 110°
- Lens has a large refractive index



# Chromatic Aberration and Correction

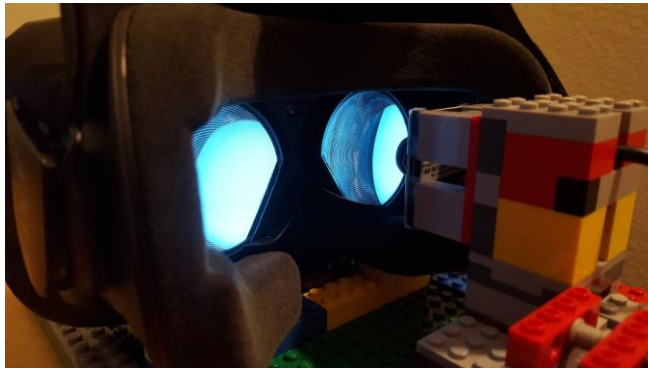
- ✓ Chromatic Aberration
  - Reason for chromatic aberration
    - The separation of light is called chromatic aberration because of different refractive indexes depending on the wavelength of light





# Chromatic Aberration and Correction

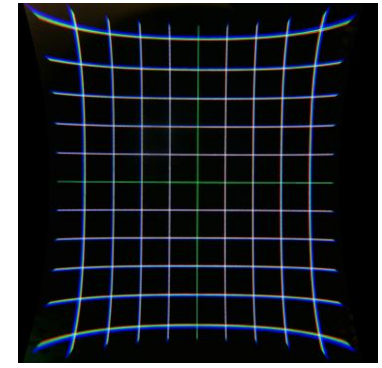
- ✓ Correction
  - Fisheye lens modeling
    - Modeling is required for the precise pre-distortion
  - Measurement method
    - (a): Measuring HMD images with wide angle lens camera
    - (b): Camera calibration with the chess board
    - (c): Photographed VR images



(a)



(b)



(c)

# Chromatic Aberration and Correction

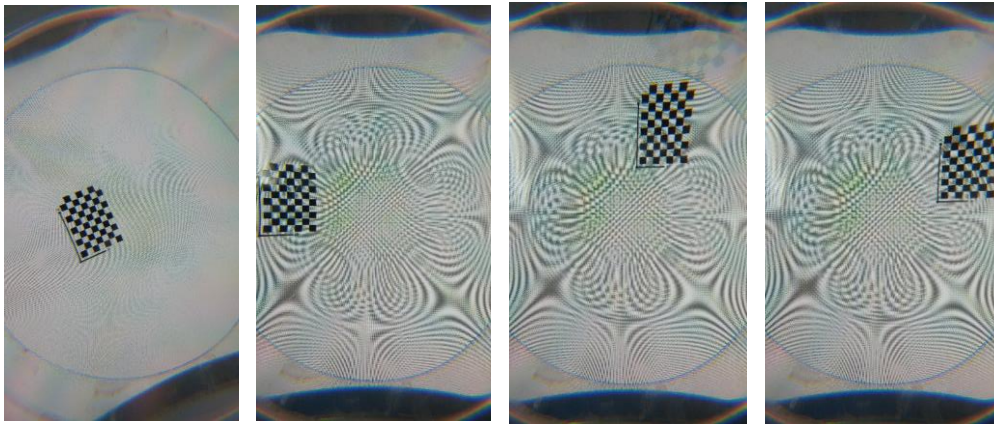
## ✓ Correction

### – Measurement method

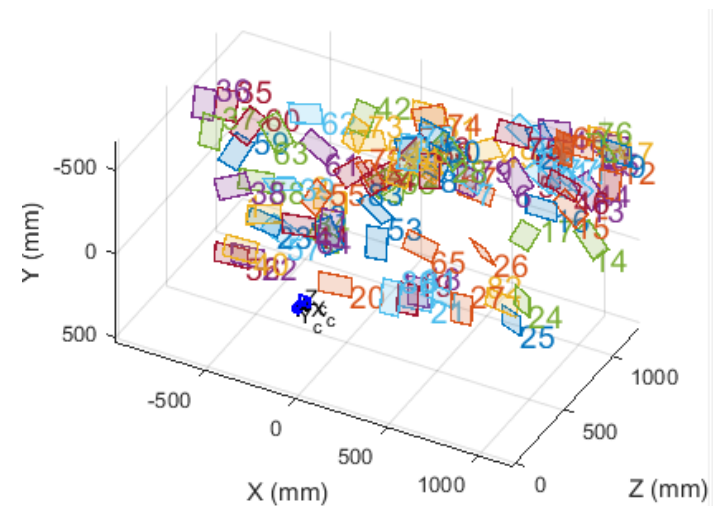
- Parameter extraction through camera calibration

(a): Photos taken by using the chess board in virtual space

(b): Optimal parameter extraction using multiple photographs



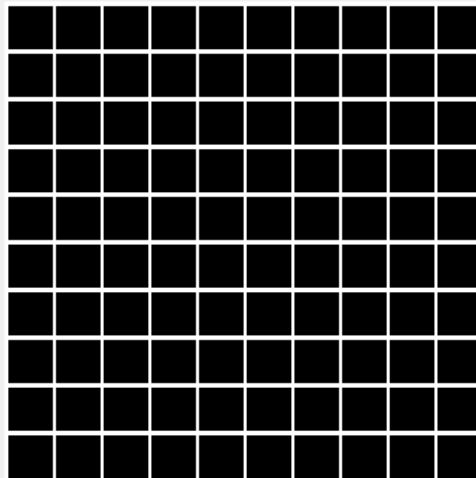
(a)



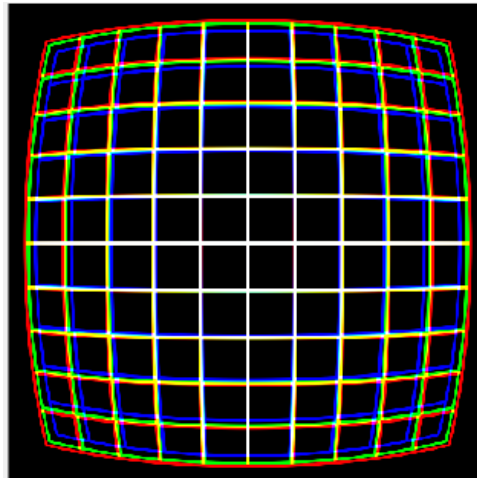
(b)

# Chromatic Aberration and Correction

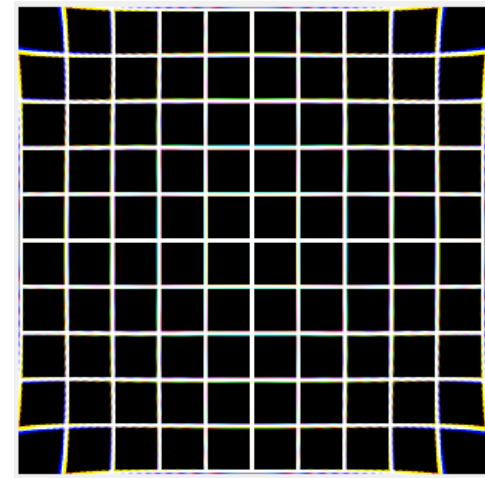
- ✓ Correction
  - Calibration result
    - (a): Original image
    - (b): Image with the pre-distortion
    - (c): User's perceptual image



(a)



(b)



(c)

## CONSIDERATIONS IN VR DISPLAYS

### **PART III: DISPLAY TECHNOLOGY TREND IN VR**

# Display Technology Trend in VR

## ✓ 2017 Display Week

TIMES	Sunday May 21		Monday May 22		Tuesday May 23				Wednesday May 24				Thursday May 25		Friday May 26		
	Short Courses	Display Metrology Training Course (Full Day or Half Day)	Seminars	Business Conf.	Symposium	OLED 30th Anniversary Celebration	Market Focus Conference	Exhibits Exhibitors Forum Sessions / I-Zone	Investors Conf.	Symposium	Exhibits Exhibitors Forum Sessions / I-Zone	Market Focus Conference	CMO Forum / Women in Tech	Symposium	Exhibits Exhibitors Forum Sessions	Symposium	
8:00 AM					Session 1: SID Business Meeting												
8:30 AM			Seminars M1 - M3	Business Conference	Session 2: Welcome / Keynote Addresses								CMO Forum				
9:00 AM	Short Courses S-1 & S-2	SID/CDM Introductory Display Metrology Training Course	Seminars M4 - M6		Ribbon Cutting Ceremony				Oral Sessions 24-30	Exhibits / Exhibitors Forum / I-Zone	Investors Conference	Market Focus Conference: AR/VR	Women in Tech	Oral Sessions 45-49	Exhibits / Exhibitors Forum / I-Zone	Oral Sessions 71-76	
10:00 AM					Oral Sessions 3-9	Market Focus Conference Automotive (11:00-5:30)	Exhibits / Exhibitors Forum / I-Zone	Investors Conference	Oral Sessions 31-37					DIA & Best-in-Show Awards Luncheon		Oral Sessions 50-56	Oral Sessions 77-82
10:30 AM				Lunch	Oral Sessions 10-16				Oral Sessions 38-44					Lunch		Author Interviews	
11:00 AM		3 morning 3 afternoon sessions (Lunch included for full day registration)	Seminars M7- M9										Oral Sessions 57-63				
11:30 AM			Seminars M10 - M12	Business Conference	Oral Sessions 17-23	OLED 30th Anniversary Celebration			Designated Exhibit Time				Oral Sessions 64-70	Author Interviews			
12:00 PM																	
12:30 PM				Lunch													
1:00 PM			Seminars M13 - M15	Bus. Conf. Recept.	Author Interviews				Author Interviews								
1:30 PM																	
2:00 PM																	
2:30 PM																	
3:00 PM	Short Courses S-3 & S-4	Supplemental Measurement Methods Demonstrations															
3:30 PM																	
4:00 PM																	
4:30 PM																	
5:00 PM																	
5:30 PM																	
6:00 PM																	
6:30 PM																	
7:00 PM		Bonus session															
7:30 PM																	
8:00 PM																	
8:30 PM																	
9:00 PM																	
9:30 PM				Honors and Awards Banquet													

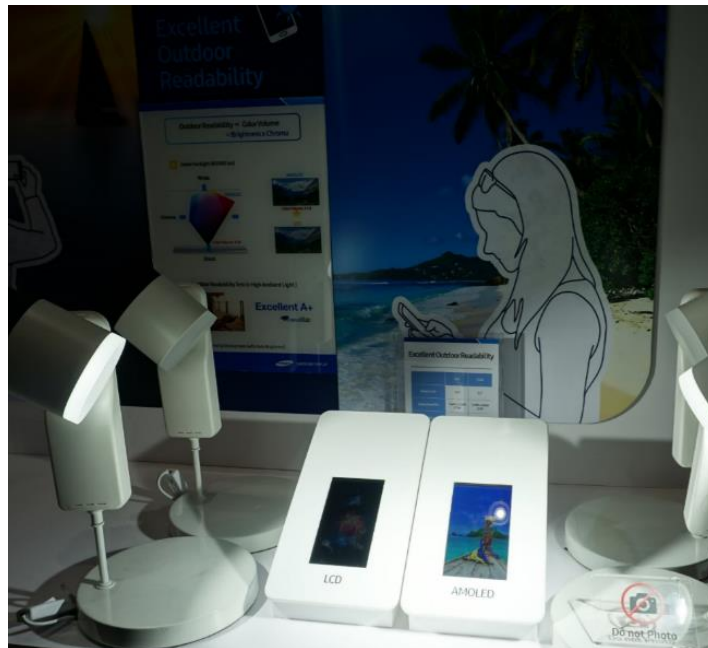
# Display Technology Trend in VR

- ✓ Samsung
  - HMD panel
  - High PPI panel



# Display Technology Trend in VR

- ✓ Samsung
  - High speed
  - HDR panel  
(Peak Brightness = 1000 nit)



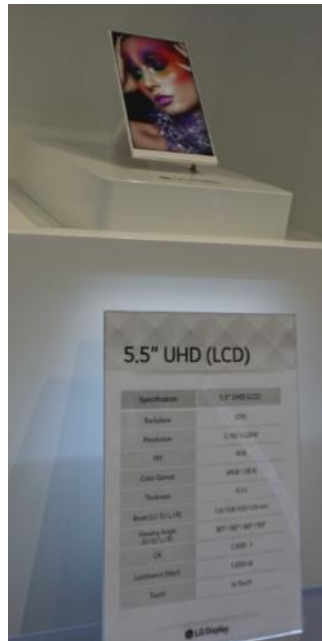
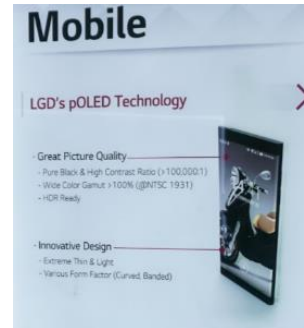
## High Speed

### 60Hz vs 120Hz

High Speed			
Driving Time (min)	60	120	
Display Size	5.7"		
Resolution (DPI)	1,080 x 1,920 (384)		
Brightness (nit)	100		

# Display Technology Trend in VR

- ✓ LG
  - HDR
  - Curved
  - 8K / UHD





# Display Technology Trend in VR

## ✓ BOE

- 1900 PPI panel
- 8K Picture
- Foldable



# Display Technology Trend in VR

- ✓ Japan display
  - Aerial display
  - Fast response panel



NEW TECHNOLOGY

## Aerial Display

12.5-inch Full HD

- ◆ Aerial display system with touch sensor
- ◆ High luminance aerial image  
High luminance LCD and high-efficiency optical system
- ◆ Crisp aerial image achieved by novel reflector film  
Retro-reflector film custom-developed for the aerial display, improving resolution and luminance

**Aerial Display System**

Japan Display Inc.

ADVANCED IPS

## Fast Response, Ultra-high PPI LCD for Head Mount Display

3.4-inch 1540x1700 LCD Module for HMD

- ◆ Realistic image with ultra-high 65 Tppi resolution
- ◆ Excellent moving picture performance based on fast response IPS, blinking backlight, and high refresh rate

**Development Specification**

Display size	3.4-inch x 2
Resolution (dot eye)	1540 (W) x 1700 (H)
Pixel layout	RGB striped
Pixel density	65 Tppi
Response time	2ms (BMP, 6ms (D-G))
Refresh rate	60Hz
Display method	Blinking backlight
BET (BMP edge time)	1ms
Contrast ratio	800:1

Japan Display Inc.

# Display Technology Trend in VR

- ✓ 3M
  - Screen-door-effect reduction in virtual reality headsets



# Display Technology Trend in VR

- ✓ Display measurement system
  - Near-eye display measurement



# Display Technology Trend in VR

- ✓ Display measurement system
  - Near-eye display measurement



# Display Technology Trend in VR

- ✓ Display measurement system
  - Perceptual resolution measurement



# Conclusion

- ✓ We have to measure and reduce the motion-to-photon latency
  - The latency measurement system is required for quantitative numerical calculations
  - Finally, the latency compensation technique is required to reduce the motion sickness
- ✓ Considerations in Displays
  - We have to use the high PPI display, but consider HW resources to render the output image
  - In order to reduce the chromatic aberration, we have to use the pre-correction technique