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SID Bay Area Chapter Presentation

The ICDM International Display Measurement Standard - SID's First Standard

at National Semiconductor *(Texas Instruments)*
Santa Clara, November 9, 2011

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Oracle

Abstract

The ICDM International Display Measurement Standard - SID's First Standard

This is the same metrology group who wrote the FPDM (Flat Panel Display Measurement standard) and derivatives in VESA. Now in SID, the ICDM is working to complete the most comprehensive display measurement standard yet produced, the IDMS (International Display Measurement Standard).

This standard is formidable in terms of content, comprehensiveness, and expertise. The principal editor was the chief display metrology scientist at NIST, and there are authored or co-authored contributions from approximately 50 of some of the best display-evaluation-related specialists in the field today.

The IDMS catalogs standardized methods to characterize displays of almost every type, with a range of measurements from somewhat basic parameters typically called out for marketing purposes of displays to very specialized and advanced methods which capture subtle operating characteristics that have never had standardized methods to quantify them.

This is the state-of-the art standard for characterizing displays at all levels and will make a major contribution to the display industry for quantifying the performance of displays. We will give an overview of the standard and touch upon some of the specialized areas it contains.

Introduction

The ICDM (International Committee for Display Metrology) became a part of SID in May of 2007. The ICDM will finalize its display measurement standard (DMS) in 2011-2012.

"ICDM: we set the standards for display metrology"

ICDM Committee
2008

http://www.icdm-sid.org

ICDM Web site QR Code

Introduction: About the ICDM

http://www.icdm-sid.org

International Committee for Display Metrology

A Committee within SID

- Part of the Definitions and Standards Committee
- First SID committee for standards

Over 200 participants from every major area of the Display Industry

- Many of the most prestigious display-related organizations in the world
  - Including all major display manufacturers, many Universities, NIST, NASA, ITRI, KRISS, NPL, most test equipment manufacturers, etc.)

Participation by many major related display standards groups

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What the ICDM is and what it will do for you

What is the ICDM?

- The standards committee within SID developing the ICDM display measurement standard.
  - Originally the FPDM committee of VESA

Who is the ICDM?

- Over 200 people — evaluation professionals from throughout the display industry.

What will the ICDM do for you?

- Will help establish standardized methods for almost all types of display measurements and characterizing
  - Will provide methods that help you to be sure that the measurements on your displays were done correctly.
  - Will answer the questions about what the specifications really mean
  - Will help reduce specsmanship

What the ICDM does for the industry?

- Provide a common language for those who measure displays to assure all are making the measurements in a consistent manner.
- Provide the tools to help all obtain and understand the true performance of displays

Organization and Structure

- Chairman - Joe Miseli, Oracle
- One Primary Editor - Ed Kelley, Keltek Research
  - Several sub-editors
- 13 Subcommittees
  - Various numbers of subcommittee participants
- Approximately 50 authors
- Approximately 120 reviewers
- Over 250 members
  - Over 200 on the active members Email list
  - Over 50 on the interest Email list
- Approximately 14 standards bodies participants

ICDM Standard Table of Contents

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ICDM Subcommittees & Chairs

1. Gamma, Gray Scale: Don Gyou Lee
2. Viewing Angle: Thierry Leroux, Eldim
3. Uniformity: Ron Rykowski, Radiant Imaging
4. 3D-Stereo: Adi Abileah, Planar
5. Low Luminance: Jens Jorgen Jensen, Radiant ZEMAX
6. Motion Artifacts: Andrew Watson, NASA
7. Reflection, John Penczek, NIST
8. Touch Screens, Peggy Lopez, Orb Optronix
9. Front-projection Screens, Michael Rudd, Consultant
10. Validation and Verification, Max Lindfors, Nokia
11. Projection Displays, Michael Rudd, Proper Sound and Vision
12. Temporal, Mike Wilson, Westar
13. Ratification and Release, Tom Fiske, Qualcomm

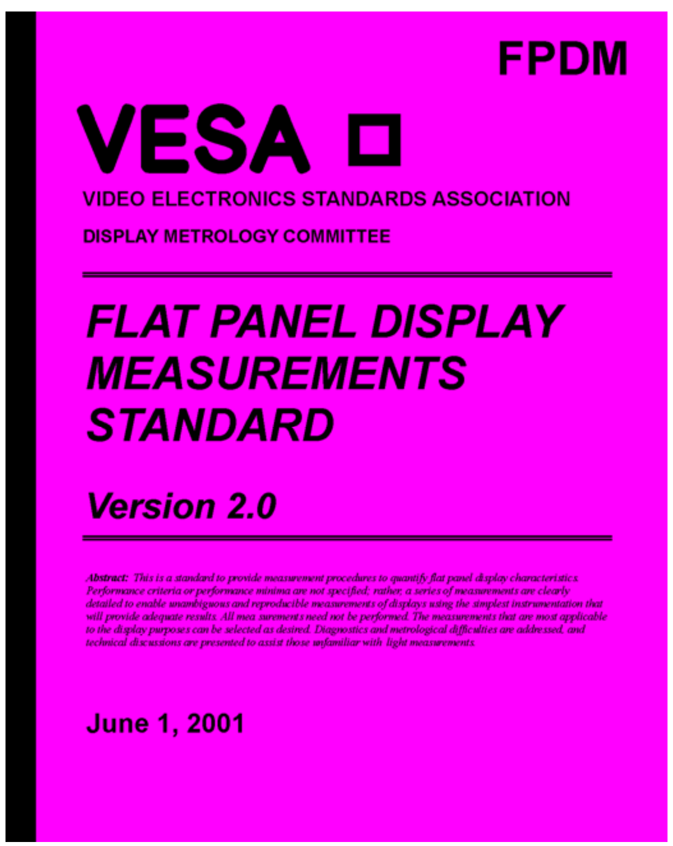
FPDM → ICDM

First there was the FPDM2 (VESA Flat Panel Display Metrology Standard)

- FPDM 2 was written in 2001 with an addendum in 2005

In 2007, the VESA FPDM group became the ICDM (International Committee for Display Metrology Standard)

- Now part of SID → And about to release the IDMS



FPDM

VESA

VIDEO ELECTRONICS STANDARDS ASSOCIATION

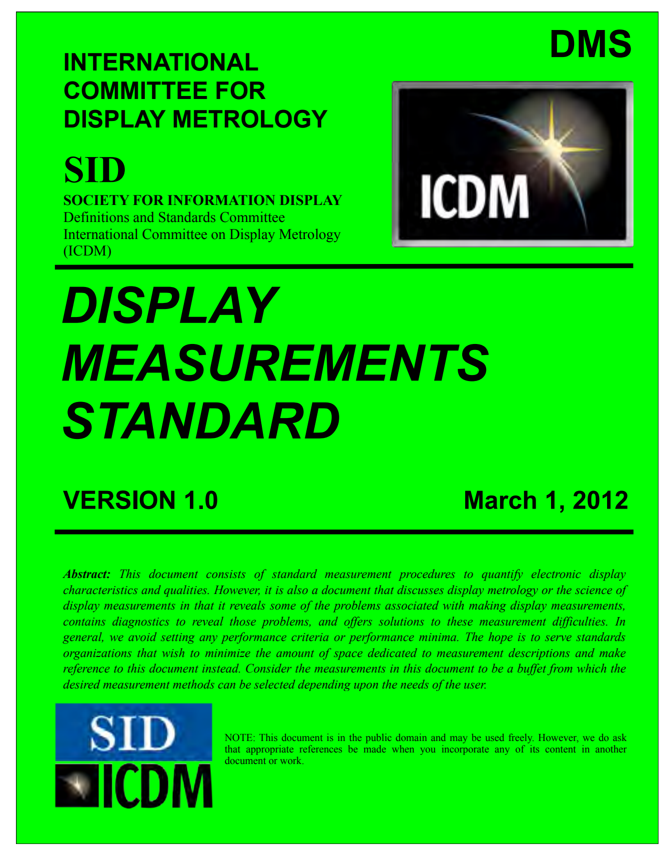
DISPLAY METROLOGY COMMITTEE

FLAT PANEL DISPLAY MEASUREMENTS STANDARD

Version 2.0

Abstract: *This is a standard to provide measurement procedures to quantify flat panel display characteristics. Performance criteria or performance minima are not specified; rather, a series of measurements are clearly detailed to enable unambiguous and reproducible measurements of displays using the simplest instrumentation that will provide adequate results. All mea surements need not be performed. The measurements that are most applicable to the display purposes can be selected as desired. Diagnostics and metrological difficulties are addressed, and technical discussions are presented to assist those unfamiliar with light measurements.*

June 1, 2001



DMS

INTERNATIONAL COMMITTEE FOR DISPLAY METROLOGY

SID

SOCIETY FOR INFORMATION DISPLAY

Definitions and Standards Committee

International Committee on Display Metrology (ICDM)

ICDM

DISPLAY MEASUREMENTS STANDARD

VERSION 1.0 March 1, 2012

Abstract: *This document consists of standard measurement procedures to quantify electronic display characteristics and qualities. However, it is also a document that discusses display metrology or the science of display measurements in that it reveals some of the problems associated with making display measurements, contains diagnostics to reveal those problems, and offers solutions to these measurement difficulties. In general, we avoid setting any performance criteria or performance minima. The hope is to serve standards organizations that wish to minimize the amount of space dedicated to measurement descriptions and make reference to this document instead. Consider the measurements in this document to be a buffet from which the desired measurement methods can be selected depending upon the needs of the user.*

SID ICDM

NOTE: This document is in the public domain and may be used freely. However, we do ask that appropriate references be made when you incorporate any of its content in another document or work.

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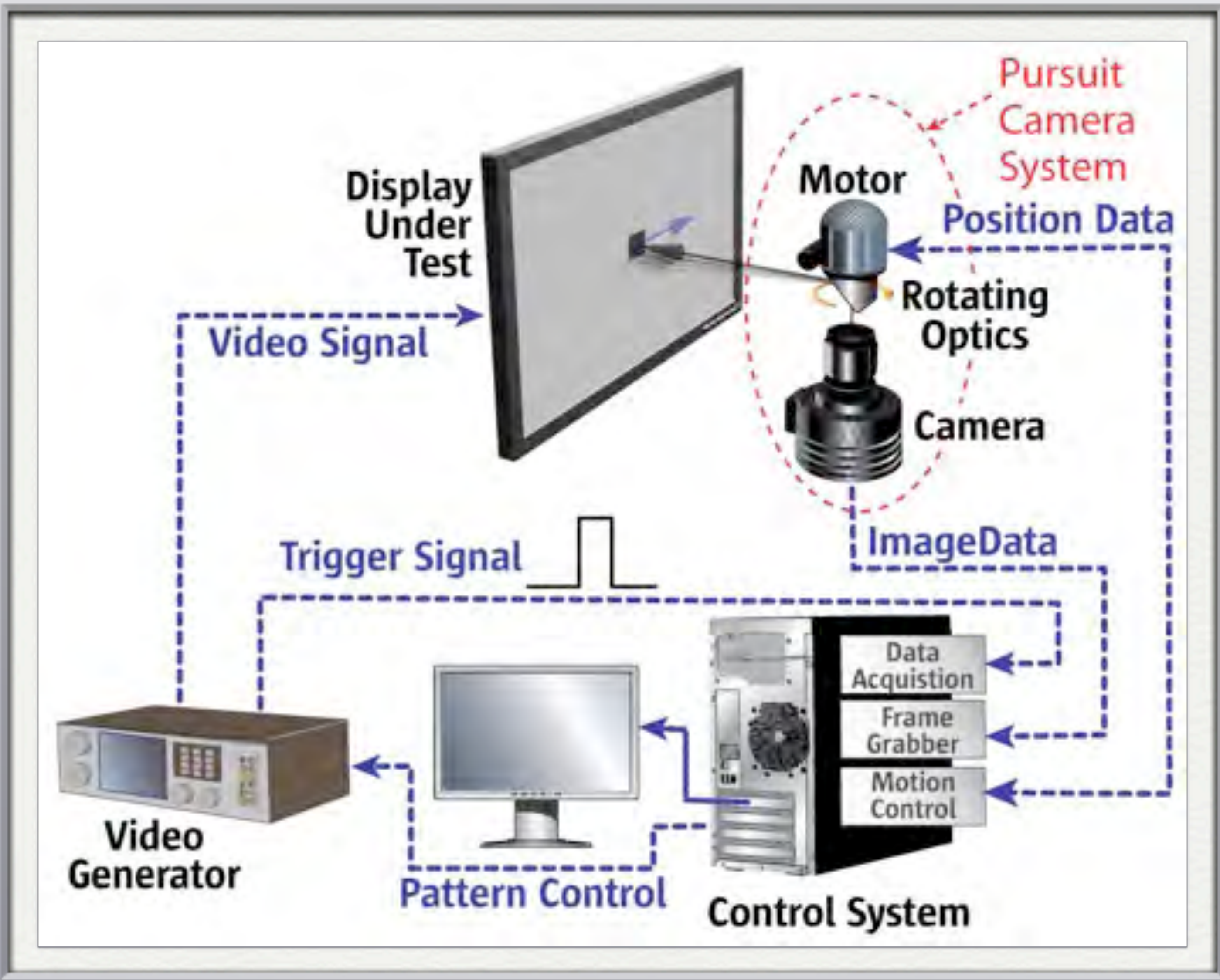
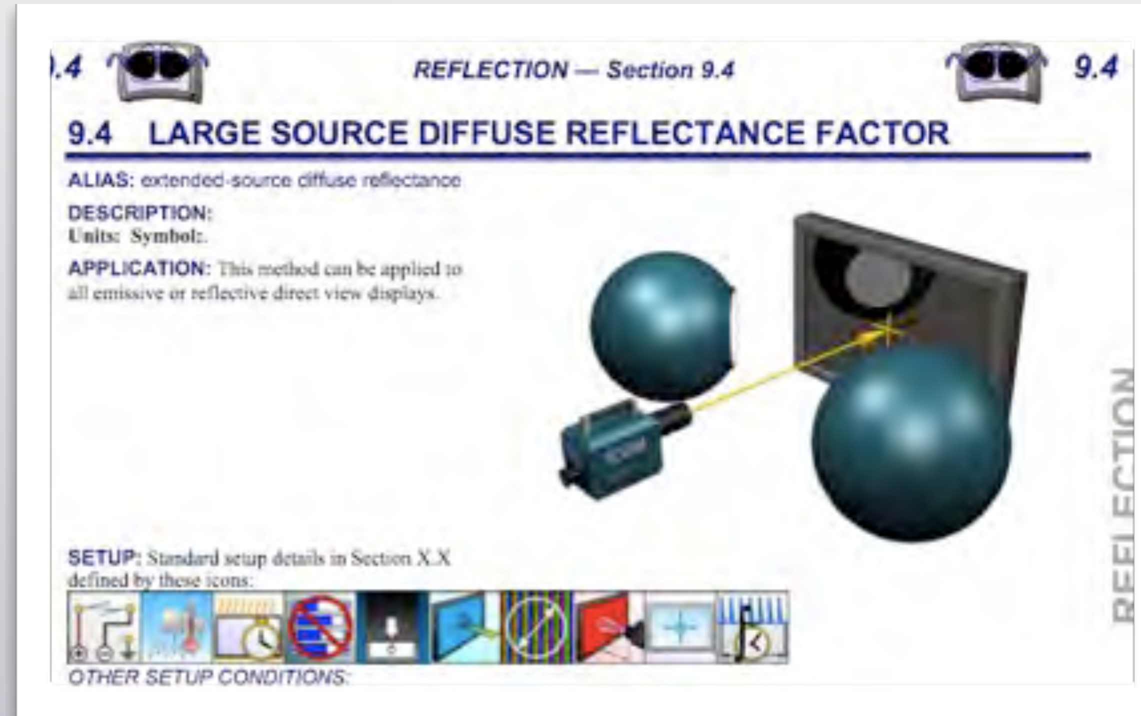
Philosophy of the ICDM and its standard

- Simple English
- Consistent structure
  - Everything contained within a single book
  - Every section is written from a single template
    - Section = 1 measurement
    - Chapter = a group of measurements of a certain category
- Friendly style and manner
  - Full color
  - Contains cartoons, many references, tables, glossary, discussions
  - Extensive use of high-quality graphics
  - Icons to explain simple and repetitive setup functions
- On measurement per page whenever possible
- Aides to help in various manners
    - Templates
    - Test patterns

Examples of graphics of the ICDM

- ICDM - Clear and friendly style, abundant use of quality graphics to simplify and clarify




.4 REFLECTION — Section 9.4 9.4

9.4 LARGE SOURCE DIFFUSE REFLECTANCE FACTOR

ALIAS: extended-source diffuse reflectance

DESCRIPTION:
Units: Symbol:.

APPLICATION: This method can be applied to all emissive or reflective direct view displays.

SETUP: Standard setup details in Section X.X defined by these icons:

OTHER SETUP CONDITIONS:

REFLECTION

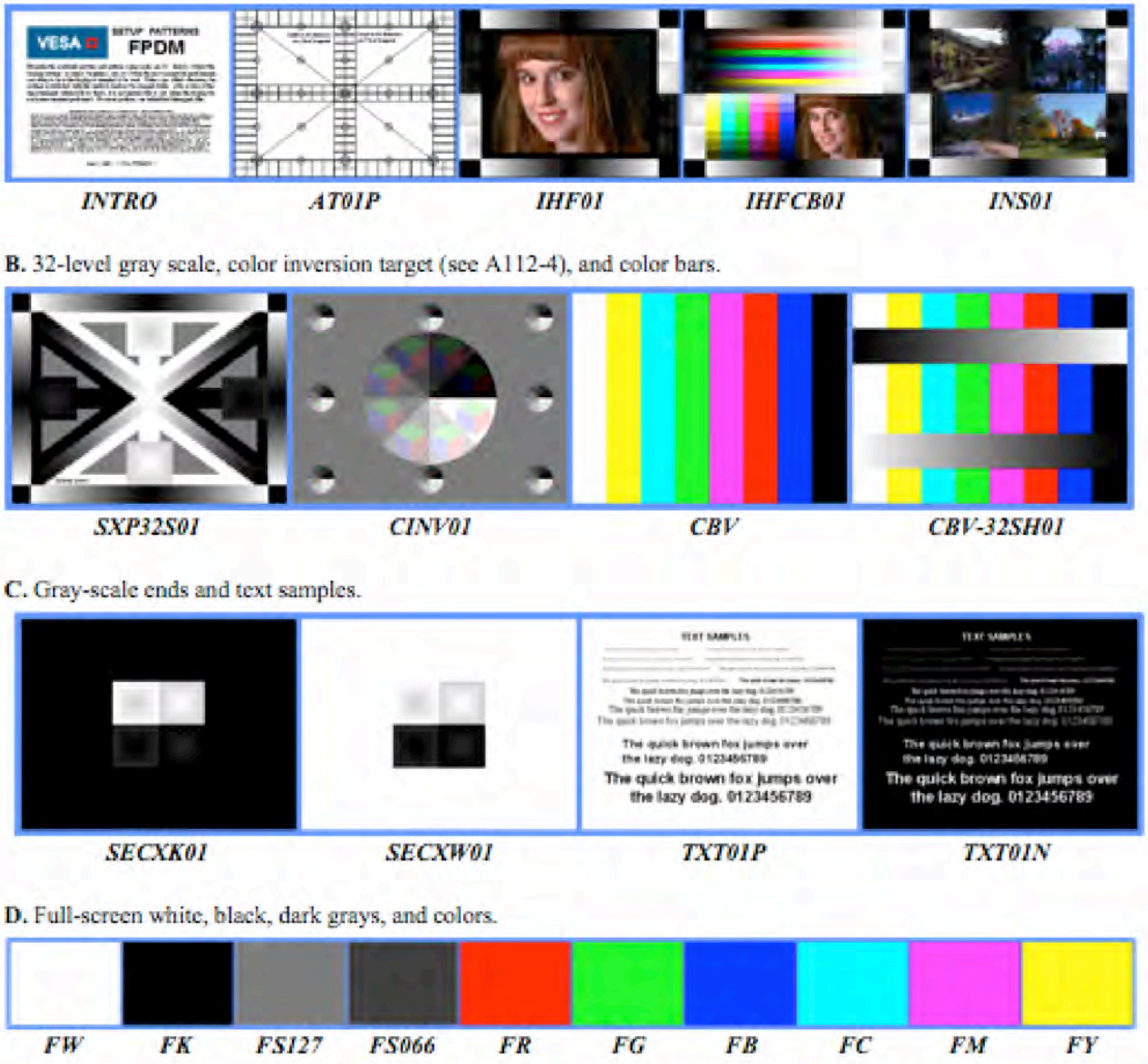

4.3 FULL-SCREEN PRIMARY COLORS (R or G or B)

ALIAS: red-, green-, or blue-screen luminance, etc.

See General Measurement Description at the beginning of this Main Section (Section 4) for general details.

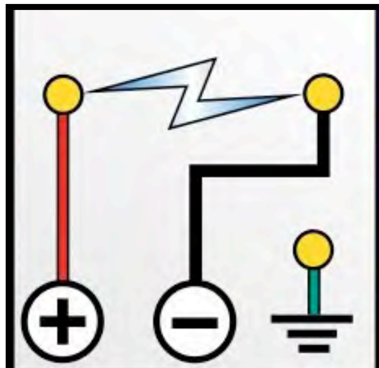
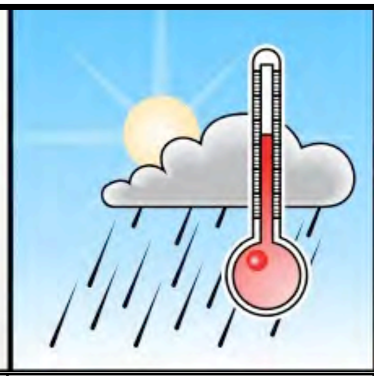
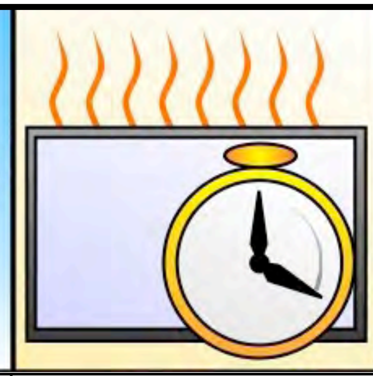
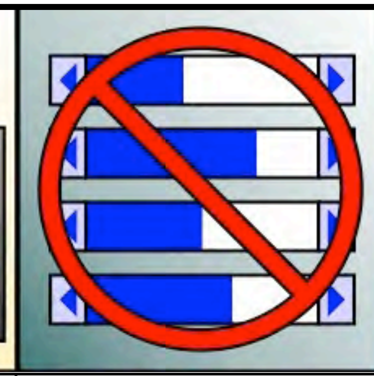
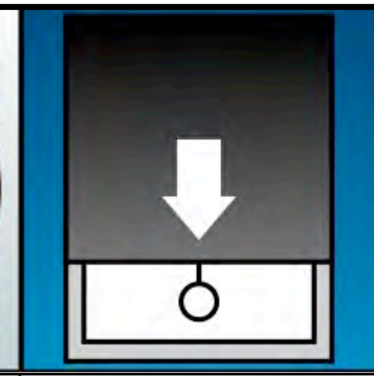
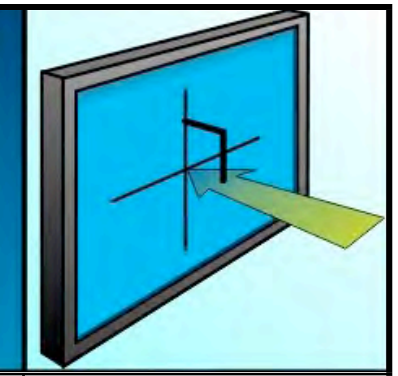
OTHER SETUP CONDITIONS: Use a full-screen pattern of the primary colors (e.g., FR, FG, FB_####x####.PNG).

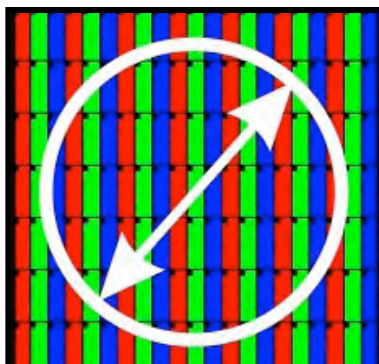
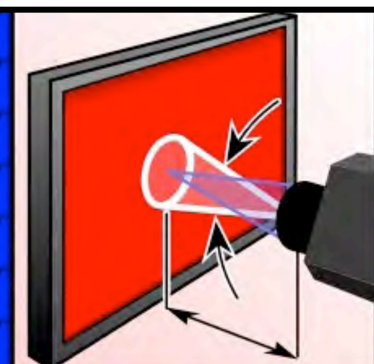
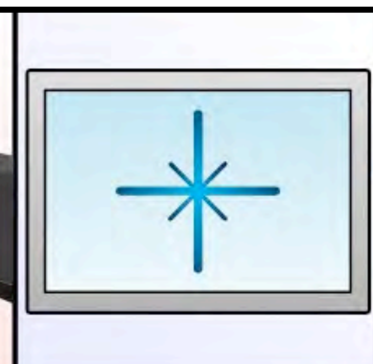
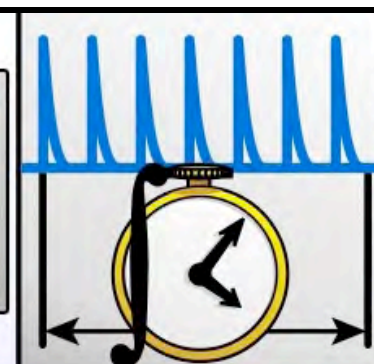
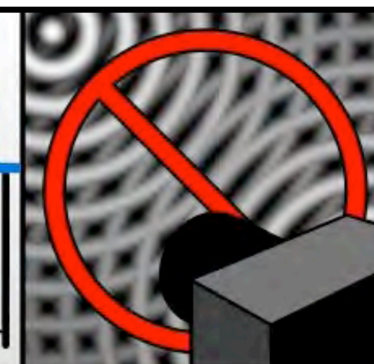
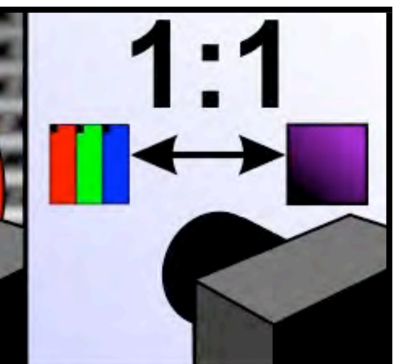
Examples of some test patterns of the ICDM



Setup information by means of icons

❖Standard Conditions (Setup Icons of the ICDM)

					
Stable power required	Temperature, humidity, and air pressure in range	Warmup required, 20 minutes minimum	Don’t change controls from initial setup	Measure in darkroom conditions E ≤1 lx	Measure normal to screen

					
Measure at least 500 pixels (circle of 26 pixel diameter)	Measurement field angle: 2° or less	Center-of-screen measurement	Adequate integration time to allow for screen refresh	Area array imagers: assured of no Moiré	Image resolution same as the display array

Reporting Forms/Records/Templates

DIRECT-VIEW FPD DATA RECORD — SUITE OF BASIC MEASUREMENTS

DISPLAY INFO: Manufacturer: ________ Model No: ________ Serial No: ________ Rev. Level: ________

DESCRIPTION: Diagonal Size: ________ Pixels: ________(hor) × ________(ver) Technology: ________ Configuration: ________

PITCH: Horizontal: Pixel: ________ Subpixel (Dot): ________ Other: ________ Measurement Direction: ________

Vertical: Pixel: ________ Subpixel (Dot): ________ Other: ________ Location of Center Meas.: ________

COLORS: Bits/color: ______ Color bits: ______ Gray Levels: ______ Total Colors: ________ Signal Source: ________ Power Source: ________

SIZE: Active Area: ________(hor) × ________(ver) LMD: Make ________ Model ________ Serial No ________ Distance ________ AFOV ________

OVERALL: Dimensions: ________(hor) × ________(ver) Depth: ________ Mass (weight): ______ Design Viewing Direction: ________

Test Person: ________ **Date:** ________ **Warm-Up Time:** ______**min Temperature:** ____**°C Run:** ______ **Page 1/2**

Full-Screen Center (302-1...4)

	L cd/m²	x	y
White			
Black			
Drkrm. C		No Units for C	
Red			
Green			
Blue			

Full-Screen Gray Scale (302-5)

Level	L cd/m²	Opt-16	L cd/m²
Wht-7		Wht-15	
6		14	
5		13	
4		12	
3		11	
2		10	
1		9	
Blck-0		8	
Gamma			

Shad. = 100% L_{box}-L_{bkg}/L_{bkg} **(303-4)**

Box at (A-E)		Lum. (cd/m²)	
Box (0-7)		L_{box}	
Bkgnd. (0-7)		L_{bkg}	
Shadowing %			

Uniformity: Nonuniformity = 100% x [1-(Min/Max)] or Δu′v′ (306-1,2,3,6)

9 pt	5 pt	L_w	L_b	C_c	x_w	y_w	u'_w *	v'_w *	CCT
1	1								
2									
3	2								
4									
5	3								
6									
7	4								
8									
9	5								
Ave.					Max Δu′v′ ↓				
Min.									
Max.									
Nonunif.									
An. Low									
An. High									
An. Non.					Anomalous Δu′v′				

Power Consumption (401-1)

	Supply	Volts	I(A)	(W)
Panel	High			
	Low			
Inverter	High			
	Low			
Other	High			
	Low			
Pattern Used: ↓	High			
	TOTAL			
	Low			

Frontal Lum. Eff. (402-1)

Pattern:	White Full Screen	
Voltage		V dc/ac(rms)
Current		A dc/ac(rms)
Power, P		W dc/ac(rms)
L_w		cd/m²
$\varepsilon = L_w/P$		cd/m²W

Checkerboard Con. (304-9)

Pattern n×m		×	
L_w		L_b	
C_c			

Response Time (305-1)

Blk-Wht		ms
Wht-Blk		ms
Total		ms

Ambient Contrast (308-2)

White L_{AW}		L_w		L_b		L'_w		L'_b	
Black L_{AB}		L_{aw}		L_{ab}		L_{ad}		ρ_{rd}	
C_A		E				E_L			

Viewing Angle (307-1 or 2)

Direct'n	Angle	White L_w	x_w	y_w	CCT(K)	Black L_b	x_b	y_b	C	Red L_{red}	x_{red}	y_{red}	Green L_{grn}	x_{grn}	y_{grn}	Blue L_{blu}	x_{blu}	y_{blu}
Up θ_U																		
Dwn θ_D																		
Right θ_R																		
Left θ_L																		

Comments:

*$u' = 4x/(3+12y-2x)$
$v' = 9y/(3+12y-2x)$

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Reporting Forms/Records/Templates

- Considerations for various Tools to help organize and give references for what is to be measured.
  - Printed forms / Records
  - Smart forms
  - Templates
  - Smart Templates
  - Programs
  - Specialized Templates

- Will look to users of the ICDM document to make additional requests and we may develop more templates and post them the the ICDM web site.

Sampling of measurements of the ICDM standard

- 3D - Stereo Displays
- Reflection
  - Ambient Contrast
- Low level contrast - Dynamic Contrast displays
  - Gamma for displays with global/local dimming (dynamic contrast)
  - Starfield contrast
- Color Characteristics — White point quality metric
  - CCT qualification based on $\Delta u'v'$

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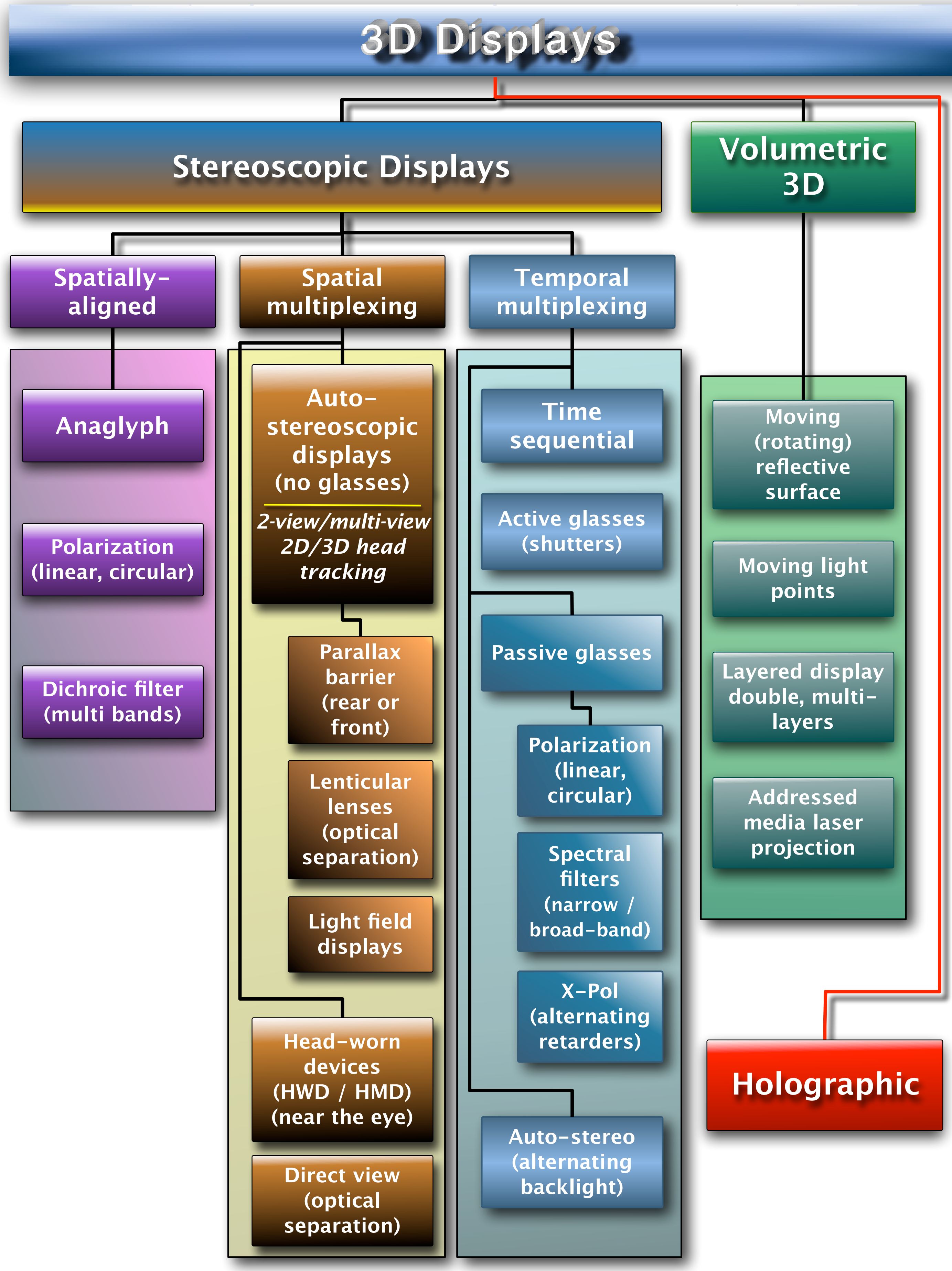
3D Measurements of the ICDM

Items related to 3D displays defined for the ICDM DMS

- Eye-glasses Testing
- Stereo Extinction Ratio
- Design Eye Point (Sweet Spot)
- Optimum Viewing Distance and Range
- Viewing Freedom and Offset
- Two-View (one viewer at one location) vs. Multi-View
- Luminance Difference
- 3D Luminance
- 3D Crosstalk
- 3D Contrast Ratio
- 3D Chromaticity Coordinates
- 3D Uniformity
- Viewing Angle
- Stereoscopic Gamma
- And more…….



Family tree of 3D Display Technologies

Graphics showing 3D Autostereoscopic System Implementations

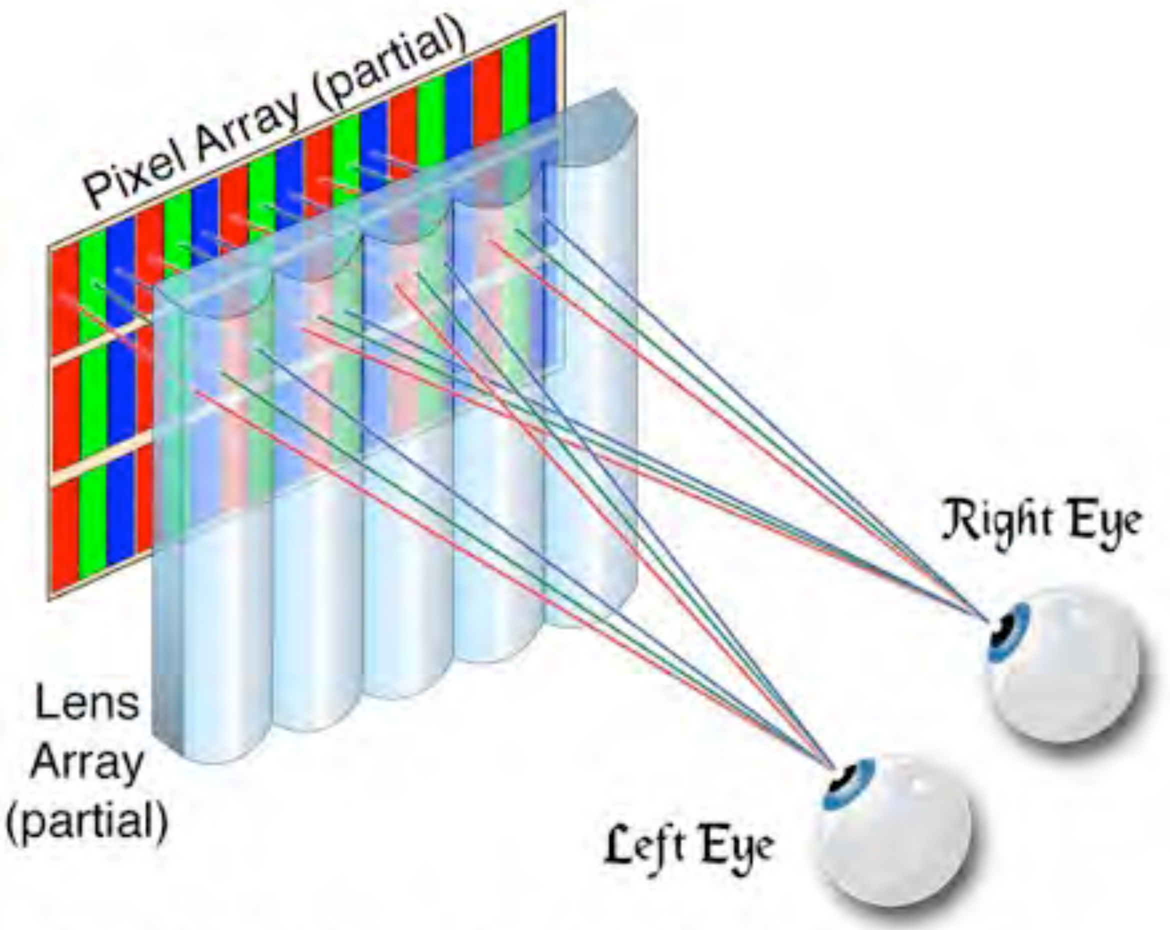


Figure 2: Lenticular Lens Array Autostereoscopic system. The microlens system steers the light path to allow each eye to see different regions of the display behind the lenses.

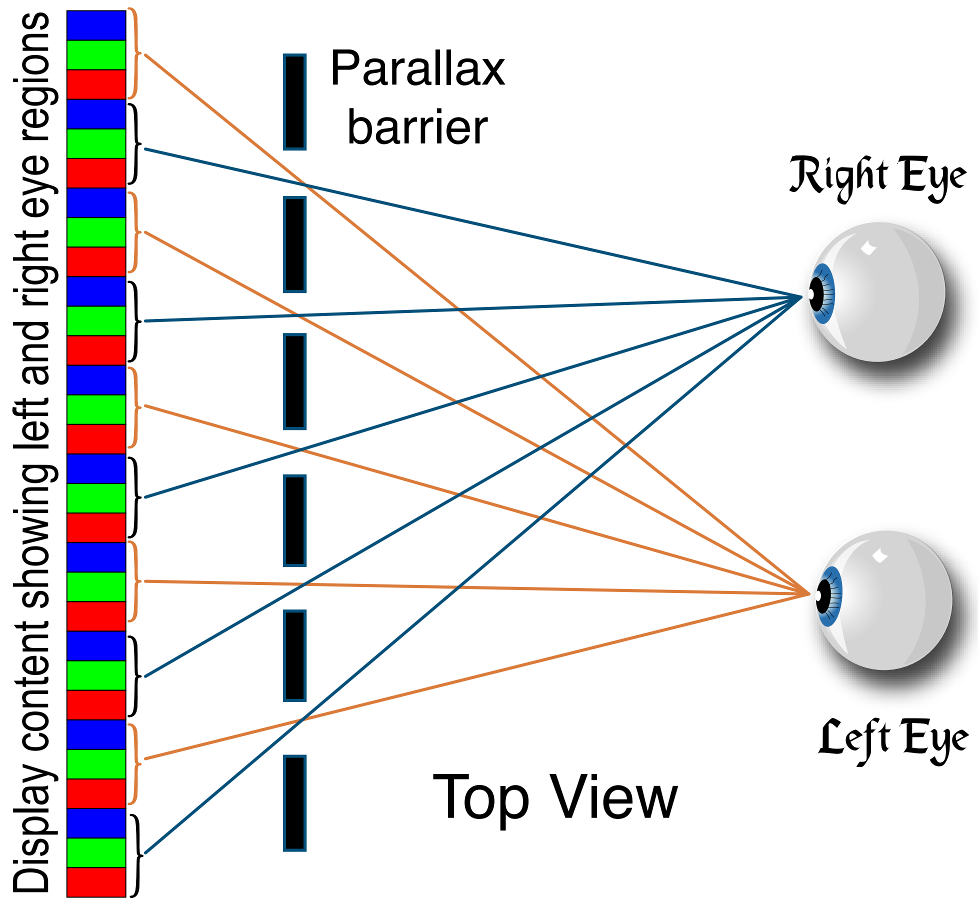


Figure 1: Parallax Barrier Autostereoscopic system (Top View). The parallax barriers are transparent and opaque strips to allow each eye to see different regions of the display behind the barrier.

Advanced Stereoscopic Topics

17.5 AUTOSTEREOSCOPIC LIGHT FIELD DISPLAYS

This chapter deals with stereoscopic displays in which the viewer is positioned in any location inside the viewing space and there is no need for eye glasses (autostereoscopic). These stereoscopic displays are called light-field displays or integral imaging (photography) displays, which reproduce light ray into real space. It is very difficult to distinguish light field displays and continuous multi-view displays. Some papers treat these issues in several aspects. [1, 2, 3]

3D & STEREOSCOPIC

Measurement methods that are listed below are not unique to light field displays and should be performed as other stereoscopic displays (see previous chapters).

1. Stereoscopic Contrast Ratio
2. Stereoscopic Luminance & Luminance Difference
3. Stereoscopic Colors & Color Difference
4. Stereoscopic Luminance Uniformity
5. Stereoscopic Color Uniformity
6. Stereoscopic Angular Behavior
7. Head Tilt

A variety of measurement methods are found in the previous chapters that are not unique to 3D and stereoscopic displays and can be performed as with 2D common displays.

Measurement methods include scanning in small angular increments to

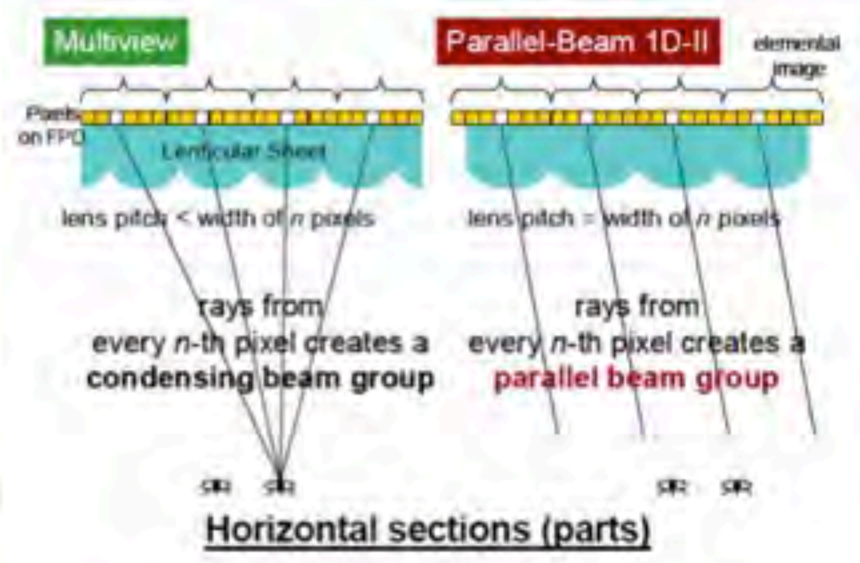


Fig. 1. Comparison of multiview and light-field

BACKGROUND:

Light Fields provide a general representation of 3D information that considers a 3D scene to be the collection of light rays that are emitted or reflected from 3D scene points. The term Light Field, was first used by Levoy et al [4] to represent 3D information based on Michael Faraday's lecture on light flow in 1846, "Thoughts on Ray Vibrations," that light be interpreted as a ray or field, and formalized by Maxwell's equations in 1874. Levoy provided a survey of the theory and practice of light field imaging that included those historical references. [5]

A surface light field is a 4-dimensional function $f(x, y, \theta, \varphi)$ that completely defines the outgoing radiance of every point on the surface of an object in every viewing

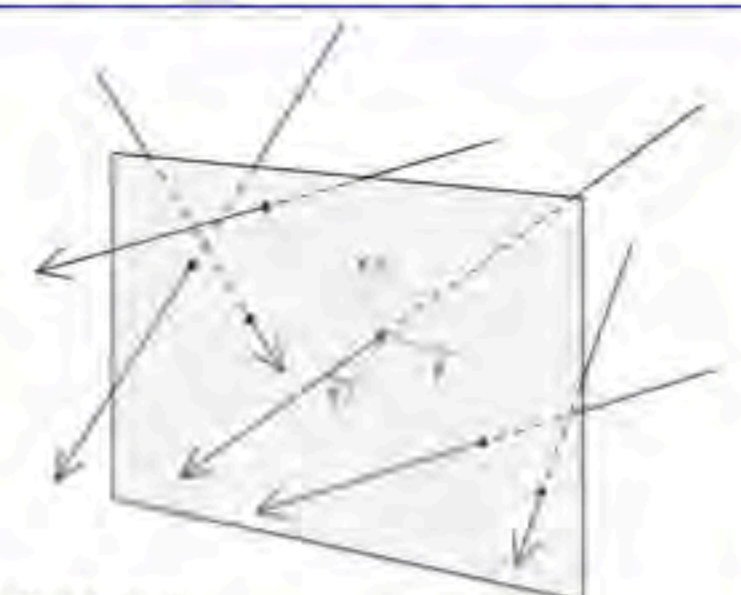


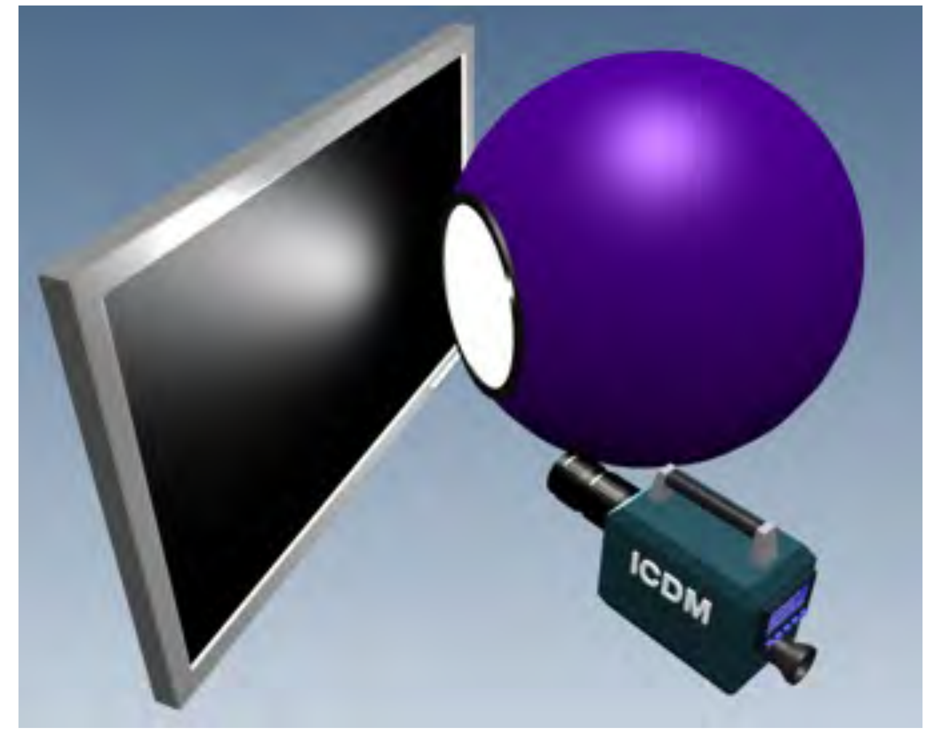
Fig.2. Light field

Sampling of measurements of the ICDM standard

- 3D - Stereo Displays
- Reflection
  - Ambient Contrast
- Low level contrast - Dynamic Contrast displays
  - Gamma for displays with global/local dimming (dynamic contrast)
  - Starfield contrast
- Color Characteristics — White point quality metric
  - CCT qualification based on $\Delta u'v'$

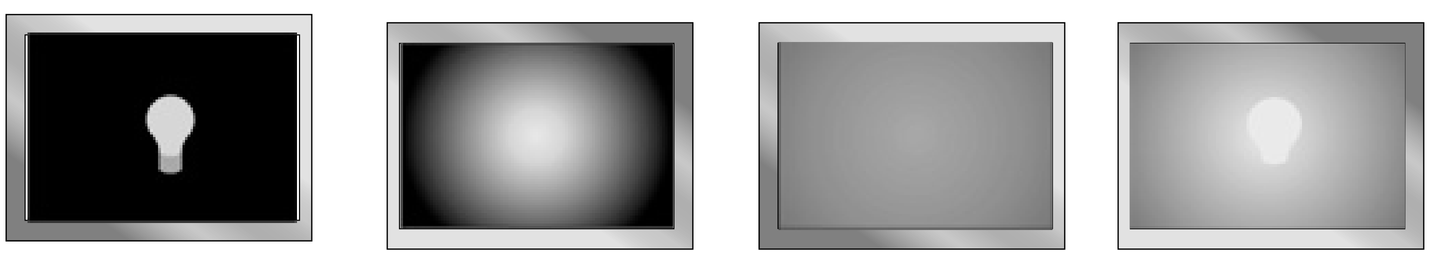
Ambient Contrast

- Ambient Contrast
  - Becoming popular
  - Very important
  - Confused by many in the industry
  - Highly requested from the ICDM



Reflection measurement example

Reflection Components



Specular Component | Haze Component | Lambertion Component | Specular + Haze + Lambertion

Ed Kelley

Determining Contrast Ratio

- Michelson Contrast Ratio used for motion contrast sensitivity & contrast degradation but not for full screen contrast
  - It is important to know the level at which perceptibility is not important
  - Michelson contrast constrains an infinite range of contrast to be from 0 to 1, so multiplying it by 100 gives percent of contrast.

$$CR_M = 100\left(\frac{L_{max} - L_{min}}{L_{max} + L_{min}}\right)$$

Michelson Contrast

$$CR = \frac{L_{max}}{L_{min}}$$

Basic Contrast

Linear and infinite, just like luminance ∴ the right metric for contrast of a display

Ambient Contrast

$$C_A = \frac{\pi L_{\mathrm{W}} + \rho_{\mathrm{W}} E_{\mathrm{hemi}} + \beta_{\mathrm{Wdir}} E_{\mathrm{dir}} \cos\theta_{\mathrm{s}}}{\pi L_{\mathrm{K}} + \rho_{\mathrm{K}} E_{\mathrm{hemi}} + \beta_{\mathrm{Kdir}} E_{\mathrm{dir}} \cos\theta_{\mathrm{s}}}$$

Where

π is the divisor for the 2nd and 3rd terms

L_{W} is the measured white darkroom luminance

ρ_{W} is the hemispherical reflectance of a white screen

-Reflectance, or flux out/flux in — from integrating or sampling sphere

E_{hemi} is diffuse illuminance (lux)

-Uniform illumination falling on the display as from a integrating sphere

β_{Wdir} is the luminance factor of direct illumination for white

-Luminance of the material/luminance of a perfect reflecting diffuser — like a white puck

E_{dir} is the directional illuminance

-Illuminance from the directed sources — the ambient light source

θ_{s} is the incident angle of directional illumination from normal

L_{K} is the measured black darkroom luminance

ρ_{K} is the hemispherical reflectance of a black screen

β_{Kdir} is the luminance factor of direct illumination for black

E_{dir} is the directional illuminance

This is well explained in the ICDM standard.

Sampling of measurements of the ICDM standard

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Dynamic Contrast

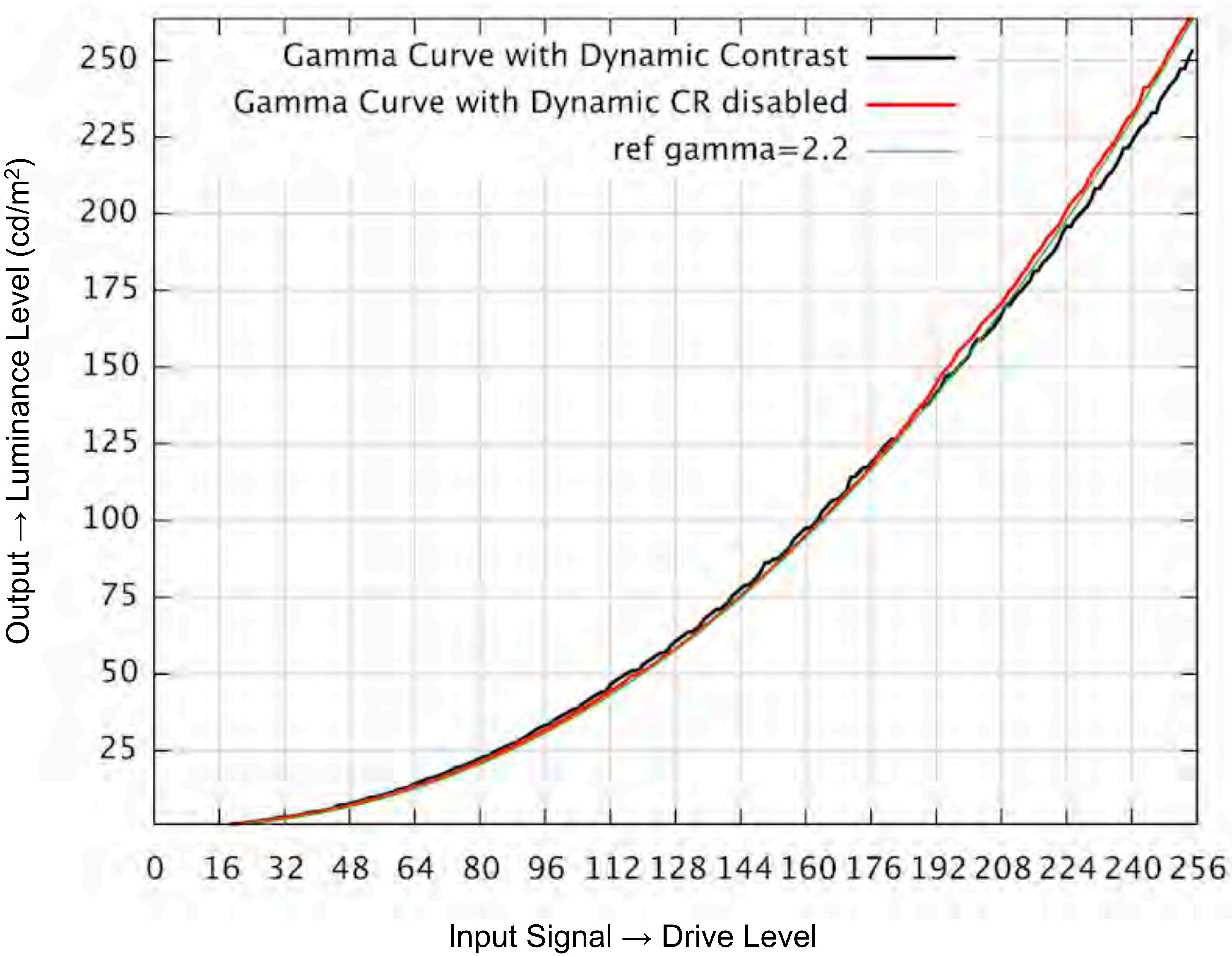
Dynamic Contrast (or global dimming, local dimming) turns off the backlight for displayed content with low luminance.

How do we measure this contrast?

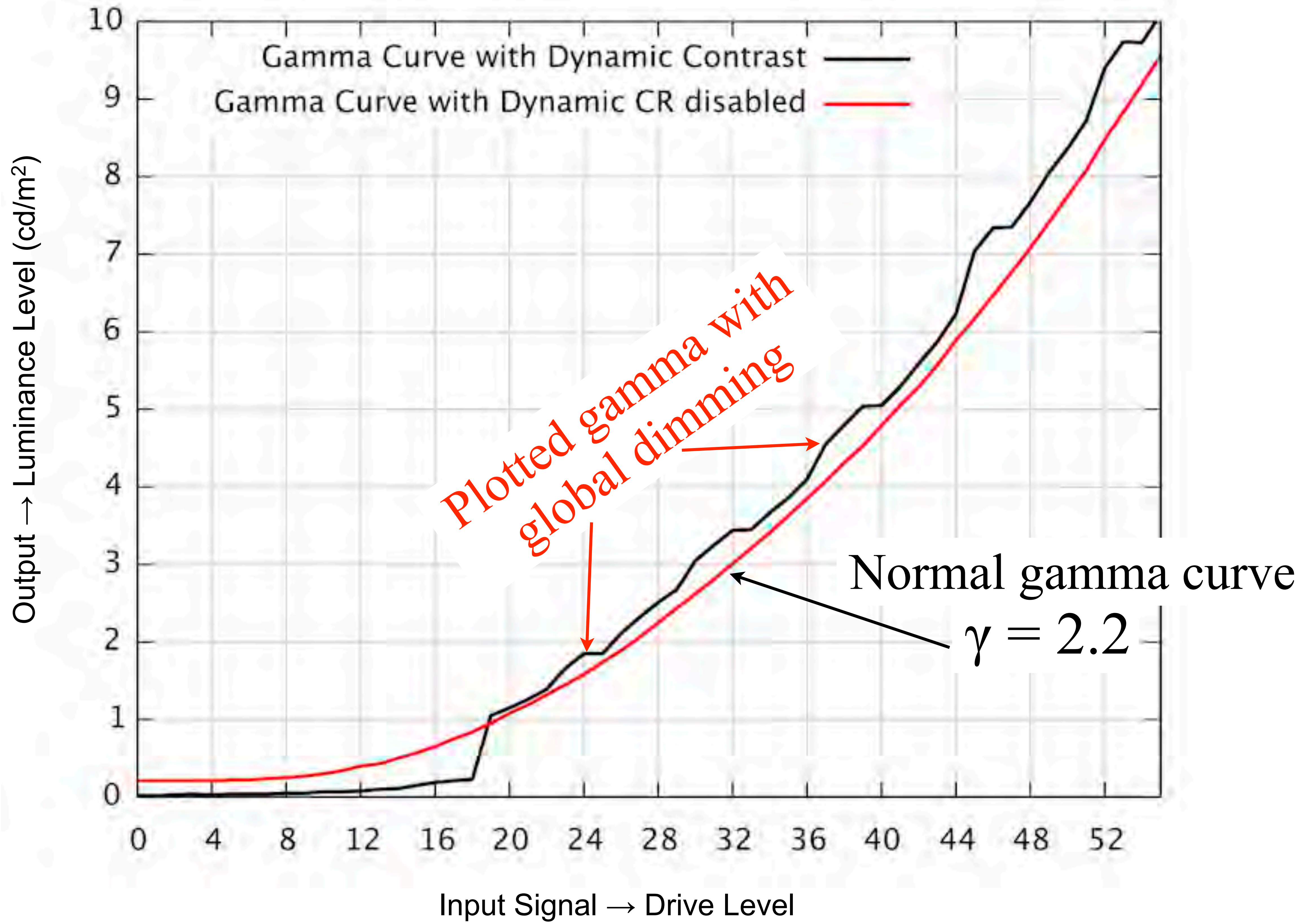
The backlight turns off, so we have infinite contrast.

- Dynamic Contrast & Adaptive or Global/Local Dimming & Boosting.
  - Dynamic attenuation of the backlight to improve contrast, black-level, and power savings, and to give highlight luminance level boosts Black luminance level decreased for black picture content
- With LED backlights arrays, we have the capability to manipulate the backlight and spatial control of contrast.
- Segmented Control
  - 0D Design – Dim entire backlight (Global Dimming)
    - Can be achievable with any dimmable backlight
  - 1D Design – Scan 1D backlight tubes (Line Dimming)
  - 2D Design – Modulate 2D LED array (Local Dimming)
- For measurements, we must assure a case where the backlight cannot be dynamically dimmed to 0, and thereby produce an artificial infinite contrast.
- The ICDM has solved this — Starfield Contrast

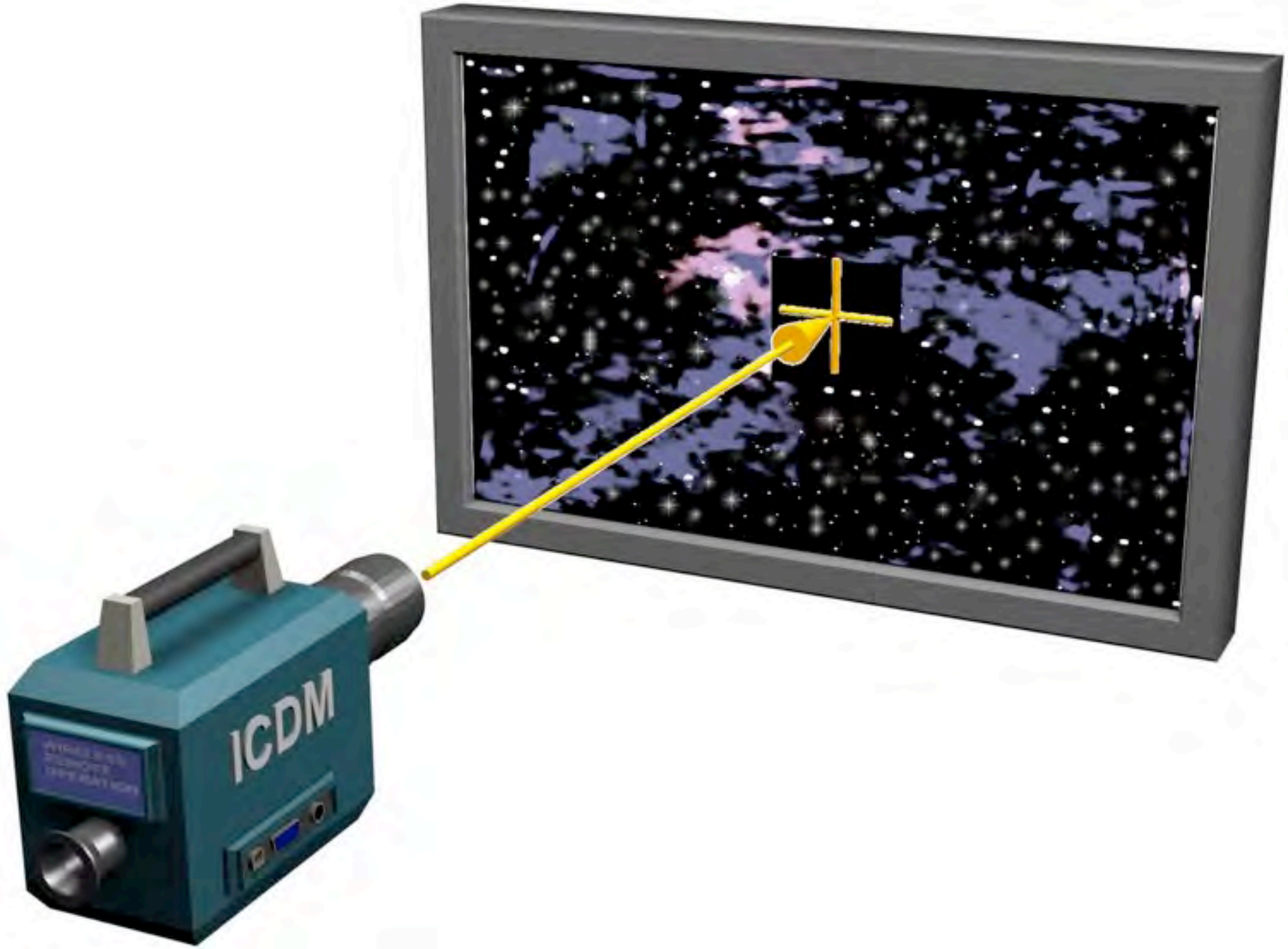
Dynamic Contrast



Dynamic Contrast - Zoomed View

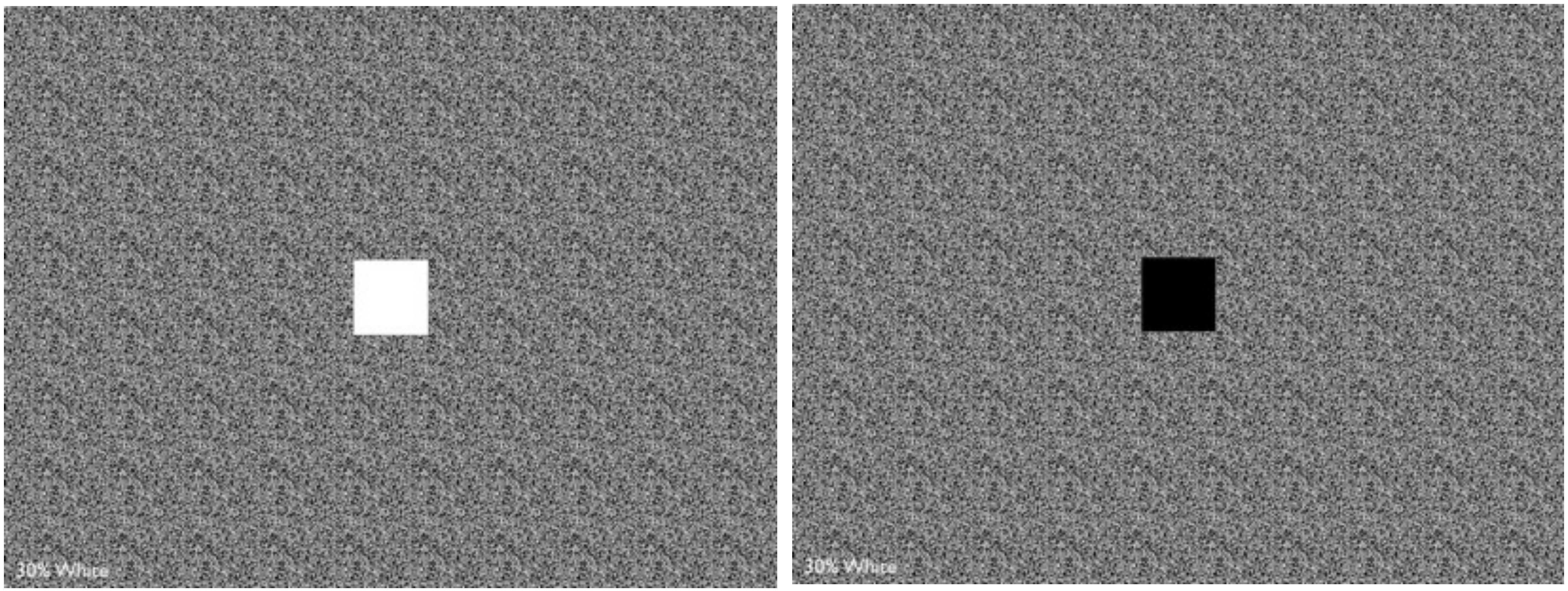


Starfield Contrast



Starfield Contrast

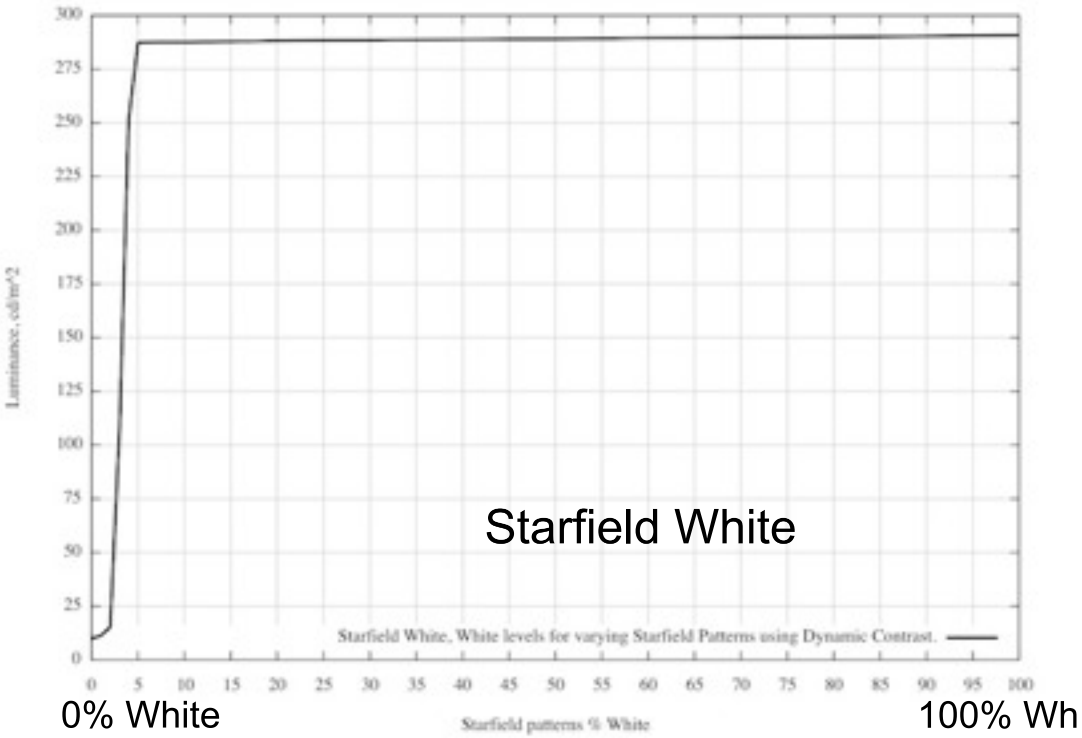
We use patterns with controlled content of white, then measure a black and white target in the center.

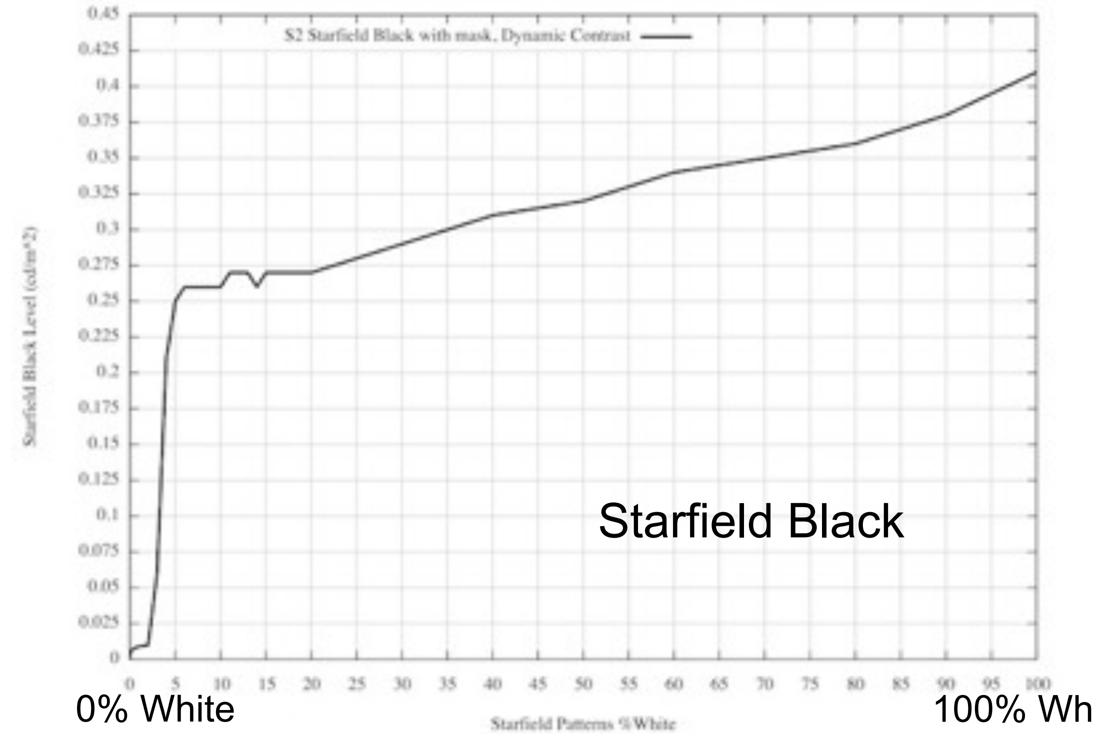


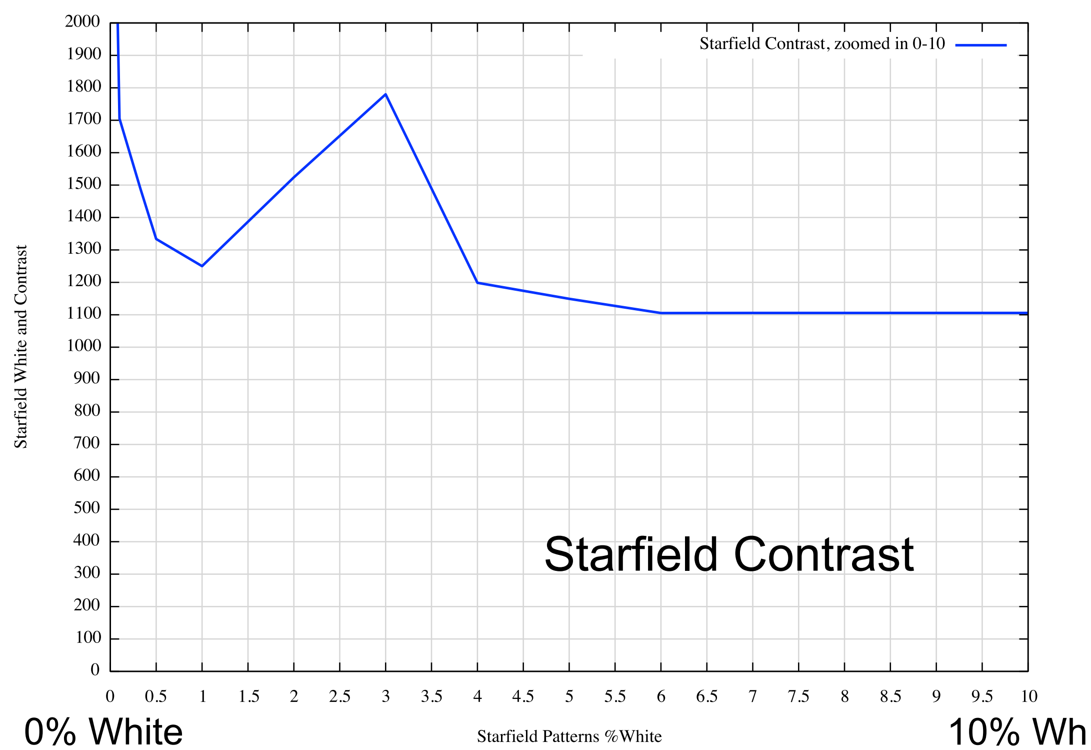
ICDM Starfield Contrast pattern example, shown for 30% white.

The ICDM pattern set ranges from 100% White To Black.

Starfield Contrast





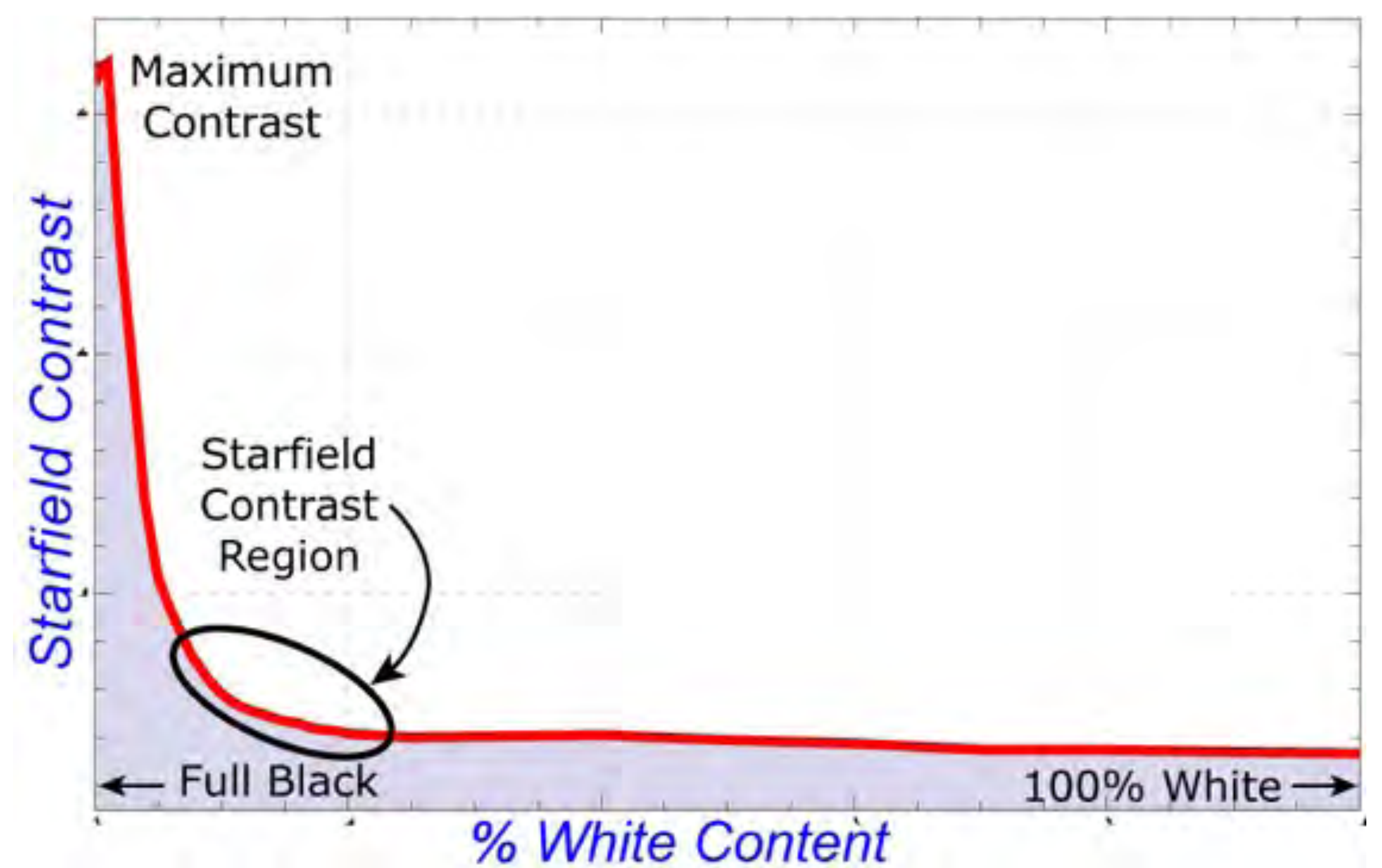


Starfield Contrast

—SAMPLE DATA ONLY—
Do not use any values shown to represent expected results of your measurements.

Table 2. Analysis Example:

Description	Value	Pattern
L_{Wmax}	255.6 cd/m^2	3
L_{Wmin}	51.68 cd/m^2	21
L_{Kmax}	0.252 cd/m^2	1
L_{Kmin}	0.0196 cd/m^2	21
Full Dynamic Contrast Range (C_{DC}) or (L_{Wmax} / L_{Kmin})	13,040	--
White Range Reduction Ratio (L_{Wmin} / L_{Wmax})	0.2022	--
Black Range Reduction Ratio (L_{Kmin} / L_{Kmax})	0.08	--
Starfield White (L_{Ksf})	242.4 cd/m^2	8
Starfield Black (L_{Ksf})	0.163 cd/m^2	
Starfield Contrast Ratio (C_s) or (L_{Wsf} / L_{Ksf})	1,478	--
Starfield Compression Ratio (C_{DC}/C_s)	8.823	
ICDM Starlight pattern set number	1	--



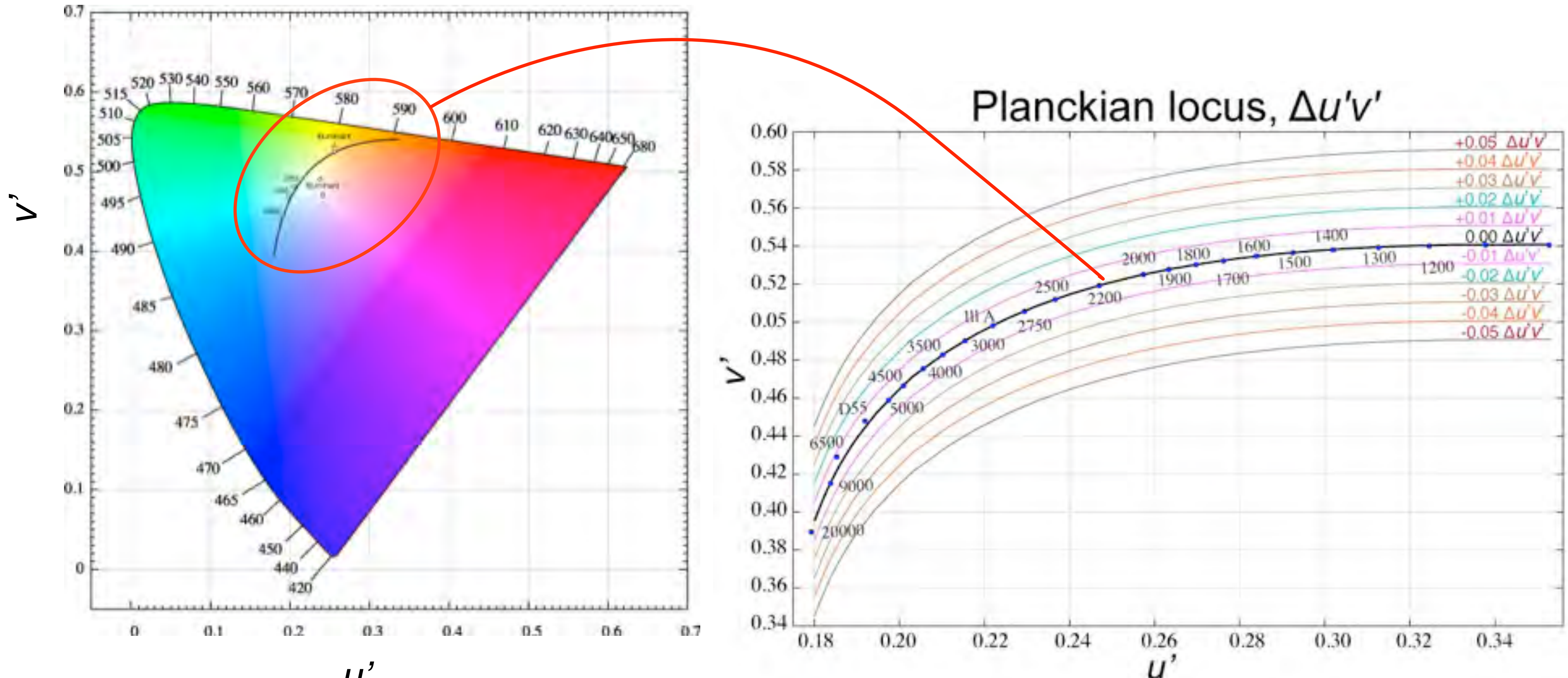
Starfield Contrast Curve

Sampling of measurements of the ICDM standard

- 3D - Stereo Displays
- Reflection
  - Ambient Contrast
- Low level contrast - Dynamic Contrast displays
  - Gamma for displays with global/local dimming (dynamic contrast)
  - Starfield contrast
- Color Characteristics — White point quality metric
  - CCT qualification based on $\Delta u'v'$

CCT and Delta u'v' Combined Metric

Validity or figure of merit for a white point in u'v' color space



We measure a white point (u'v') and we want to know how good it is as an indicator of white.

We can calculate CCT for any *u*'*v*' or *xy* value. CCT is meant to define a white point. Here is how we determine if it is a valid representative of a white point or not.

How to determine the validity of a white point in *u'v'* color space

1. Measure *u'v'* (u'_W u'_W) for the white point of interest.

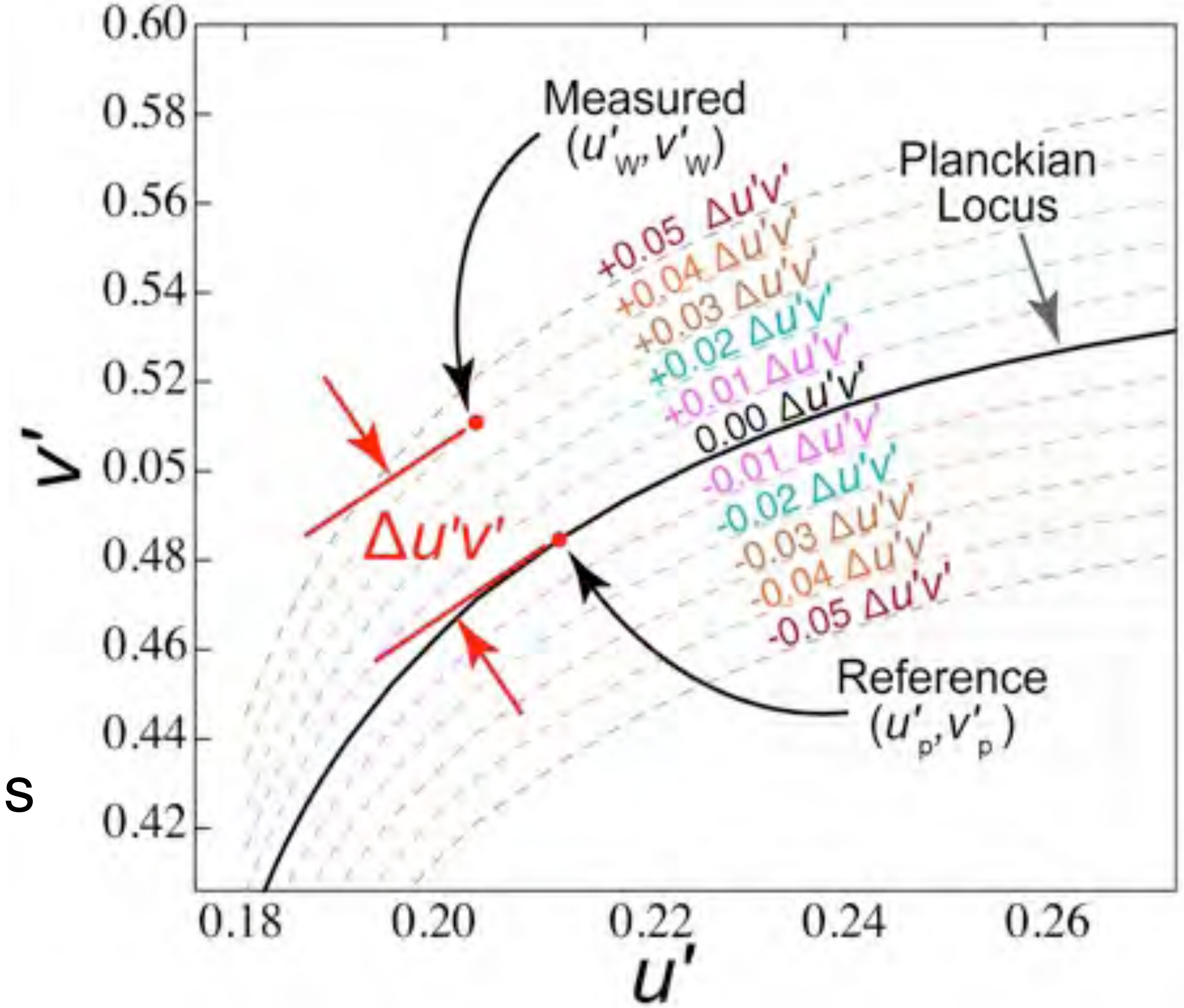
2. Calculate CCT from the measured u'_W u'_W points

$$T=\frac{(146413u'_W+59240)v'^2_W-179737u'_W(u'_W+0.01497)v'_W+51870(u'_W-0.18272)u'_W(u'_W+0.5793)-92673v'^3_W-21306v'_W+3133.5}{(0.5574u'_W-3.4864v'_W+1.1148)^3} \quad (1)$$

3. From the CCT (T) find the *u'v'* values for T that lie on the Planckian Locus by the following equations.

$$u'_p=\frac{(128.641\times10^{-9})T^2+(154.118\times10^{-6})T+860.118\times10^{-3}}{(708.145\times10^{-9})T^2+(842.42\times10^{-9})T+1}$$

$$v'_p=\frac{(63.0723\times10^{-9})T^2+(63.4209\times10^{-6})T+476.098\times10^{-3}}{(161.456\times10^{-9})T^2-(28.9742\times10^{-6})T+1}$$



4. Calculate delta *u'v'* to determine the distance of the measured *u'v'* (or CCT) from the Planckian locus

$$\Delta u'v'=\sqrt{(u'_p-u'_W)^2+(v'_p-v'_W)^2}$$

Summary

- The ICDM has written the most comprehensive Display Measurement Standard (DMS) ever produced in the display industry.
  - *It has more measurements and more categories of display measurements than any other display standard before it.*
- We look to make it usable and available to all.
- It will define the industry-leading language and methods for display measurements and metrology.
- It standardized many areas which have never had display metrology standards before.
- We welcome members who are interested in evaluation of displays.
- Today, we have shown a few examples of some of the metrology items we are addressing.
- Thank you for your attention.

SID Bay Area Chapter Presentation

The ICDM International Display Measurement Standard - SID's First Standard

at National Semiconductor
Santa Clara, November 9, 2011

Joe Miseli
Oracle