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Laser Based Projection Safety and Measures in Simulation

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September 24, 2015

Outline

- Laser Based Projection definitions and the latest safety classifications
  - Laser Illuminated Projectors (LIP)
  - Laser Phosphor light engine
  - Safety classification
    - IEC
    - FDA
- Speckle contrast Measurements
  - ICAO 9625 edition 3 / 4
  - Data from Sim

Solid State Light Sources (SSLC)

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- Solid state light sources are designed in four different basic architectures:
  1) All-Laser – uses red, green and blue lasers
  2) **Laser Phosphor** – uses blue lasers and a phosphor to create white, green or yellow light - JVC
  3) All LED – uses red, green and blue LEDs – Barco/eyevis
  4) Hybrid – uses a combination of LED and lasers
- Each of these approaches has its strengths and weaknesses – Solid state light sources can replace lamps in projectors using DLP, LCOS or LCD imagers.

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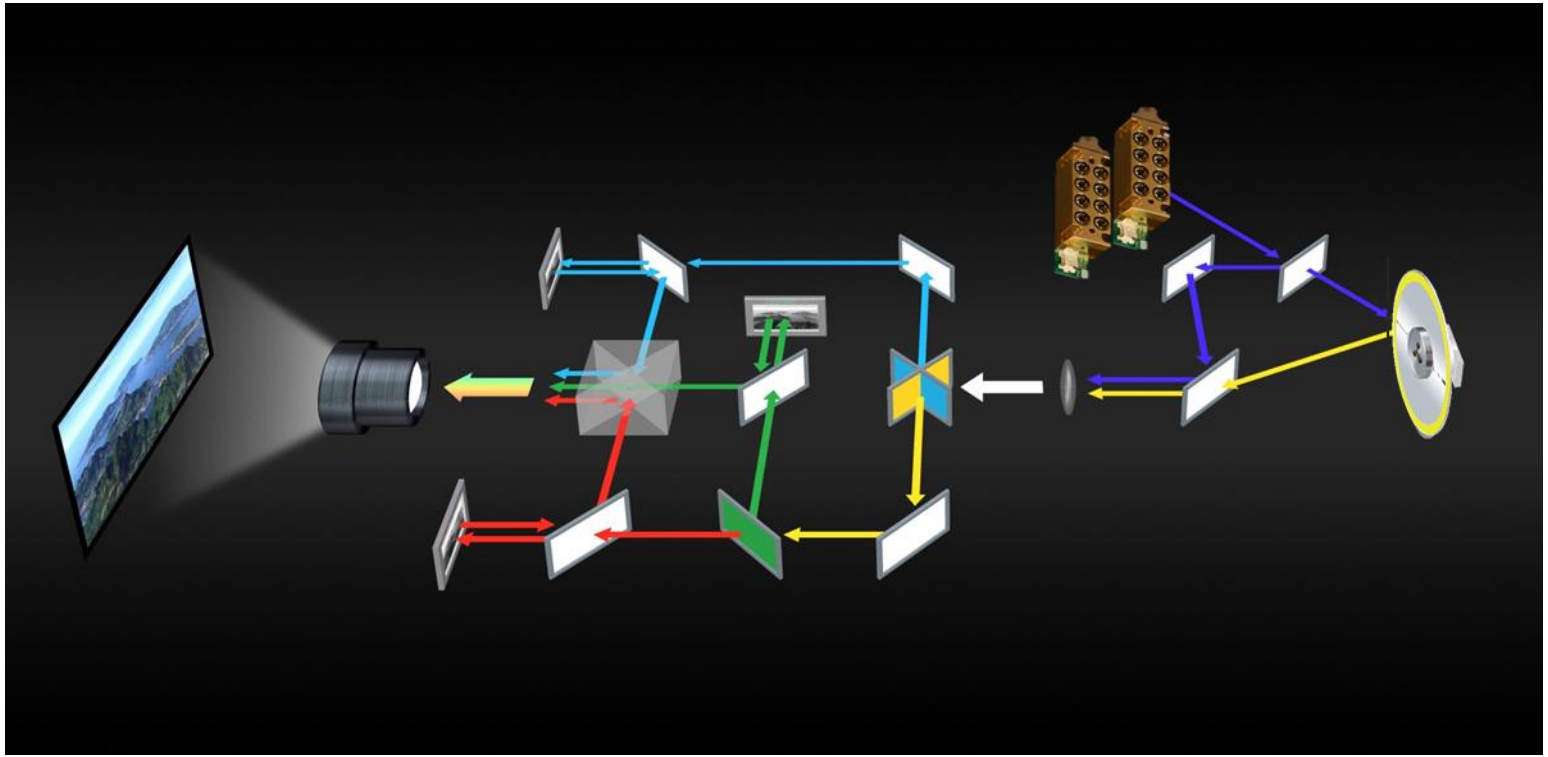
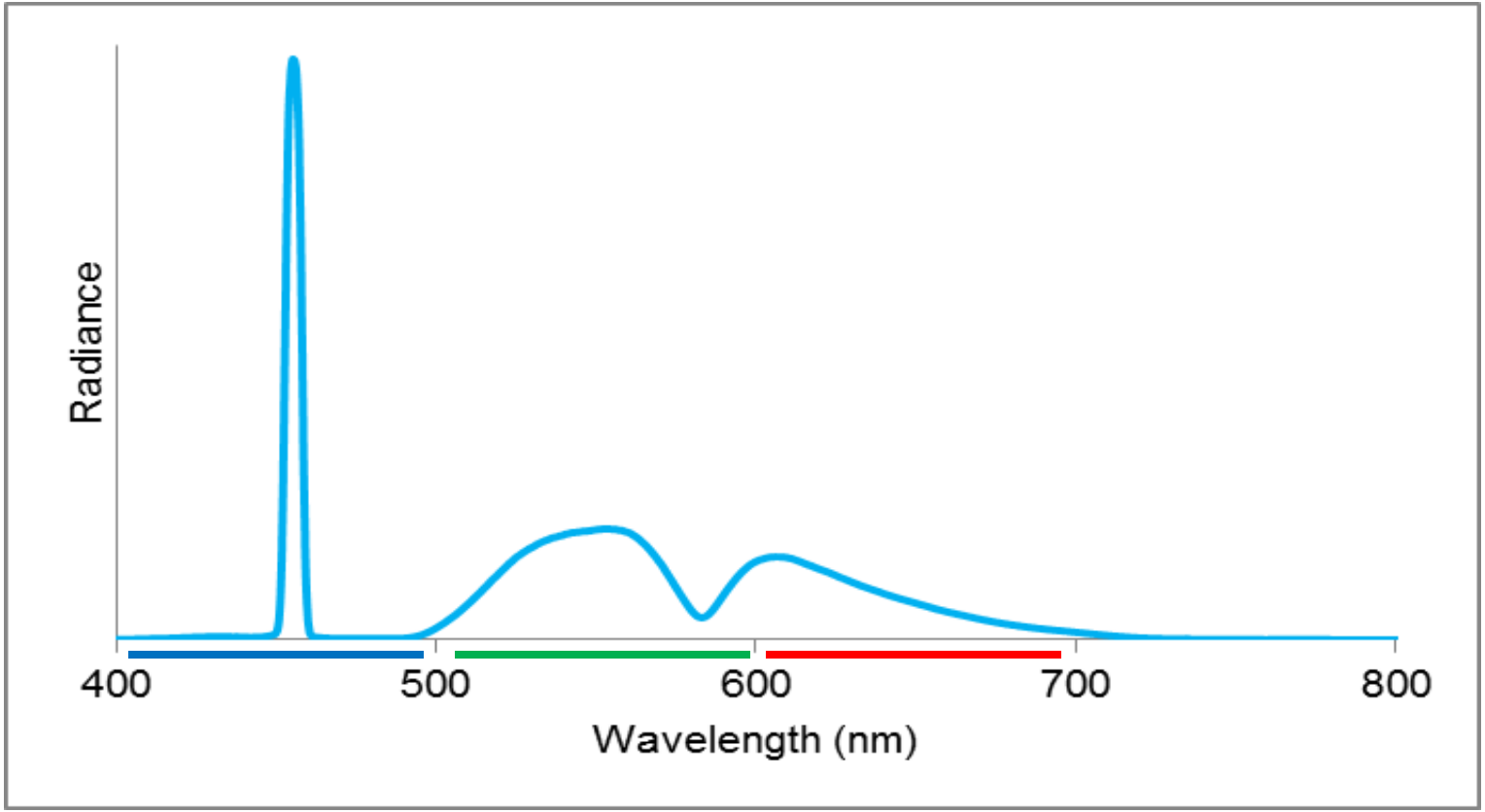
Laser Phosphor light engine – JVC VS2300



JVC, "*DLA-VS2300-VS2500 White Paper*" *(5)*

Laser Phosphor spectral scan



Advantages of SSLC

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- Longer lifetime over lamps
  - No lamps to change periodically
  - No recurring recalibration
- More stable light output
  - Long life diodes and phosphor
  - Feedback circuitry keeps RGBW constant
  - No touch-up of colors and brightness due to variations in lamp aging
- Reduced maintenance cost due to the above

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Additional Advantages of SSLC

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- Extends life of the Optics module and imaging devices
  - No UV to damage or shorten life in optical elements
  - No UV to damage imager
- Environmentally friendly
  - Mercury (Hg) free: Meets all regulatory requirements
  - ECO mode saves power and extends lifetime
  - Better light efficiency, lower power and HVAC

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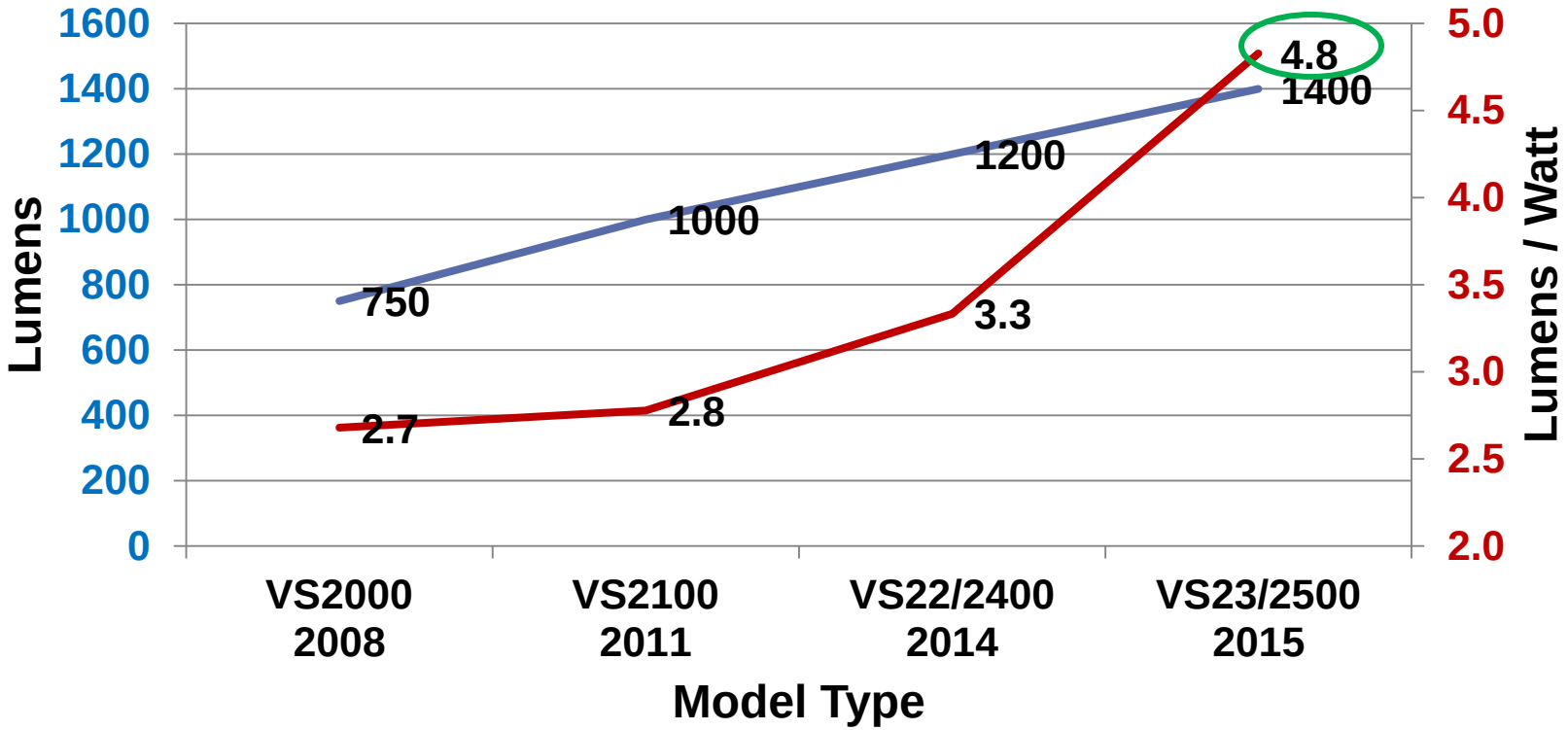
Higher efficiency of lamp based light source



Laser Illuminated Projectors (LIPs) - IEC

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- As defined by the **International Electrotechnical Commission** (IEC), Laser Illuminated Projectors, are no more dangerous than lamp based projectors
- From **Laser Illuminated Projector Association** (LIPA) :

  IEC – recently changed its categorization of laser illuminated projectors from a laser standard (60825-1:2014) to the lamp standard (IEC 62471). As of July 2015, the lamp standard contains a 'vertical' standard, IEC 62471-5, which directly addresses safety requirements for projectors. (LIPA website, 2015). This includes lamp, LED, and laser illumination
- FDA issues new **Guidance Document: Classification and Requirements for Laser Illuminated Projectors (LIPs) , Feb 18, 2015** which also reflects similar treatment for LIP

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Laser Illuminated Projectors (LIPs) - FDA

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- For purposes of this guidance, the term "**laser illuminated projector**" (LIP) refers to a type of demonstration **laser product** defined in 21 CFR 1040.10(b) that is **designed to project full-frame digital images.**

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Laser Illuminated Projectors (LIPs) - FDA

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- This guidance only applies to LIPs with extended source emissions that meet all of the following criteria:
  - (a) The projector is neither a children's toy laser product nor a medical device.
  - (b) **The projector does not produce scanned laser radiation.**
  - (c) **The projector's laser illumination system is an alternative to a conventional projector light source.**
  - (d) The apparent light source subtends an angle greater than or equal to 0.005 radians (rad), when determined at a distance of 0.2 meter from the nearest point of human access6 (see Par. 6 of IEC 62471:2006).
  - (e) **The emissions are only within the visible wavelength range of 400 nm to 700 nm.**
  - (f) The unweighted peak radiance levels do not exceed 1 MW * m-2 sr-1/α where α is the angular subtense of the source at 0.2 m from the closest distance of human access and the radiance is averaged over a 0.0017 rad acceptance angle (see Par. 4.2.2 of IEC 62471:2006).

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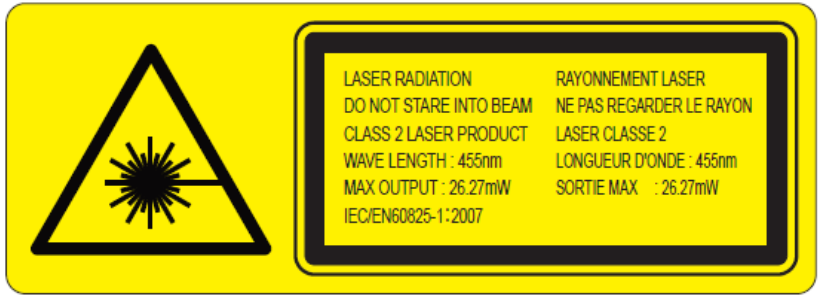
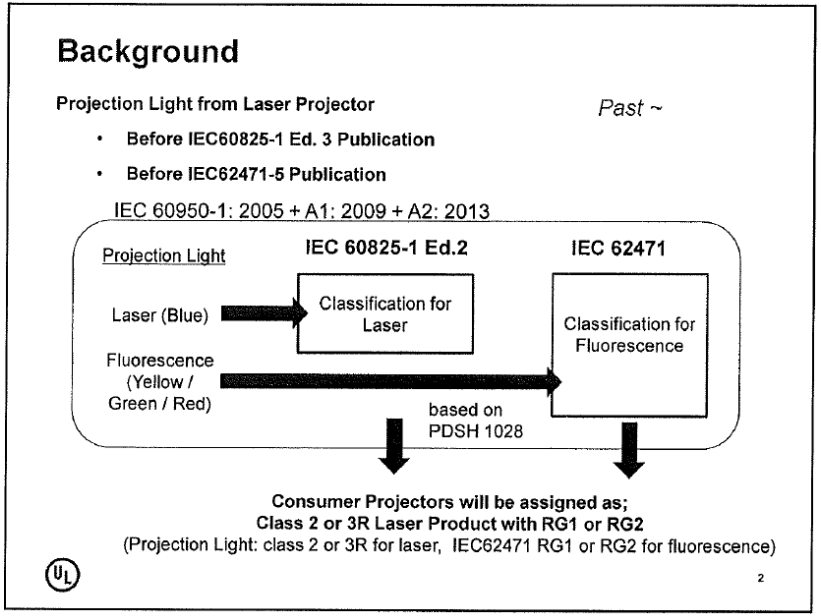
DLA-VS2300/2500 Laser details



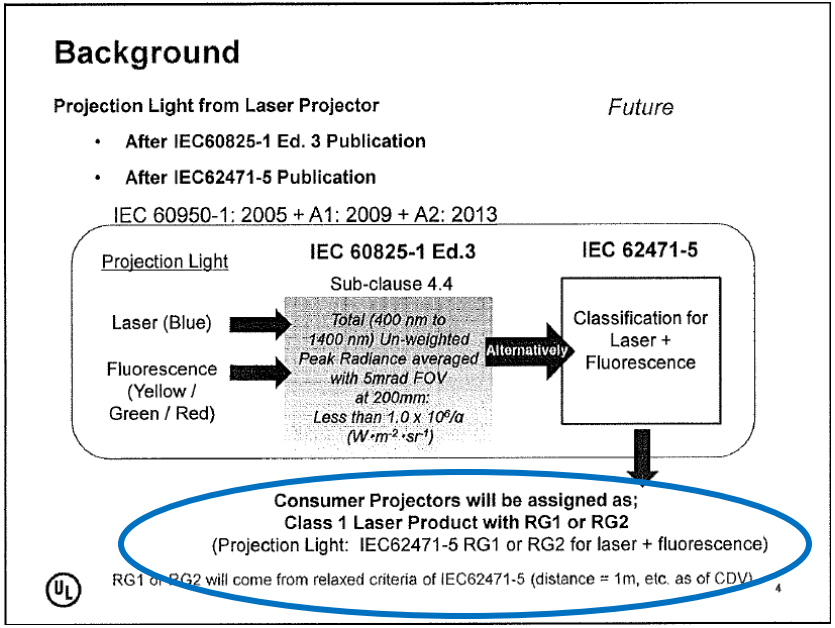
- Light source specifications
  - 30 W Laser diodes ×2
  - Dominant wavelength 455nm
  - Maximum output 27.27mW
- Under old classification these projectors are Class 2 laser

New FDA laser Classification

Original JVC VS2300 - Class 2



New JVC VS2300 - Class 1 Risk 2



FDA Risk Categories

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EN 62471:2008 sources of optical radiation are classified into risk groups

Risk Group	Philosophical Basis
Exempt	No photobiological hazard
Group 1 (Low-Risk)	No photobiological hazard under normal behavioral limitations
Group 2 (Moderate-Risk)	Does not pose a hazard due to aversion response to bright light or thermal discomfort
Group 3 (High-Risk)	Hazardous even for momentary exposure

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What does this mean

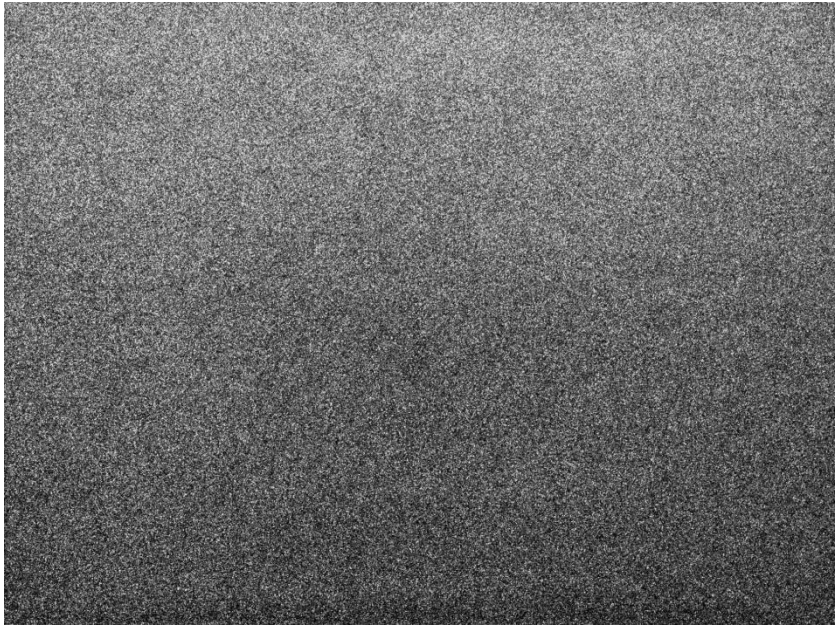
- Your normal eye “blink reflex” protects your eye just as a lamp based projector
- Projector is interlocked to prevent direct laser contact
- No special shielding is required
- Treat just like a standard lamp based projector

What is Speckle

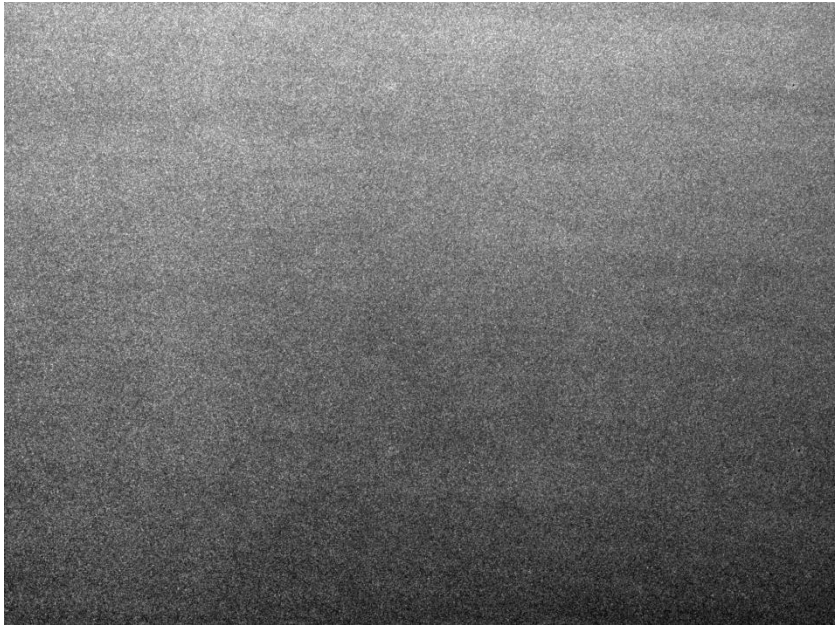
- **Speckle** refers to a random granular pattern which can be observed e.g. when a highly coherent light beam (e.g. from a **laser**) is diffusely reflected at a surface with a complicated (rough) structure, such as a piece of paper, white paint, a display screen, or a metallic surface.
- **Encyclopedia of Laser Physics and Technology - speckle ...**
- *https://www.rp-photonics.com/**speckle**.html*

What does Speckle look like

Speckle ~15%



Speckle ~5%



Coherence Length for two types of non laser displays

	9“ CRT Projector	.9" Diagonal LCOS
Screen Width (inches)	54	54
Object Width (inches)	6	0.72
f/#	1	2.7
Magnification	9.0	75.0
Pupil Size (inches)	4.3	0.2
Coherence Length (µm)	6.0	135.9

(from Goldenberg, SPIE Vol. 3013 [1])

ICAO 9625 3rd Edition – Speckle Contrast

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- 3.6.4 *Laser speckle contrast ratio (Laser Projection system)*

$$C = \frac{\sqrt{m \cdot n \cdot \sum_{FOV} I_{m,n}^2 - \left(\sum_{FOV} I_{m,n} \right)^2}}{\sum_{FOV} I_{m,n}}$$

- Work done by Rheinmetall and submitted by Jochan Osterman, 2007

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ICAO 9625 3rd Edition Speckle Contrast Spec

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- Per ICAO manual, if Speckle contrast C <10%, then no affect on resolution or focus
- Actual measured Speckle Contrast:
  - **Laser Phosphor – 4.67%**
  - **VS2400 lamp – 5.17%**
  - Note: error in measurement is estimated to be between 1-2%
  - *Details see IMAGE2015 paper "SPECKLE CONTRAST MEASUREMENTS OF A LASER HYBRID LCOS PROJECTOR " (3)*

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Measurements in SIM

ProFlight Sim II / RSI Visual

Visual Specifications

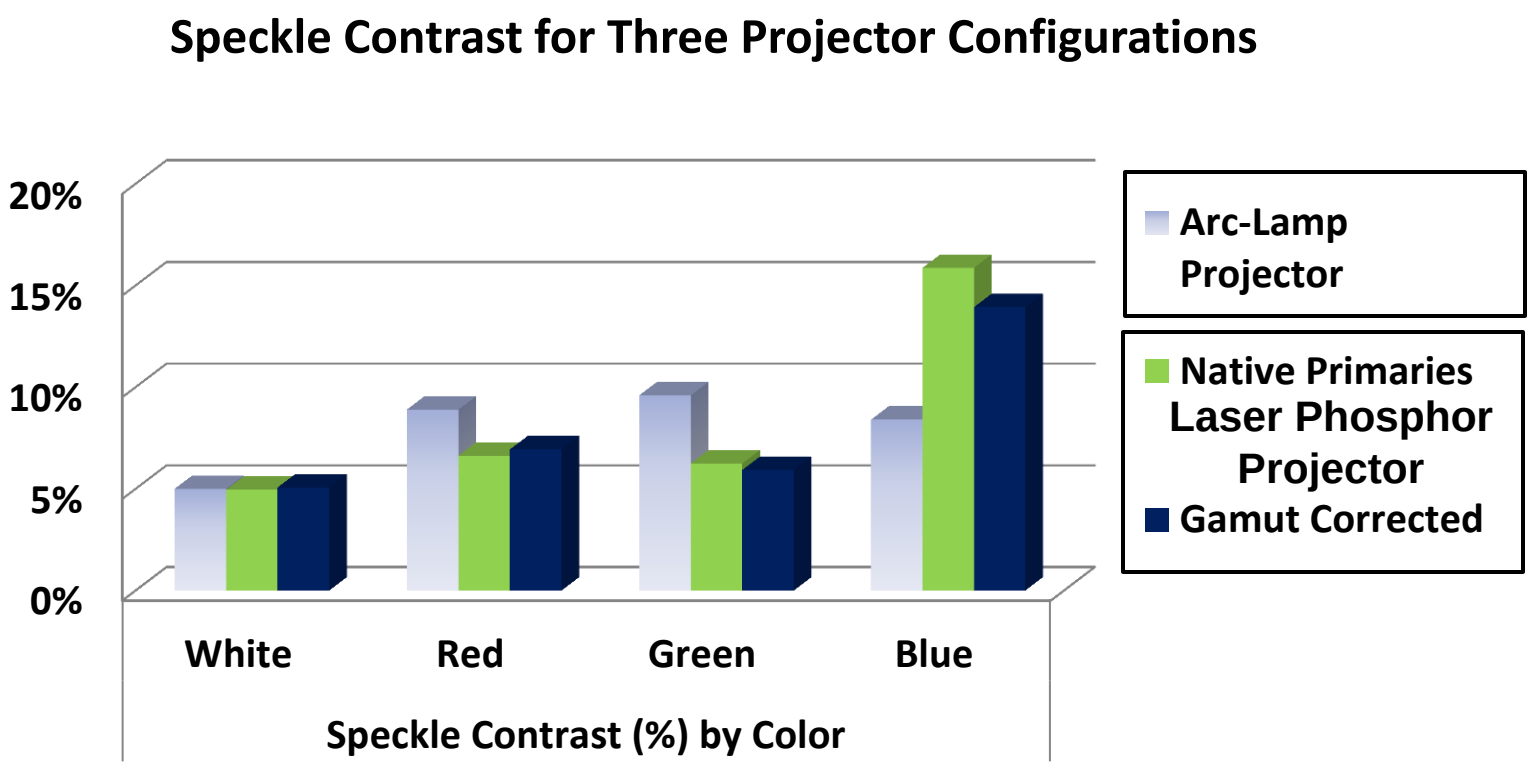
Characteristic	Value
Mirror Radius	9 ft.
Field of View	200ºx40º
Screen Type	Front Projected
Screen Gain	0.6 to 0.7
Brightness @ eye point	6.6 ft. L

Data supplied by RSI

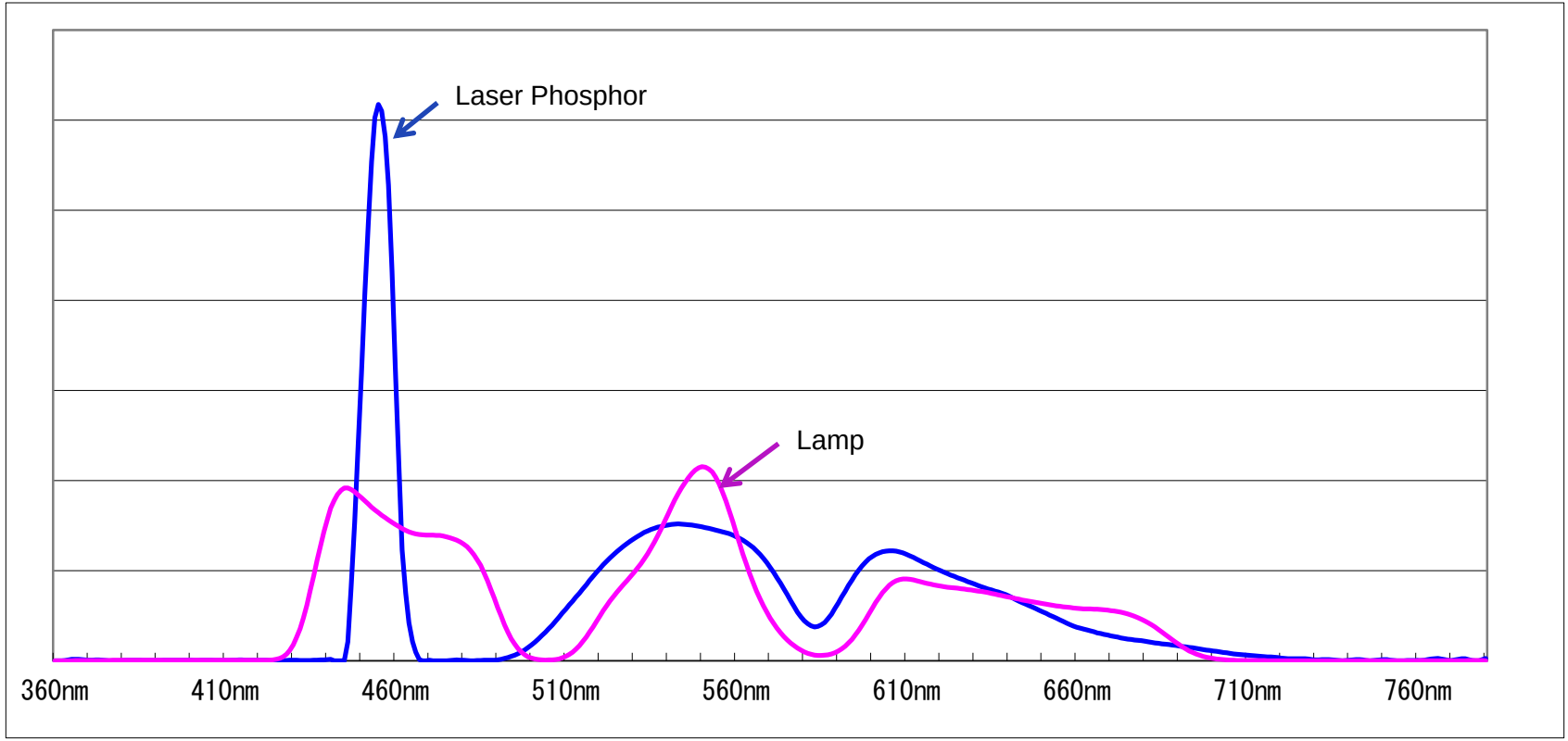
Data Collection

- Lamp data was taken on JVC DLA-VS2100, DLA-VS2200 and DLA-VS2400 projectors
- Laser Phosphor data was taken on JVC DLA-VS2500 “BLUEscent” projector (5)
- Screens used were from Stewart® Filmscreen and Draper®
- Test were taken in ProFlight Sim II civil simulator with RSI visual
- For more details, reference IMAGE2015 papers (3), (4)

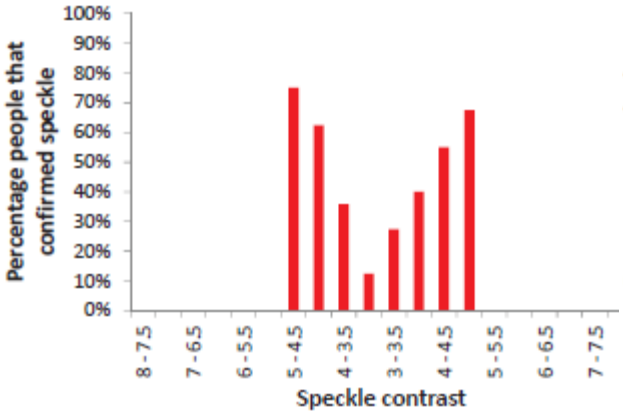
Speckle Contrast for Lamp and Laser Projectors

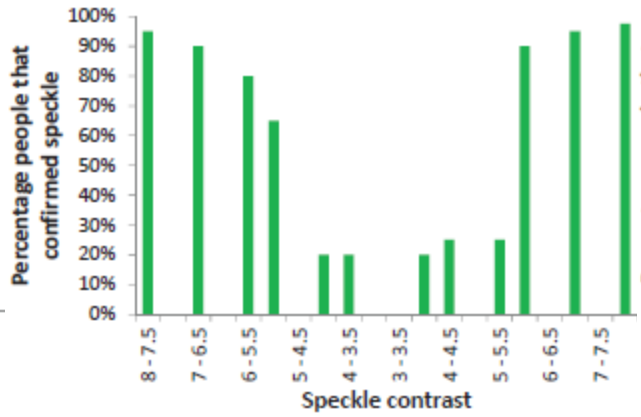


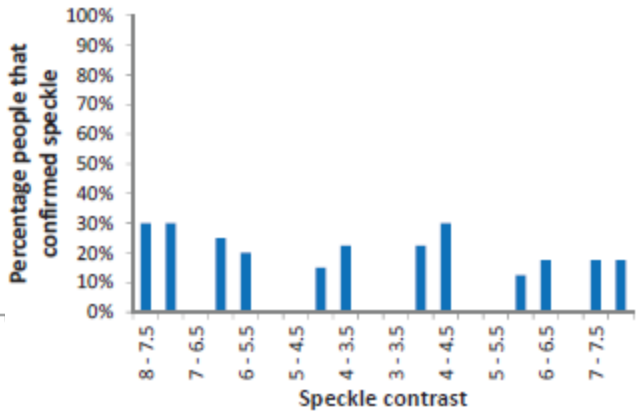
Laser Phosphor vs Lamp spectrum



Speckle Contrast Perception by Color

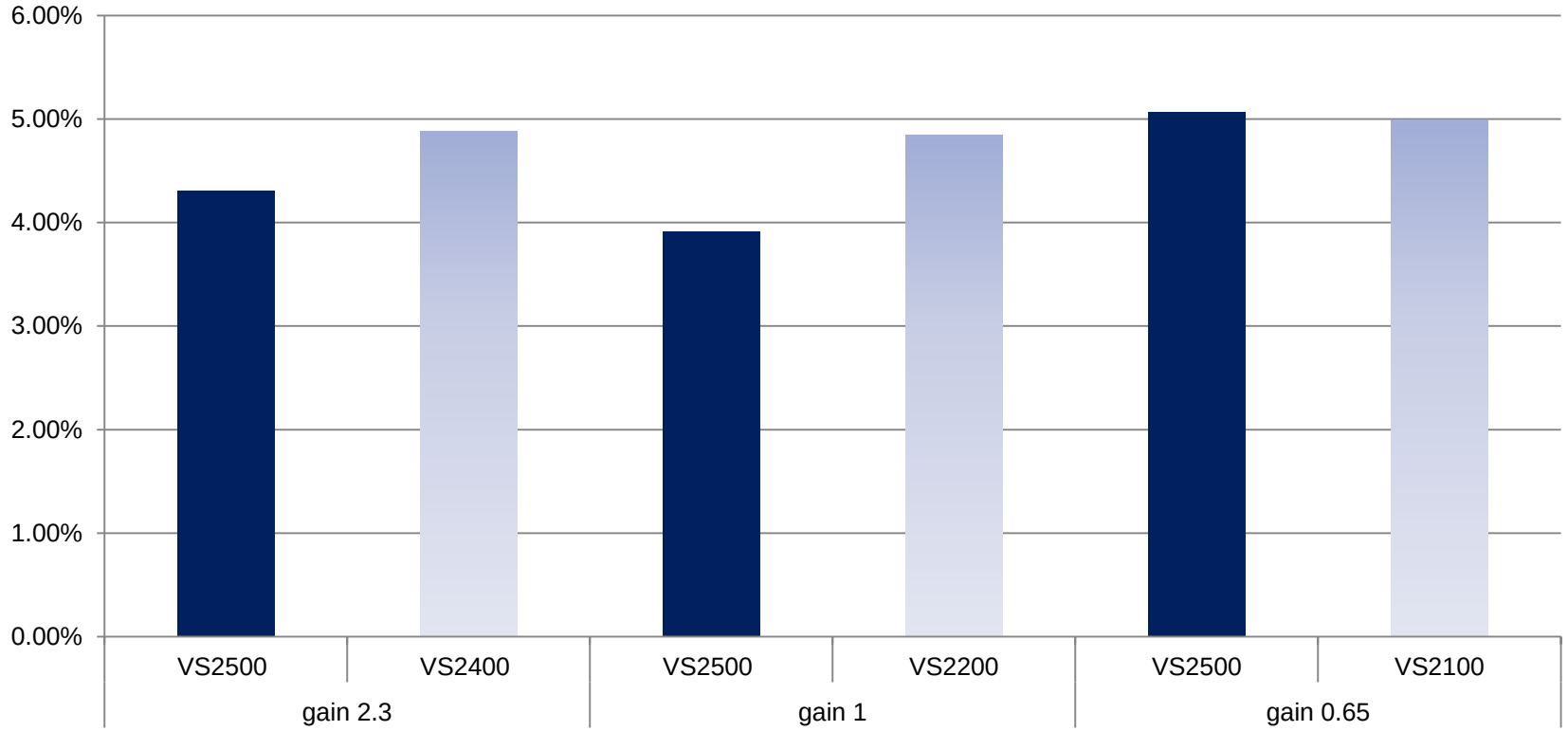






- Green and Red perceptive speckle much stronger than Blue. Most people in study did not see blue speckle.
- Roelandt (2)

Speckle Contrast vs Screen Gain



Summary

- Latest guidelines from IEC and FDA treat Laser Illuminated Projectors (LIP) below certain power levels, the same as Lamp and LED projectors
- Current Laser Phosphor projectors exceed ICAO laser speckle standard
- Lamp and Laser Phosphor are not statistically different from each other
- Screen difference is only about 1% variation on screens measured

Acknowledgments

- Mark Bushaw at ProFlight for use of the sim
- Jeff Everett at RSI for the Visual specifications
- Dennis Hartley at Rockwell Collins for FAA and ICAO insights

Papers and references

1. Goldenberg, “Rear Projection Screens for Light Valve Projection System”, SPIE Vol. 3013
2. Roelandt, “*Standardized speckle measurement method matched to human speckle perception in laser projection systems*” Optical Society of America, 2013
3. Sterling, Streid, Mihalco, “*SPECKLE CONTRAST MEASUREMENTS OF A LASER HYBRID LCOS PROJECTOR”,* IMAGE2015
4. Sterling, “*SOLID STATE, LASER HYBRID LIGHT ENGINE IN A LCOS PROJECTOR*”, IMAGE2015
5. JVC, “*DLA-VS2300-VS2500 White Paper”,* *http://pro.jvc.com/prof/attributes/color_broch.jsp?model_id=MDL102324&feature_id=12*