Laser Based Projection Safety and Measures in Simulation

Rod Sterling
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)

• 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.
Laser Phosphor light engine – JVC VS2300

JVC, “DLA-VS2300-VS2500 White Paper” (5)
Laser Phosphor spectral scan
Advantages of SSLC

• 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
Additional Advantages of SSLC

• 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
Higher efficiency of lamp based light source

![Graph showing lumens per watt for different model types of lamps: VS2000 (2008), VS2100 (2011), VS22/2400 (2014), VS23/2500 (2015). The graph displays an increase in lumens and lumens per watt over time.]
Laser Illuminated Projectors (LIPs) - IEC

- 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.
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.
• 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 access (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 $1 \text{ MW} \cdot \text{m}^{-2} \cdot \text{sr}^{-1}/\alpha$ where $\alpha$ 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).
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

Background

- Projection Light from Laser Projector
  - Before IEC60825-1 Ed. 3 Publication
  - Before IEC62471-5 Publication


Past ~

No Laser (Blue) or Fluorescence (Yellow / Green / Red)

Based on PDSH 1028

Classification for Laser

Classification for Fluorescence

Consumer Projectors will be assigned as:
Class 2 or 3R Laser Product with RG1 or RG2
(Projection Light: class 2 or 3R for laser, IEC62471 RG1 or RG2 for fluorescence)

New JVC VS2300 - Class 1 Risk 2

Background

- Projection Light from Laser Projector
  - After IEC60825-1 Ed. 3 Publication
  - After IEC62471-5 Publication


Future

Sub-clause 4.4

Total (400 pm to 1100 nm) Un-weighted Peak Radiance averaged with Spatial FOV
at 200mm

Less than 1.0 x 10^4 (W/m^2*sr)

No Laser (Blue) or Fluorescence (Yellow / Green / Red)

Alternative

Classification for Laser + Fluorescence

Consumer Projectors will be assigned as:
Class 1 Laser Product with RG1 or RG2
(Projection Light: IEC62471-5 RG1 or RG2 for laser + fluorescence)

RG1 or RG2 will come from relaxed criteria of IEC62471-5 (distance = 1m, etc. as of CDW).
FDA Risk Categories

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

<table>
<thead>
<tr>
<th>Risk Group</th>
<th>Philosophical Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exempt</td>
<td>No photobiological hazard</td>
</tr>
<tr>
<td>Group 1 (Low-Risk)</td>
<td>No photobiological hazard under normal behavioral limitations</td>
</tr>
<tr>
<td>Group 2 (Moderate-Risk)</td>
<td>Does not pose a hazard due to aversion response to bright light or thermal discomfort</td>
</tr>
<tr>
<td>Group 3 (High-Risk)</td>
<td>Hazardous even for momentary exposure</td>
</tr>
</tbody>
</table>
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](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

<table>
<thead>
<tr>
<th></th>
<th>9” CRT Projector</th>
<th>.9” Diagonal LCOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen Width (inches)</td>
<td>54</td>
<td>54</td>
</tr>
<tr>
<td>Object Width (inches)</td>
<td>6</td>
<td>0.72</td>
</tr>
<tr>
<td>f/#</td>
<td>1</td>
<td>2.7</td>
</tr>
<tr>
<td>Magnification</td>
<td>9.0</td>
<td>75.0</td>
</tr>
<tr>
<td>Pupil Size (inches)</td>
<td>4.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Coherence Length (μm)</td>
<td>6.0</td>
<td>135.9</td>
</tr>
</tbody>
</table>

(from Goldenberg, SPIE Vol. 3013 [1])
3.6.4 Laser speckle contrast ratio (Laser Projection system)

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

- Work done by Rheinmetall and submitted by Jochan Osterman, 2007
ICAO 9625 3rd Edition Speckle Contrast Spec

• 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)
Measurements in SIM

ProFlight Sim II / RSI Visual
## Visual Specifications

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mirror Radius</td>
<td>9 ft.</td>
</tr>
<tr>
<td>Field of View</td>
<td>200°x40°</td>
</tr>
<tr>
<td>Screen Type</td>
<td>Front Projected</td>
</tr>
<tr>
<td>Screen Gain</td>
<td>0.6 to 0.7</td>
</tr>
<tr>
<td>Brightness @ eye point</td>
<td>6.6 ft. L</td>
</tr>
</tbody>
</table>

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 Three Projector Configurations

Speckle Contrast (%) by Color

- White
- Red
- Green
- Blue

Arc-Lamp Projector

Native Primaries Laser Phosphor Projector

Gamut Corrected
Laser Phosphor vs Lamp spectrum

- Laser Phosphor
- Lamp
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

<table>
<thead>
<tr>
<th>Model</th>
<th>Gain</th>
<th>Contrast (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VS2500</td>
<td>2.3</td>
<td>4.00%</td>
</tr>
<tr>
<td>VS2400</td>
<td>1</td>
<td>6.00%</td>
</tr>
<tr>
<td>VS2500</td>
<td>0.65</td>
<td>5.00%</td>
</tr>
<tr>
<td>VS2200</td>
<td></td>
<td>0.00%</td>
</tr>
<tr>
<td>VS2500</td>
<td></td>
<td>1.00%</td>
</tr>
<tr>
<td>VS2100</td>
<td></td>
<td>2.00%</td>
</tr>
</tbody>
</table>
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


4. Sterling, “SOLID STATE, LASER HYBRID LIGHT ENGINE IN A LCOS PROJECTOR”, IMAGE2015