IMAGE 2022 Conference

SPECKLE CHARACTERISTICS OF TRUE SOLID-STATE ILLUMINATION TECHNOLOGY PROJECTORS

Primary Author: Craig Maddock
Norxe
Dokka 6, 1671, Fredrikstad, Norway

Co-Author Name: Kjell Einar Olsen
Norxe
Dokka 6, 1671, Fredrikstad, Norway

Co-Author Name: Tobby Simonsen
Norxe
Dokka 6, 1671, Fredrikstad, Norway

ABSTRACT

Speckle is visible noise within a projected image. It is best described as a shimmering or sparkle effect. Speckle severity can vary depending upon illumination source, optical architecture, projection screen and viewer perception.

Speckle occurs when a rough surface (optical component or projection screen) is illuminated by coherent (constant phase difference, constant frequency, constant waveform) light. Speckle is present in all illumination sources, albeit in varying degrees of intensity.

In this paper Norxe discusses the speckle characteristics of true solid-state illumination technology simulation projectors. It explains what the artefact is, why it occurs and how it should be measured – most notably that some solid-state illumination technology projectors and projection screen combinations exhibit noticeably less speckle than others.

INTRODUCTION

The design team behind Norxe's products have been working in the projection industry for more than 3 decades and has designed more than 20 different projector platforms based on LCD, LCoS and DLP imaging device technology and various illumination sources (lamp - Halogen, HID, UHP, LED and LASER).

Based upon this wealth of experience, Norxe has chosen single chip DLP as the imaging device and true solid-state as the illumination technology. Both technologies provide long life and low maintenance (true solid-state illumination technology has no moving parts within the optical engine).

BACKGROUND

Speckle is present in all illumination sources, albeit in varying degrees of intensity.

Speckle occurs when a rough surface (optical component or projection screen) is illuminated by coherent (constant phase difference, constant frequency, constant waveform) light.

Excessive speckle disturbance within a simulation visual display is undesirable and ultimately degrades perceived display resolution.

Speckle distractive modulation artefacts can be broken down into two categories as follows:

<u>Subjective Speckle.</u>
Subjective Speckle structure changes according to viewing parameters.

- Lens aperture (F#) which effects speckle pattern size.
- Image content change which induces speckle pattern change.
- An individual viewers perception.

<u>Objective speckle.</u>
Objective speckle pattern structure occurs when light is scattered off one rough surface onto another. The resultant pattern is fixed.

- A speckle diffuser in itself is a rough surface which scatters light. The diffuser itself may subsequently create a static pattern.

Presented at the **IMAGE 2022** Conference
Dayton, Ohio – 20-21 September 2022

Simulation centric display users are increasingly '*speckle aware*'. They understand the subjective nature of the associated artefacts and subsequently the requirement to measure speckle contrast using calibrated camera equipment in accordance with recommended practices.

The 'European Union Aviation Safety Agency - Notice of Proposed Amendment 2020-15. Update of the flight training device requirements RMT.0196' document and 'Doc 9625. Manual of Criteria for the Qualification of Flight Simulation Training Devices. Volume 1 – Aeroplanes. Fourth Edition, 2015' both advise that measurement is generally only required for LASER illumination technology projectors whilst stipulating that respective speckle contrast should be < 10%.

The Laser Illuminated Projector Association (LIPA) Measurement of Speckle in Laboratory Conditions document provides measurement process, test equipment and result calculation instruction and is increasingly recognized as the de facto standard for speckle contrast measurement.

NORXE SOLID-STATE ILLUMINATION TECHNOLOGY PROJECTORS & PROJECTION LENS OPTIONS

Norxe true solid-state illumination projection technology features no moving parts within the optical engine and utilizes RGB primary color illumination sources.

Primary colors are emitted directly from the light source itself; white is the sum of red, green and blue. Colors are subsequently vibrant and highly saturated. This is especially relevant for simulation centric visual displays which focus on accurately recreating real world training scenarios to exacting standards.

Norxe projection lens options comprise all glass, aspherical, no doublet optical elements. Lenses are designed for F# 2.2 with minimal working variation (Zoom position dependent) to project high resolution, high trans-mittance, low distortion, minimum Chromatic Aberration content.

TEST ENVIRONMENT, TEST EQUIPMENT, SPECKLE CONTRAST MEASUREMENT & CALCULATION PROCESS

Test Environment:
Norxe Optics Development Laboratory at Dokka 6, Fredrikstad, Norway.

Test Equipment:

- 1 x Norxe P2 WQXGA resolution, 5,000 lumen projector (with RGB LASER illumination sources) and N1 projection lens.
  - Projector RGB Power (luminous intensity) = 100%.
  - Projector Native White Point x = 0.300, y = 0.340
  - N1 projection lens set to the wide angle (0.8:1) zoom position. F#2.2.
- 1 x Norxe P1+ WQXGA resolution, 3,000 lumen projector (with RGB LED illumination sources) and N1 projection lens.
  - Projector RGB Power (luminous intensity) = 100%.
  - Projector Native White Point x = 0.300, y = 0.340
  - N1 projection lens set to the wide angle (0.8:1) Zoom position. F#2.2.

- 1 x Norxe 'concept' 4K resolution, 5,500 lumen projector (with RGB LASER illumination sources) and N1 projection lens.
  - Projector RGB Power (luminous intensity) = 100%.
  - Projector Native White Point x = 0.300, y = 0.340
  - N1 projection lens set to the wide angle (0.7:1) Zoom position. F#2.2.
- 1 x calibrated Sony DCU224M Measurement Camera with ICX 204 Sensor and Tripod mount.
- Various manufacturer supplied COTS front and rear projection screen samples which for the purpose of this paper will not be identified beyond their type, Gain (reflectivity rating) and sample reference.

Speckle Contrast Measurement Process:
The following measurements were performed in accordance with the LIPA Measurement of Speckle in Laboratory Conditions document Chapter 5 and Appendices 3-7.

The LIPA Measurement of Speckle in Laboratory Conditions document was created for Digital Cinema applications. It states that any speckle contrast measurement is performed using a 12m wide (DCI Format) front projection screen and that camera Throw Distance equals projection screen height.

On the basis that this size and format projection screen is not relevant to applications outside of Digital Cinema the projection screen samples, and respective camera Throw Distance used by Norxe were as follows:

- Front projection screen sample height = 1.24m, camera to projection screen Throw Distance = 1.24m.
- Projector and camera placement relative to the projection screen sample were as per Illustration Fig. 1 below.

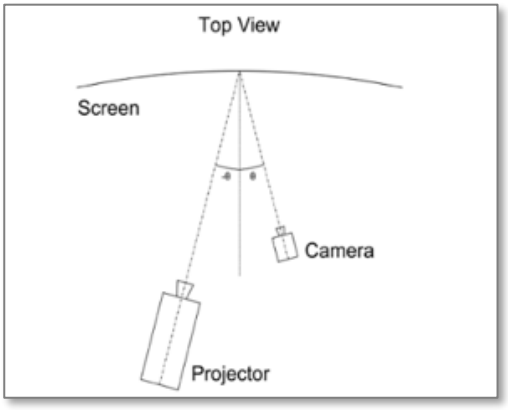


Illustration Fig. 1

- Rear projection screen sample height = 0.60m, camera to projection screen Throw Distance = 0.60m.
- Projector and camera placement relative to the projection screen sample were as per Illustration Fig. 2 below.

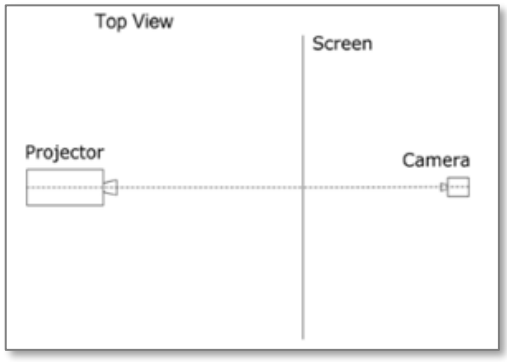


Illustration Fig. 2

Sony DCU224M Measurement Camera settings:

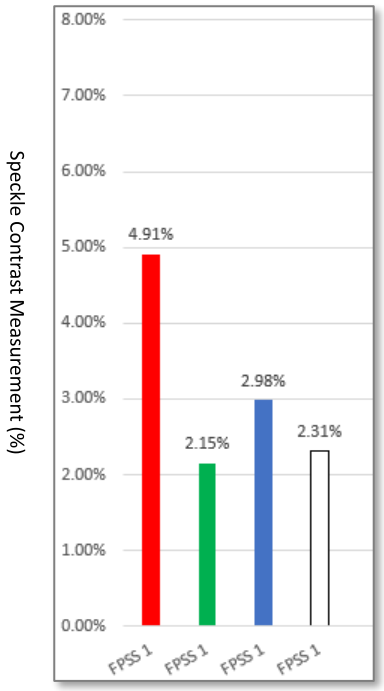
Pupil size (mm)	4
Pixel six (micrometres)	4.65
Focal Length	16
F#	4
Integration time	50
Oversample factor	0.58

Speckle Contrast Calculation Process:
Speckle contrast calculations performed in accordance with the LIPA Measurement of Speckle in Laboratory Conditions document using the following speckle contrast calculation in conjunction with a PYTHON 3.X script to calculate speckle contrast from greyscale bitmap images.

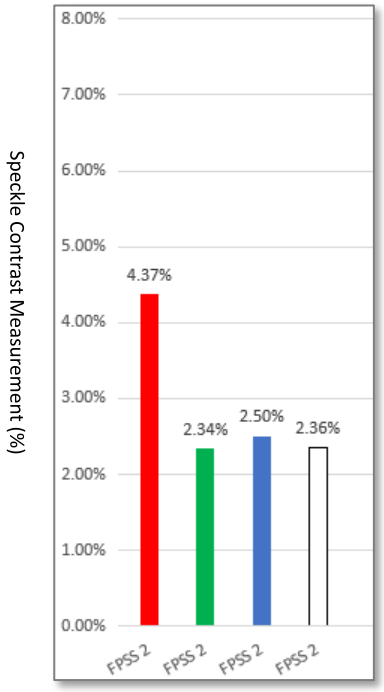
$$C_s = \frac{\sigma_{corrected}}{<I>}$$

P2 PROJECTOR FRONT PROJECTION SCREEN SAMPLE RGBW TEST RESULTS

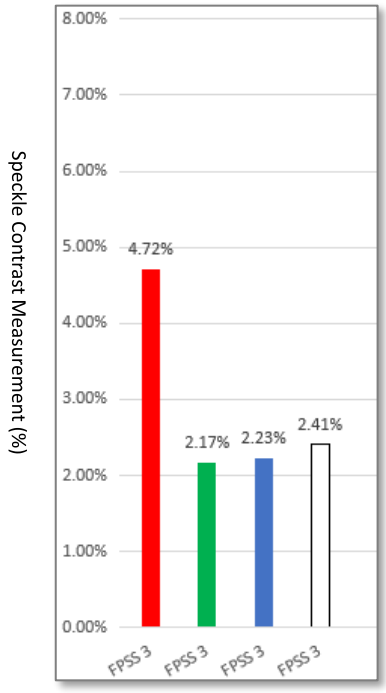
- Front Projection Screen Sample (FPSS) 1 - Fabric Surface, 0.5 Gain:



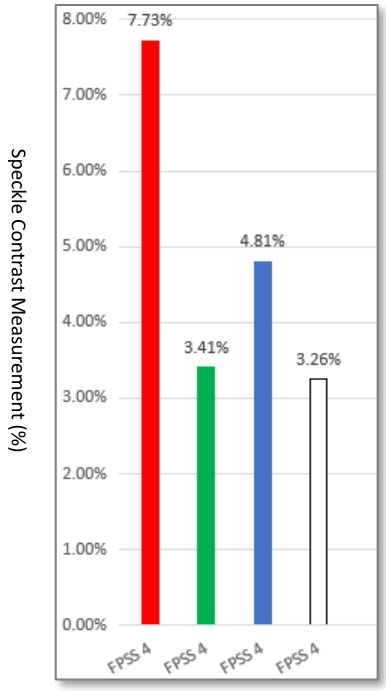
- Front Projection Screen Sample (FPSS) 2 - Fabric Surface, 0.9 Gain:



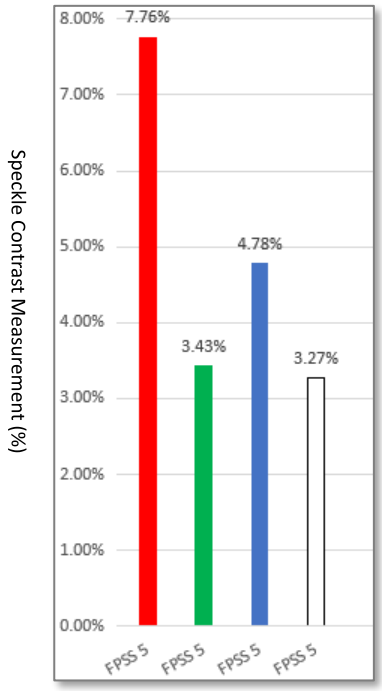
Front Projection Screen Sample (FPSS) 3 - Solid Surface, 1.0 Gain:



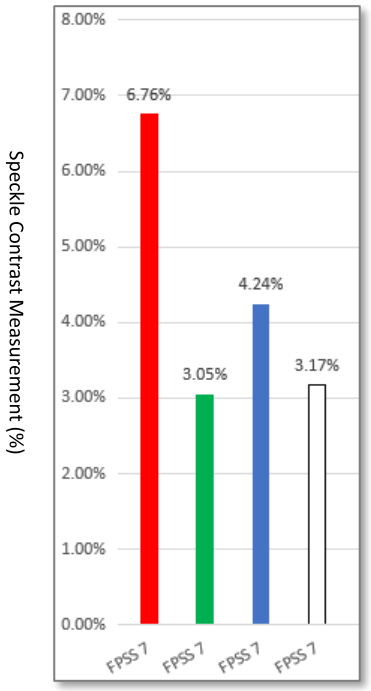
Front Projection Screen Sample (FPSS) 4 - Solid Painted Surface, 0.6 Gain:



Front Projection Screen Sample (FPSS) 5 - Solid Painted Surface, 0.7 Gain:

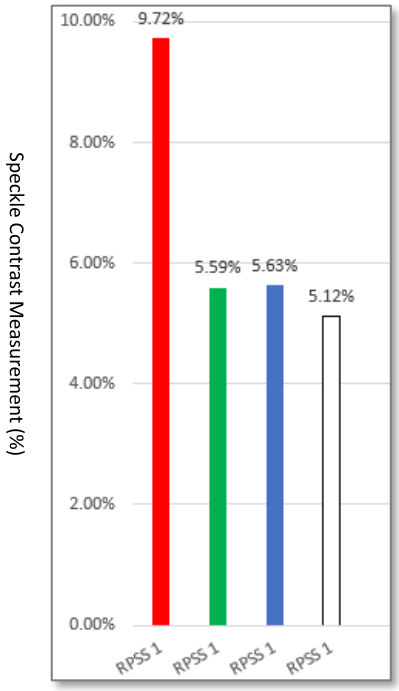


Front Projection Screen Sample (FPSS) 6 - Solid Painted Surface, 1.0 Gain:

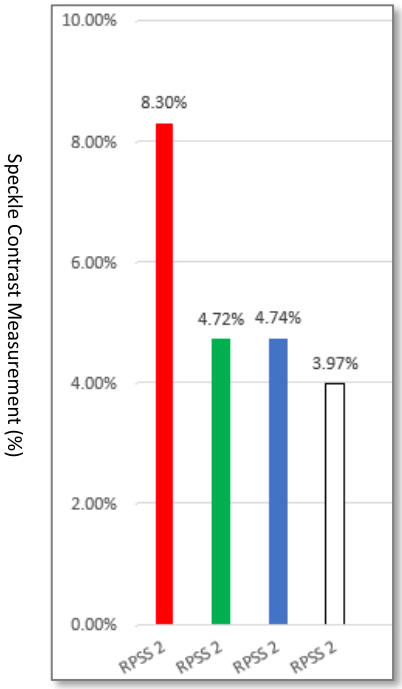


P2 PROJECTOR REAR PROJECTION SCREEN SAMPLE RGBW TEST RESULTS

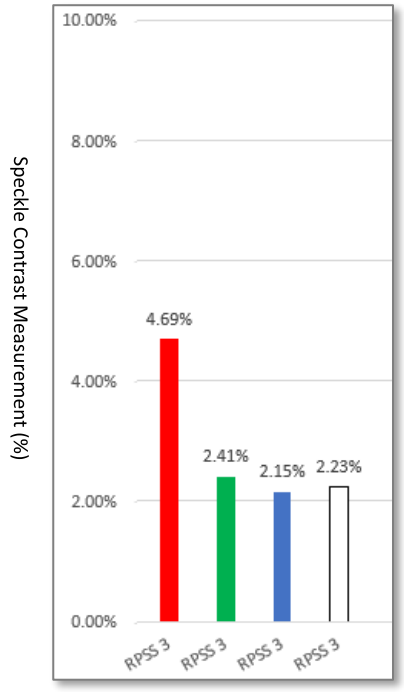
Rear Projection Screen Sample (RPSS) 1:



Rear Projection Screen Sample (RPSS) 2:

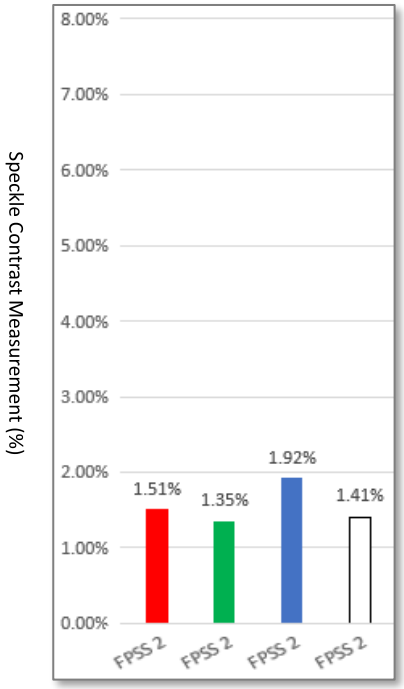


Rear Projection Screen Sample (RPSS) 3:



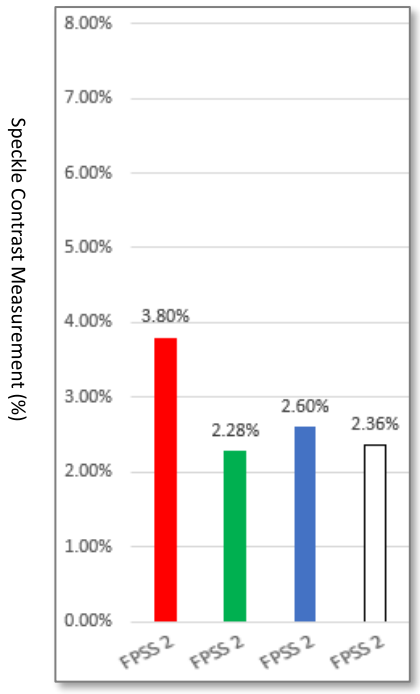
P1+ PROJECTOR FRONT PROJECTION SCREEN SAMPLE RGBW TEST RESULT

Front Projection Screen Sample (FPSS) 2 - Fabric Surface, 0.9 Gain:



'CONCEPT' PROJECTOR FRONT PROJECTION SCREEN SAMPLE RGBW TEST RESULT

Front Projection Screen Sample (FPSS) 2 - Fabric Surface, 0.9 Gain:



CONCLUSIONS

Whilst measured speckle contrast test results confirm that the Norxe P2 RGB LASER illumination source projector exhibits increased speckle contrast compared to the Norxe P1+ RGB LED illumination source projector and the Norxe 'concept' RGB LASER illumination source projector using the same front projection screen sample (FPSS 2) the 10% criteria threshold is not exceeded.

Results confirm that the various COTS front and rear projection screen samples have a significant effect on measured speckle contrast test results. Further, that front projection screen samples, surface finish dependent, are generally less prone to exhibiting speckle artefacts than their rear projection screen sample counterparts.

We at Norxe have developed and will continue to develop true solid-state illumination projector technology which utilizes optimal speckle suppression. Thus, ensuring the suitability of our products for use in the most demanding simulation visual display applications.

An example of this is illustrated above. The 'concept' RGB LASER illumination source projector utilizes new generation technology to further reduce speckle contrast.

- Measured speckle contrast test results show that the Norxe 'concept' RGB LASER illumination source projector exhibits significantly reduced speckle contrast compared to the Norxe P2 RGB LASER illumination source projector using the same front projection screen sample (FPSS 2).

Norxe operates transparently and subsequently emphasises caution when considering RGB LASER illumination source projectors in conjunction with projection screen combinations whilst emphasizing that products should not be automatically excluded based on illumination source technology alone. Norxe rather encourages the evaluation of projectors and projection screen combinations ahead of any final selection process.

Norxe's findings are substantiated in Terry C. Scmidt (Chief Scientist, Christie Digital Systems) 2014 Paper 'Standardization of Speckle Measurement for Large Screen Laser Illuminated Video Projection Systems' which notes that "on different screen types, the surface roughness, and the optical reflectance, seems to be the big factor in the amount of speckle reflected into an observers' eye." Before going on to say that projection screen surfaces with <1.5um surface roughness perform quite well.

In short it is imperative that simulator manufacturers, system integrators, screen manufacturers, projector manufacturers & image generator manufacturers work together to achieve the common goal of creating the best overall visual display.

PRIMARY AUTHOR BIO

Craig Maddock is Director Product Support at Norxe AS which he co-founded in 2015. Craig studied engineering and industry management prior to starting work in the projection industry in 1998. He worked for a simulation centric system integrator before transitioning to work for several projector manufacturers where he has since been involved in the design and development of both LCoS and DLP projectors. Craig is an inventor of 1 Patent within the display field.

REFERENCES

[1] Kjell Einar Olsen, Craig Maddock, Jørn Eriksen, 2018, "Projection: Superb Image Quality & Longevity", *Proceedings of the IMAGE 2018 Conference*, The IMAGE Society.

[2] Kjell Einar Olsen, Craig Maddock, 2019, "Solid State Projection – Image Quality Differentiation", *Proceedings of the IMAGE 2019 Conference*, The IMAGE Society.

[3] European Union Aviation Safety Agency - Notice of Proposed Amendment 2020-15. Update of the flight training device requirements RMT.0196.

https://www.easa.europa.eu/document-library/notices-of-proposed-amendment/npa-2020-15

[4] Doc 9625. Manual of Criteria for the Qualification of Flight Simulation Training Devices. Volume 1 – Aeroplanes. Fourth Edition, 2015.

http://www.icscc.org.cn/upload/file/20190102/Doc.9625-EN%20Manual%20of%20Criteria%20for%20the%20Qualification%20of%20Flight%20Simulation%20Training%20Devices%20Volume%20I%20-%20Aeroplanes.pdf

[5] LIPA 'Measurement of Speckle in Laboratory Conditions'

https://www.lipainfo.org/laser-illumination-sources/speckle-metrology

[6] Terry C. Scmidt (Chief Scientist, Christie Digital Systems) 2014 "Standardization of Speckle Measurement for Large Screen Laser Illuminated Video Projection Systems"

https://www.researchgate.net/publication/263701963_314_Standardization_of_Speckle_Measurement_for_Large_Screen_Laser_Illuminated_Video_Projection_Systems