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Temporal Anti-Aliasing Techniques for HDR Imaging in 1D and 2D Systems

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Westboro Photonics

Outline

- Intro to Westboro Photonics
- Why measuring modulated light can be difficult
- How HDR imaging works
- TAA HDR for spectroscopy
- TAA HDR for imaging (global shutter)
- What’s next

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Company Overview

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- Located in Ottawa, Canada
- Light measurement equipment and analysis software
  - Imaging photometers
  - Imaging colorimeters
  - Imaging spectral colorimeters
- ISO 17025:2017, >CY2021

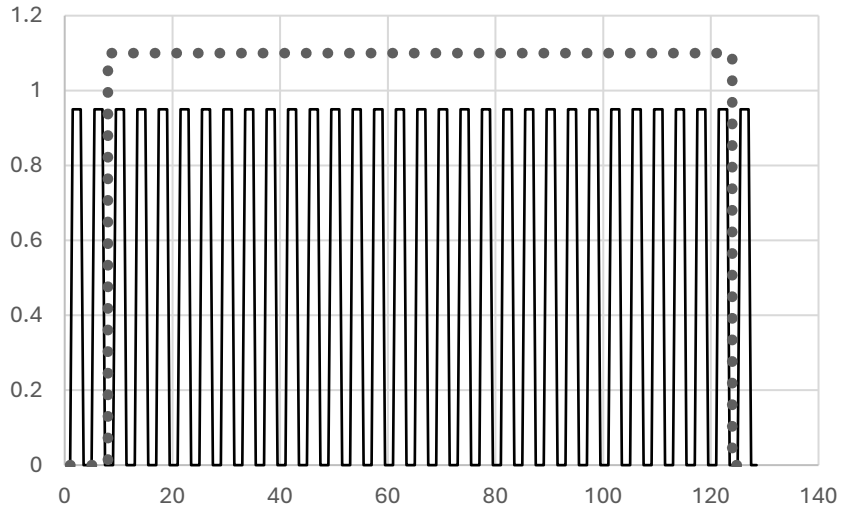
NVLAP® CALIBRATION
NVLAP LAB CODE 600285-0

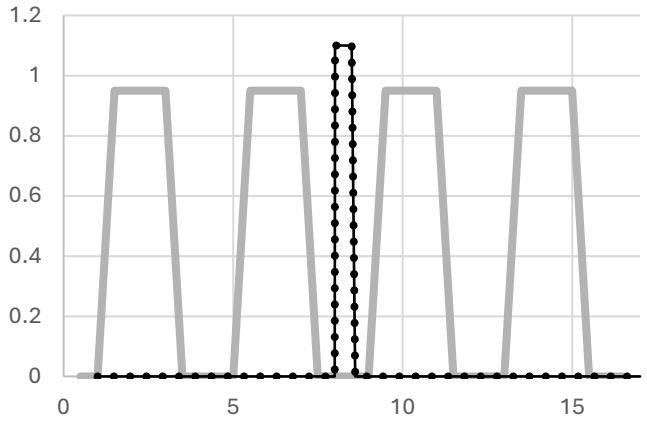
ilac-MRA

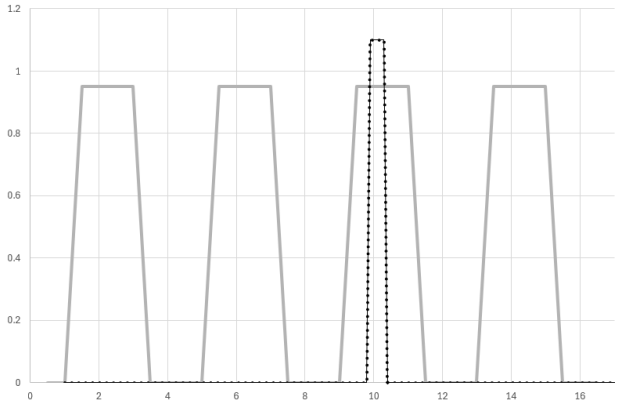
Light modulation

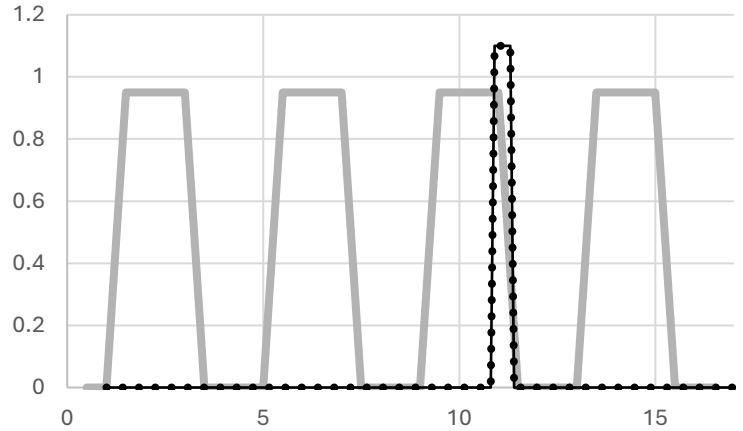
Displays and lighting can have a periodic emission by design

- Pulse width modulation (PWM) is commonly used to dim LEDs, because DC dimming via voltage or current has a lot of drawbacks.
- Asynchronous measurements of modulated light can capture varying amounts of light from exposure to exposure.
- Measurement precision can be low.









HDR Imaging

- The goal of HDR (exposure bracketing) is to report low, medium and high level signals, all with optimal precision.
- A pixelated detector can accumulate a limited number of quanta before the pixel is saturated -> Full Well Capacity
  - about 10k e- is typical for sensors under 4 um pixel pitch
  - Up to 10M e- is possible for large area or binned pixels.
- There are other limits the signal to noise:
  - Photon Shot noise,
  - Dark Current noise (and its shot noise)
  - Read noise
    - Transistor Noise
    - Reset Noise (kTC Noise
    - Sense Node Reset Noise

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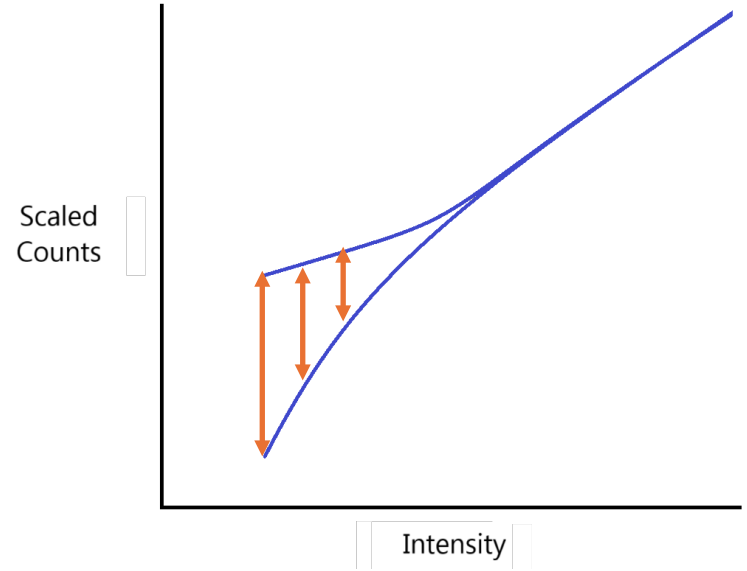
Non-HDR Imaging

Single Exposure



- A single exposure will provide optimal signal to noise for only some of the pixels

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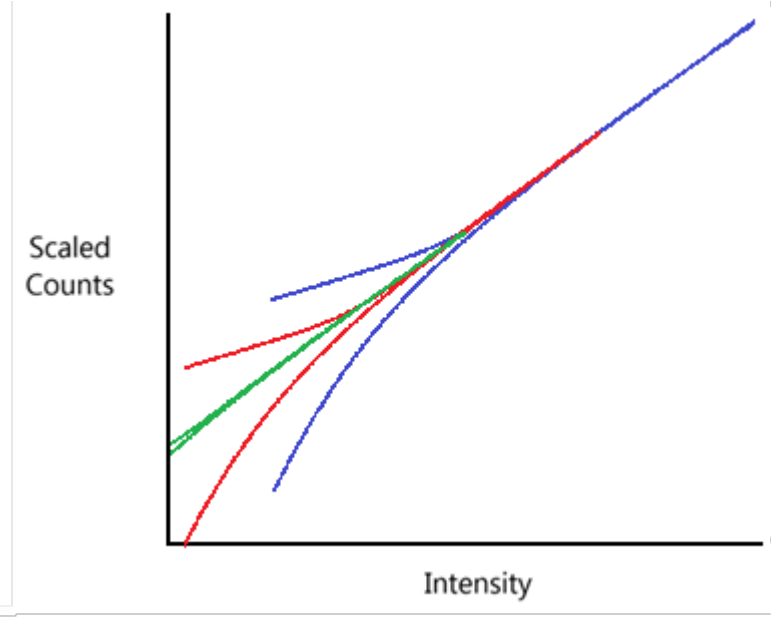
HDR Imaging

HDR Exposure



- Multiple single exposures at different exposure times will provide better precision for a greater number of pixels.

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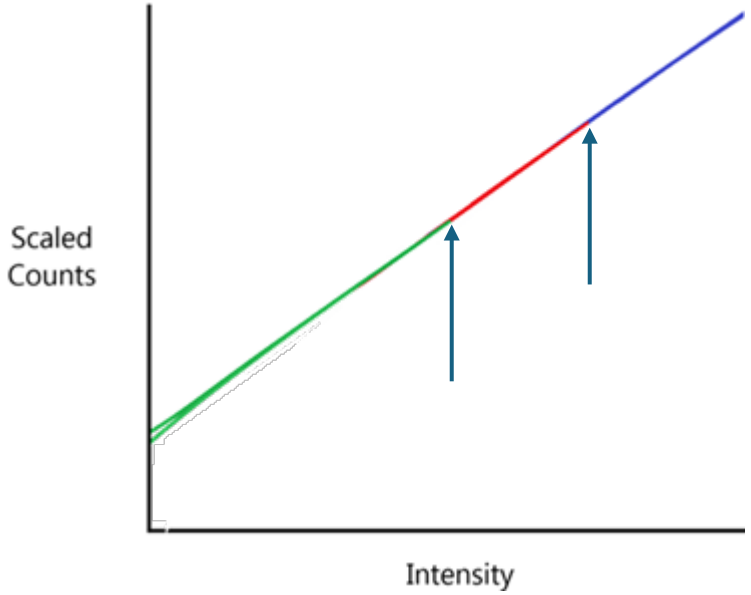
HDR Imaging

HDR Exposure



- Longer exposure data overwrites shorter exposure data - if not saturated.

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Small Spectrometers. Big Performance.

- The spectro in our WP525 is about the size of a deck of cards.
- Top of the market array spectrometers have 10x more silicon per nm in the detector.
  - ➔Bigger quantum well
  - ➔better dynamic range
  - ➔reduced need for HDR
- Small detector spectrometers can HDR to match or exceed the single exposure dynamic range of reference grade spectrometers.
- The other key attributes for spectrometers: **stray light**, **bandpass**, **linearity** and **wavelength accuracy** are not dependent on the spectrometer size.

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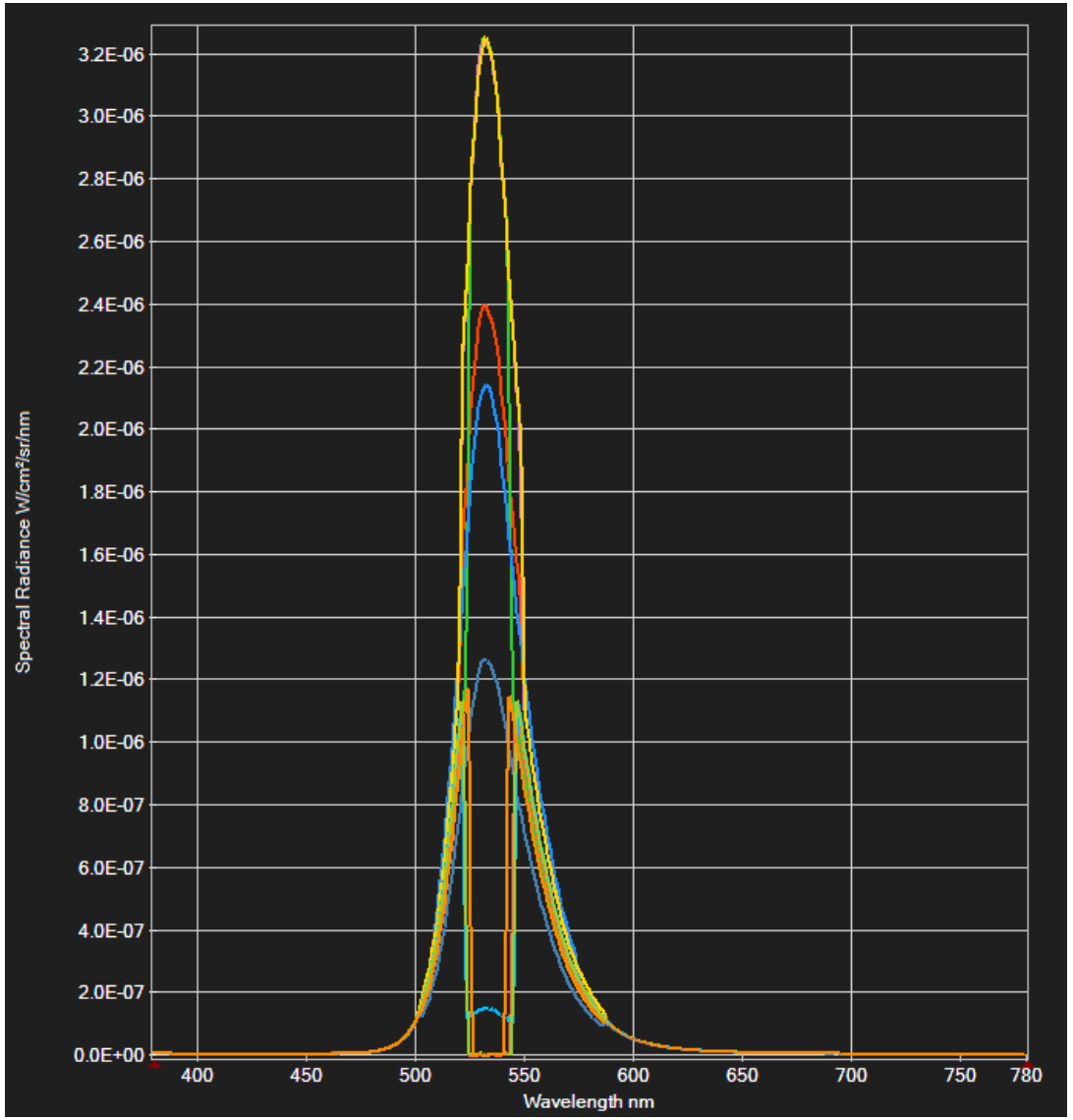
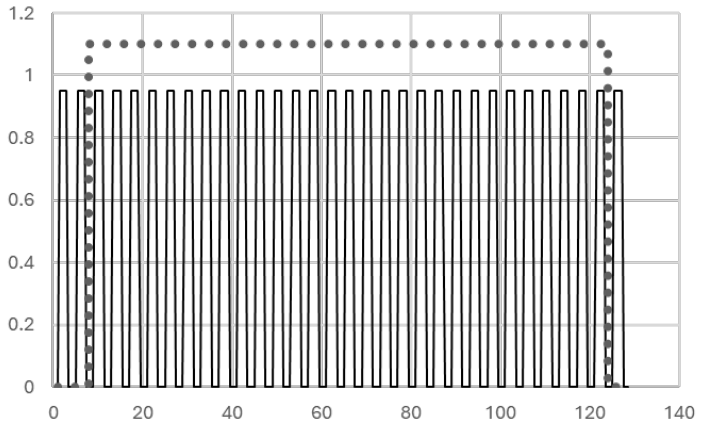
Spectrometer Aliasing

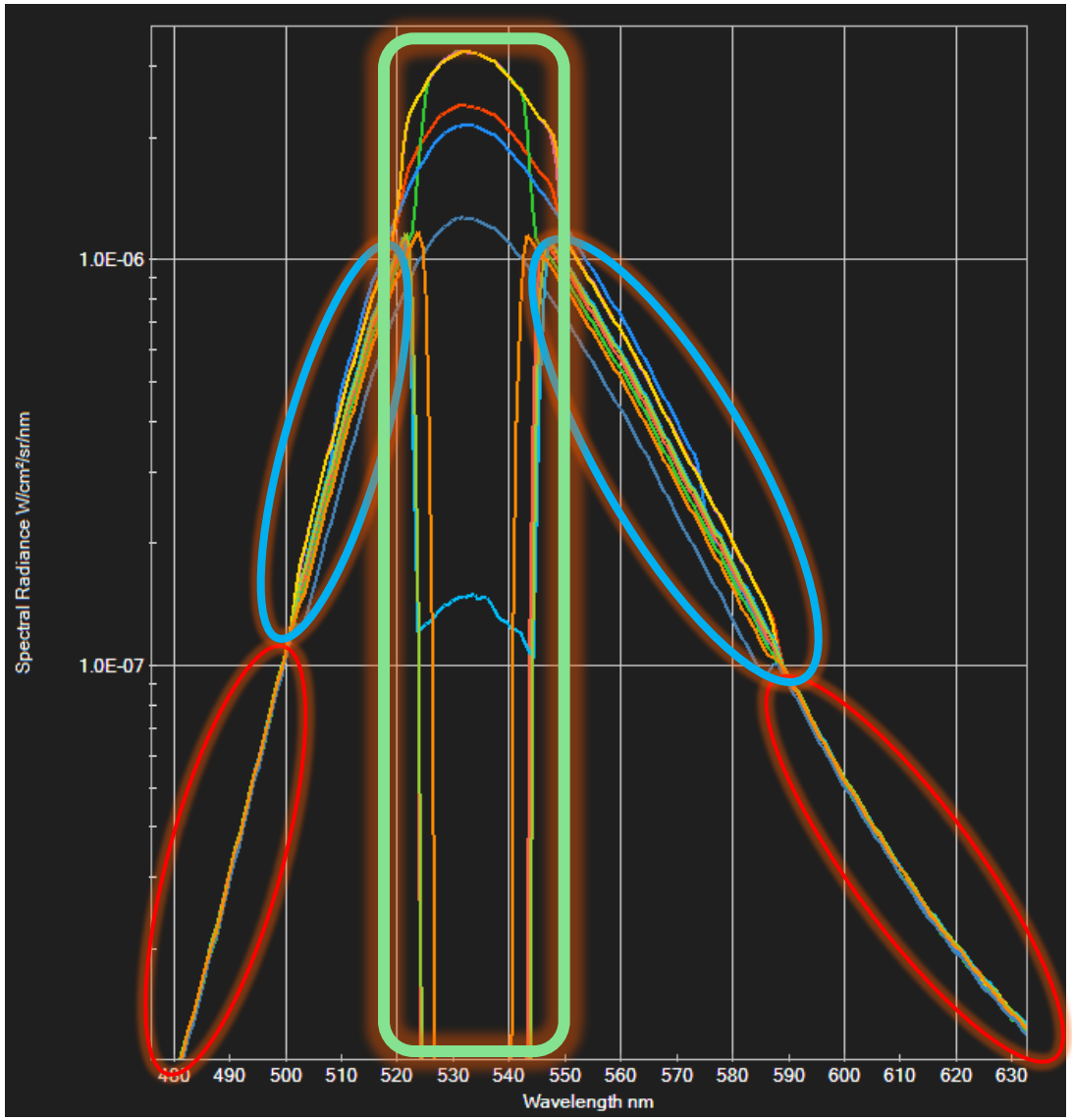
- 10ms period low duty cycle PWM Green LED
- HDR exposures at 8, 64 and 512 ms
- Using standard HDR stitching methods
- Aliasing errors are egregious.



Spectrometer Aliasing

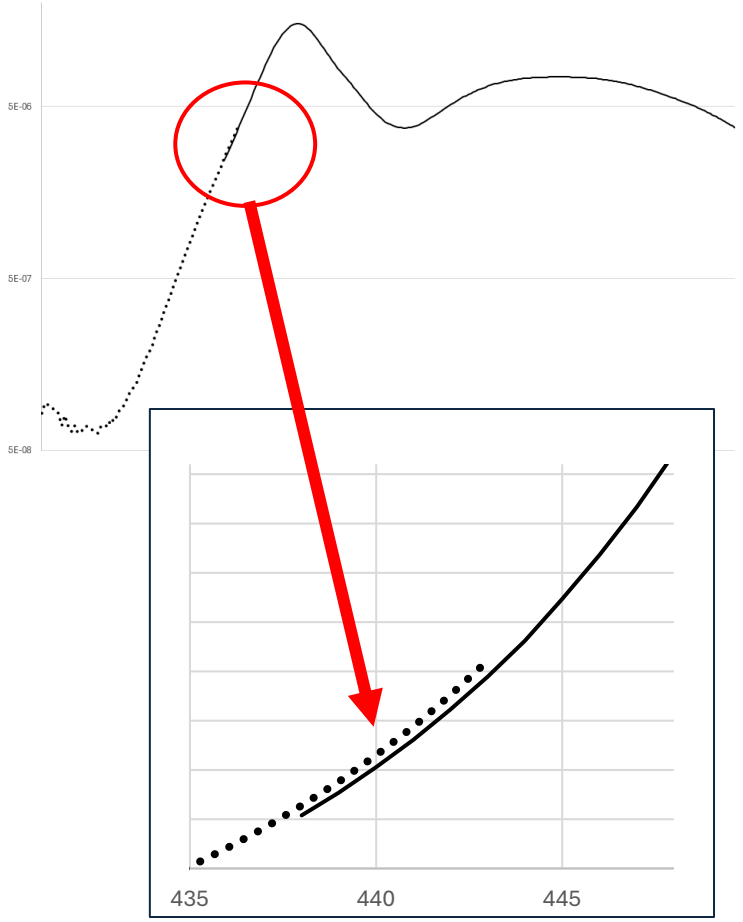
- In log scale notice:
- The short exposures are extremely aliased.
- Medium less so.
- Long exposures appear stable.





TAA HDR - Spectrometer

- In HDR multiple acquisitions at different exposure times are acquired.
- Calibration factors are applied (exposure scaling).
- If the signal is not aliased, the data should match at the stitching point when joining HDR data.
- If there is a mismatch, the method is to adjust the data from the shorter exposure up or down so that the overlap region matches the longer exposure.
- **“Anchoring”** the measurements to the longest exposure.



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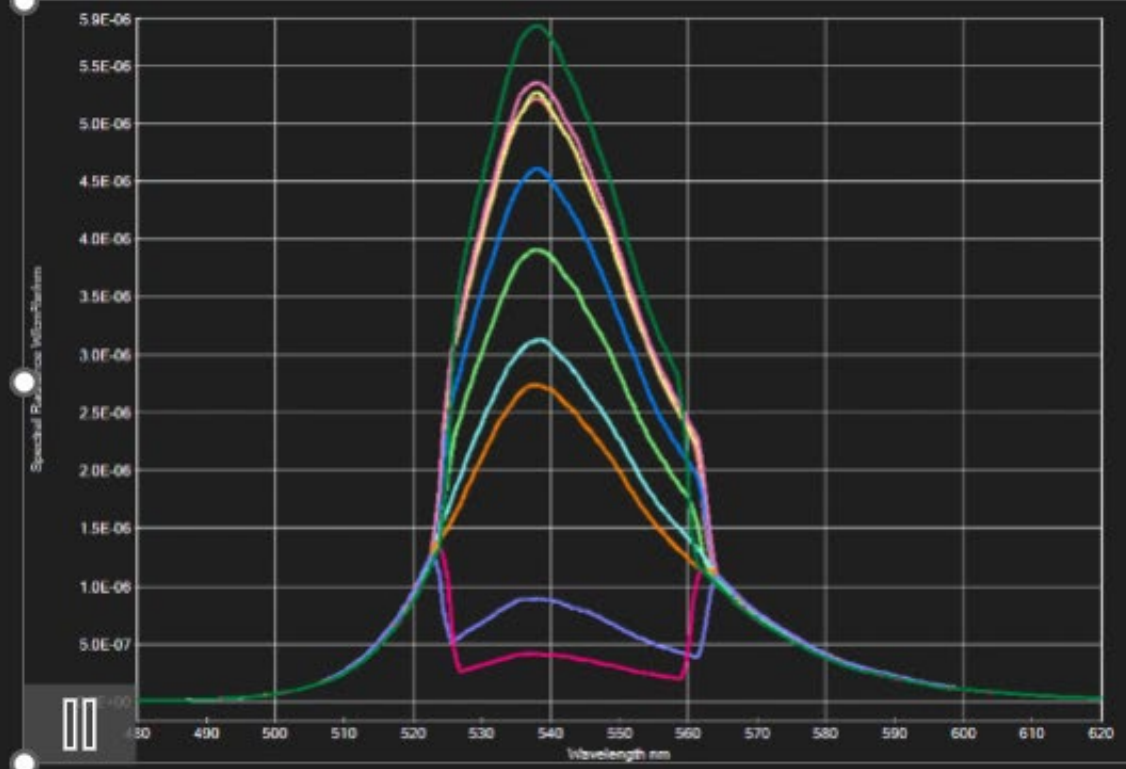
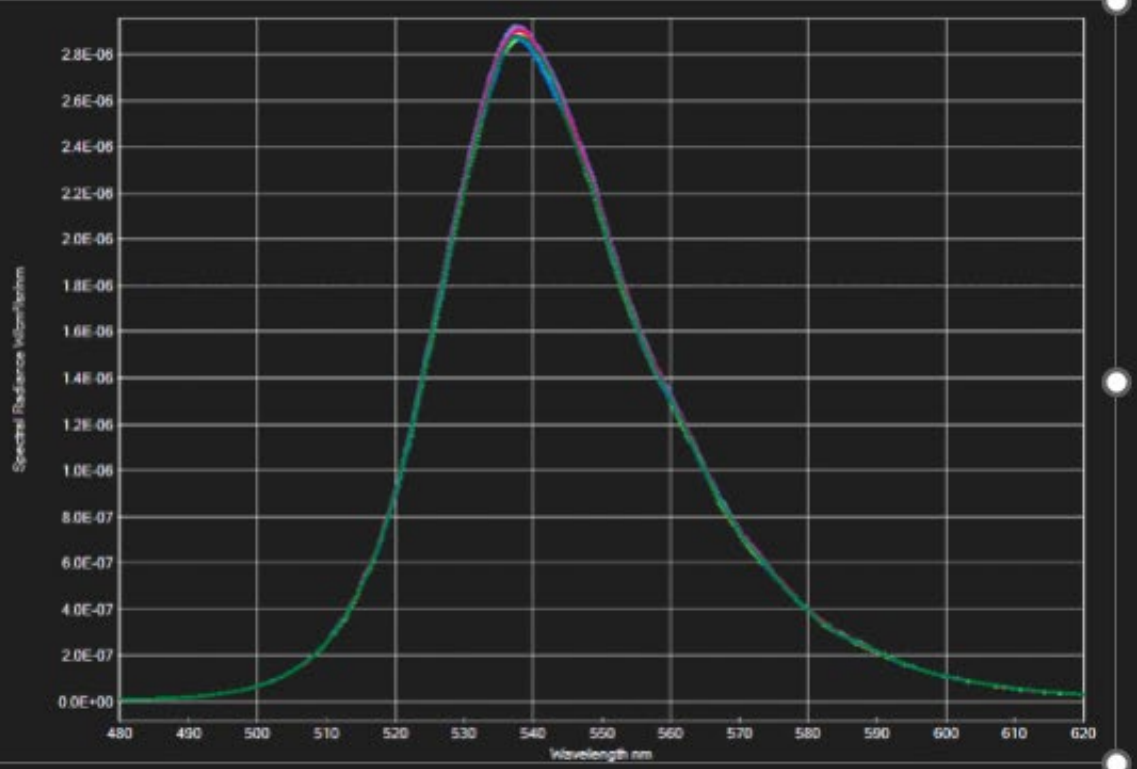
Standard HDR



TAA HDR



TAA HDR - Spectrometer

- Precision for 10 successive measurements of a modulated LED light source using the vis spectrometer in the WP525.
- Auto range measurements using exposures at 8x steps (8.33, 66.7, 533 ms)

Modulation?	45Hz, 20% duty, 100% mod, square		DC
TAA?	No	TAA on	No
Luminance	85%	0.65%	0.07%
u'	0.09000	0.00007	0.00005
v'	0.02260	0.00009	0.00005
x	0.03570	0.00005	0.00000
y	0.04699	0.00005	0.00000
Dom Wl, nm	5.90	0.05	0.00

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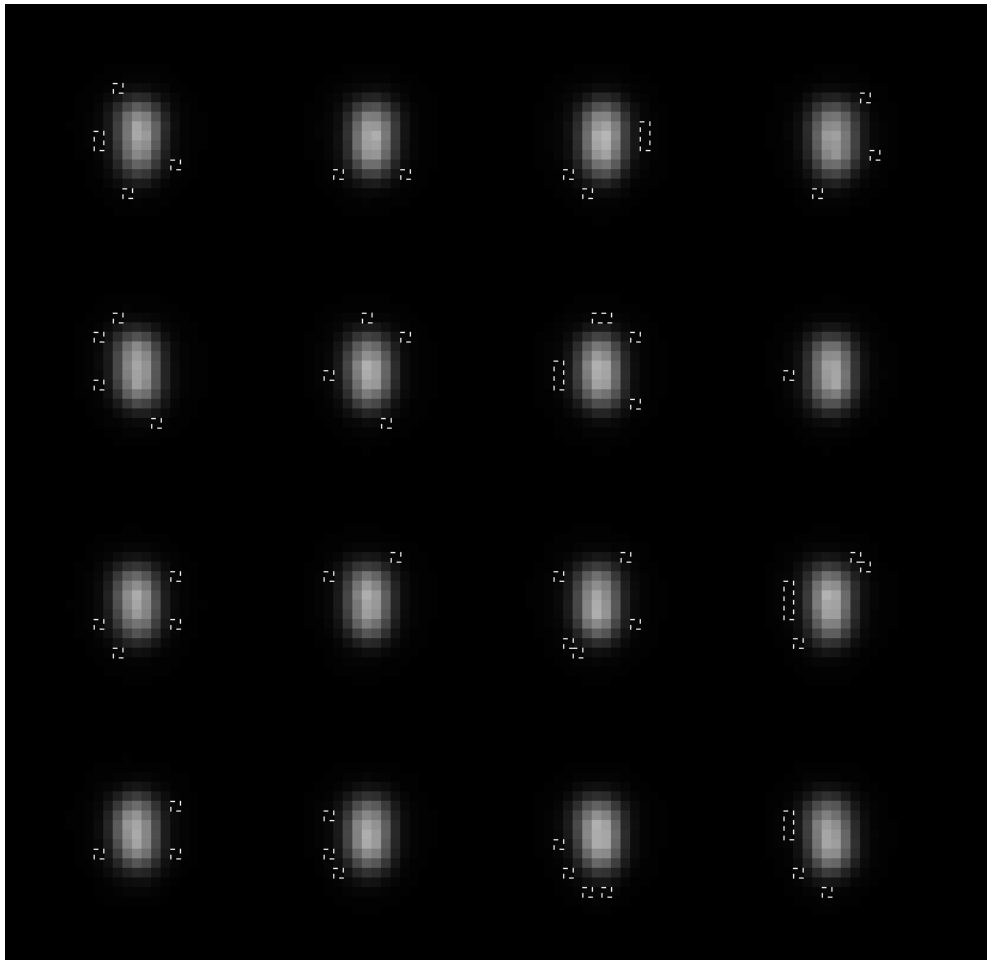
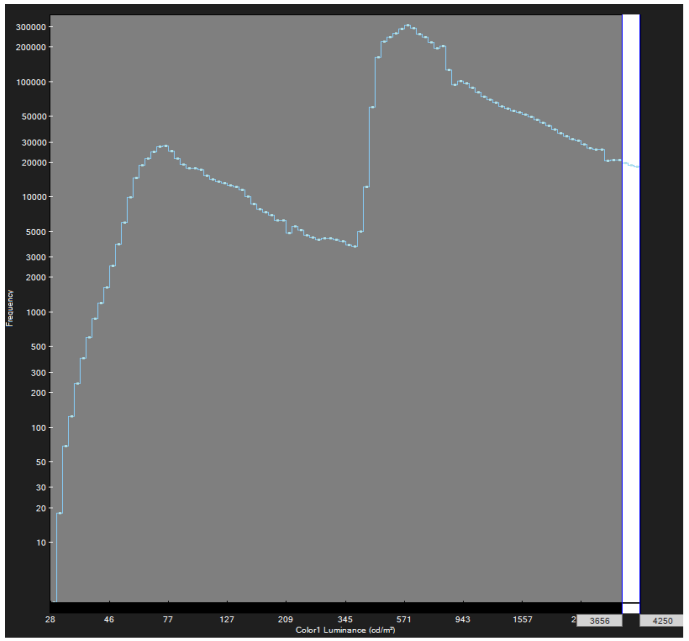
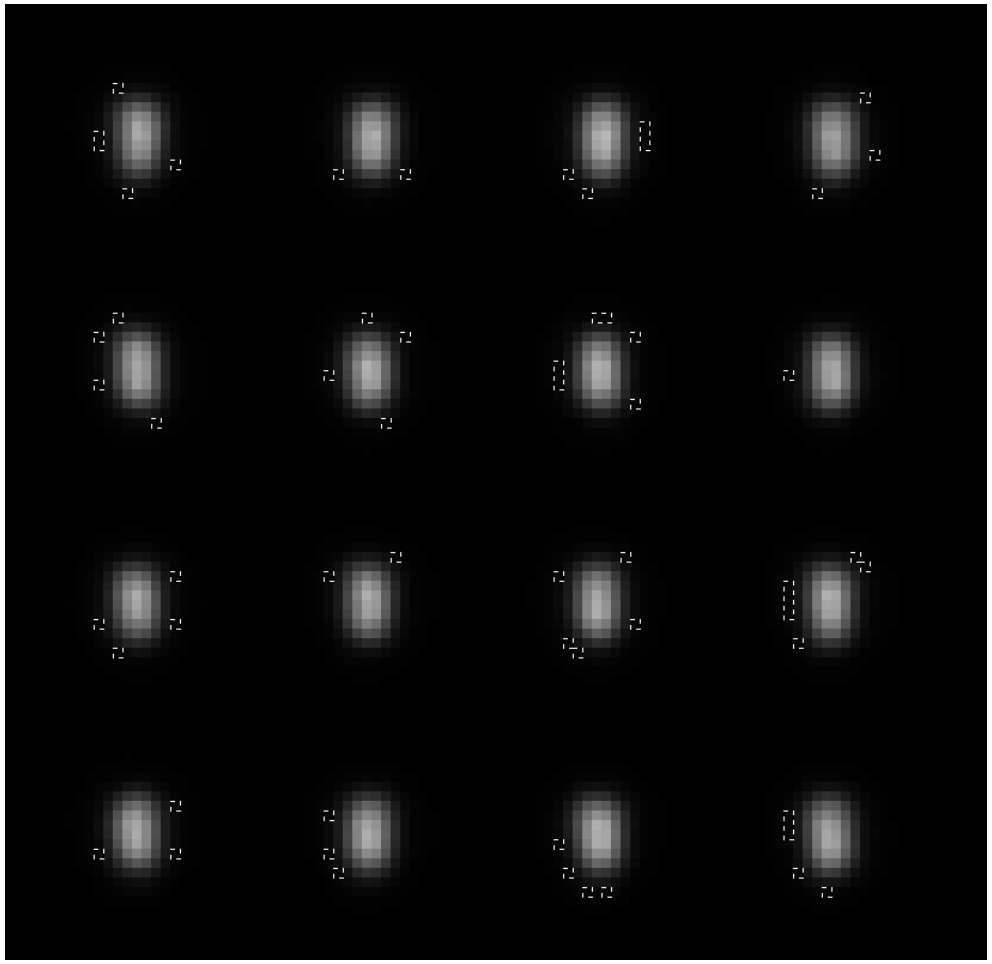
TAA HDR with Imagers (XYZ, Y etc.)

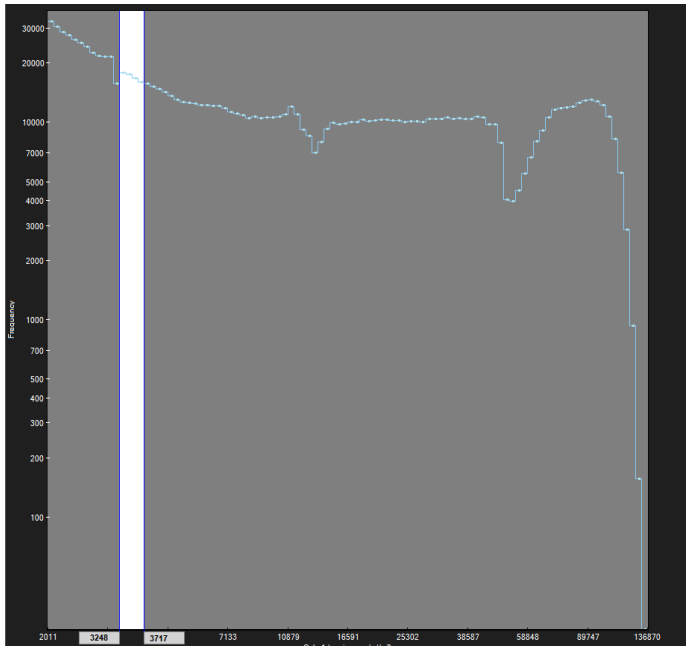




- Long exposure image
- Identify a selection of pixels high S:N.
- Get their average value

TAA HDR with Imagers (XYZ, Y etc.)

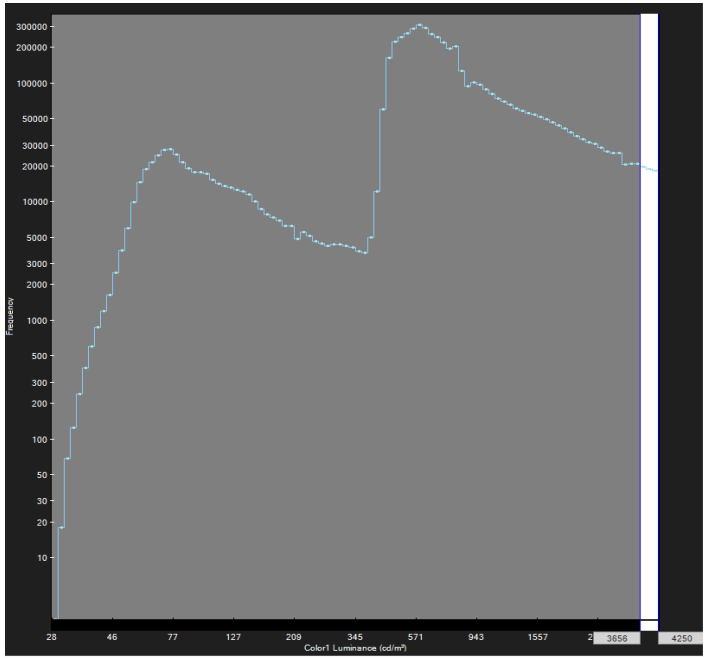




- Shorter exposure
- Get comparative pixels’ average value

Anti-aliasing feature – Imagers (XYZ, Y etc.)

- Apply a scalar to the shorter exposure image data so the average value compared pixels match.



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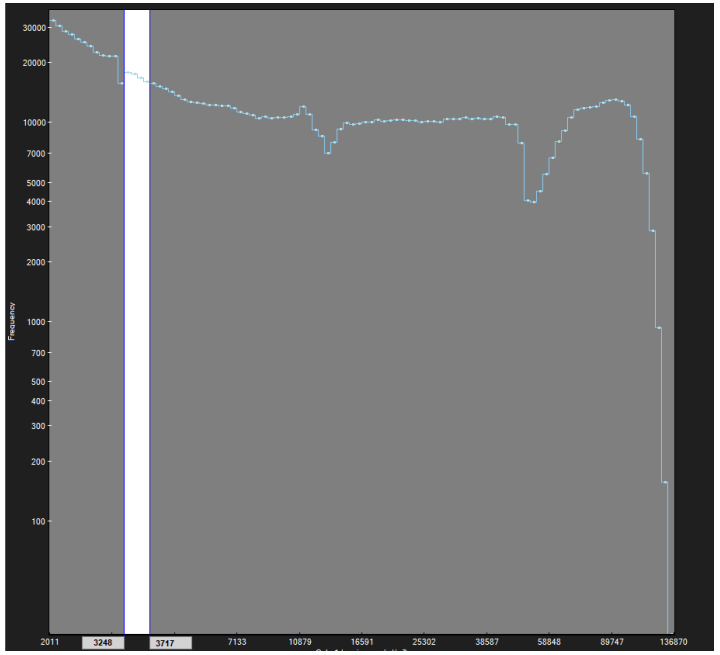

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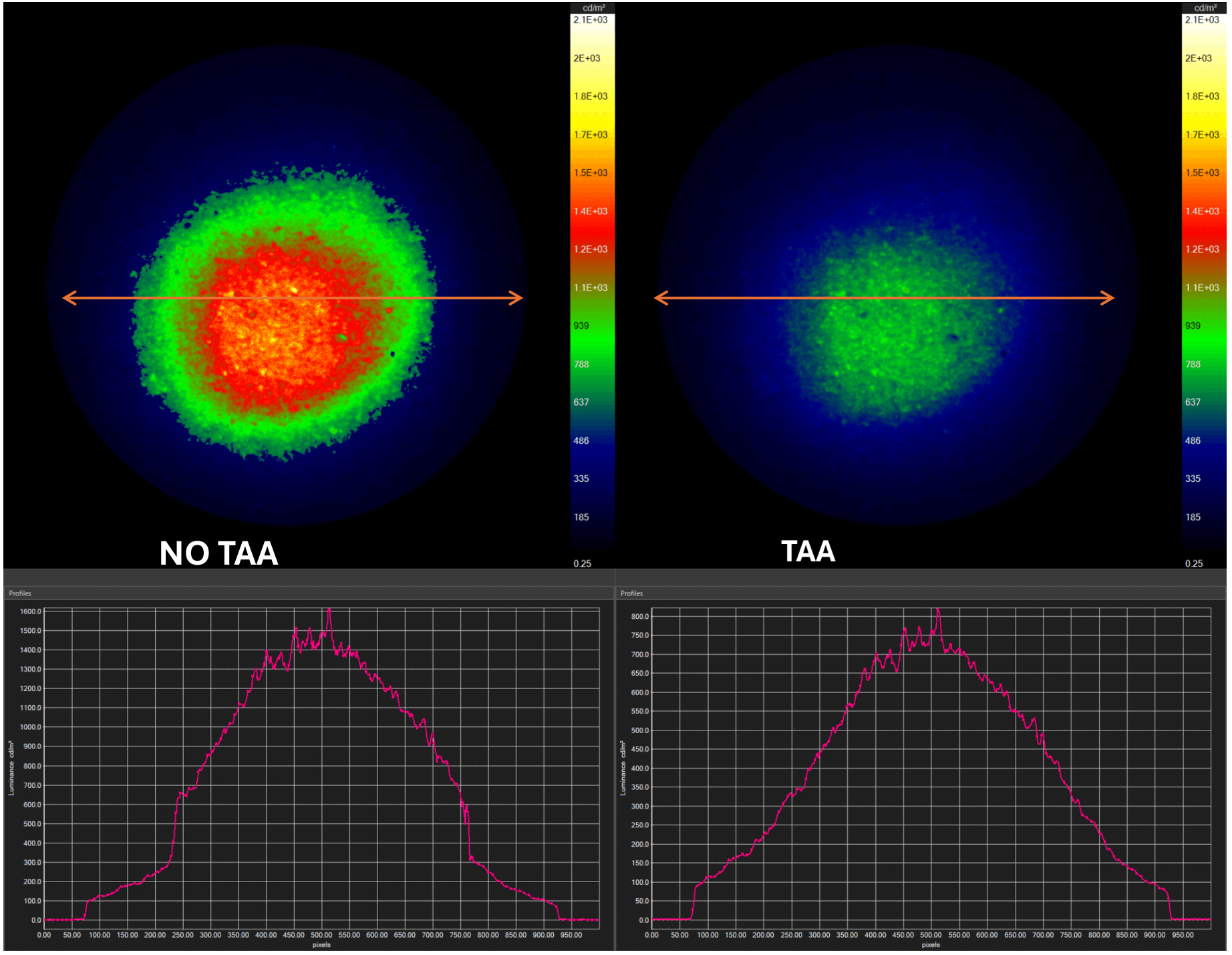
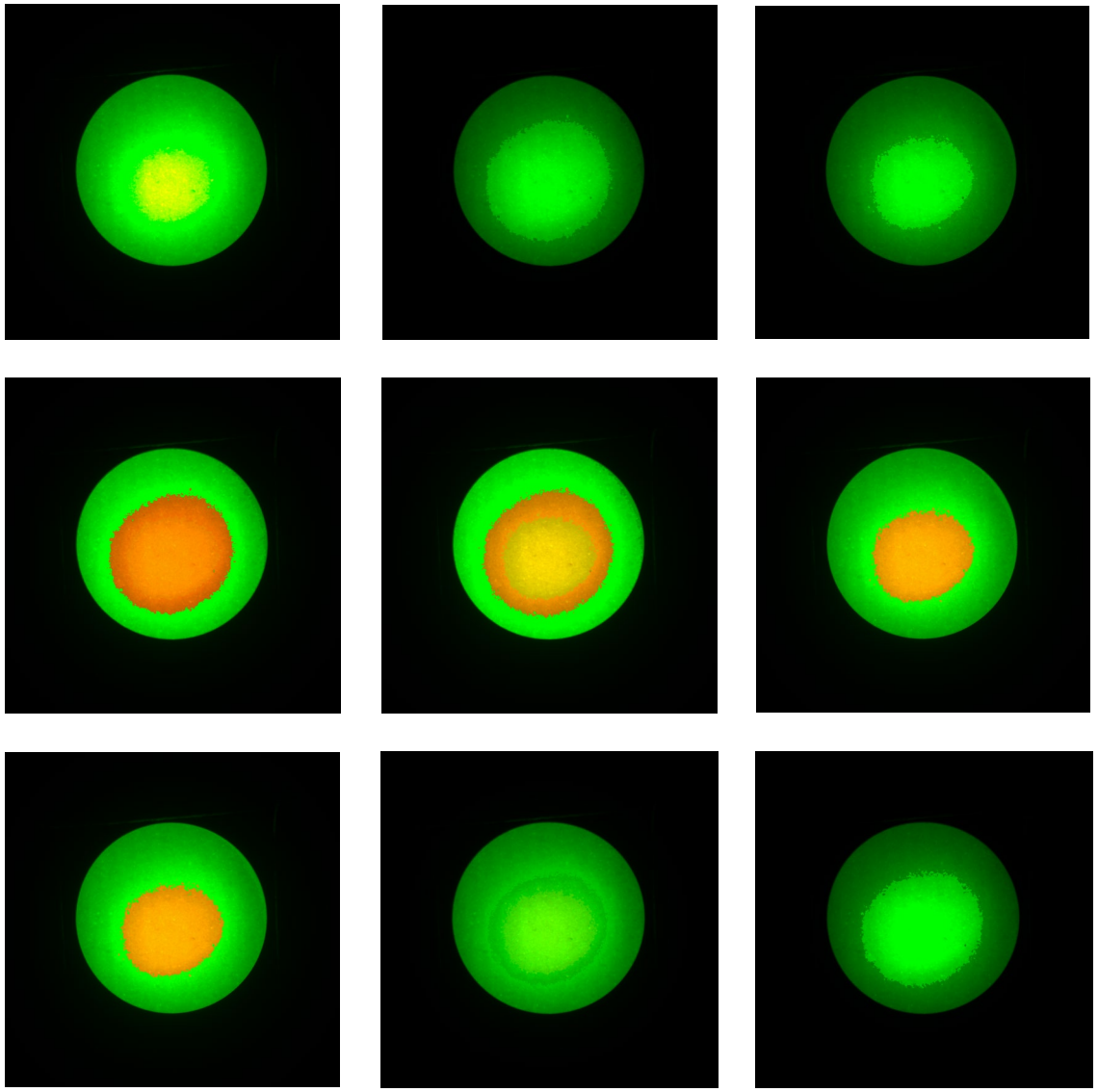

cd/m²
2.1E+03
2E+03
1.8E+03
1.7E+03
1.5E+03
1.4E+03
1.2E+03
1.1E+03
939
788
637
486
335
185
0.25
NO TAA
TAA
Profiles
Luminance cd/m²
pixels
Profiles
Luminance cd/m²
pixels



Nine successive HDR Imaging colorimeter measurements at 45 Hz modulated source at 20% duty cycle and 100% depth of modulation

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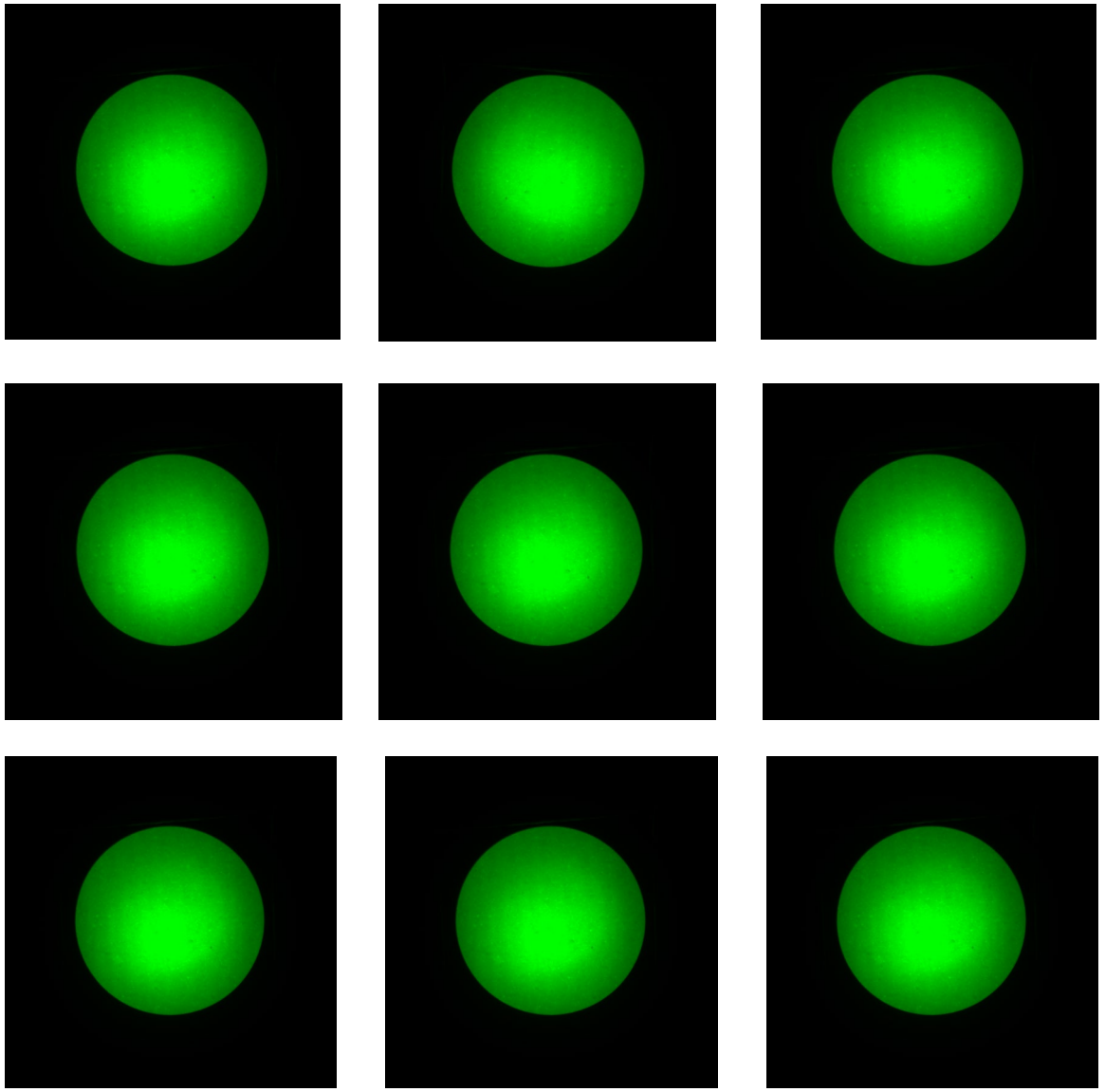

Same conditions as previous nine measurements, except TAA-HDR is enabled.

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TAA HDR Alternatives

1. Custom timebase
   - Adjust the exposure times to be an **integer multiple** of the mod period
     - Risk: Information may not be available, or the frequency may be varying.
     - Advice: Always check the measurements have adequate precision
2. Use long, single (or very long HDR) exposures and density filters.
   - Density filters introduce new errors:
     - Not neutral -> additional filter mismatch errors
     - Degrade image fidelity -> reflections and ghosting
   - This strategy has the slowest acquisition time.
   - Uncooled detectors may not be useable at long exposures – limiting HDR dynamic range.
   - Cost/reliability: additional hardware, mechanics, processes and calibrations
3. Take a large number of averages
   - Slow

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TAA HDR Summary

- Low cost to implement
  - Software method only.
  - Requires no extra calibration factors.
  - Easy for users to deploy.
- Can extinguish aliasing errors in both spectral and imaging measurements, if the longest measurement has acceptable precision.
- Patent Pending
- Available now

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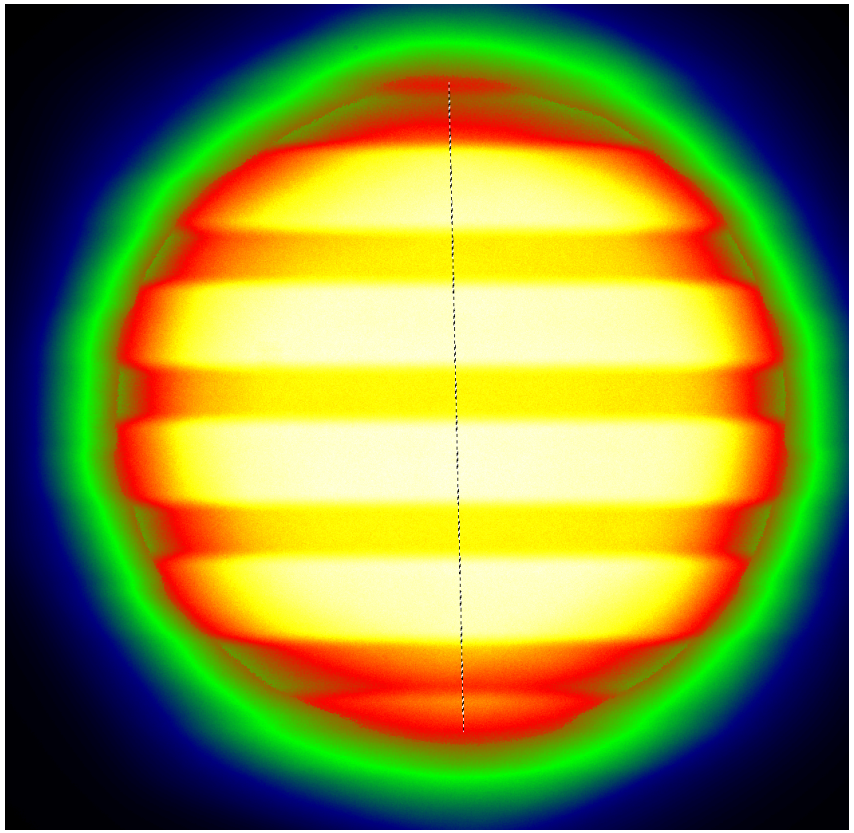
What's next?

Rolling shutter sensors have significant aliasing issues!

- Westboro Photonics is working on a release of TAA-HDR in Photometrica for rolling shutter imagers.



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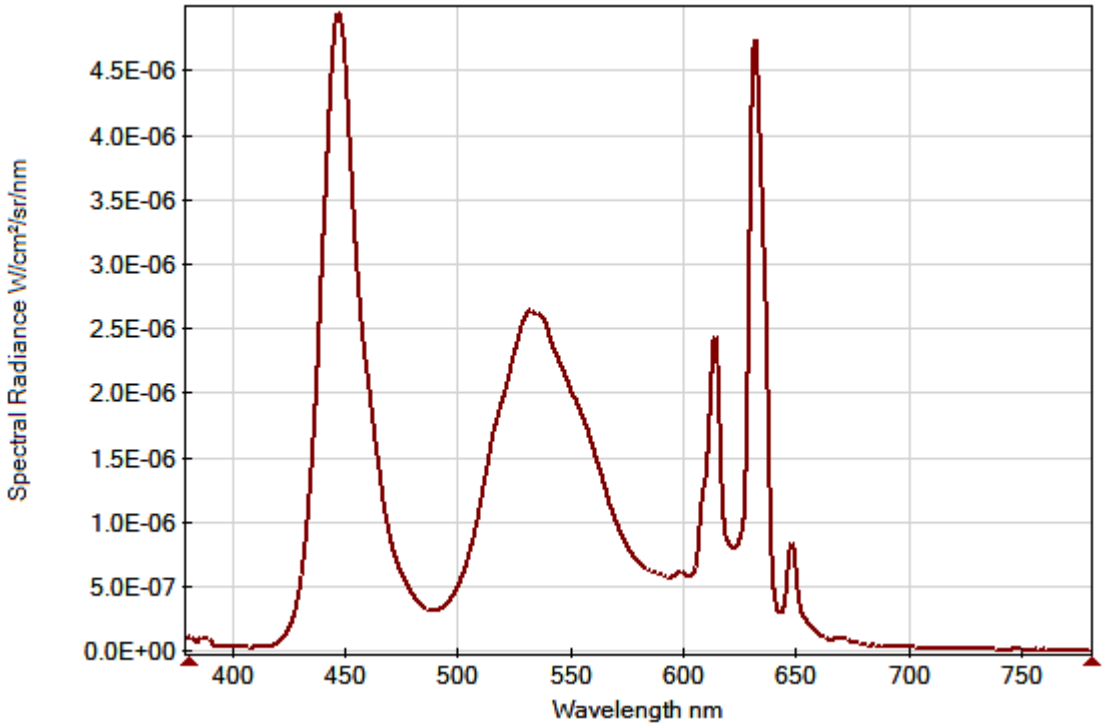
What’s next?

Special adaptation of TAA HDR to measure **KSF phosphor LEDs**. The red phosphor has persistence does not pulse with the green and blue primaries.

Stay tuned. ☺



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