Measurement errors due to limitations of lenses to focus wide wavelength light

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Wide Wavelength Range Spectral Imaging

1. Spectrometer:
   - Detector 200-1100 nm
   - Grating 300-1100 nm
2. Fiber coupling:
   - 370-1650
3. Imaging Optics:
   - Lenses 370-1650 nm

= net coverage of 370-1100 nm

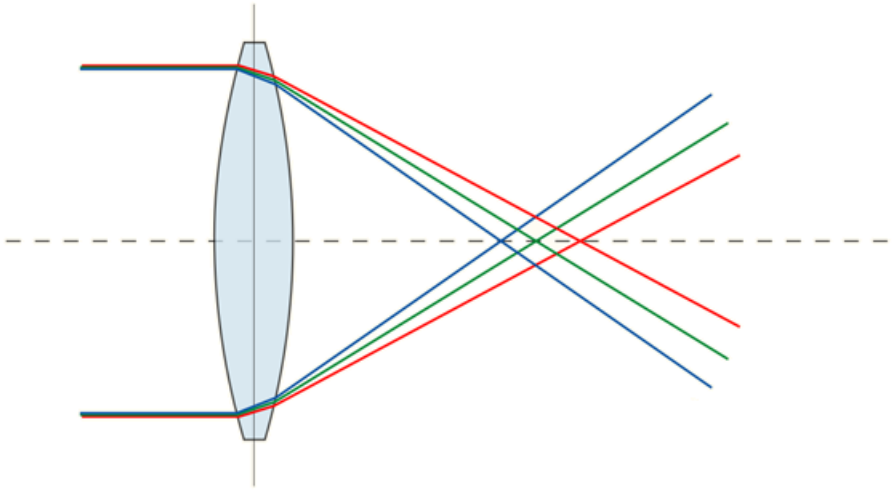
… One would expect we could make a system that would cover the range that all the components transmitted light over…

Lenses

- Glass refracts light as a function of wavelength = diffraction

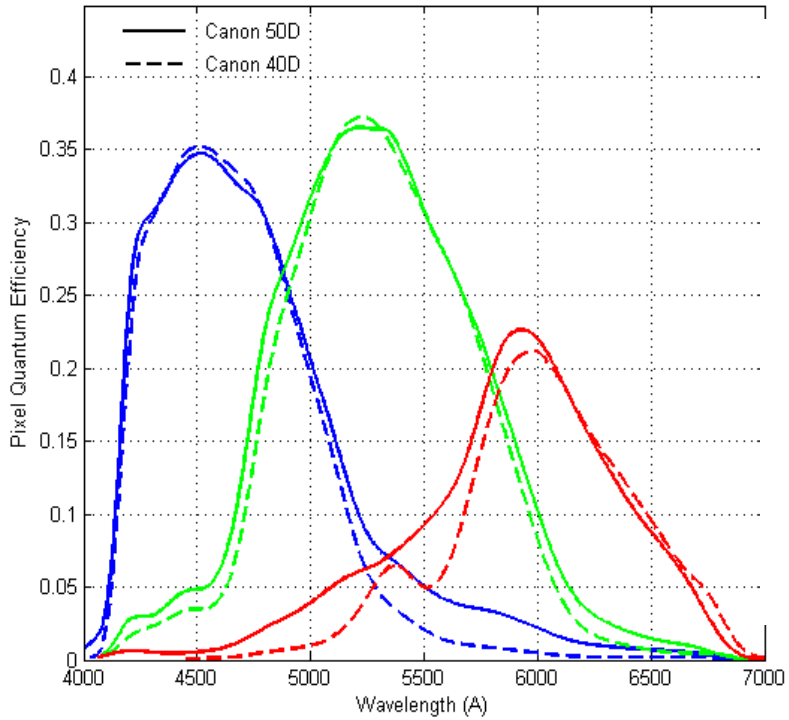
Simple Lenses

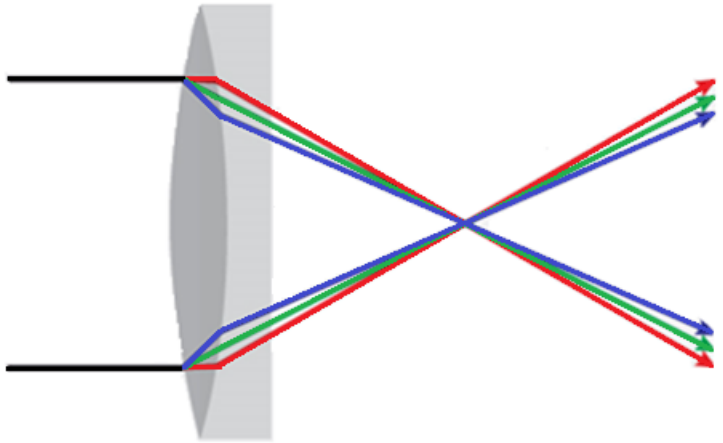
- A simple lens will have focus at one wavelength, but not at others.
- Also called “focal shift”
- Chromatic aberration (or chromatic distortion) is the failure of a lens to focus all colors at the same point.



Photographic Lenses

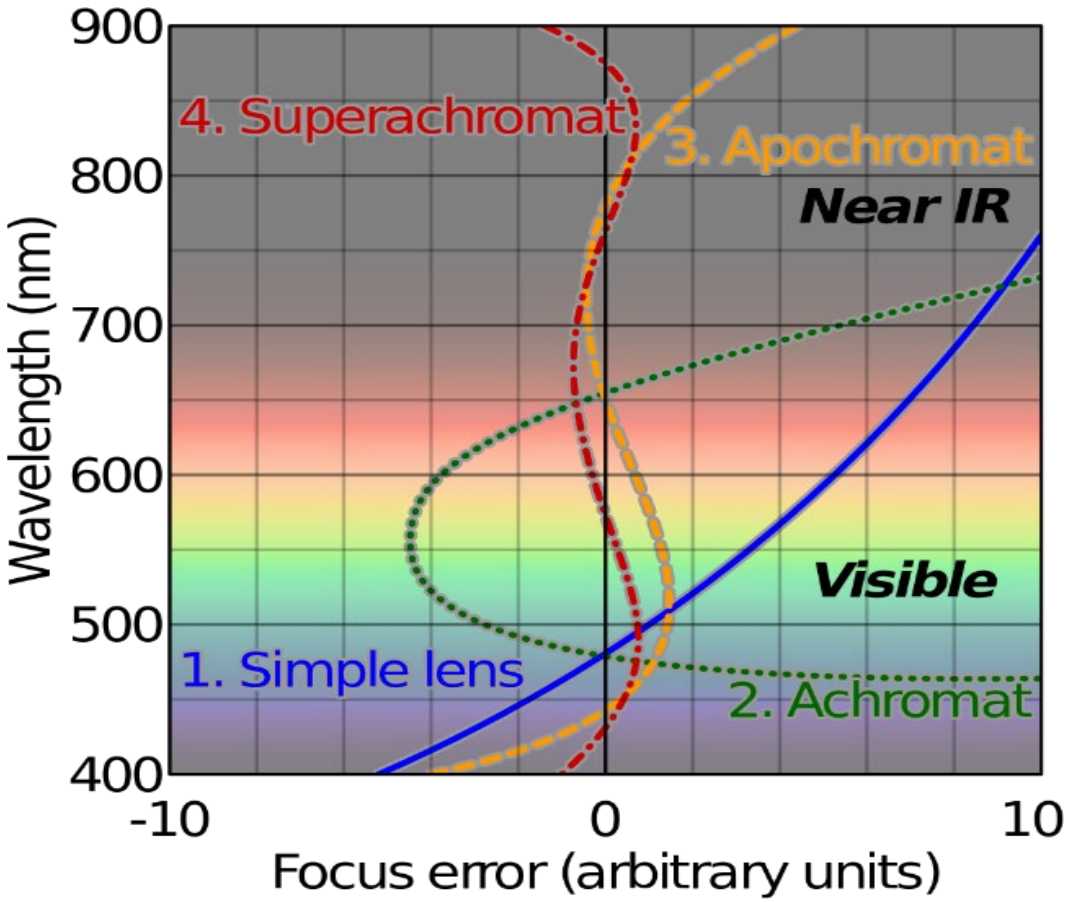
- 450 to 620 nm





Lenses

- Simple lens
- Achromatic lens
- Apochromatic
- Superachromatic

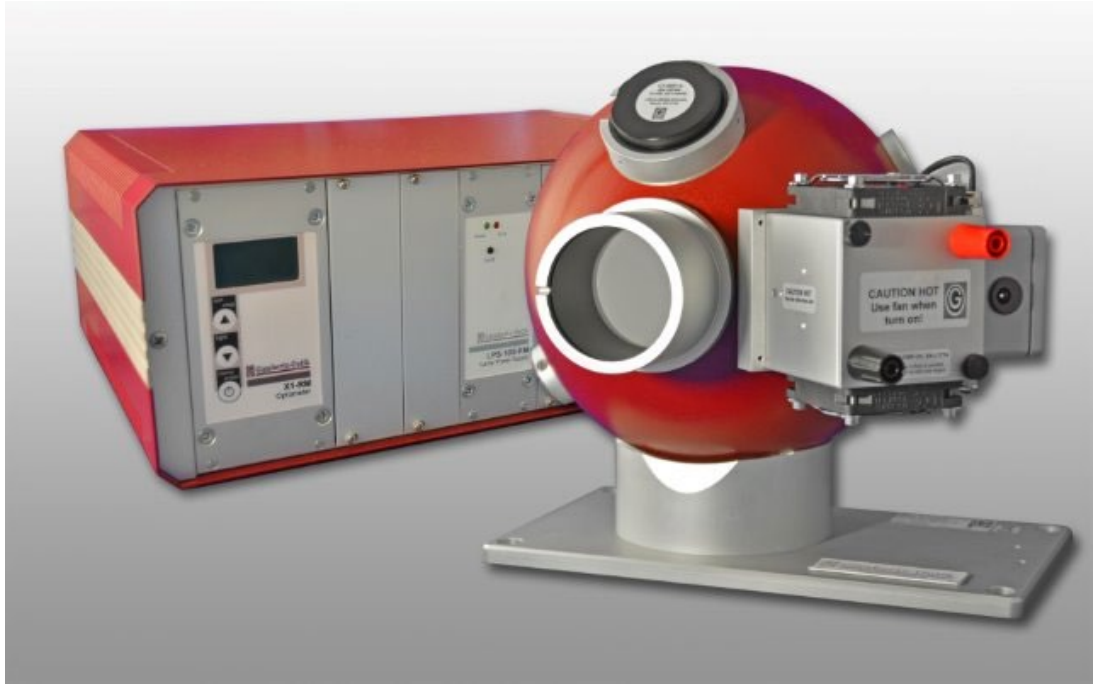


Lenses

- Photographic
  - Violet (< 450nm) or NIR (> 650nm) are not critical design criteria
  - Expect high distortion and poor focus for consumer and “prosumer” lenses outside of design wavelengths.
- Astronomy and special-purpose multi-spectral imaging lenses may be found that cover wider ranges.
- Microscope lenses might only be simple lenses or apochromatic. Magnification and distortion are key performance specs…

CALIBRATION

- Calibrated to NIST/PTB traceable illuminant A sources
- Image an integrating sphere
  - 50 mm port
- Validation done with same/similar sphere



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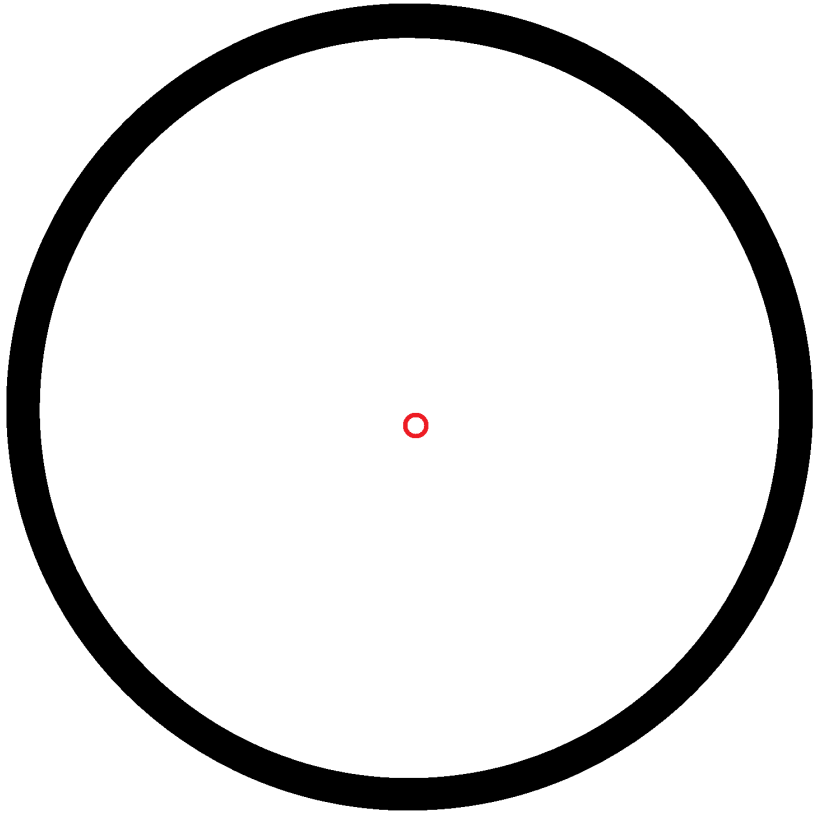
Sample not Like Calibration Condition

Calibration condition

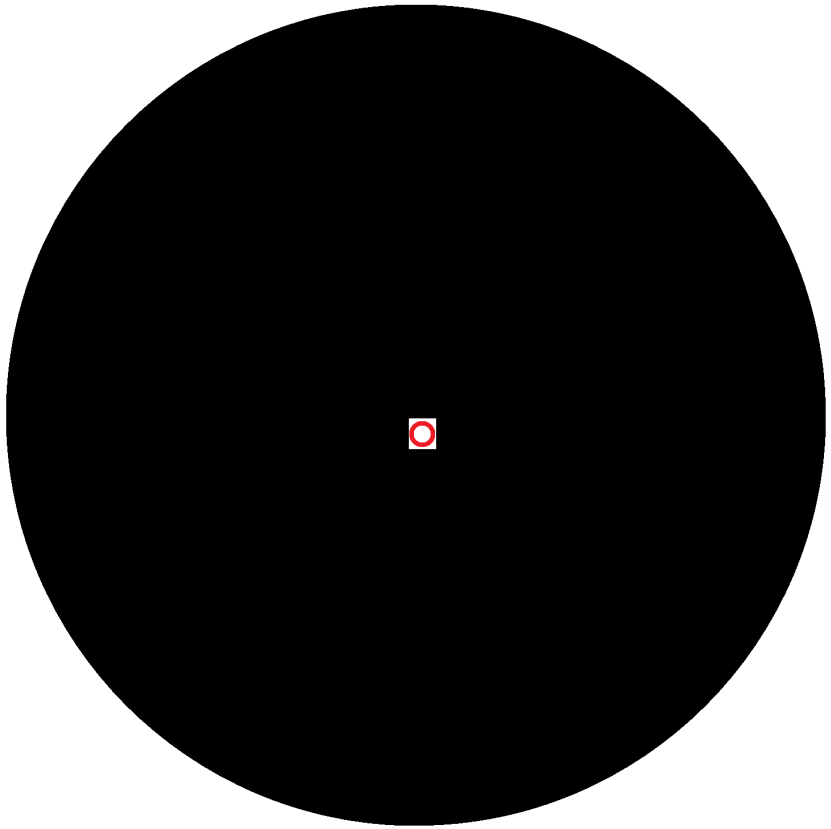
- 5 cm measurement port
- 150 um measurement spot



Sample not Like Calibration Condition

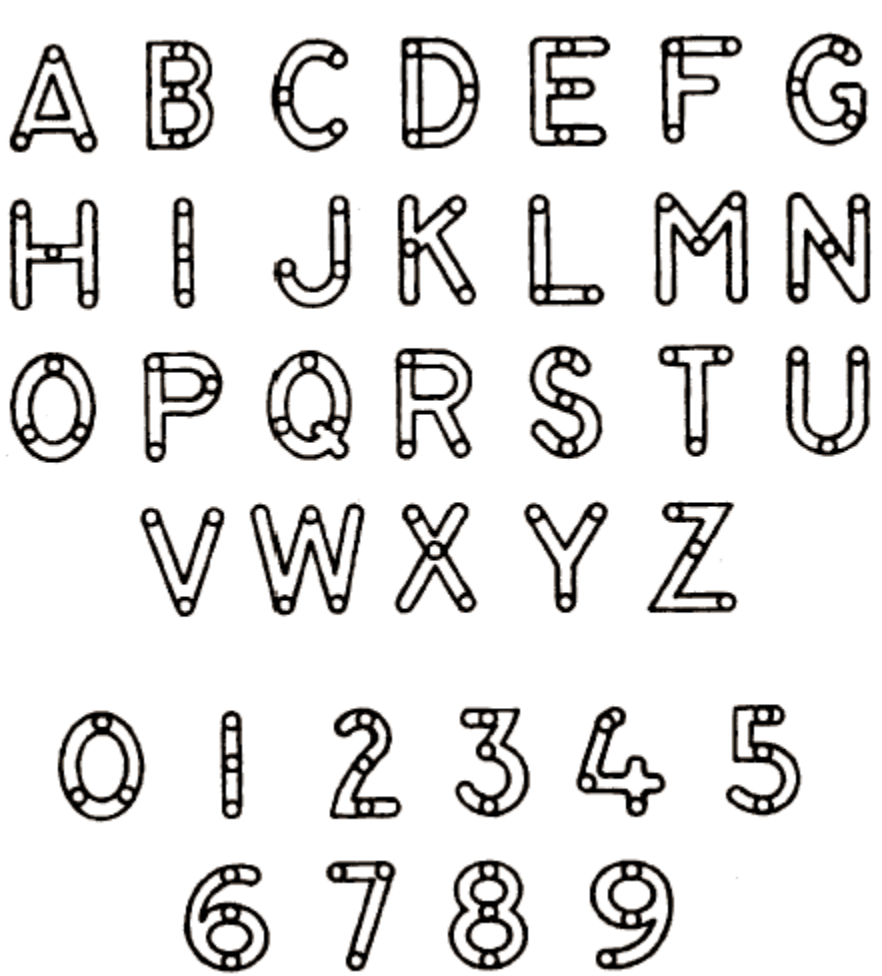
Measurement condition

- 150 um measurement port
- 150 um measurement spot
- Is the measured spectrum the same? Probably not.
  - Expect lower spectral data in violet and IR regions
  - Some color error too



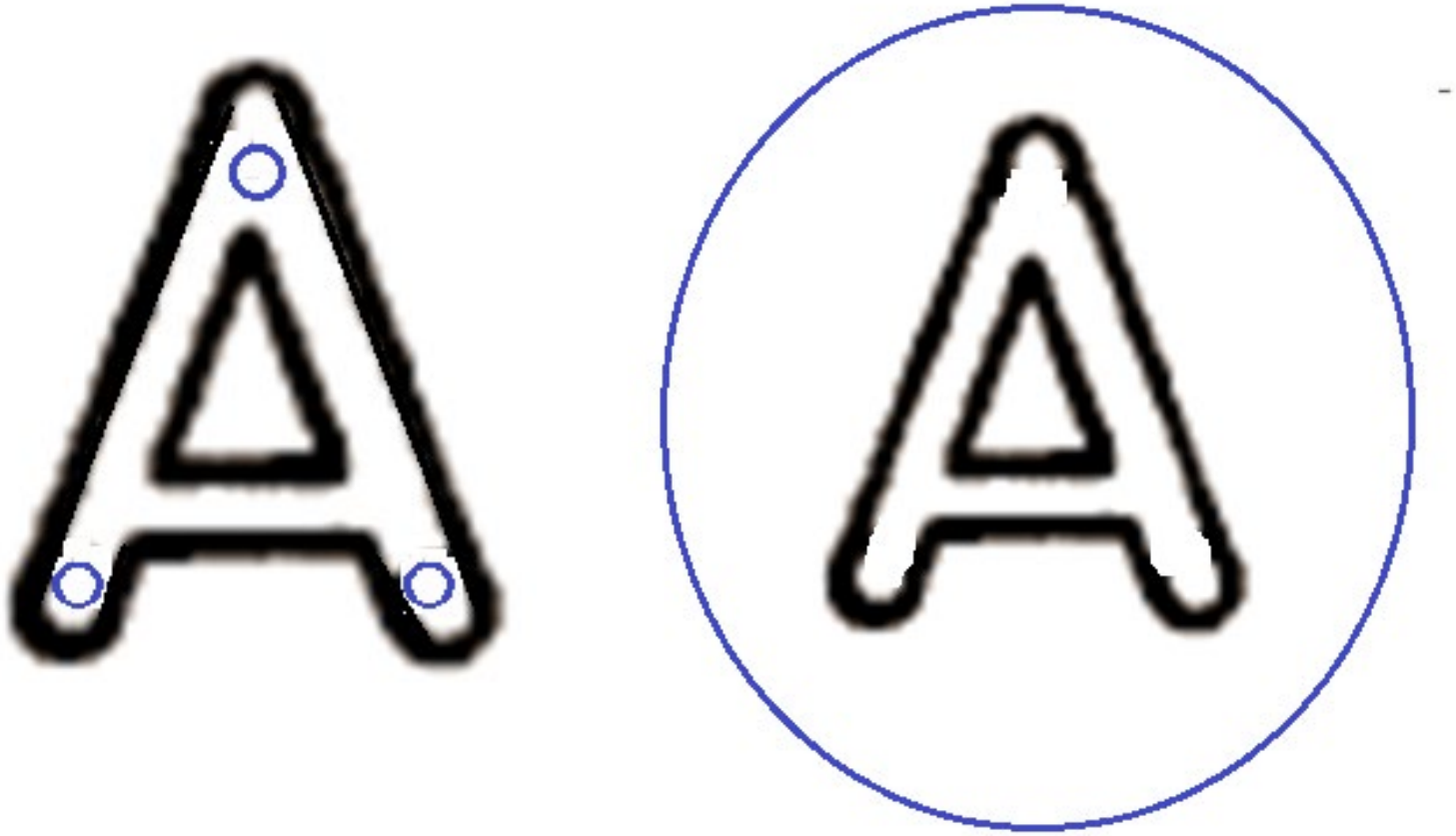
Spot Spectroradiometry for Graphics Testing

- SAE AS7788 constrains measurements to specific spots



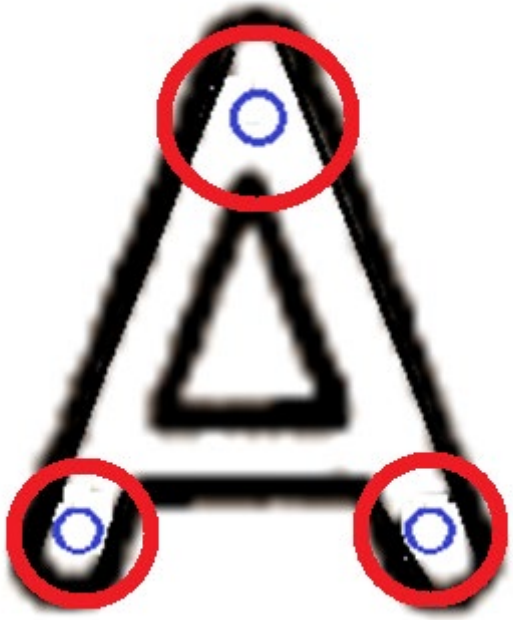
Spot Spectroradiometry for Graphics Testing

- Can the relative spectrum be measured equally well if the spot is inside or encompassing a graphic?
- Will the methods correlate?



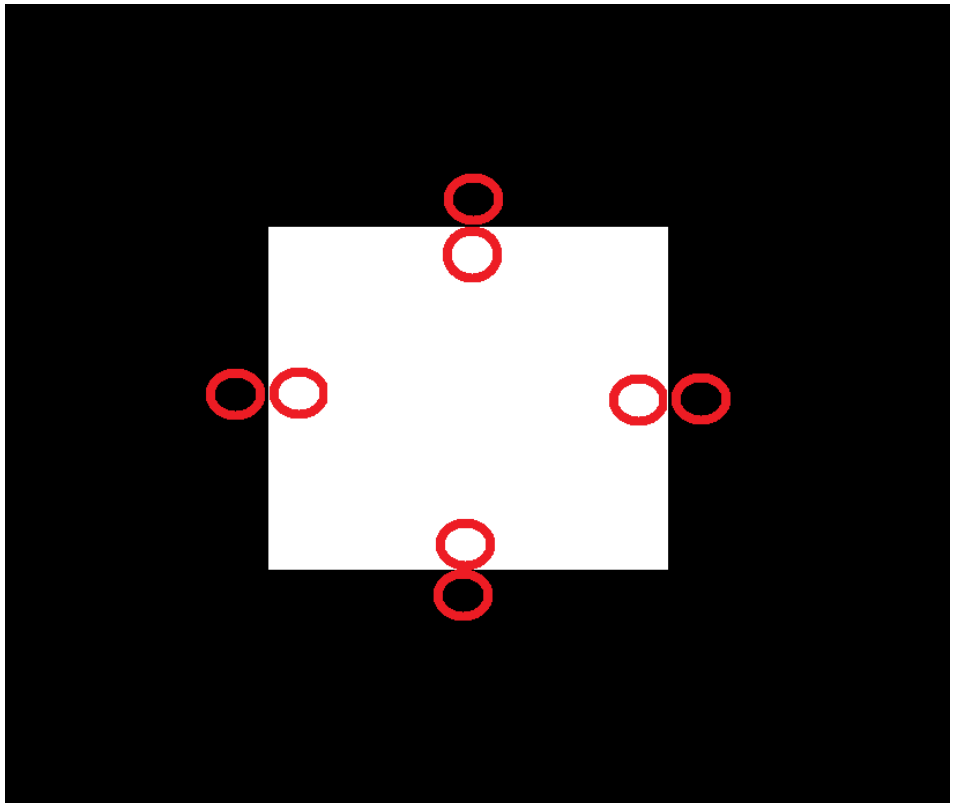
Poor focus

- If the focus for IR is poor, the IR will read low, but the luminance will be more reliable.
- --> Erroneously low scaled NVIS radiance



Spectroradiometer Spot Alignment Validation

- Measure these 8 locations
- Black **luminance** measurements must not be more than 5% of white measurement **luminance**.
- Not required by avionics standard for “Pritchard” style optics
- Assumption is that if luminance <5%, then spectral radiance from 380-930 is also right



Experiment

- Backlit transmissive MIL target with monochrome light
- Focused at 550 nm
- Stepped wavelength from 400 to 950 nm and take images at 50 nm increments.
- No refocusing!

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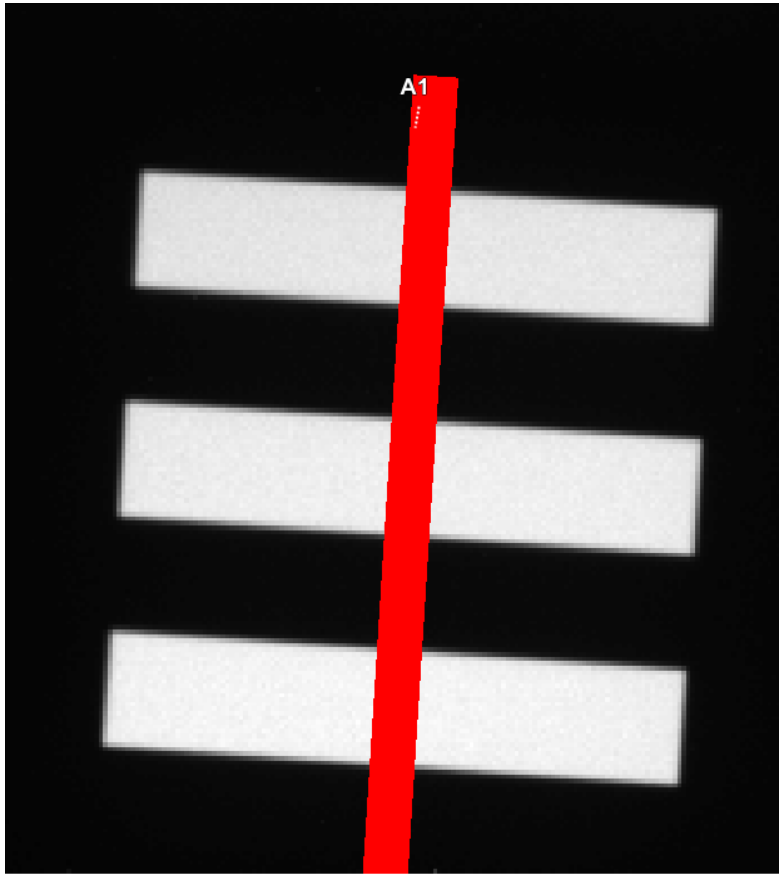
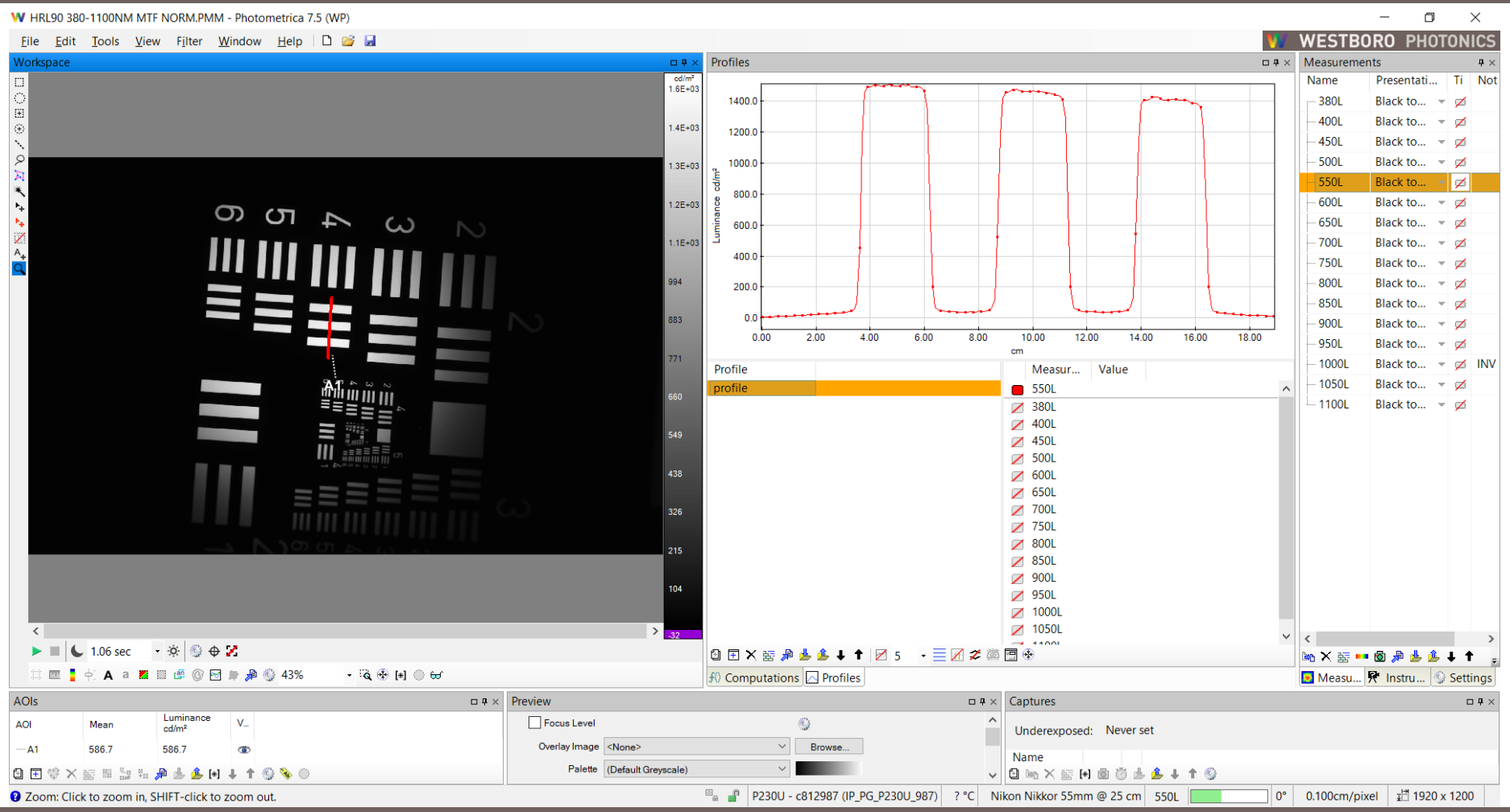
Lens

- Instrument Systems lens “HRL90”
- Minimum telescope spot size of 150 um (6 thou)
- Test will simulate focus capability when looking at Profiles across line pairs with 355 um wide white and black lines (710 um line pairs)

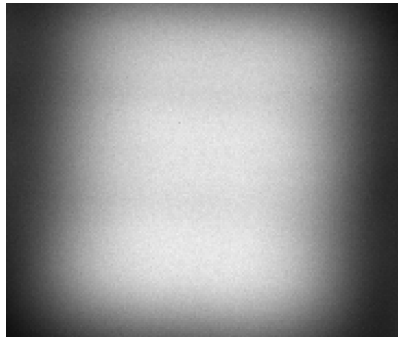


Measurements

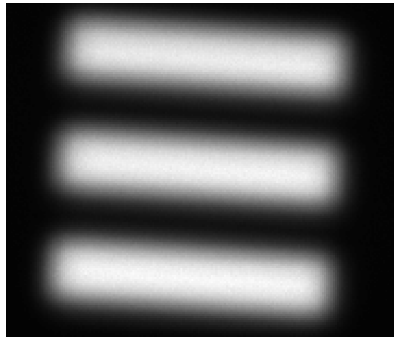


710um Line Pairs

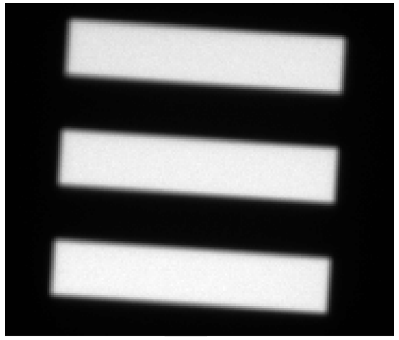
400nm



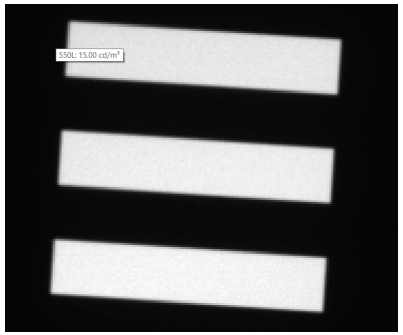
450nm



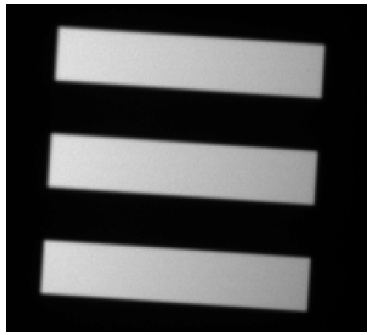
500nm



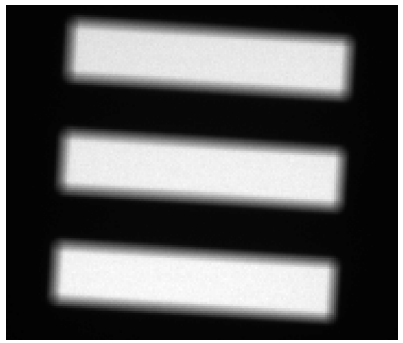
550nm



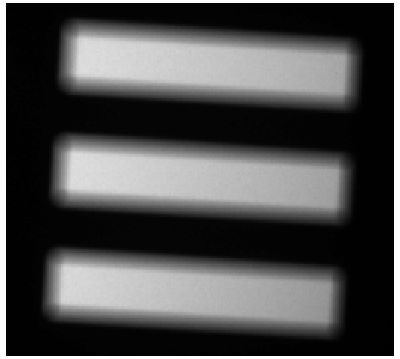
600nm



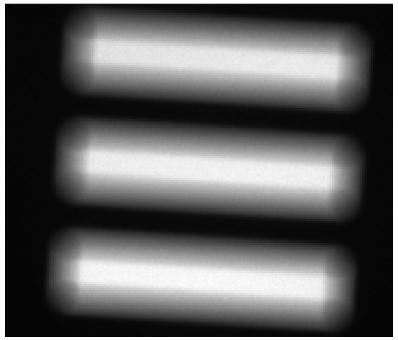
650nm



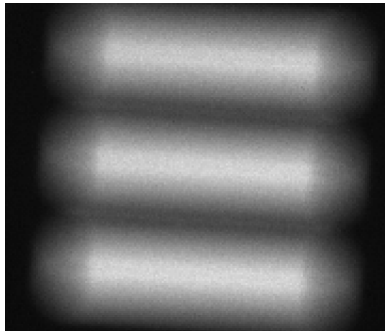
700nm



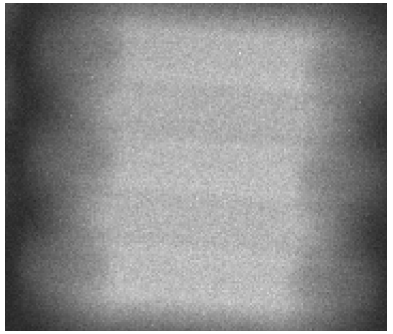
750nm



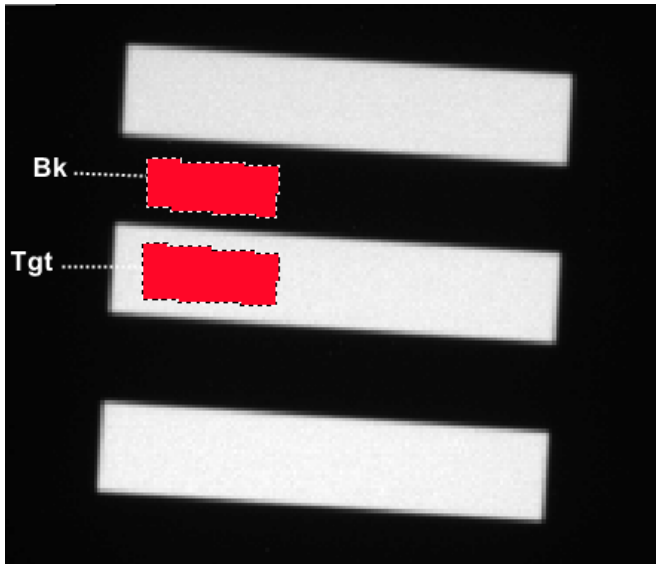
850nm

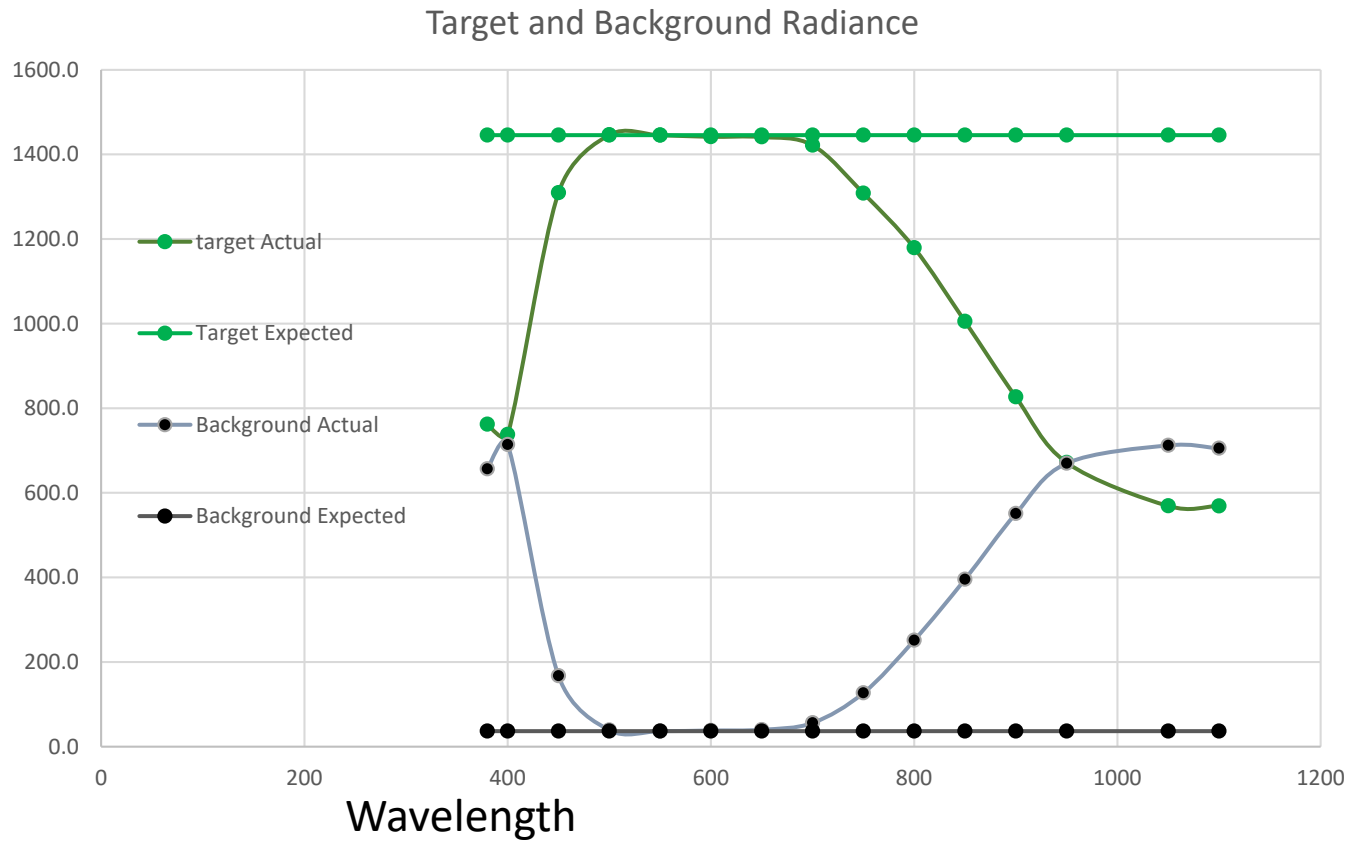


950nm



Measurements





Examples of Wide Wavelength Imaging Systems

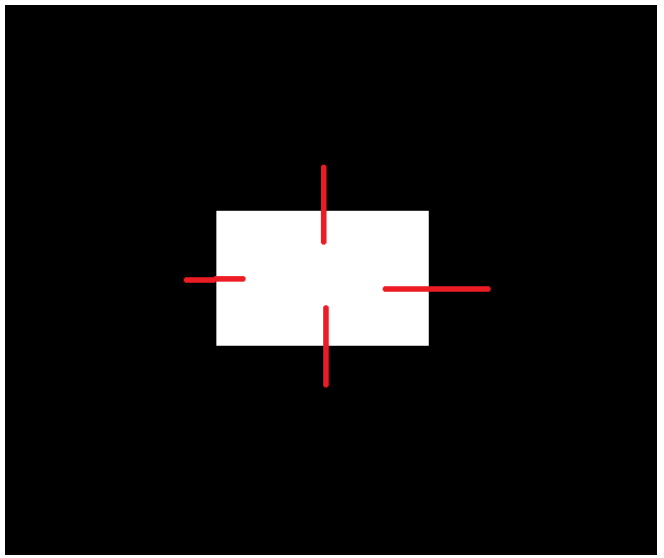
- Spectometer attached to a microscope tube
- NVIS radiance spectroradiometers
- Hyperspectral & multispectral imagers
  - Push broom type
  - Mosaic filter type
  - Sequential filter type

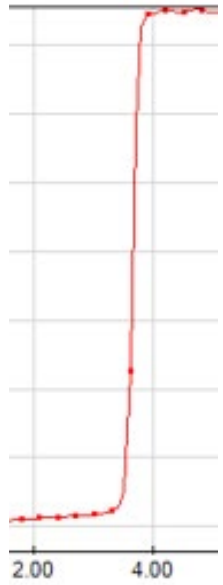
Solutions

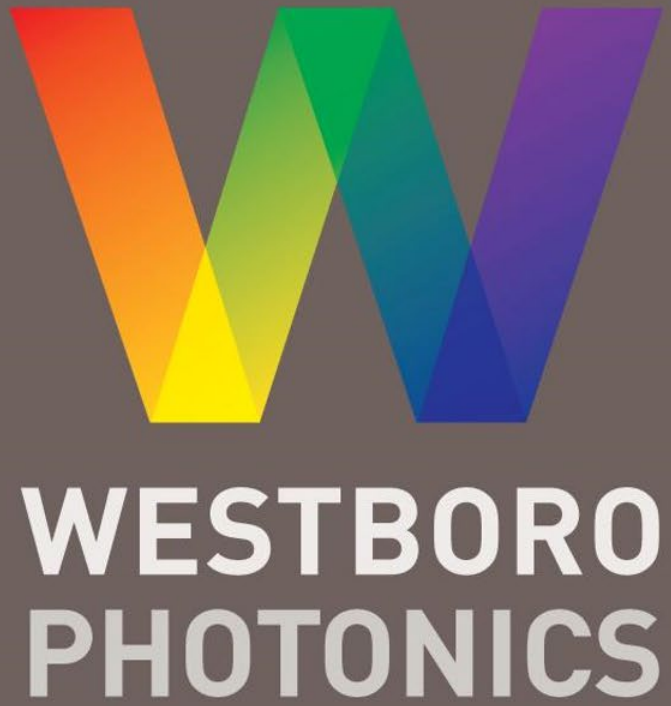
1. Use reflective optics
2. Only use lenses over their designed wavelength range
3. Measure the spectrum in chunks refocus for each successive range and stack the measurements into a single wide wavelength range set.

Tests

- Image broadband light directly beside a light trap.
  - Expect all spectral values to drop from the illuminated side to the trap side of the target.
  - Check on the optical axis
  - Also check in the corners of the field of view







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