Spectral Lamp Model Performance Variations

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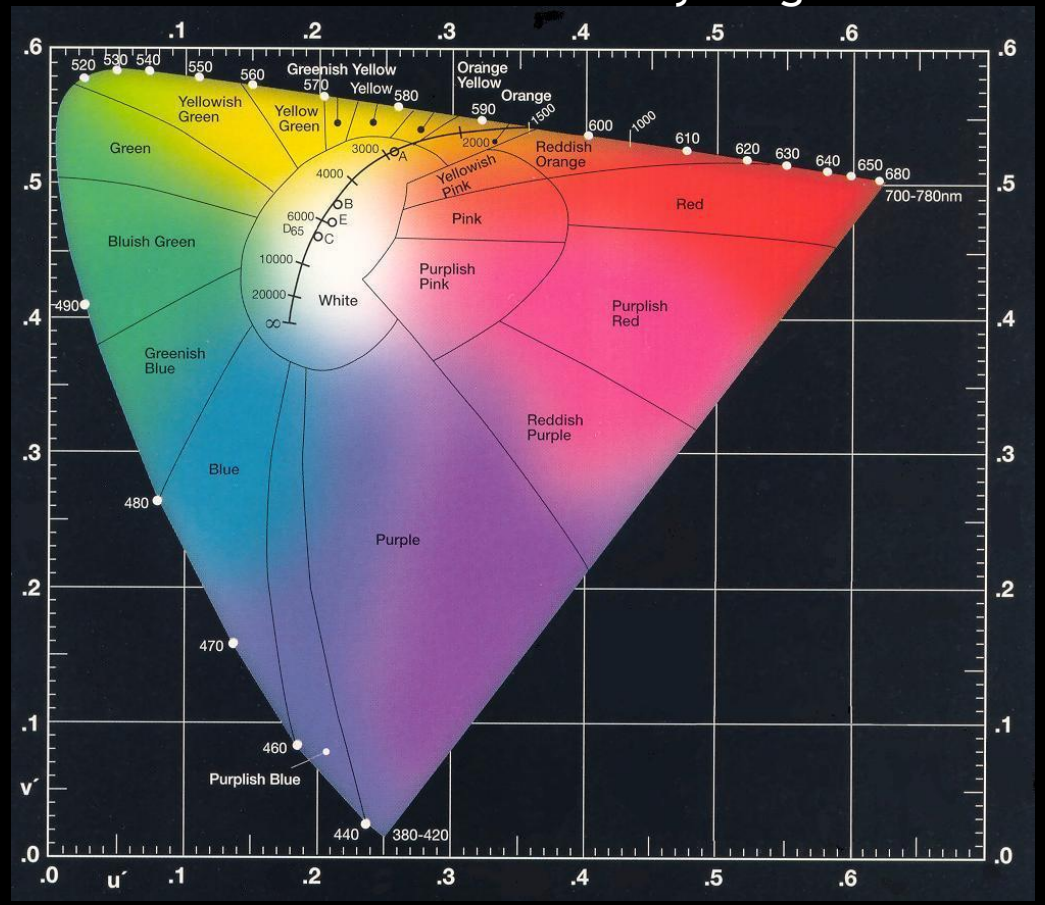
Color Data

CIE 1976 Chromaticity Diagram



www.color-theory-phenomena.nl

CIE Color Space data (u’v’)

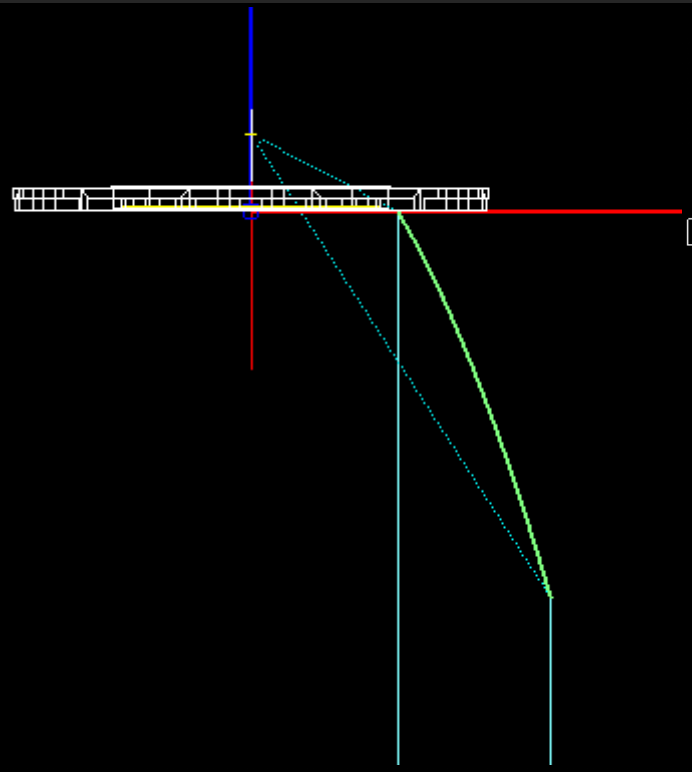
Change Over Emission Angle

Overview

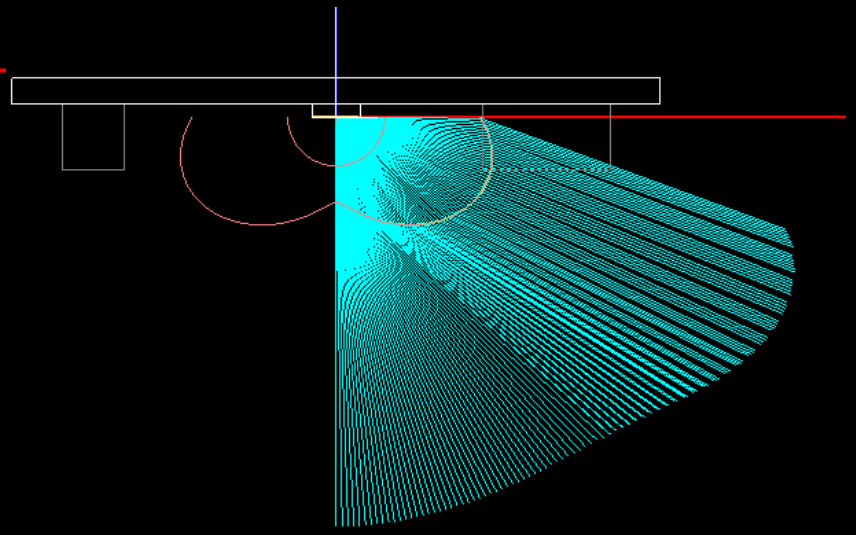
- There are various levels of detail required for color data modeling in optical simulations

- How accurate must this data be? The answer is optic dependent
  - Three different Optics
    - Three modeled and two measured

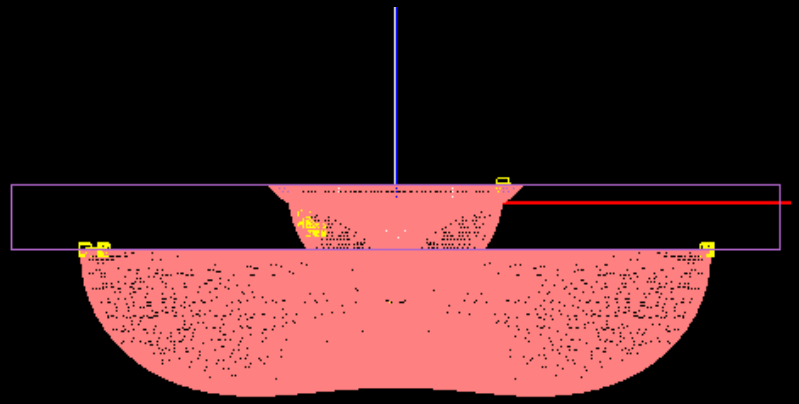
Optics



Smooth Parabolic Reflector



Symmetric Linear Batwing Lens

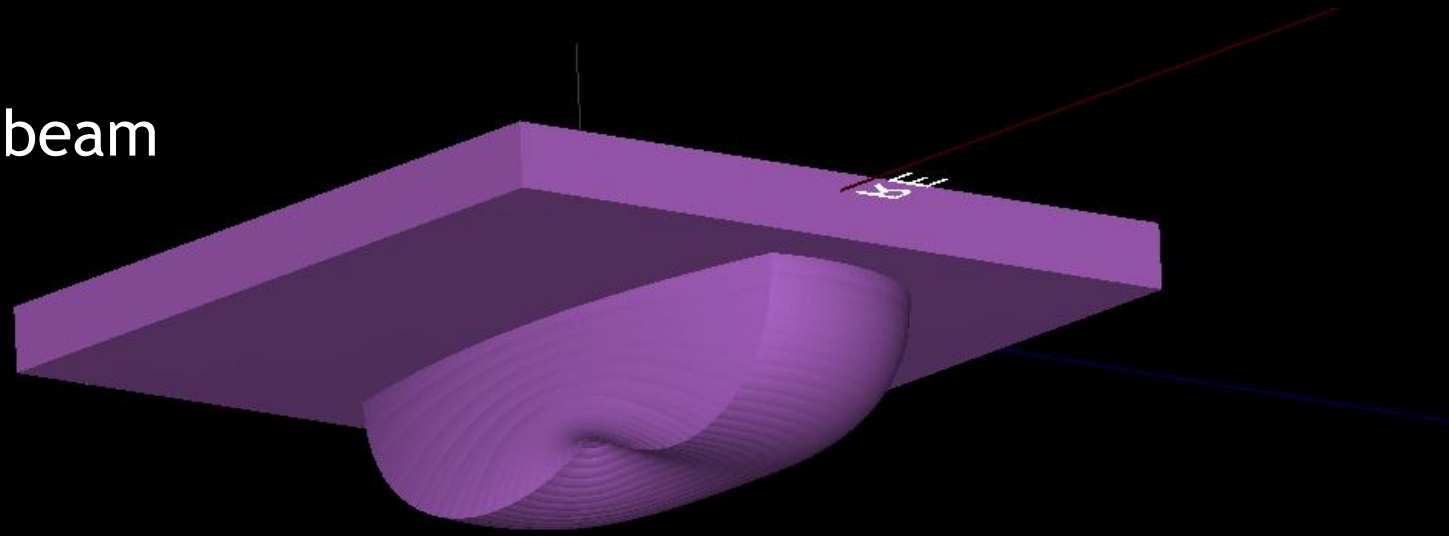


Type III Roadway Lens

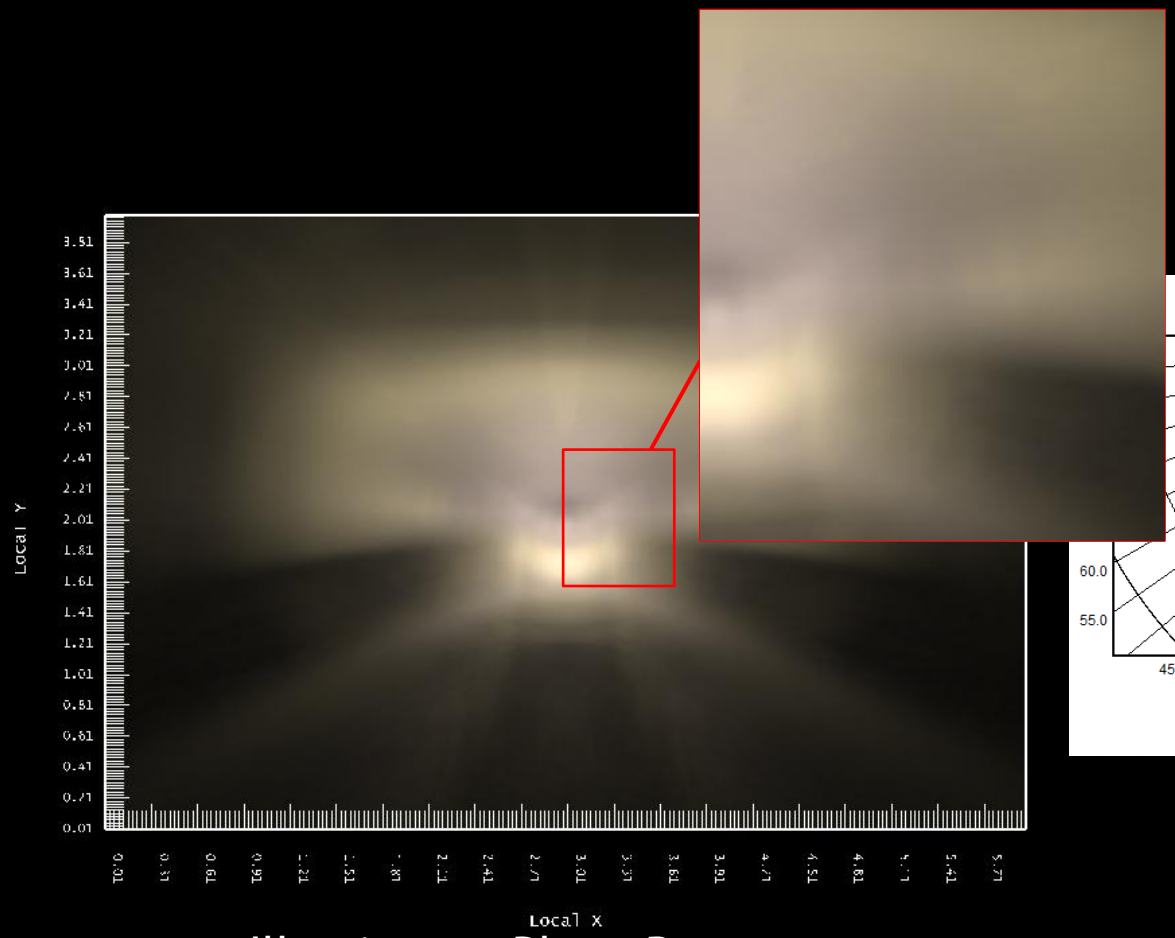
Roadway Lens

- Type III Roadway Lens
  - Forward throw wide spread beam
  - Acrylic
  - Index of refraction = 1.491

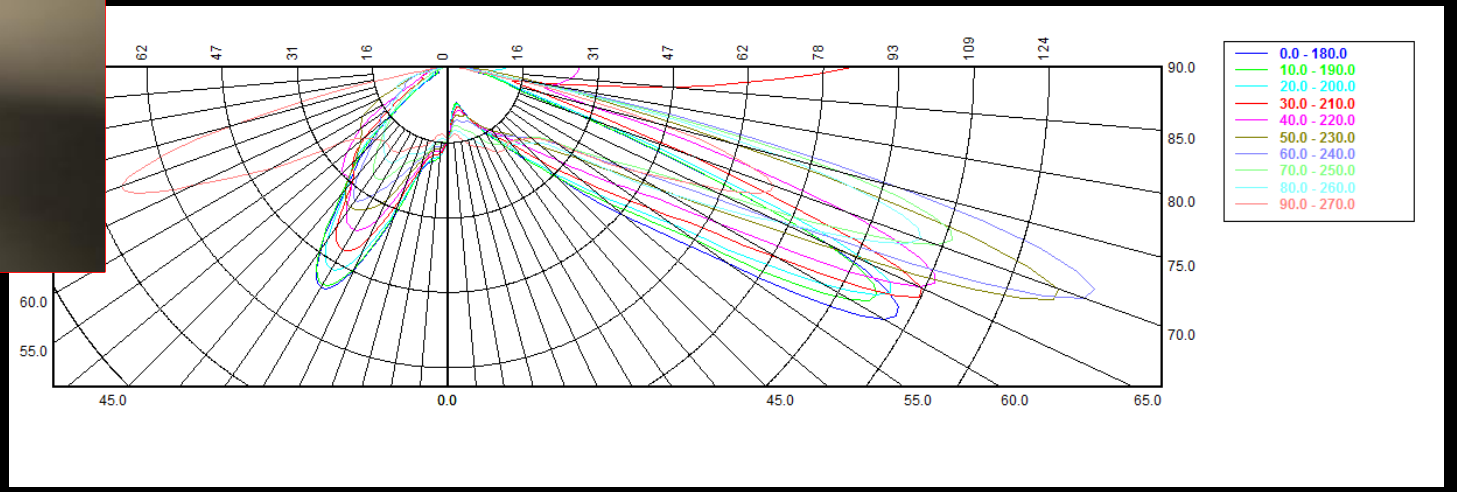
- Lamp
  - 1.96W Luxeon T LED
  - CCT – 3800K



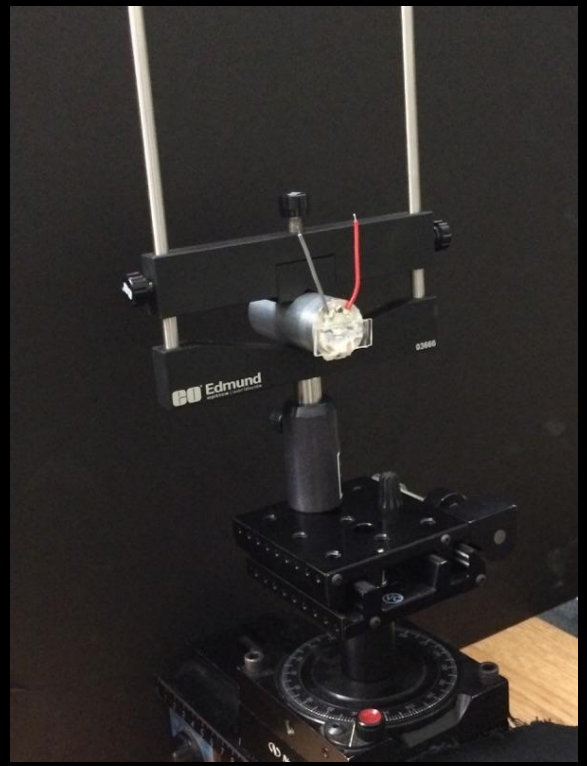
Photopia Results

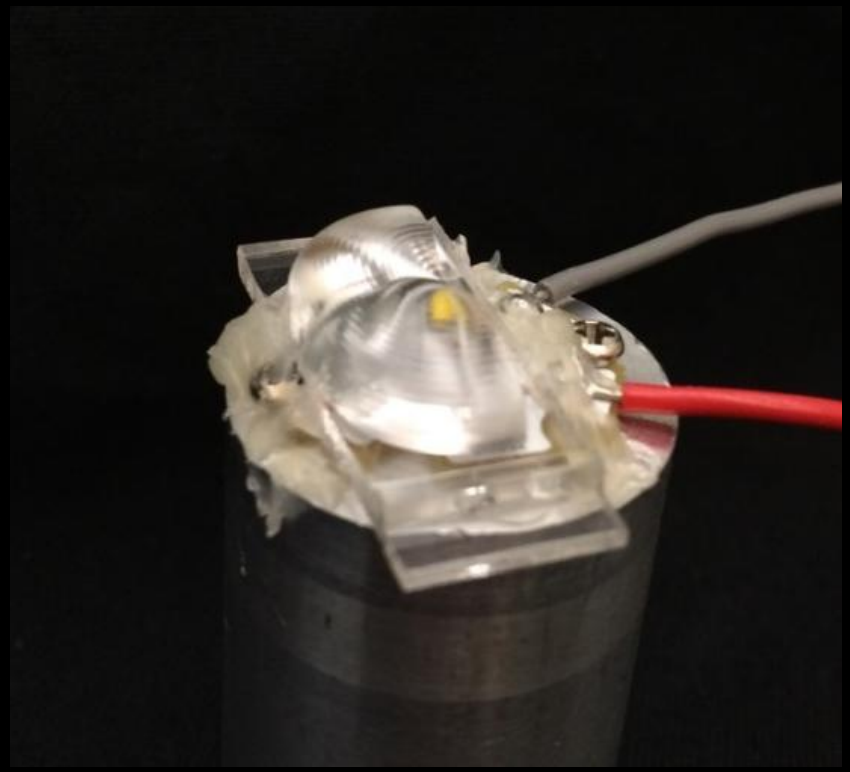


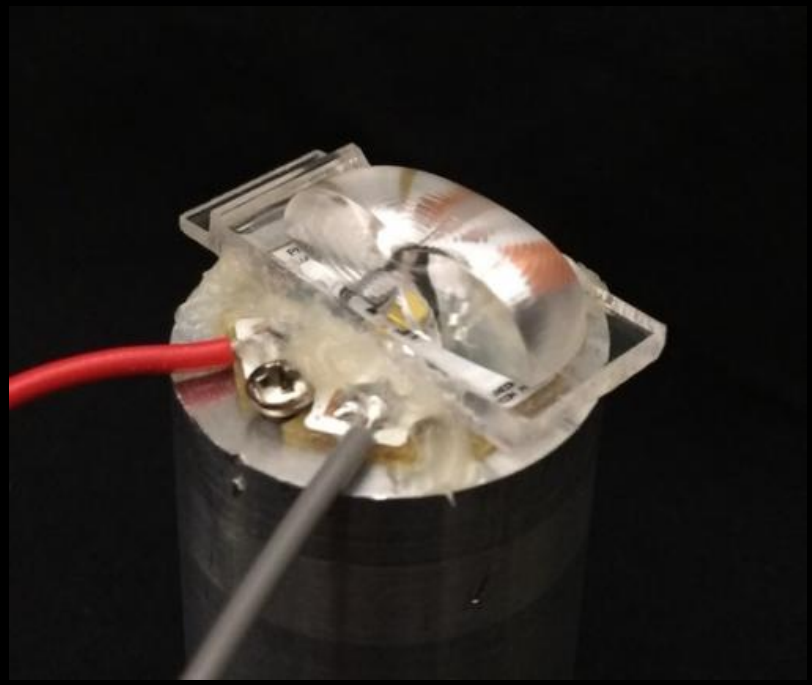
Illuminance Plane Raytrace



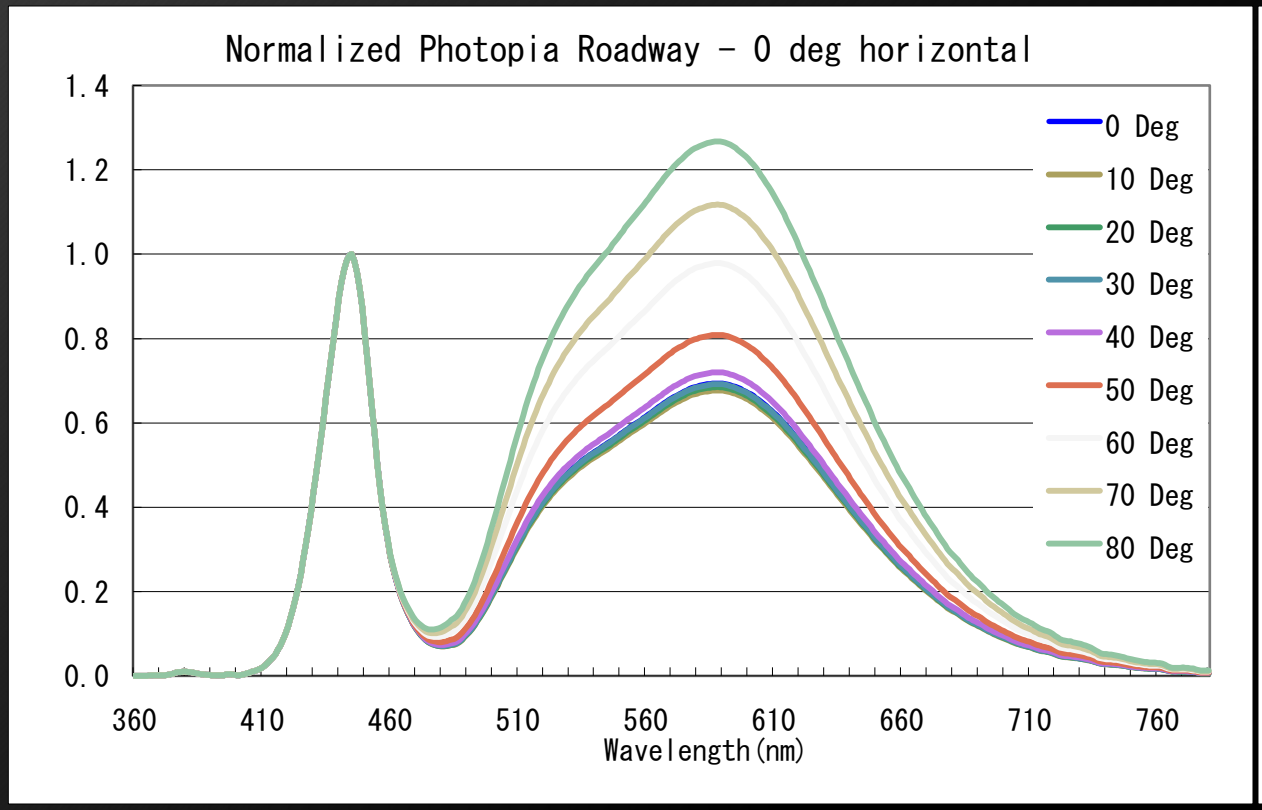
Measurements



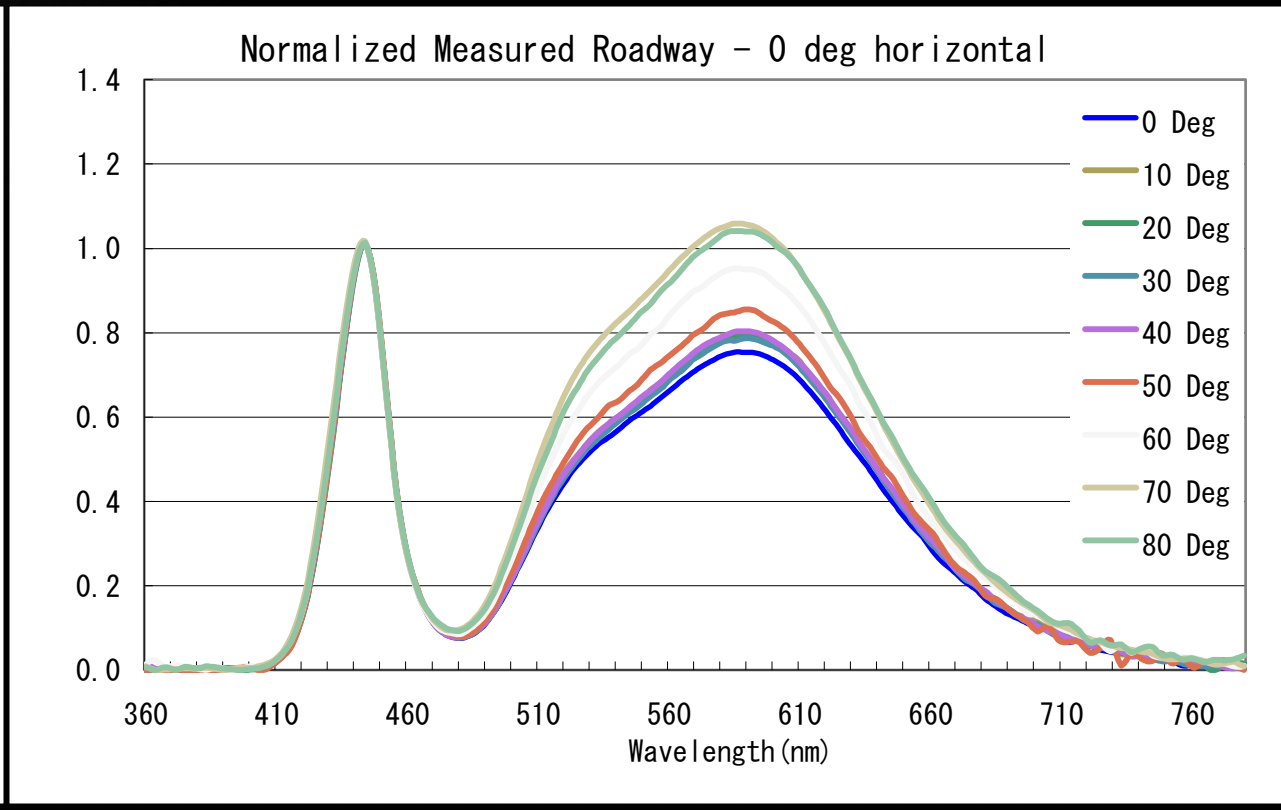




Roadway 0 Degree Horizontal Plane (front) Irradiance Comparison

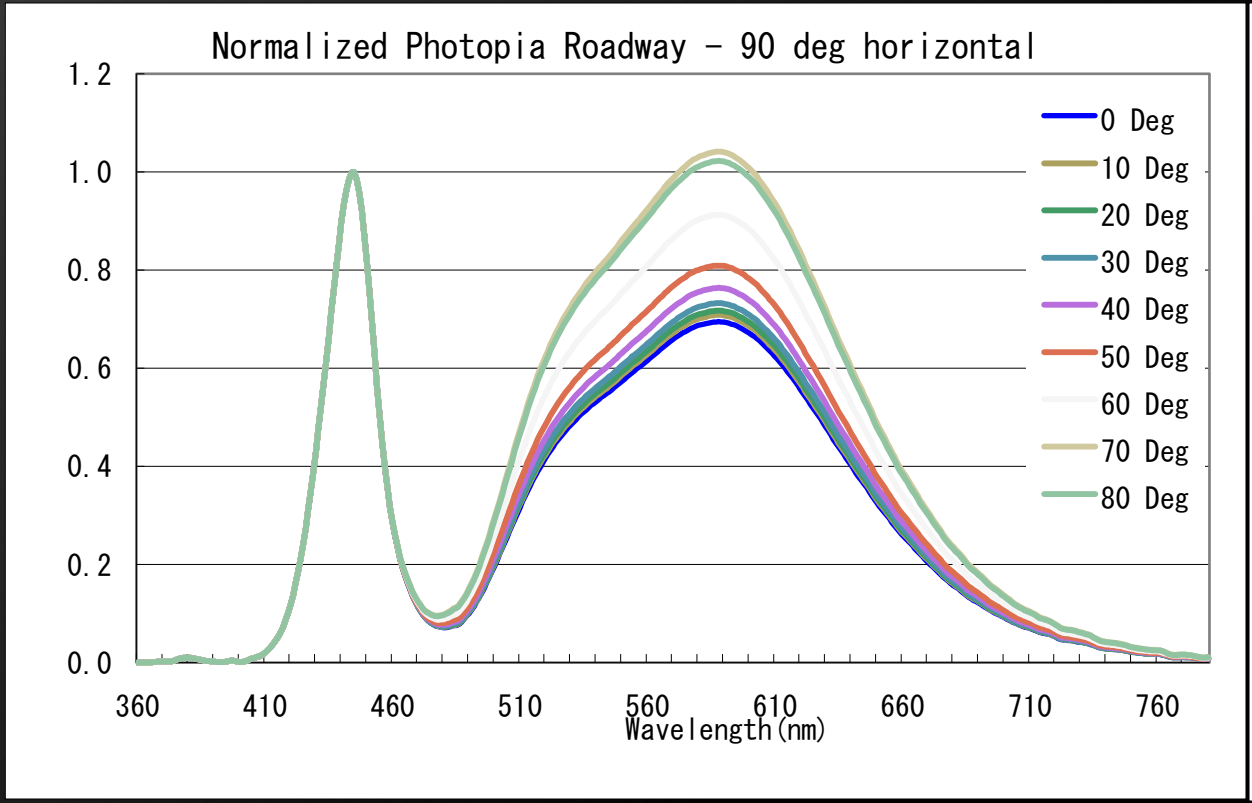


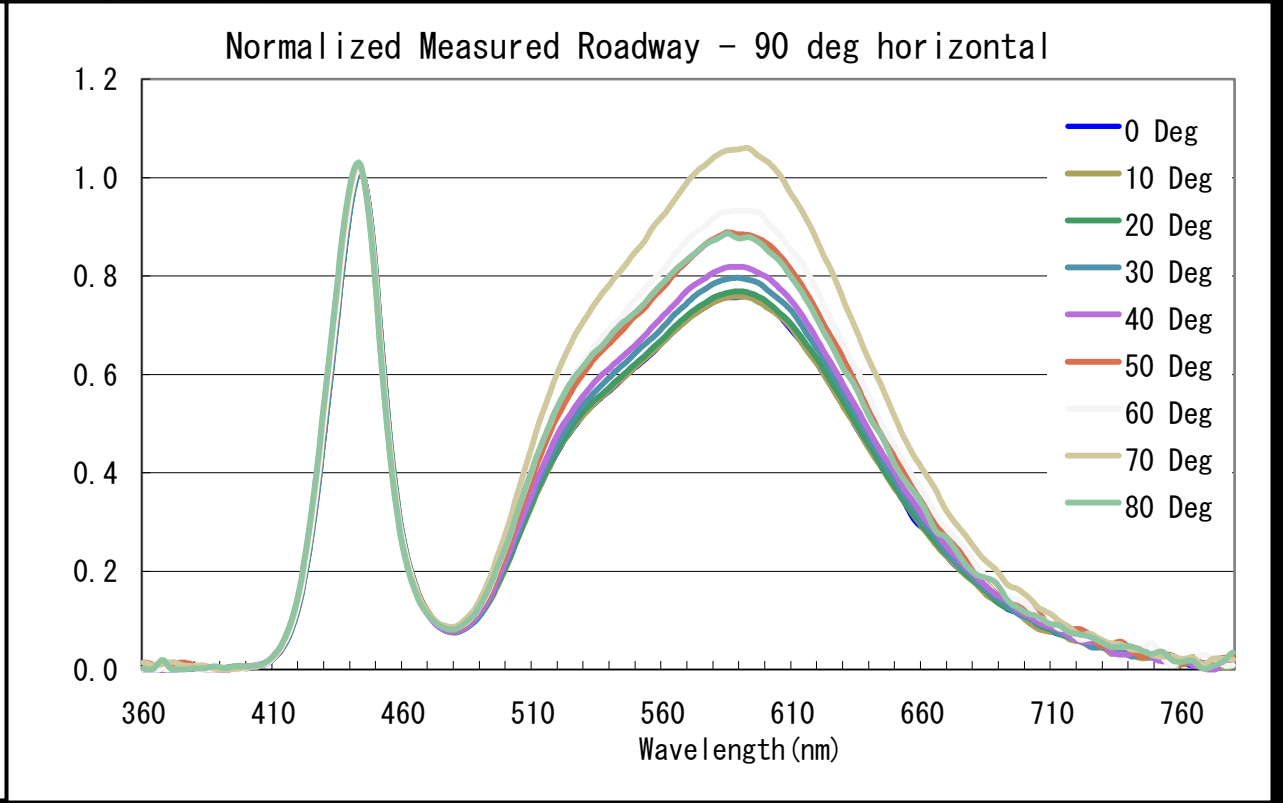
Photopia Model Spectral Distribution



Measurement Spectral Distribution

Roadway 90 Degree Horizontal Plane (side) Irradiance Comparison





Photopia Model Spectral Distribution

Measurement Spectral Distribution

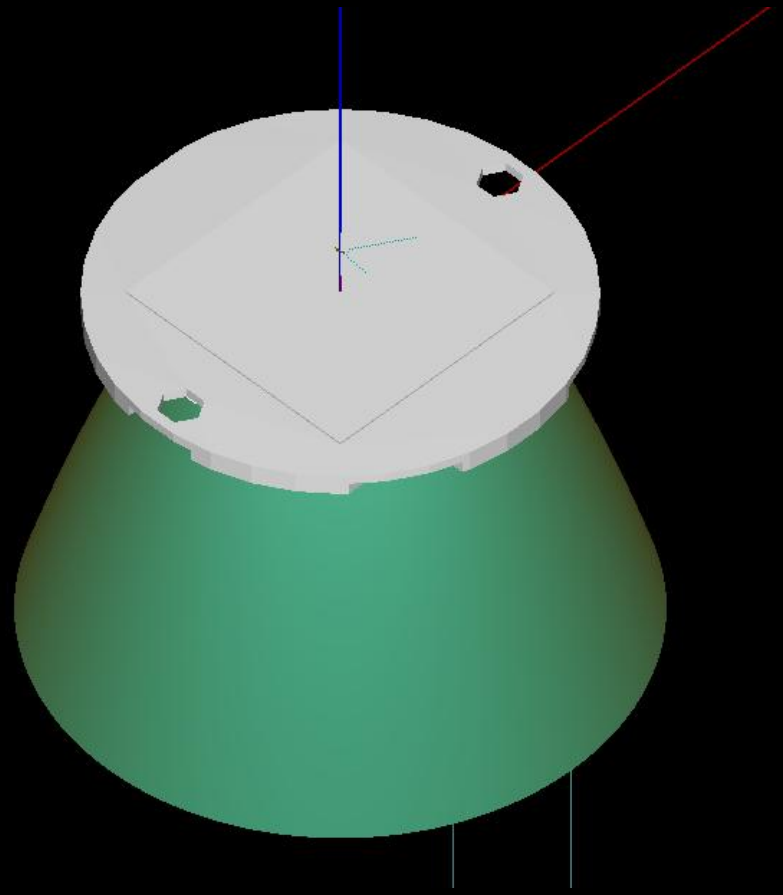
Roadway Lens Difference

- Delta u’v’ over beam angle
  - Photopia – 0.008332
  - Measurements – 0.009361
  - Difference of 1 MacAdam Ellipse
- Illuminance
  - Photopia results more exaggerated (about 20%)
  - Generally same distribution shape
  - Disconnect at 20 degree vertical angle

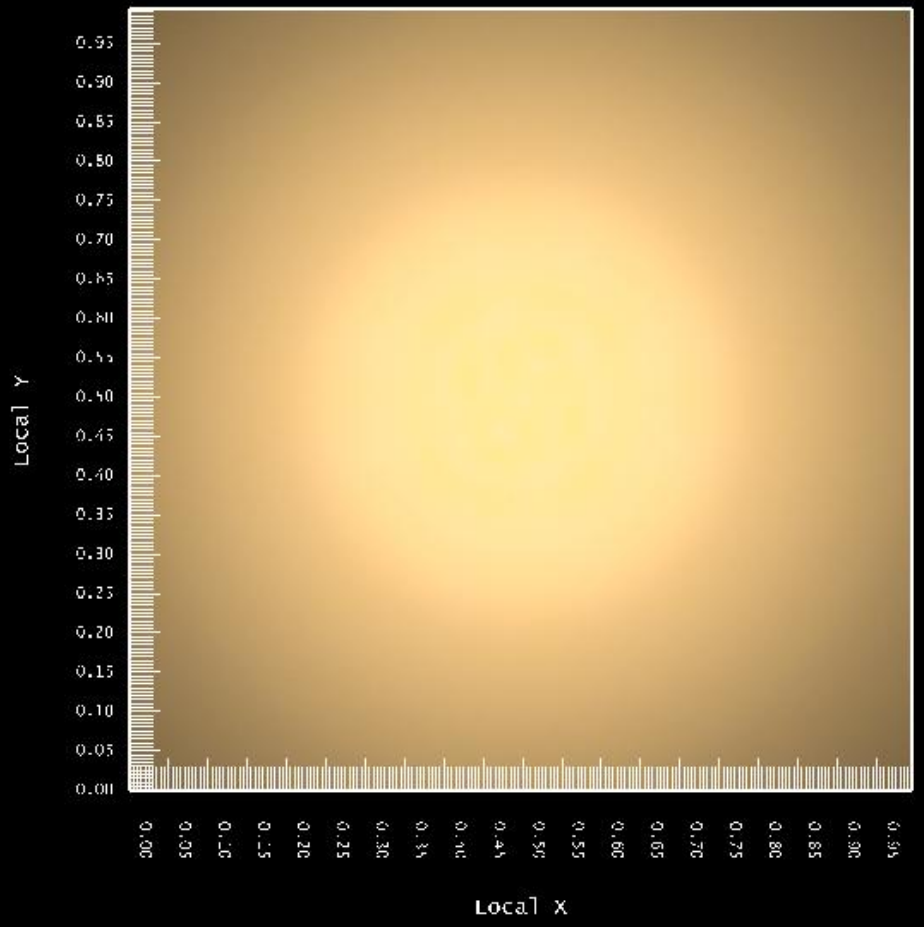
Parabolic Reflector

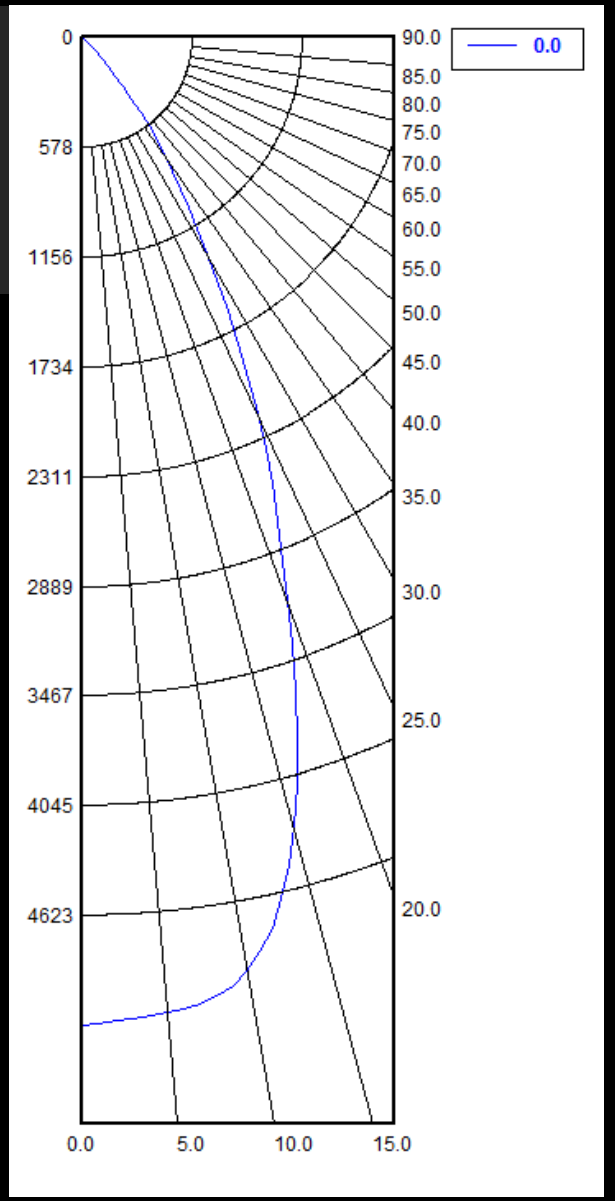
- Smooth Revolved Parabolic Reflector
  - Luminous opening = 16 cm^2
  - Specular reflectance of 85%

- Lamp
  - 32.1 W Bridgelux Vero 29 COB Array
  - CCT – 2900K



Photopia


Local Y
Local X


0.0
0
578
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2311
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3467
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4623
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85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
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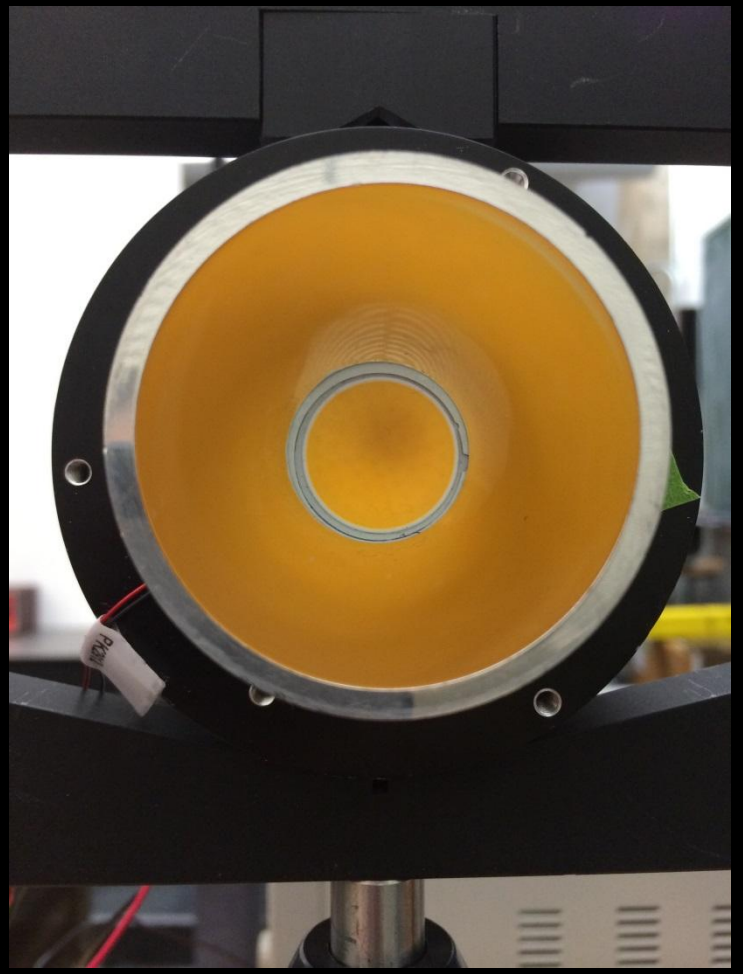
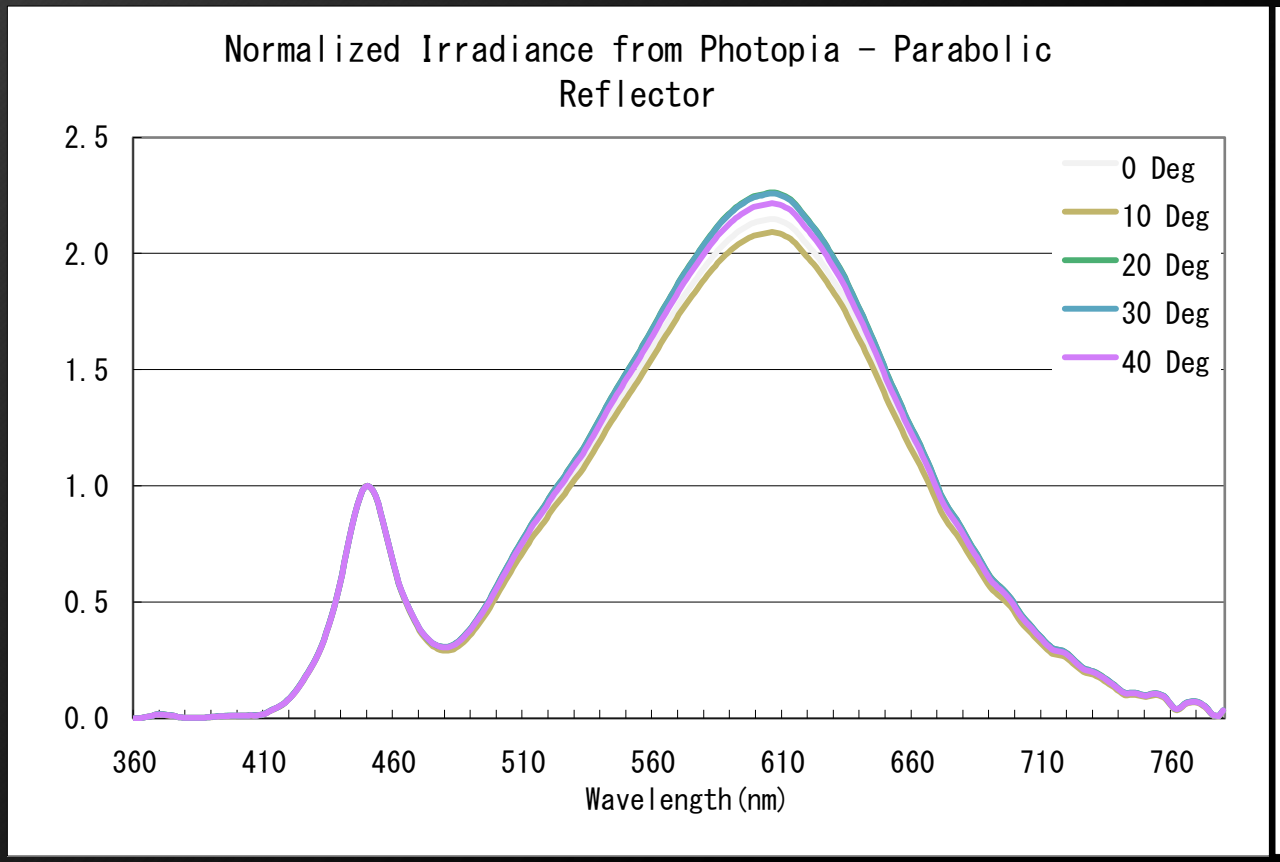
40.0
35.0
30.0
25.0
20.0
0.0
5.0
10.0
15.0

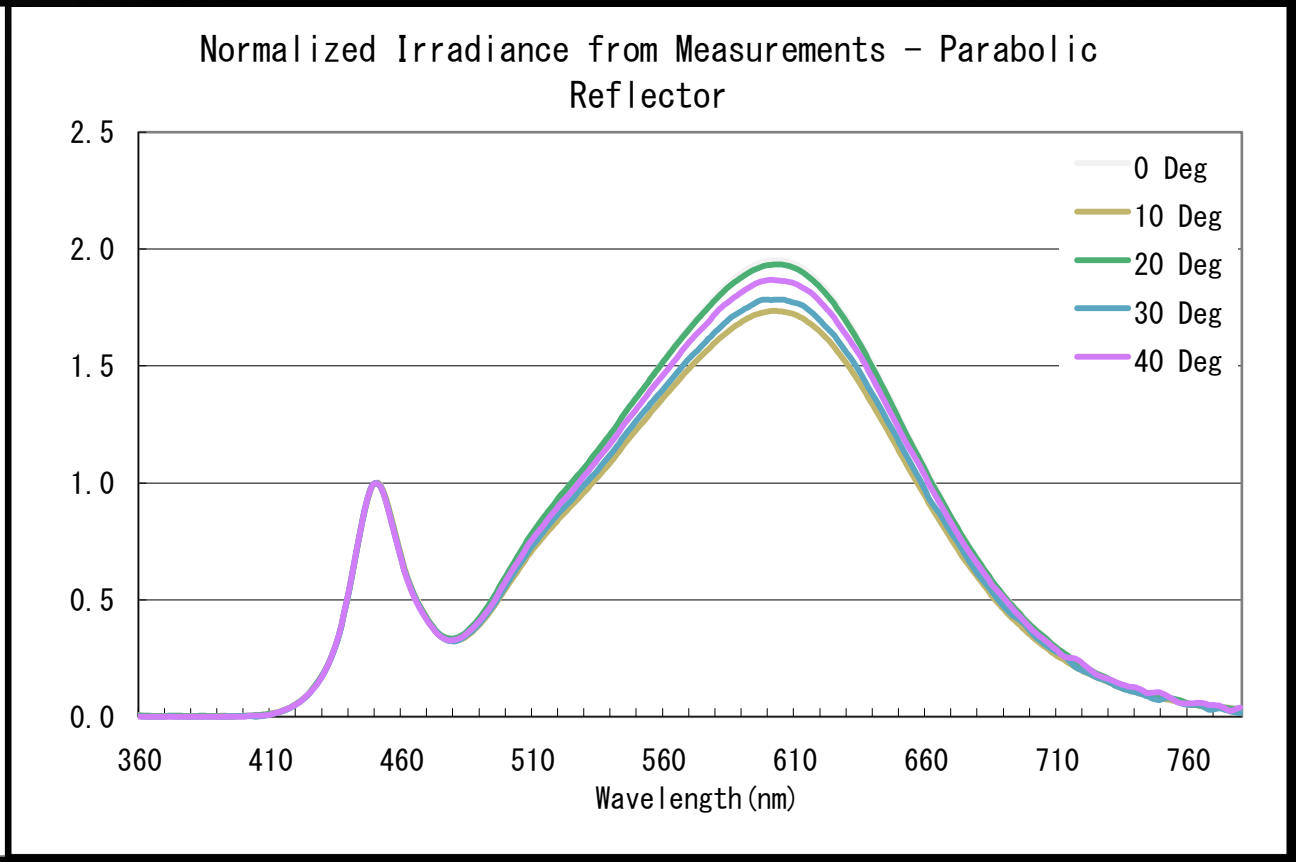
Measurements



Parabolic Reflector Irradiance Comparison

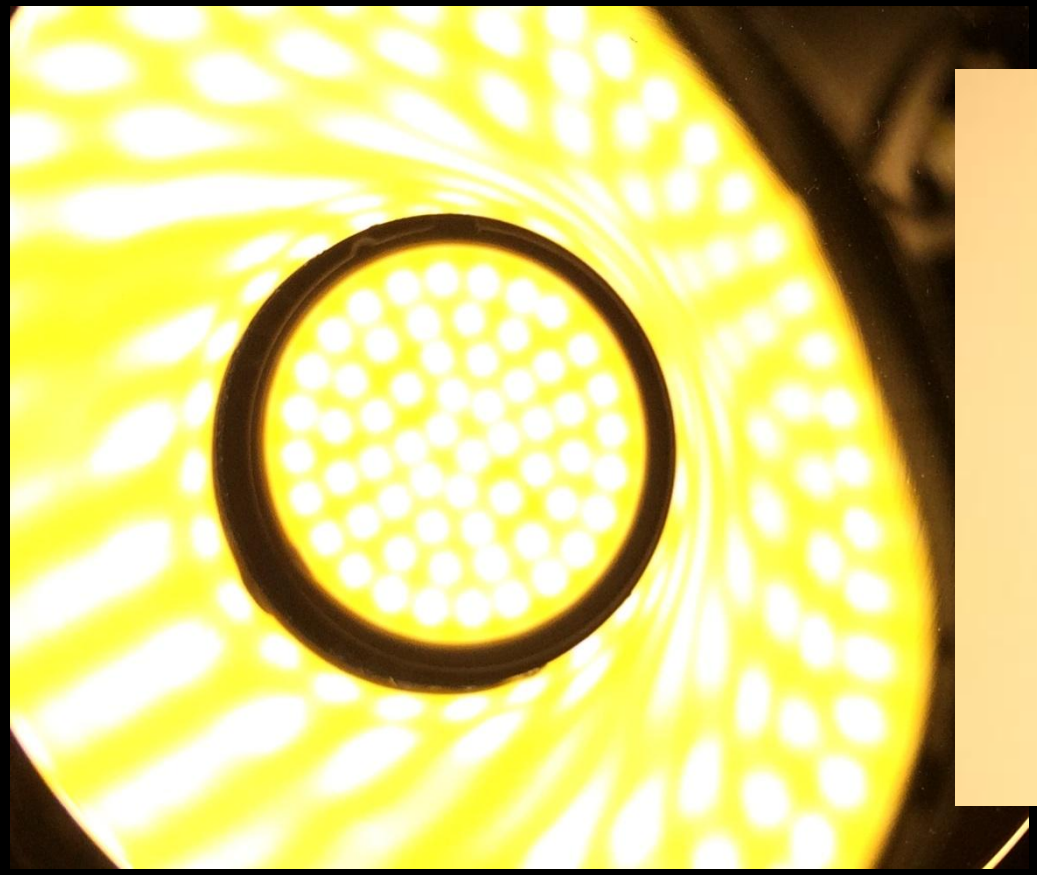


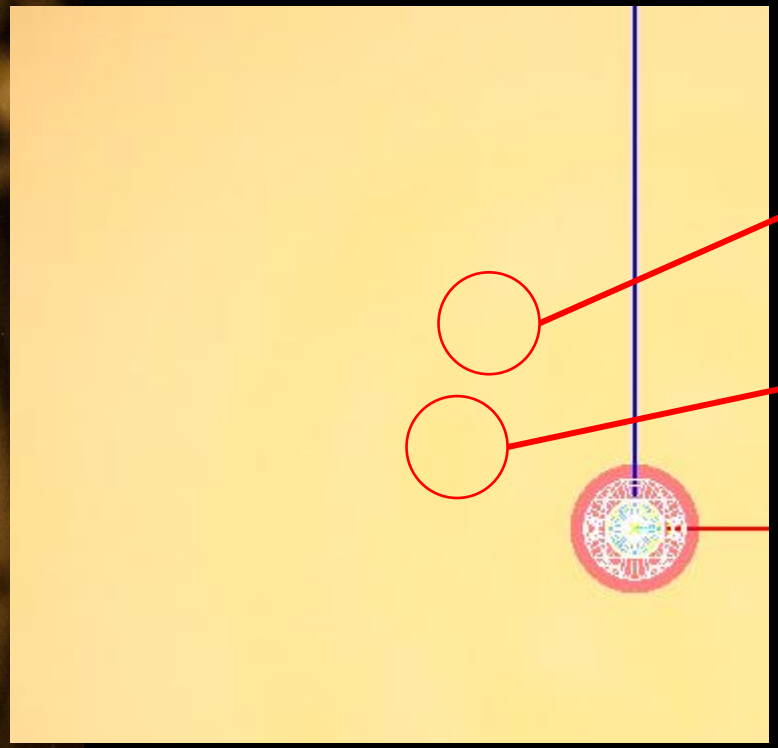
Photopia Model Spectral Distribution



Measurement Spectral Distribution

Point Color Data



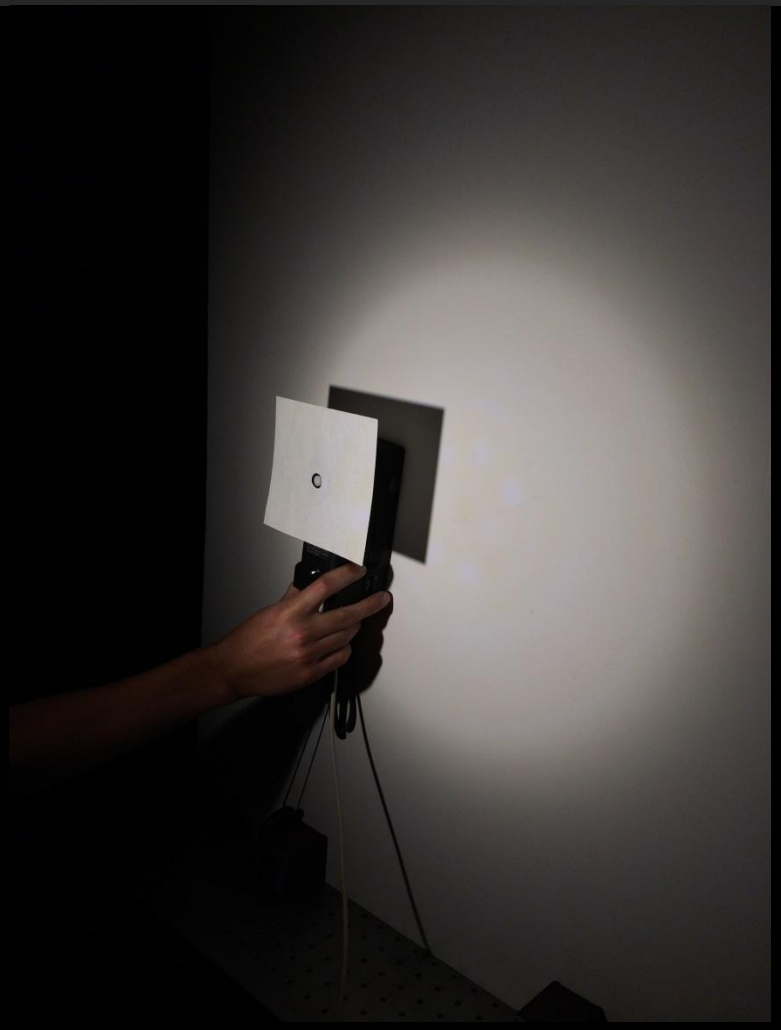


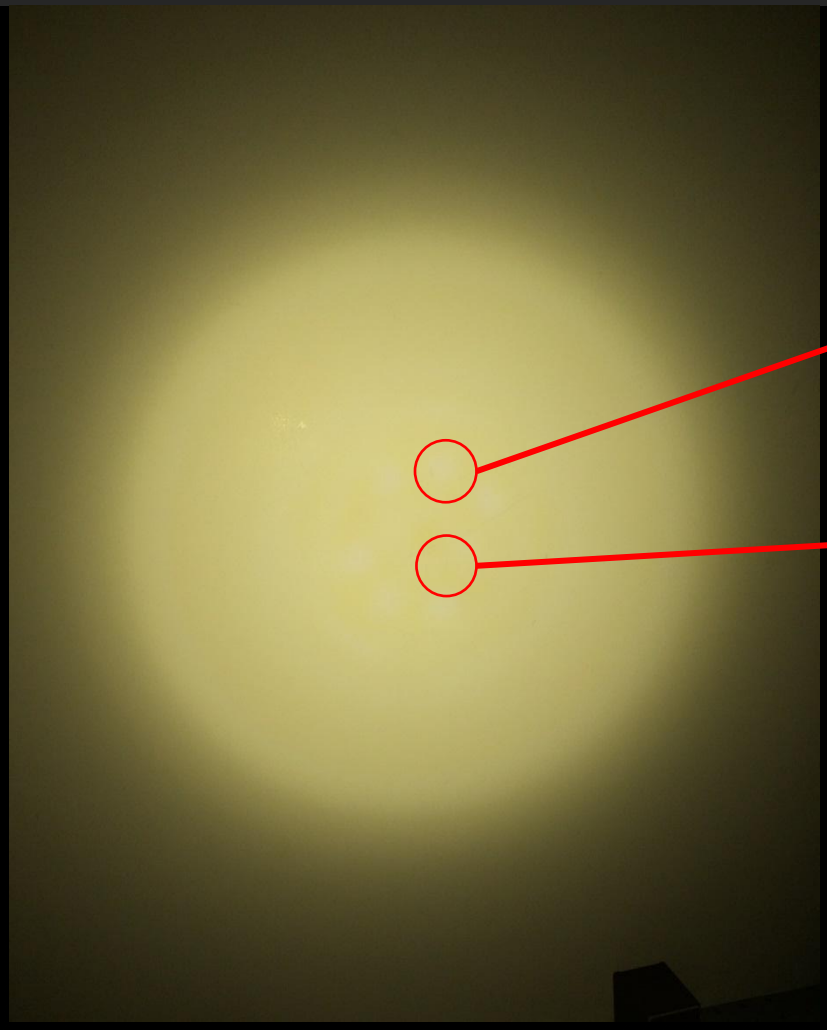
Blue spot
u’ = 0.25433
v’ = 0.52165

Yellow spot
u’ = 0.25517
v’ = 0.52611

Color Difference = 0.004536
4.5 MacAdam Ellipses

Point Color Data





Blue spot
u’ = 0.24409
v’ = 0.51392

Yellow spot
u’ = 0.24720
v’ = 0.52121

Color Difference = 0.007922
8 MacAdam Ellipses

Parabolic Reflector Difference

- Delta u’v’ over beam angle
  - Photopia – 0.001103
  - Measurements – 0.003795
  - Difference of 70% or 2.6 MacAdam Ellipses

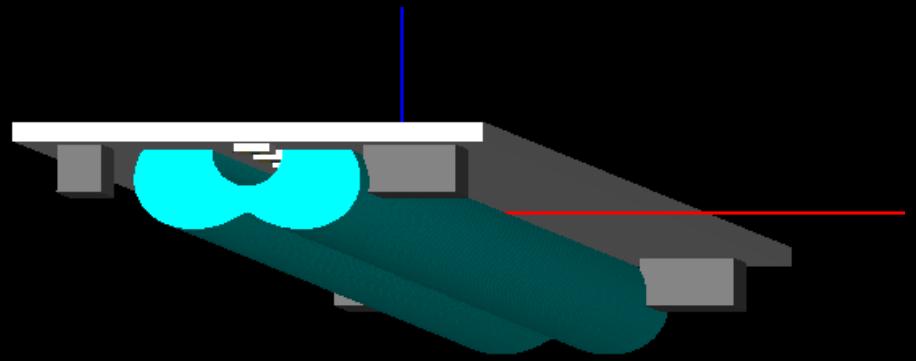
- Point u’v’ data
  - Photopia – Difference of 0.004536
  - Measurements – Difference of 0.007922
  - Difference of 43% or 3.4 MacAdam Ellipses

Parabolic Reflector Difference

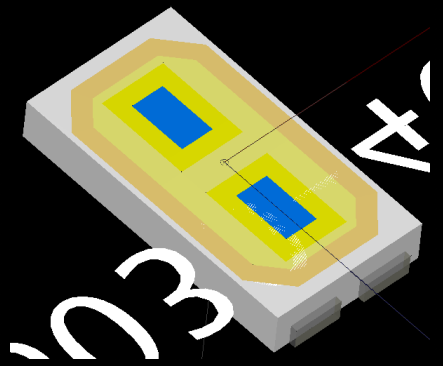
- Illuminance
  - Color change across angles matches very well
  - Photopia results appear more yellow
  - Angles follow the same pattern of blue to yellow

Linear Symmetric Lens

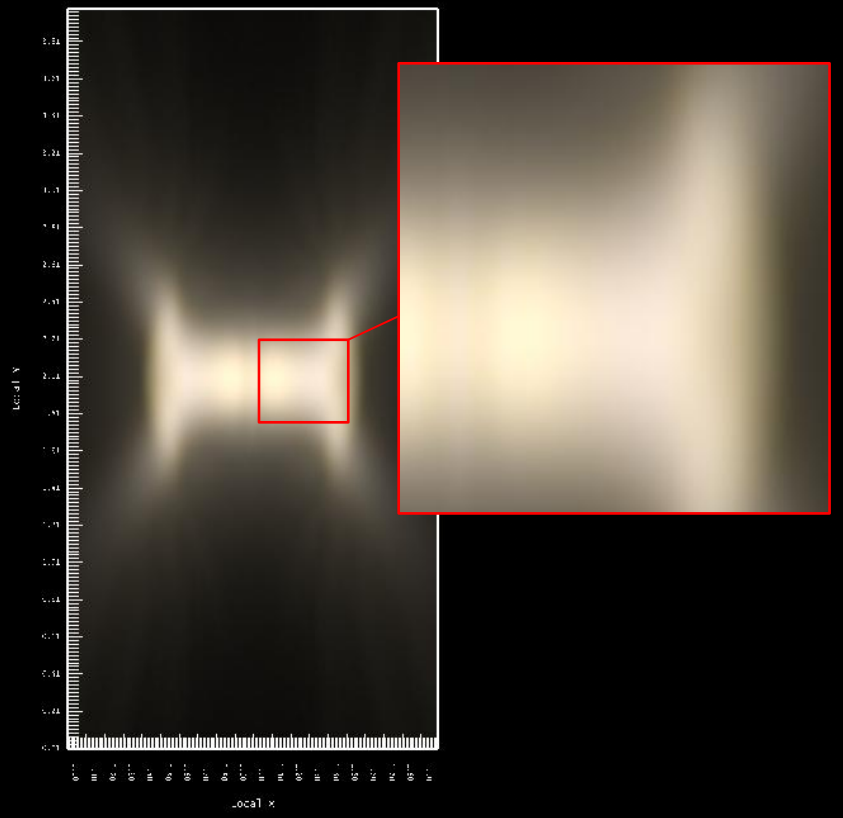
- Extruded Symmetric Lens
  - Wide Batwing Distribution
  - 140° Beam Angle



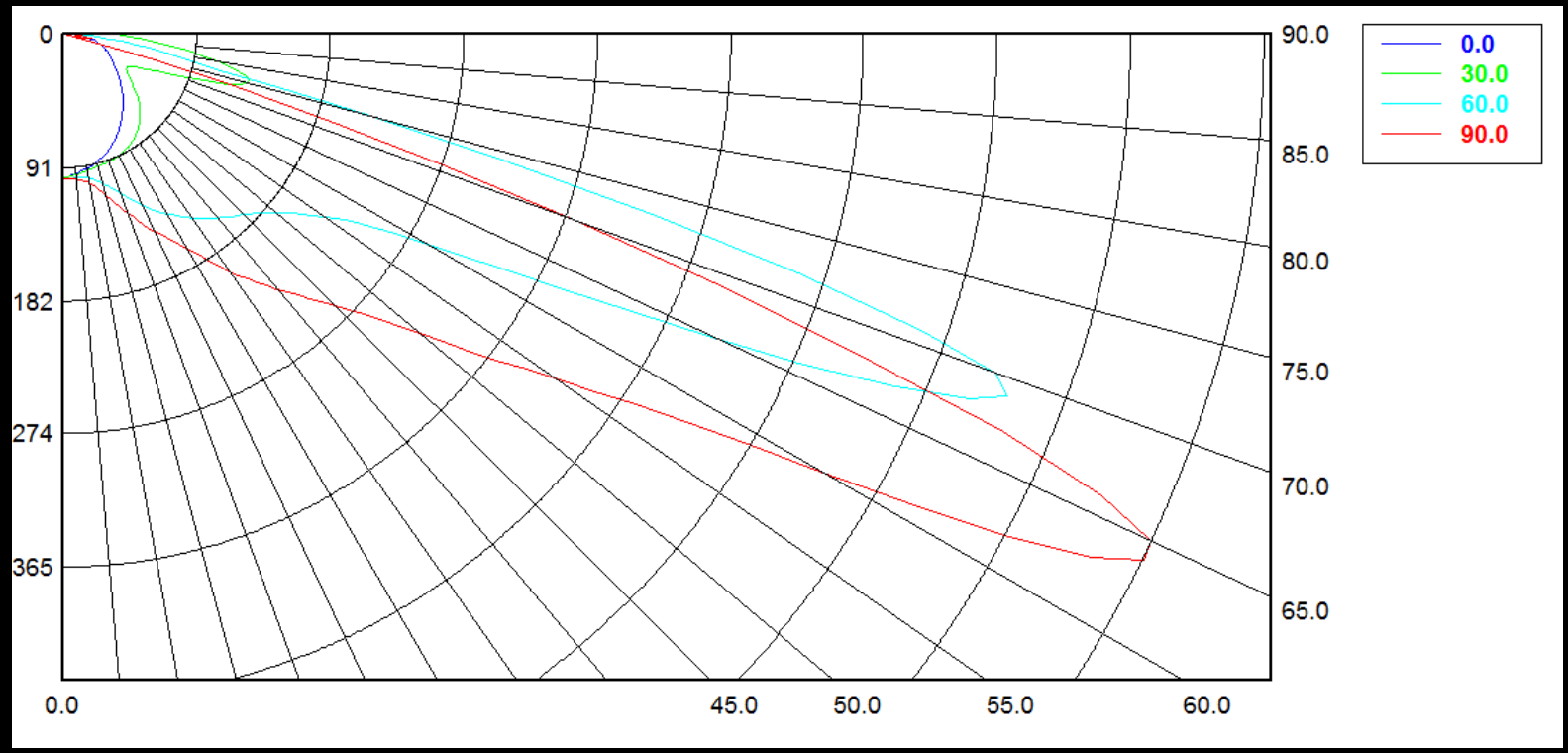
- Lamp
  - 9.73W LED Linear Board
  - Mid-power LG 6030 LED
  - CCT – 4000K



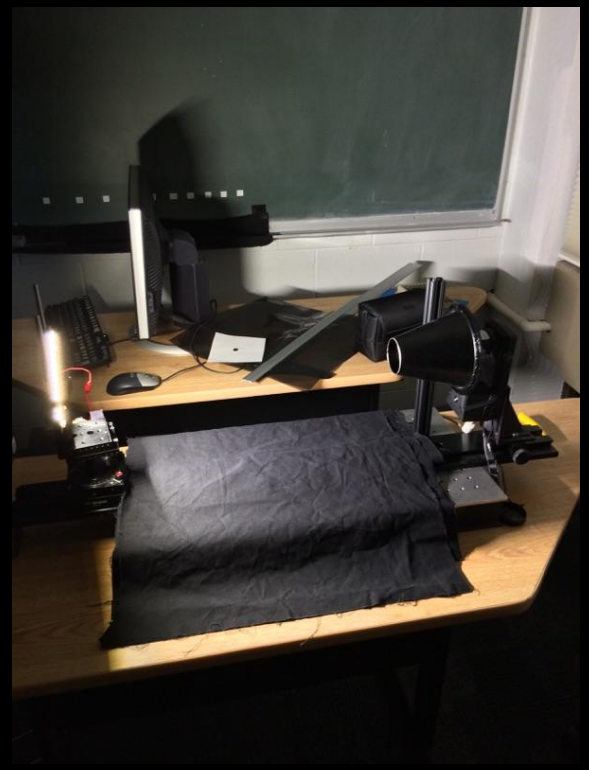
Photopia Results

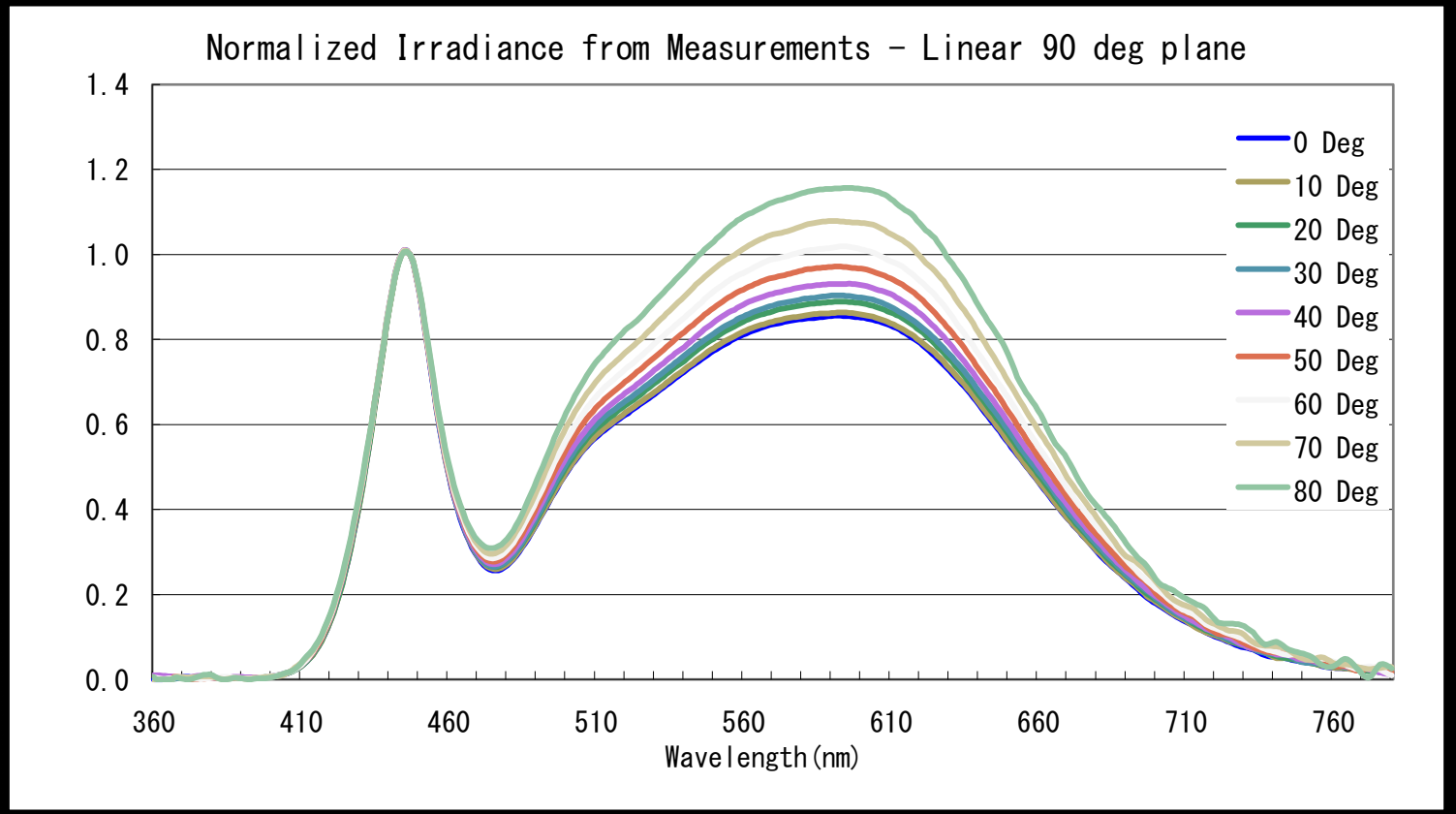


Illuminance Plane Raytrace



Measurements (Non-optic)





Linear Lens Observations

- The wide beam linear lens shows color separation due to the different sized luminous areas of the blue chips and surrounding phosphor region.
- The wide beam lens also shows color separation since the wide angle emission of the LED that is most yellow is directed to the widest angles in the distribution and not mixed with the rest of the beam.

Conclusion

- The accuracy of the models varied across the different optic types
  - Parabolic – Leaves center beam unaltered and hardly blends color
    - As a result, a large difference in lamp modeling and actual measurements is found
  - Roadway – Refracts light to higher angles and minor effects on beam directly below
    - As a result, values are similar however more accurate color modeling is needed on lower angles

Conclusion

- Smooth reflectors without any color mixing features can have color separation problems in the beam. Very detailed color lamp models are required to match the measured color performance.

- The color over angle properties of the roadway lens matched relatively well between simulated and measured performance.

- The accuracy required for color modeling in LEDs depends on the type of optic, but this data shows that when color mixing features are not included in the optics, the color separation effects can be seen in the optical models. Therefore, color mixing features that improve color uniformity can be evaluated in the simulations.

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