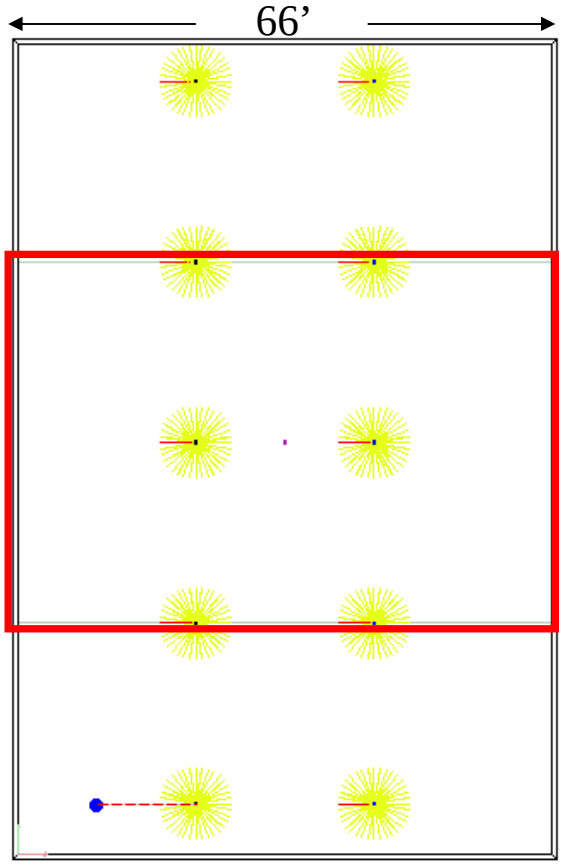
Optical Analysis
Wide Lens Secondary Optics
for LED Retrofit

Background

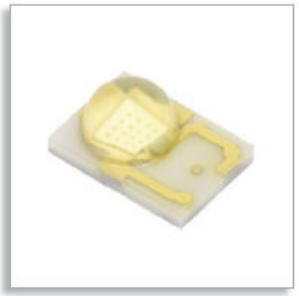
- Garage Layout and Specs
  - 22 foot spacing
  - 8.5 foot mounting height
  - 5 fc average
  - Uniformity 1:4 min to ave
  - Correction factor 0.8

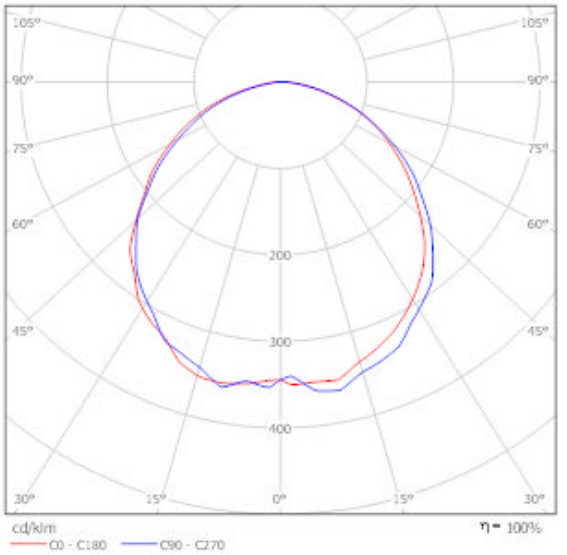
- We consider a number of options for secondary optics to meet the requirements above
- The area in red is used as the calculation area



Optical Analysis
Bare Rebel LEDs

- The first analysis considers using just the bare LUXEON Rebel LEDs, no secondary optics
  - 4000 lumens emitted
    - Considers correction factor
      - 0.80
    - Does not consider losses due to
      - Optics (8%)
        - » Fixture cover
      - Thermals (~10%)



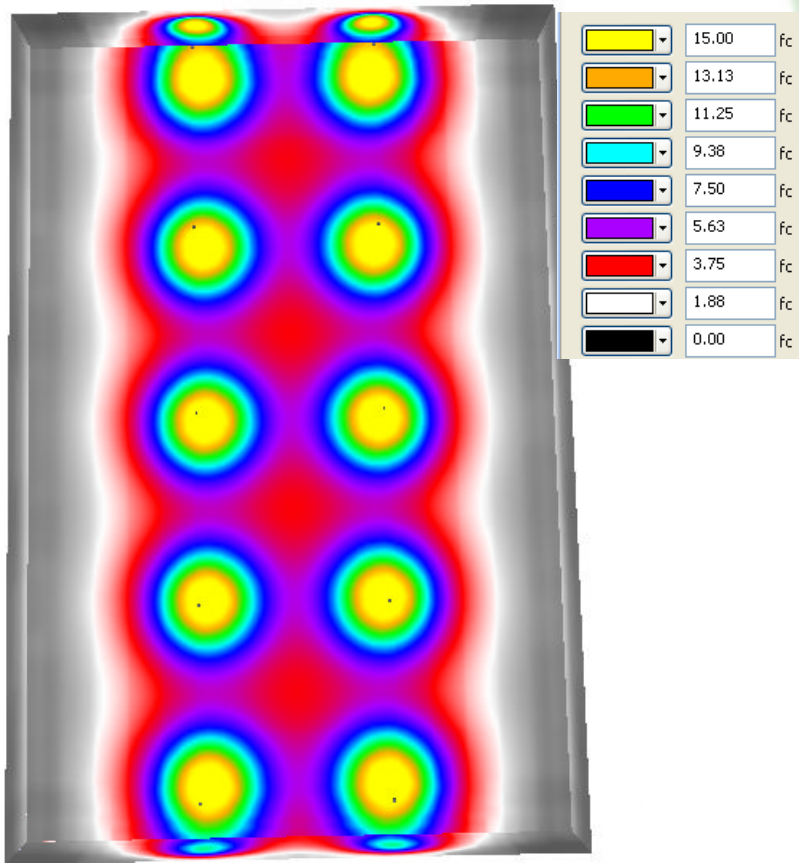


Rebel Intensity Distribution

Optical Analysis
Bare Rebel LEDs

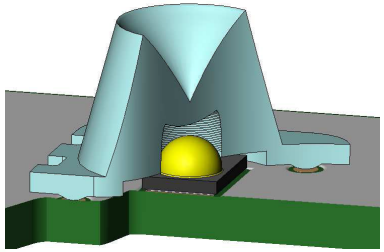
- Eave = 5.02 fc
- Emax = 17 fc
- Emin = 1 fc
- Emin/Eave = 0.2
  - Fails uniformity requirement of 0.25
- Emin/Emax = 0.06

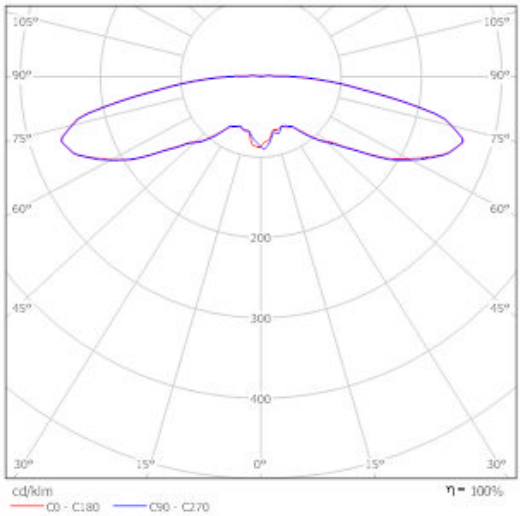
- Uniformity (min/ave) is low, need secondary optics to improve performance



Optical Analysis
Fraen F360

- Second analysis considers using a the Fraen F360 side emitting lens over each Rebel in the array
  - 4000 lumens emitted
    - Considers correction factor
      - 0.80
    - Does not consider losses due to
      - Optics (18%)
        - » F360 + fixture cover
      - Thermals (~10%)



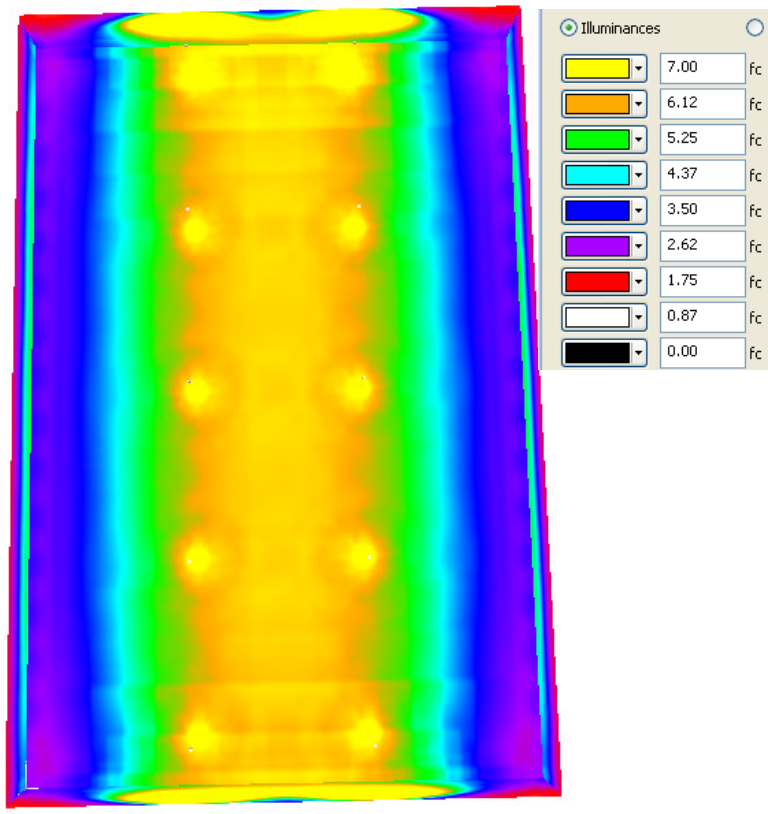


F360 Intensity Distribution

Optical Analysis
Fraen F360

- Eave = 5.08 fc
- Emax = 8.02 fc
- Emin = 3.02 fc
- Emin/Eave = 0.59
  - Passes uniformity requirement of 0.25
- Emin/Emax = 0.38

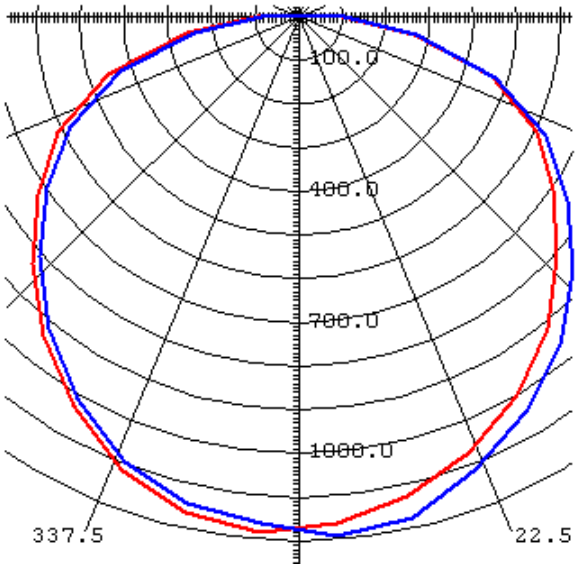
- Uniformity (min/ave) is very high, combine F360 optic with bare LED to find meet requirement and reduce system cost



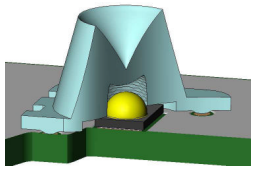
Optical Analysis

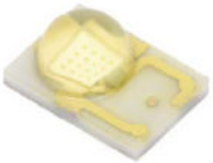
Bare Rebels + Fraen F360

- Last analysis considers using the appropriate combination of Bare Rebels and Fraen F360 optics in order to meet the minimum requirement for uniformity
  - 4100 lumens emitted total
    - 3100 by bare Rebels
    - 1000 by Fraen F360
  - Considers correction factor
    - 0.80
  - Does not consider losses due to
    - Optics (~12%)
      - F360 + fixture cover
    - Thermals (~10%)



F360 + Bare Rebel Intensity Distribution





Summary

- A bare LED solution will not allow for the uniformity specification to be met based on the luminaire spacing and mounting height
  - Note: adding a collimating optic will only make this worse
- Adding the side emitting Fraen F360 optics to the Rebel LEDs will far surpass the uniformity specification
- A combination of bare Rebels and Fraen F360 optics will produce the required uniformity
  - A minimum flux ratio of 3:1, bare Rebels to F360 optics, is required to meet the uniformity spec.

LED High Output Retrofit

4 x 1000W MH at Highway Cloverleaf

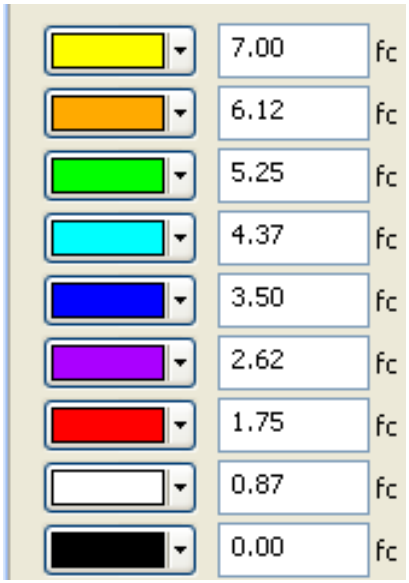
Replaced with 4 x 3x98W HO LED

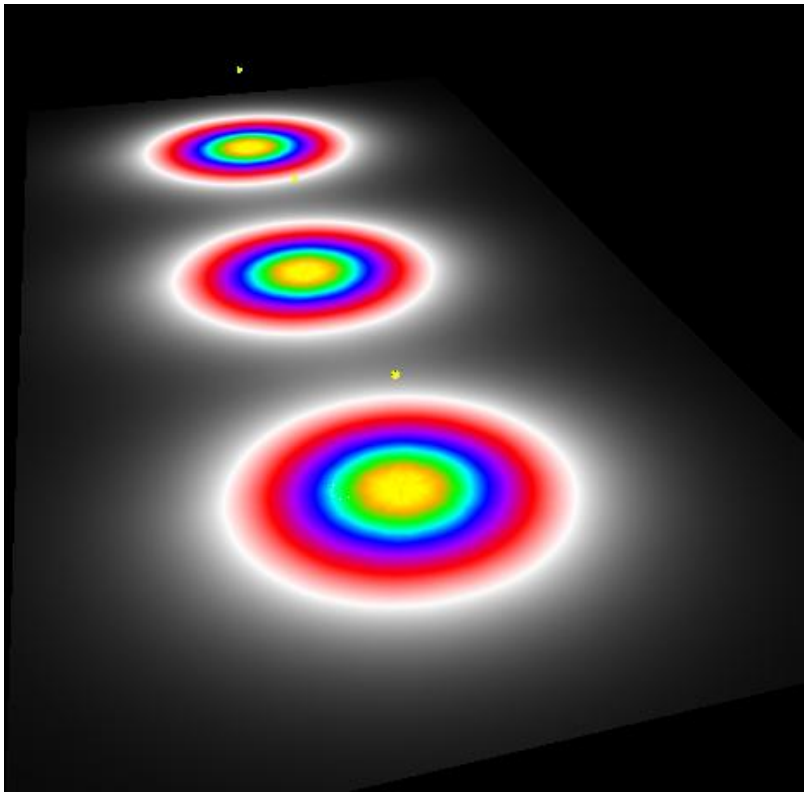
Background

- LED lighting project
  - Fixture layout
    - 1400 masts in total
    - 100 foot mounting height
    - 400 foot spacing
  - Mast Details
    - 12 fixture per mast
    - Up to 4 LED light engines per fixture
    - 42 LEDs per light engine
    - Up to 2016 LEDs per mast
  - Photometric requirements
    - 1 footcandle on the ground between poles
    - 4 to 5 footcandles desired directly beneath fixtures

Optical Analysis

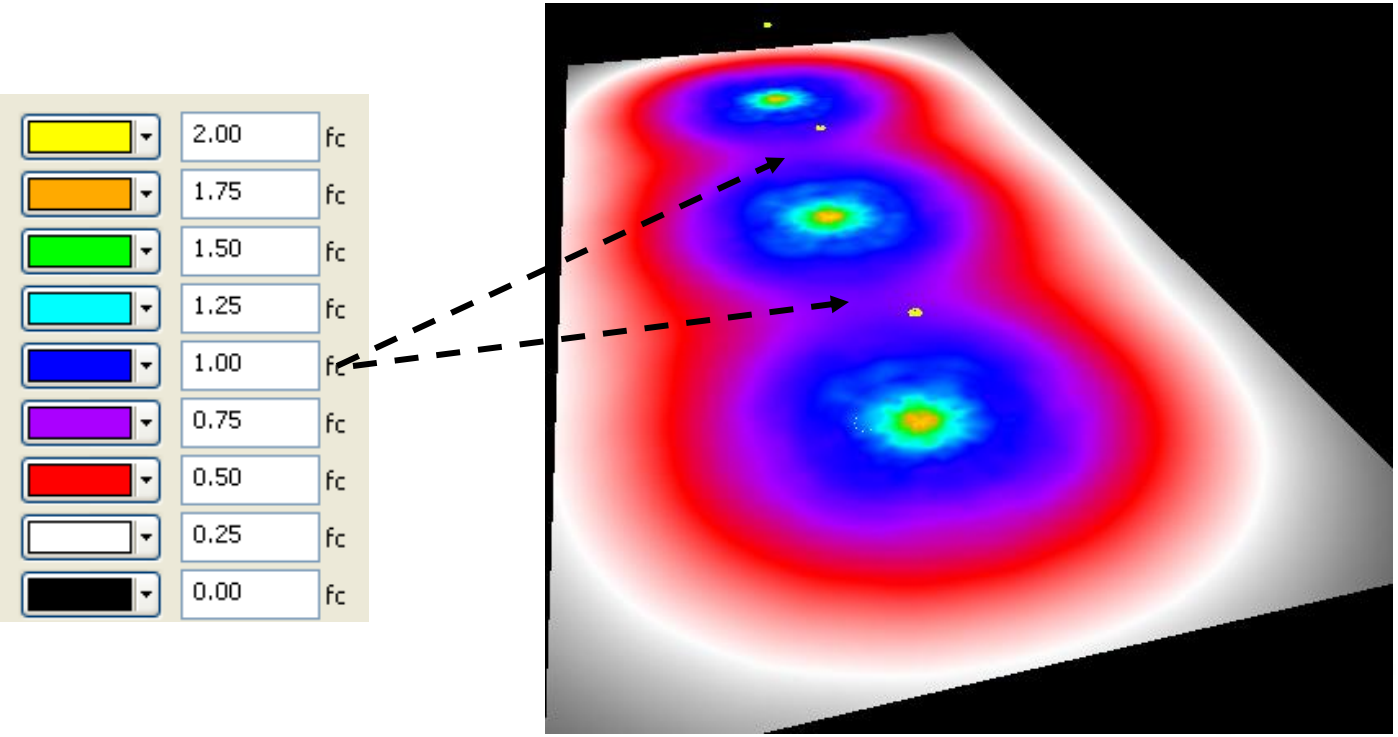
- Bare LUXEON Rebel LEDs
  - 200,000 lumens per mast
  - Dark areas!





Optical Analysis

- LUXEON Rebel with Fraen F360 optic
  - 200,000 lumens emitted per mast
  - 8% optical loss through F360



Summary

- Fraen F360 optic is going to be required over each Rebel LED

- 200,000 lumens total are required to exit the fixtures on each mast in order to get that 1 footcandle on the ground between fixtures

Lumens Requirement

- Analysis showed that a single high mast must deliver 200,000 lm to meet the illumination requirement.
- Each head uses 42 LXML-PWC1-0100 Rebel LEDs.
- Each high mast includes 12 fixtures with 4 heads per fixture.
- Each head uses a drive current of 500mA for each LED. The Rth= approx 1.12 C/W for the heatsink and the PCB used is Ltherm. Assume an ambient temperature as high as 70C (158F) in each mast as a worst case scenario.
- The Usable light tool results show that 4,880 HOT lumens per head is generated. This results in 234,240 HOT lumens per mast. See ULT output next page.
- Including 8% optical loses, that results in 215,660 lm.

Usable Light Tool Results

Input Variables:			
	LXML-PWC1-0100		
Power LED Manufacturer:	Philips Lumileds		
Power LED Product Family:	LUXEON Rebel (GP White)		
Power LED Color:	Cool White (6500K)		
Power LED Part Number:	LXML-PWC1-0100		
Current Optimization Algorithm:	Maximize Current		
Number of Power LEDs:	42		
Ambient Temperature:	70		(°C)
Circuit Board R_{th} for Single LED:	4		(°C/W)
Heat Sink Thermal Resistance:	1.12		(°C/W)
Maximum Allowable Tj:	135 (default)		(°C)
Maximum Allowable Drive Current:	500 (override)		(mA)
Typical Vf at Nominal Current:	3 @350mA (default)		(V)
Typical Flux at Nominal Current:	110 @350mA (default)		(lm)

Calculated Results:			
	LXML-PWC1-0100		
Calculated Drive Current:	500		(mA)
Calculated Forward Voltage:	2.78		(V)
Calculated LED Power Consumption:	1.39		(W)
Calc. Array Power Consumption:	58.4		(W)
Calculated LED Radiometric Flux:	0.35		(W)
Calculated LED Efficiency:	25.2%		(W/W)
Datasheet Junction-to-Case Rth:	10		(°C/W)
Calc. Junction-to-Ambient Rth:	1.45		(°C/W)
Calculated Junction Temperature:	134		(°C)
Calculated Usable LED Flux:	116		(lm)
Calculated Usable Array Flux:	4880		(lm)
Calculated Usable Efficacy:	83.56		(lm/W)