

NONIMAGING OPTICS IN LIGHTING TO REDUCE LIGHT POLLUTION

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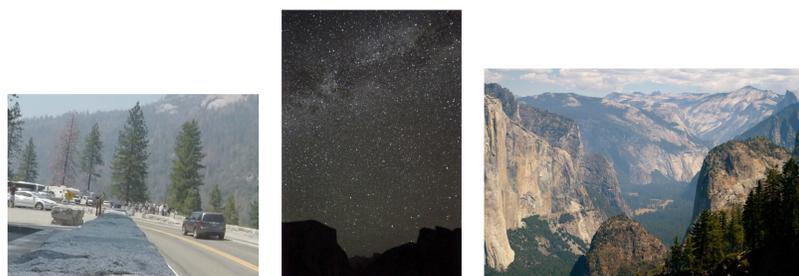
Acknowledgements

- Yosemite National Park
- National Park Service (NPS)
- UC Solar
- Matthew Mitchell

ABSTRACT

Light pollution has become a prominent issue, specifically in National Parks such as Yosemite, where visitors go to enjoy the natural 'night sky'. In an effort to reduce light pollution, a particularly obtrusive light source has been selected for retrofit. Using nonimaging optics and light emitting diodes (LEDs), light can be controlled to achieve a desired prescribed illumination distribution. This distribution possesses a sharp cut-off such that light leakage is minimal. Nonimaging optical designs are 3D printed, retrofitted into the candidate fixture, and tested in Yosemite National Park. The end goal is to drastically reduce and even eliminate the excess light from sources around the park.

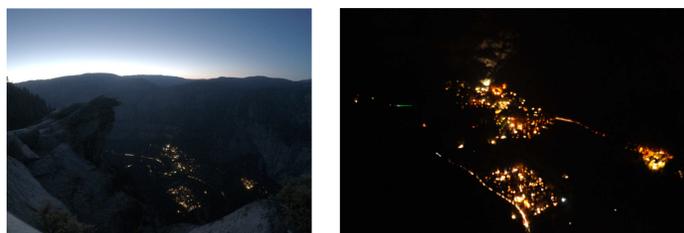
Yosemite National Park



Approximately 4 million people visit Yosemite National Park each year to enjoy its naturally occurring wonders – including the awe-inspiring views of the Milky Way.

Light Pollution

Unfortunately, light pollution from the park and surrounding communities is encroaching on the night sky experience.



Yosemite Valley at Dusk and 10:00pm

Constraints

We are not allowed to make any changes to the light pole, nor can we switch out the light to something new.



Lights must look old fashioned "circa 1860s, and have hoods on them to direct illumination downwards.

The Offender



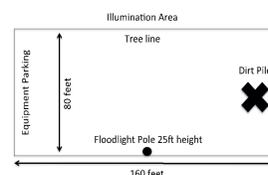
Despite using the area mainly in winter, the light is kept on year around.

A particularly offensive light source in the park was selected next to an equipment storage facility. This offender can be seen glowing on the cliff face next to the iconic Yosemite Falls.



The Sand Pile Project

- Parameters: Maximize the illumination on an area of 160 feet by 80 feet while minimizing the illumination to the surrounding trees and cliff face.

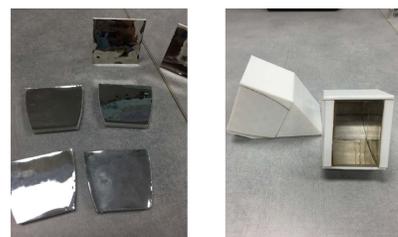
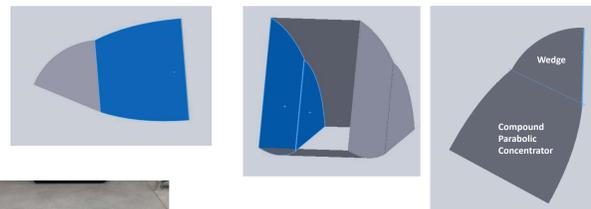


- Main requirement: Maintain adequate light levels in the target area comparable to those with the original light.

Light Type	3 ft (lx)	40 ft (lx)	80 ft (lx)
Original LED	80	18	6

CPC + Wedge Prototyping

Prototypes were designed using Matlab and SolidWorks. These to the right are in "sheet form" with infinitesimal thickness.



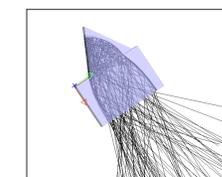
Initial prototypes had size and depth to their walls (not sheet form as above). They were printed on our Makerbot 3D printer.



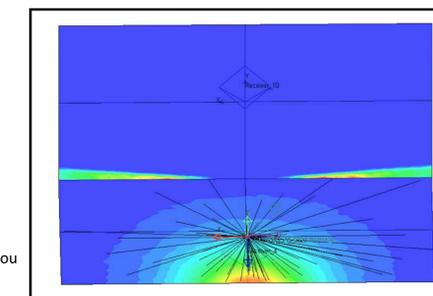
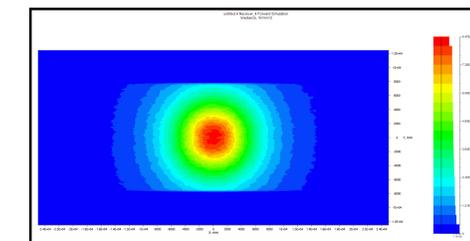
Once printed, pieces were covered in reflective sheet material (Reflectech) and glued together using super glue. They were then attached to a small test light and following preliminary tests they were taped to the replica of the Yosemite flood light (Image to the right).

Simulation

- Simulation was conducted using Light Tools to find the correct acceptance angle for the given height so as to limit light to the surrounding trees and wildlife.
- A Compound Parabolic Concentrator simulation for a target plane 25ft away (7,500mm)



As you tilt the design to fill the whole area, you see a \cos^2 effect take place.



Final Version of Prototype



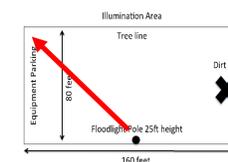
Anolux Silver sheeting was used for the final reflector. Anolux Silver is highly reflective: ~98%. The reflector was shaped using a mold printed from the 3D printer. Duration: 8 hours to make and 24 hours to cure the JB weld.



Results!!!



Data was taken using a lux meter - measuring lx (lumens/m²) – at set distances from the light pole up to 80 feet.



Light Type	3 ft (lx)	40 ft (lx)	80 ft (lx)
LED w/o optics	80	18	6
LED with optics	50	14	0.5
Sodium	15	5	2

Data for LED with optics

DISTANCE FROM LIGHT (FT)	LUX READINGS (LX)
3	50
5	63
10	58
15	57
20	48
25	36
30	27
35	18.5
40	14
45	8
50	4
55	3
60	1.9
65	0.8
70	0.8
75	0.5
80	0.5