U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

PEDESTRIAN-FRIENDLY NIGHTTIME LIGHTING (OR, WHO CARES ABOUT FOOTCANDLES?)

DOE Solid State Lighting Program

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This talk

1. Is not gospel
2. Is full of evolving ideas
3. Is based on mockups, observations, and feedback on multiple pedestrian sites
4. Relies heavily on work and discussion by
    1. Rita Koltai, Koltai Ltg Design
    2. Terry McGowan, Lighting Ideas
    3. Dr. Bill Neches, Chautauqua POA
5. Couldn’t have happened without input and product from Acuity Brands (Tersen and Holophane), Architectural Area Lighting, Cree, Xeralux/Sensity, Philips, and others
6. Couldn’t have happened without funding from the DOE’s GATEWAY Demonstration Program

Conventional approach to outdoor lighting

Visibility and environmentally focused goals:

- Illuminance or luminance on pavement
- Uniformity (max:min illuminance)
- Min vertical illuminance on faces, targets
- Pole spacing for economy and uniformity
- Cutoff (or BUG system ratings) for dark-sky considerations
- Efficacy

Works pretty well for drivers. What about pedestrians?

What do pedestrians care about?

- Safety from tripping, falling
- Safety from being hit by bicycles, cars
- Personal security from harm, intimidation
- Unwanted light in residential windows
- Appearance of the neighborhood/campus/area
- Glare
  - Discomfort and disabling glare that affects adaptation

Photo courtesy of Philips Lumec

Pedestrian-focused goals

Safety from tripping, slipping, falling

- Angle of illuminance that enhances contrast of the hazard
- Illuminance uniformity along the path to minimize dark patches
- Lighting the edge of the path, especially if pavement is wet
- Controlling disability glare that
  - Shifts adaptation level too high (1000:1 luminance range)
  - Superimposes veil across visual field, reducing contrast in visual image

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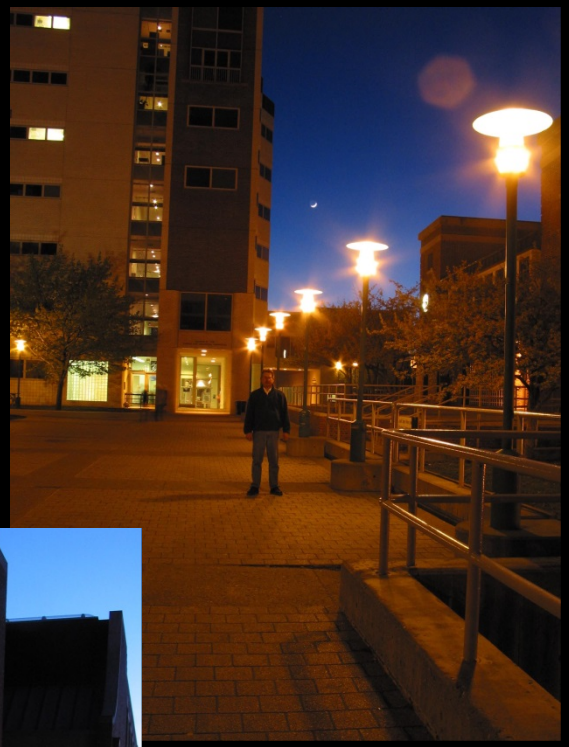
Pedestrian-focused goals

Personal security from harm, intimidation

- Seeing faces and bodies of people around you
  - Face, body, and clothing identification
  - Spotting furtive actions and weapons
- Boyce principles for perception of safety
  - Seeing at sufficient distance to identify danger in time to react
  - Seeing where to go for safety or refuge if needed



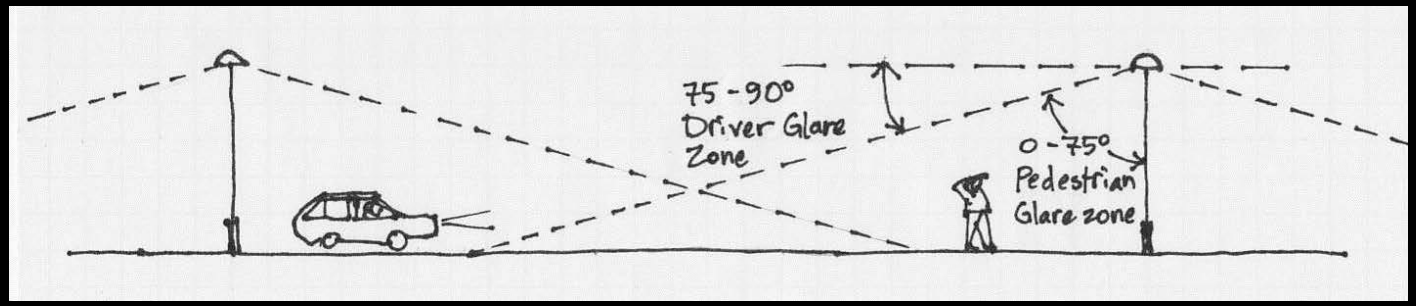
Pedestrian-focused goals

- Unwanted light in residential windows
  - Back light from a street light can be annoying
  - Usually emitted from 60°-90°
- Appearance of the neighborhood or campus or area
  - Luminaires
  - Light patterns on grounds and buildings
  - Color of light

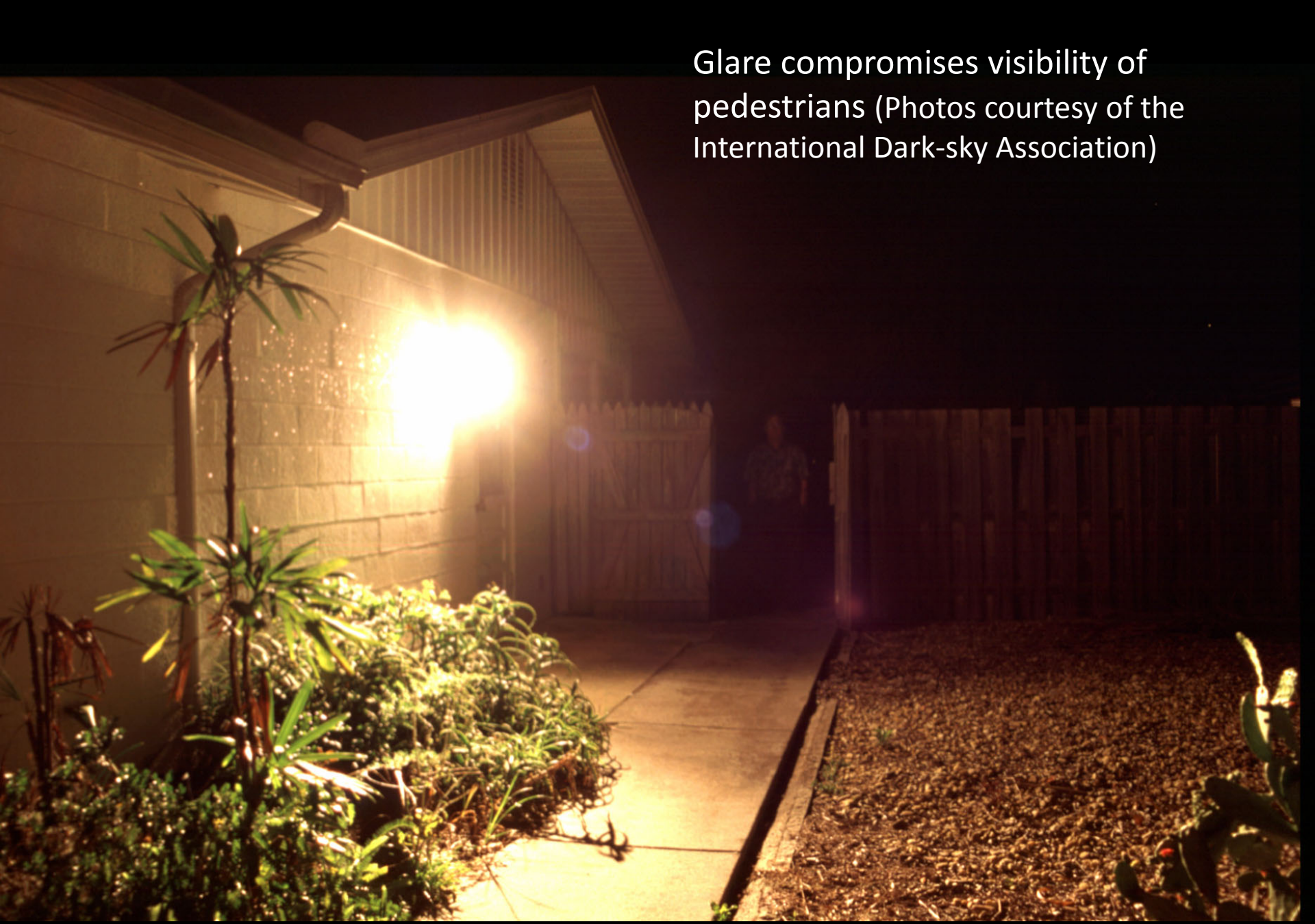
Pedestrian-focused goals

Glare

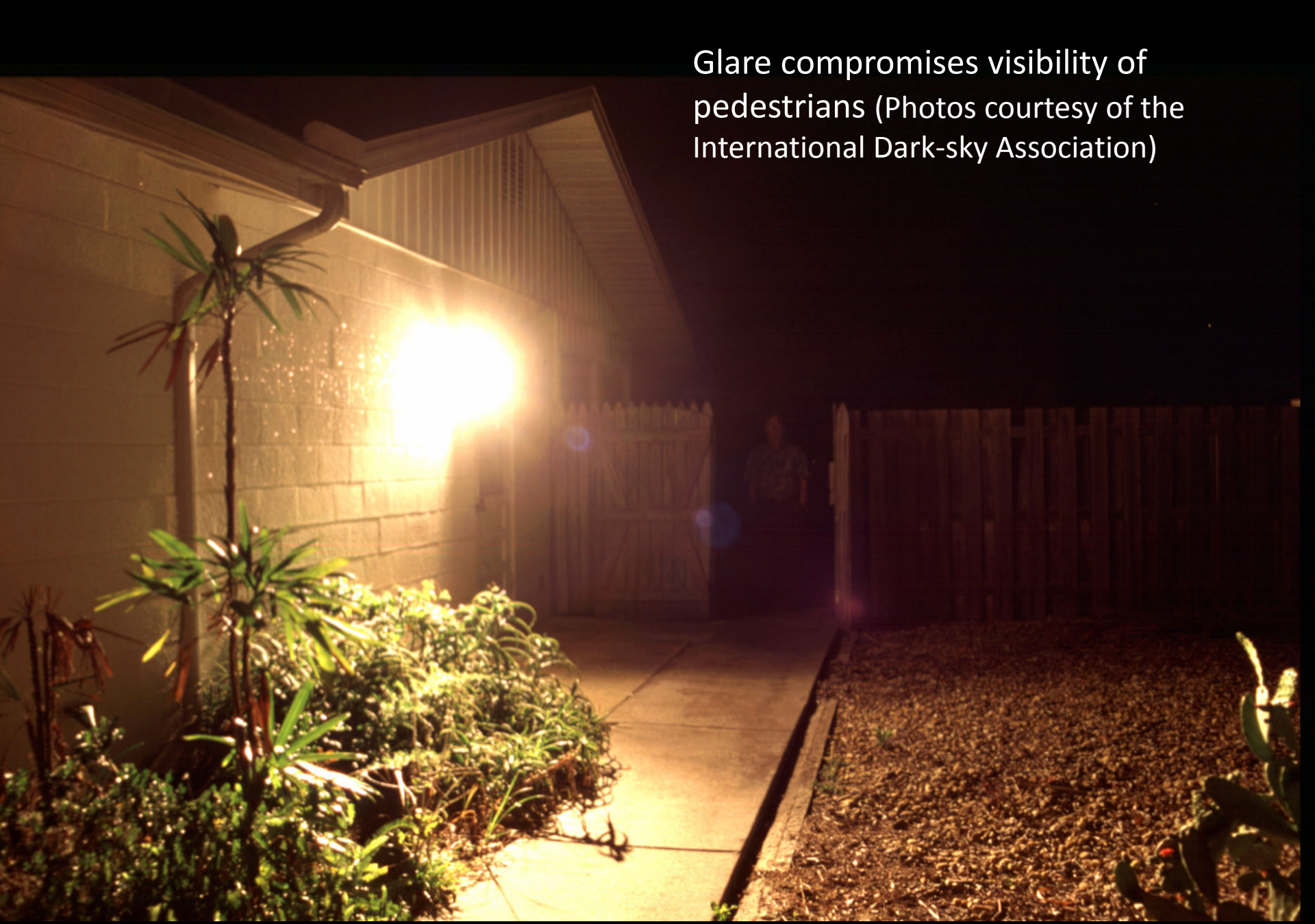
- Discomfort glare (Driver's glare angles [≈ 75° - 90°] are different from pedestrian's glare angles [≈ 0° - 75°])



- Disabling glare that scatters light and affects adaptation



Glare compromises visibility of pedestrians (Photos courtesy of the International Dark-sky Association)



Glare compromises visibility of pedestrians (Photos courtesy of the International Dark-sky Association)

What kind of places may want pedestrian-friendly lighting?

Some…..

- Summer camps/private clubs/retreats/cultural institutions
- College campuses
- Private schools/boarding schools
- Parks/cafes/outdoor festivals
- Quiet neighborhoods where neighbors know each other, spend time outdoors, walk dogs on the street, and crime is less of a concern

Stanford University

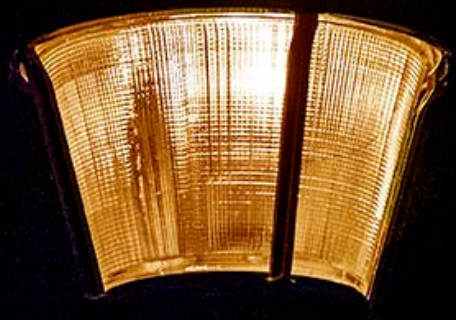
Pedestrian lighting:

- University wants soft, warm lighting with better color rendering (100W HPS is standard now)
- Goal to reduce energy use, improve campus appearance, reduce glare for pedestrians
- Unify fixture appearance on campus and residential neighborhoods with somewhat traditional style
- Reuse existing poles and spacing
- Rita Koltai, Koltai Lighting Design, hired to consult and advise on options

Stanford University

Existing pedestrian lighting:

- 100W HPS lamps in glass refractor post-top, 10’ pole
- 51 LPW, 24000+ hours rated life



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Options that didn't work:

- Replace luminaire with full cutoff LED lantern with open sides. 3000K 100W CMH lamp. Clear glass.
- 110W, 50 LPW fixture efficacy
- Clear arc tube lamp very glaring.
- Produced strong shadow around base of pole

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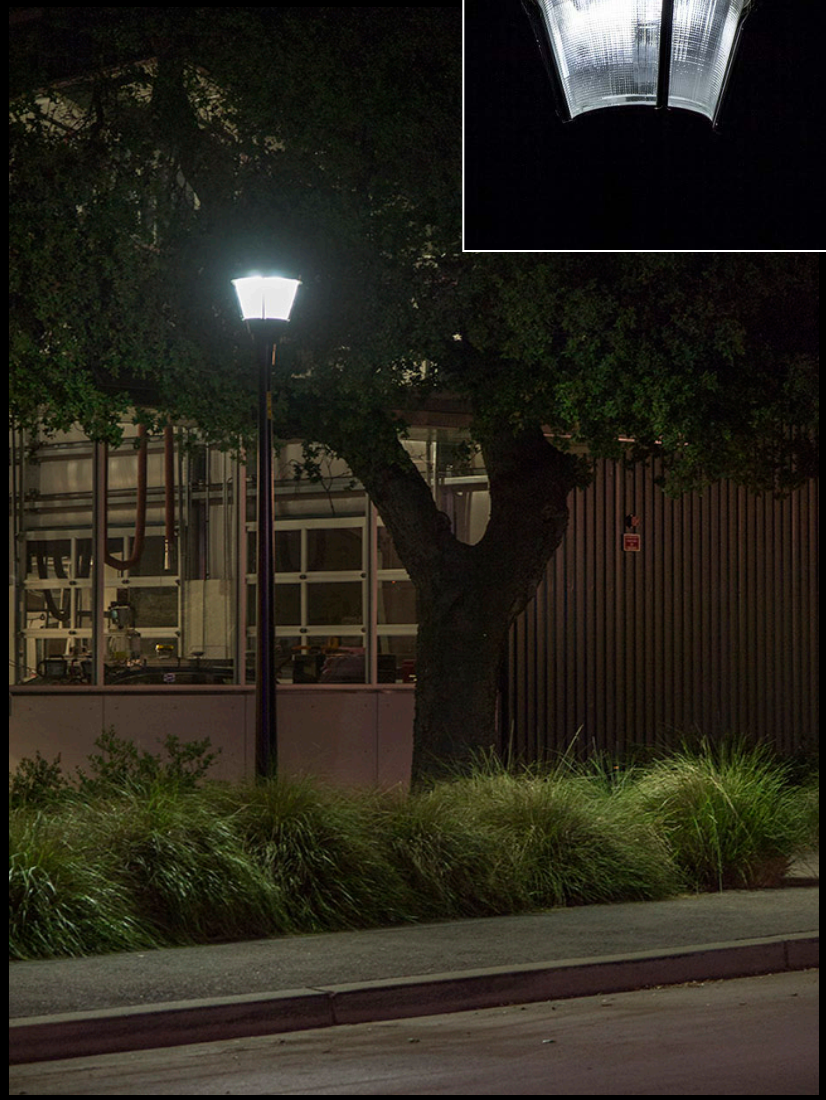
More options that didn't work:

- Reuse existing glass refractor
- Remove ballast. Install screwbase ~50 to 70W LED retrofit lamp (3 different models tried)
- Light distribution poorer on the ground
- Very glaring because refractor produced very bright dot pattern or stripes on glass
- 4100K unit too cool; 3000K unit too white; 2700K unit right tone for this campus



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Options that did work

Option A:

- Reuse existing glass refractor
- Change lamp and ballast to 60W Cosmowhite CMH lamp
- 67W, 67 LPW fixture efficacy
- Facilities folks liked the color
- Only 18,000 hours rated lamp life, 67 LPW fixture efficacy
- Compares poorly to LED life

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Option B:

- Change to new utility series full-cutoff luminaire (Holophane “PUL”)
- 70W 3000K 80CRI LED
- Flat glass in aperture changed to diffuse glass to eliminate sharp pole shadows on ground
- 63 LPW fixture efficacy, 50,000+ life

Stanford University

Option C:

- Reuse existing glass refractor, but contractor frosts interior of glass ($50 cost per luminaire)
- Replace ballast and hood. Install Holophane RSL-350 LED retrofit kit with 50W 3000K LED module
- Light distribution on ground no worse than original HPS
- Glare acceptable
- Looks the same as original
- 62 LPW fixture efficacy, 50000+ hrs life
- Good. Can the color be warmer?

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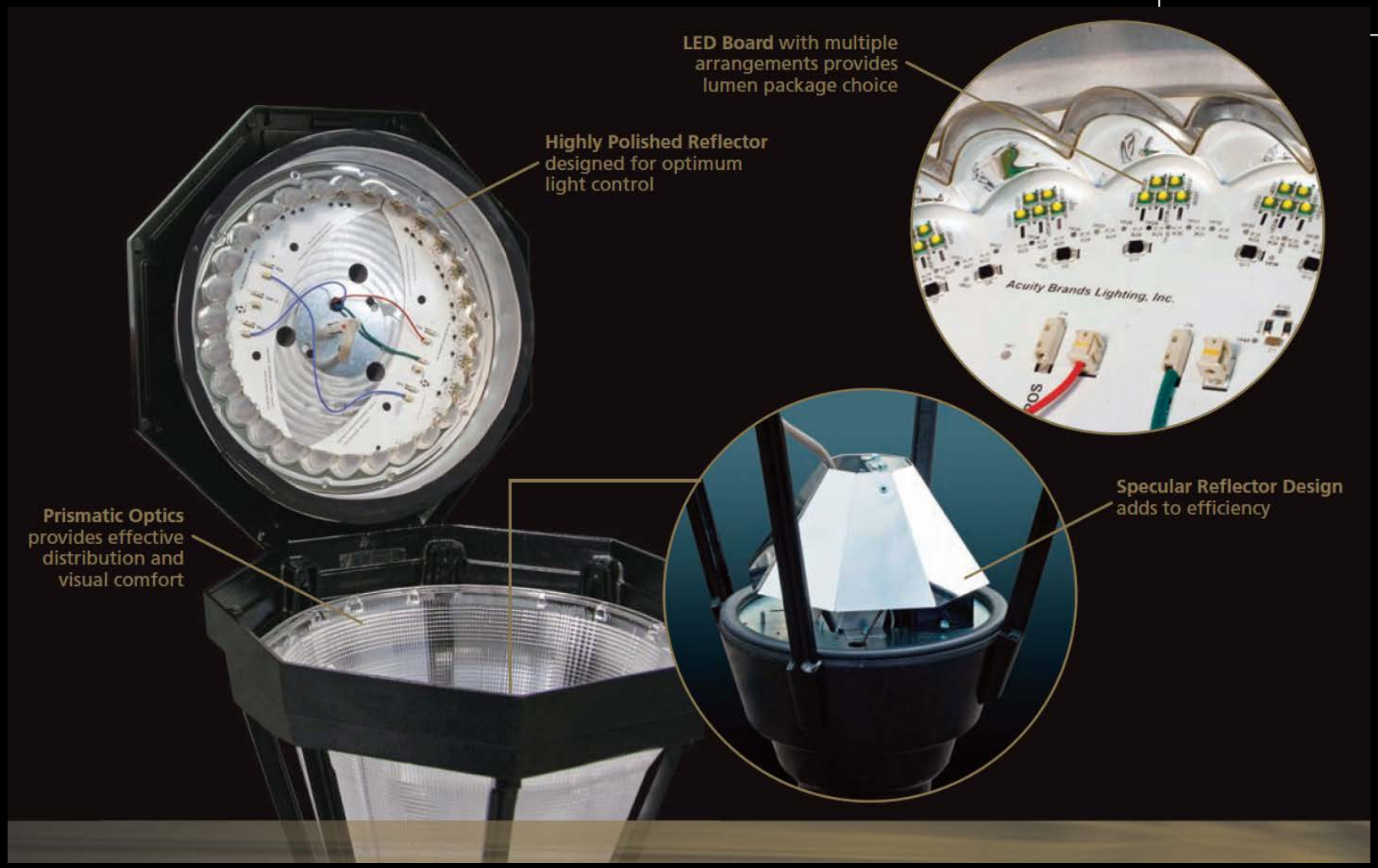
Option C:



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Option D:

- Same as Option C, reusing existing glass refractor, frosting interior of glass
- Install Holophane RSL-350 LED retrofit kit with 50W 2700K LED module
- Light distribution on ground no worse than original HPS
- Glare acceptable
- Perfect color tone for campus!
- 57 LPW fixture efficacy, 50000+ hours rated life
- Pending LCC analysis, this is the likely approach for the campus

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Lighting for the neighborhoods, Options that didn't work:

- Contemporary look
- 3000K LED and 2800K Cosmowhite CMH color good
- Wanted traditional appearance instead

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Best option for neighborhoods:

- Replace luminaire with full cutoff LED lantern with open sides. Diffusing glass.
- 70W 3000K LED.
- 70W, 59 LPW fixture efficacy
- Diffused LED matrix produced more tolerable glare
- Produced soft (acceptable) shadow around base of pole
- This is the best solution so far for the residential neighborhoods

Chautauqua NY

Street/Pedestrian lighting:

- Arts, Music, Culture, Lecture summer program
- Dense housing and cute-as-a-bug streets and plazas
- Vehicles discouraged
- Bicycles and pedestrians everywhere
- Environmentally conscious, bat-, critter-, darksky-, sleep-conscious community

Chautauqua Institution

Street/Pedestrian lighting:

- Existing utility-supplied poles/fixtures deteriorating (mercury and incandescent)
- Goal to provide soft, warm lighting without glare for pedestrians
- Minimal light trespass in windows and porches
- Luminaire style that suits the traditional early-1900s appearance of Chautauqua
- Reduce energy use and maintenance

Chautauqua Institution

Evidence of glare and light trespass concern:






Chautauqua Institution

Inconsistent maintenance by local utility

Chautauqua Institution

Demo #1 – Post top with indirect asymmetrical optics

- Early 20th Century ambiance
- 60 W Cosmowhite CMH lamp, dimmed by 25% at night
- 6900 lamp lumens, 1230 luminaire lumens
- Expected Life 15K-20K hrs (3.5-5 yrs)
- 67W system watts, 18 LPW fixture efficacy
- Very poor system efficacy
- Warm familiar color
- No glare - Light levels deemed acceptable

Chautauqua Institution

Demo #2 – Post top with LED matrix in hood

- Early 20th Century ambiance
- 49 LEDs in 7x7 square, with prismatic glass diffusing lens
- 3000 lumens, 3000K color, Type III distribution
- 58W system watts, 72 LPW fixture efficacy
- Expected Life 70K hrs (17 yrs)
- Light directed downward
- Warm familiar color
- Unacceptable glare, even with lens

Chautauqua Institution

Demo #3 – Post top with round pattern of LEDs aimed optics

- Early 20th Century ambiance
- 32 LEDs in round configuration, with small prism lens, then diffusing glass lens
- 76W
- 3500 lumens, 3000K color, Type III distribution
- Warm familiar color
- Expected Life 100K hrs (24 yrs)
- Light directed downward
- Unacceptable glare, even with lens

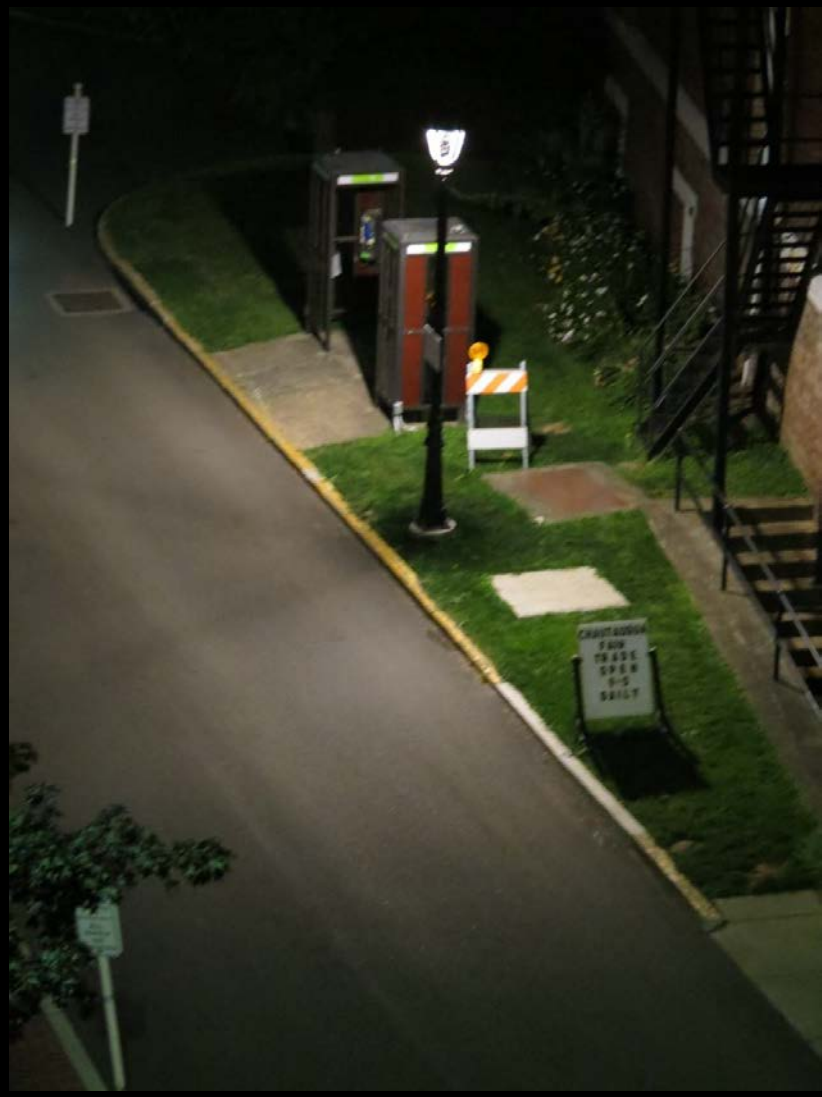
Chautauqua Institution

Demo #4 – Post top Lantern with Linear LED module in hood

- Early 20th Century ambiance
- Linear LED module with remote phosphor panel, with and w/o diffusing glass lens
- 37W, 81 LPW fixture efficacy
- 3000 lumens, 3000K color, Asymmetrical distribution
- Warm familiar color
- Expected Life 70K hrs (17 yrs)
- Light directed downward
- Glare more tolerable, but still deemed high, even with lens

Chautauqua Institution

Demo #4 – Post top Lantern with Linear LED module in hood



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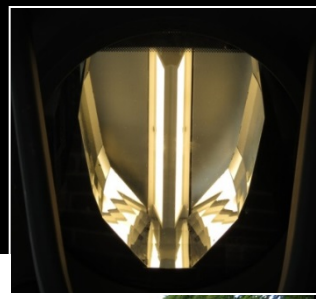


Demo #5 – Post top Lantern *dimmed*

- August 2013
- 0-10V dimmer installed in pole
- Dimmed to 60% of original level (~1800 lumens)
- Good light distribution - about 75 ft spread from 12’ pole height, estimated 0.4 fc average (0.1 to 0.9 fc afg. 0.1 fc measured on face at 32’)
- Same luminaire available with a 24 watt, 1800 lumen LED module
- 27W, ~66LPW fixture efficacy
- Glare and light trespass acceptable
- Mockup of 9 poles planned for 2014

What factors affect pedestrian glare?

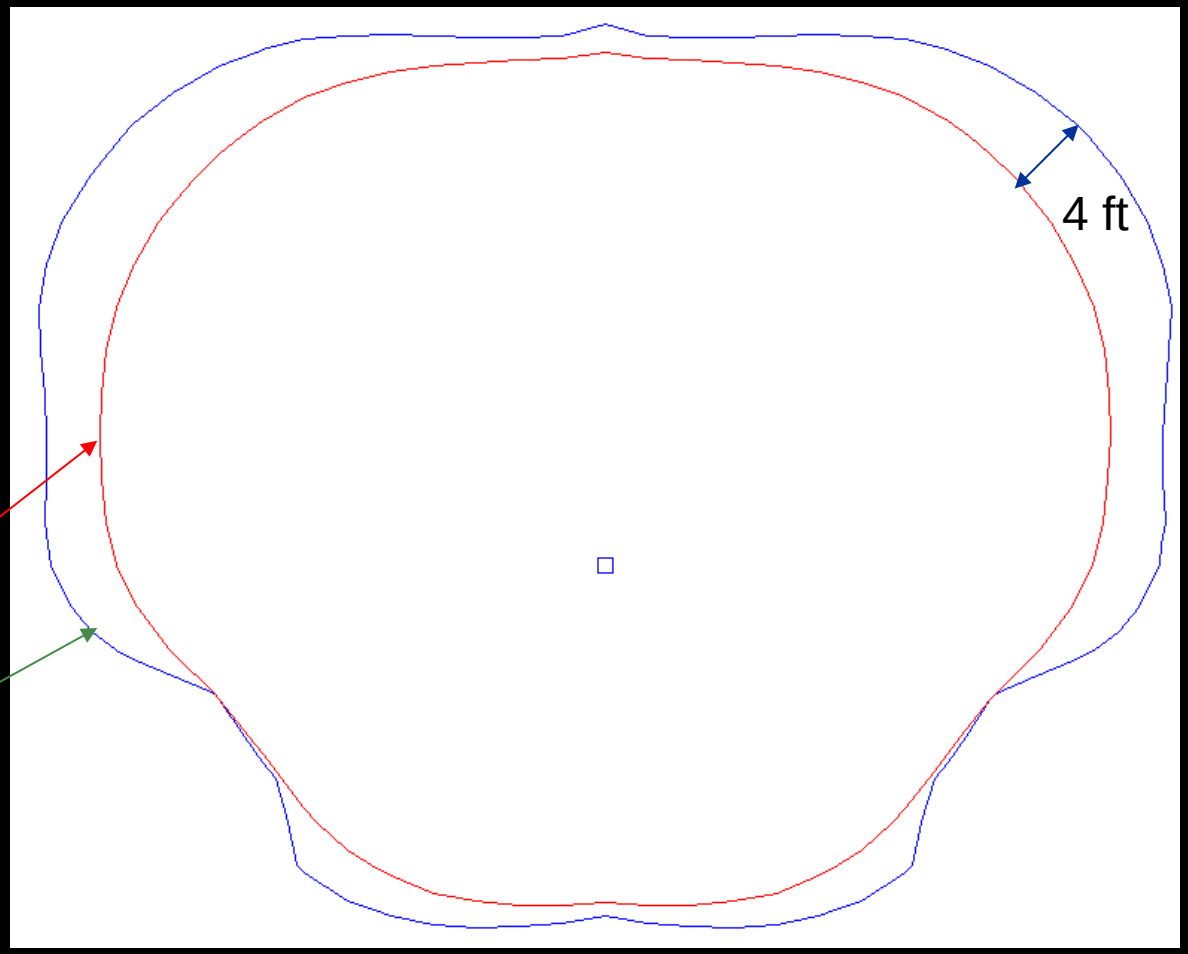
- Viewing angle for pedestrian (emitted from luminaire from 0°-75°)
- Luminance of luminaire relative to viewer adaptation luminance (1000:1)
- Luminaire's luminance distribution
  - Spreading intensity over larger area can reduce max luminance and perceived glare
  - Small, intense patches may appear more glaring
- Higher CCT usually perceived as brighter

Acuity Lighting

Doesn’t diffusion turn the optics to mush?

Illuminance contour at 0.5 fc,
15 ft. mtg. ht.

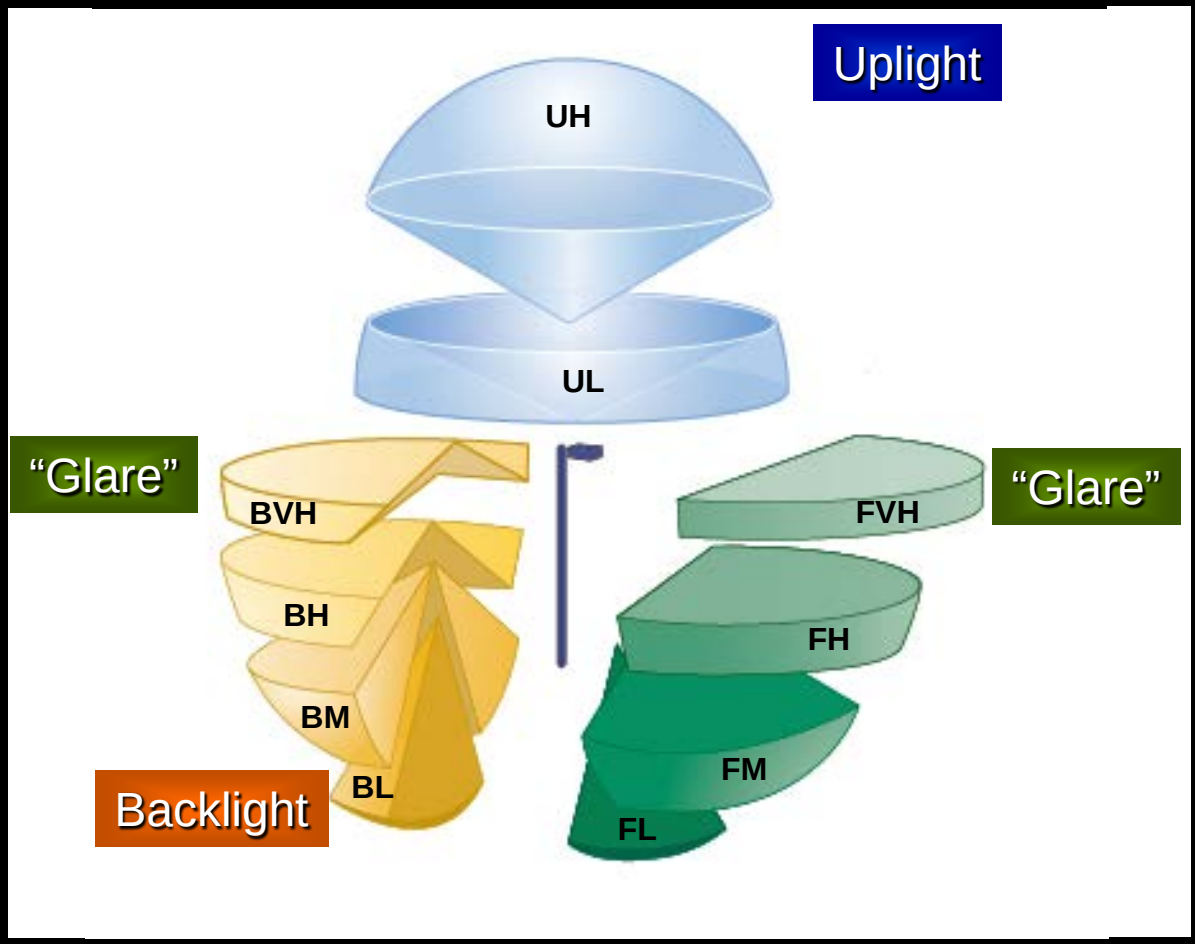
63 LED
530mA
Type 3



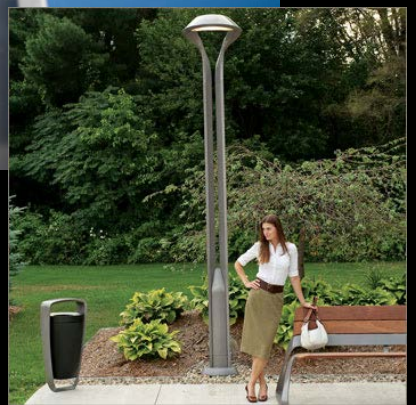
Clear Glass vs. Prismatic Lens

(Diffusion reduces spread of light)

IES Classification System for Outdoor Luminaires doesn't account for pedestrian glare



How do you mitigate glare?



Consider

- Using lower lumen output luminaires
- Luminaires that spread brightness over a larger area
- Luminaires with less optical punch and sharp cutoff
- Luminaires delivering warmer color light

Tradeoffs

Warm-color, soft, low-glare pedestrian luminaires

- Lower lumen output luminaires produce lower light levels and probably reduced visibility
- Warm color lighting delivers lower S/P ratios, lower off-axis visibility at very low light levels
- 3000K LED packages are less efficacious than 6500K packages
  - 8 to 10% for 4000K packages
  - 20% for 3000K packages (Improving with time?)
- Mushy light distributions produce less uniform ground plane lighting (but may improve vertical light on faces)
- Efficacy losses due to lenses and diffusers can be significant
  - 10 to 20% or more

Conclusions

- Every project is different, needs vary according to client and users
- The best lighting solution will vary from project to project
- There is no glare metric that works for pedestrian lighting
- The problems of pedestrian lighting occur with all technologies
- But! LEDs offer optical options and opportunities we've never had before
- Should the IES investigate pedestrian-friendly lighting and a modified Recommended Practice?

This talk is meant to stimulate discussion, investigation, and new thinking

Thank You!

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