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**TOO MUCH OF A GOOD THING - WHY
MORE LUMENS ARE NOT ALWAYS
BETTER.....
AND OTHER THOUGHTS ON LIGHTING TODAY**



What is “GOOD LIGHTING”?

There are three kinds of lighting.

- Bad lighting has faults. It is unattractive, or glaring, or fails to provide appropriate light.
- Nondescript lighting has no faults. It works as it should.
- Good lighting excites the soul.

Peter Boyce



Benya's Postulate

“Lighting can be appealing, efficient and inexpensive. Pick two.”

- **Cost driven** projects (unappealing or inefficient)
- **Appearance driven** projects (expensive or inefficient)
- **Energy driven** projects (expensive or unappealing)



Lighting Quality to a designer is...

1. Controlled or eliminated glare
2. Proper quantity of light
3. Appropriate spectrum of light
4. Appropriate spatial luminances
5. Mitigated temporal artifacts
6. Appropriate style and integration into the built environment
7. Controllable to meet project requirements



Lighting Quality to an Owner is...

- Adds to the market value of the property
- Maximizes return on investment
- Supports productivity and employee well being
- Requires little or no maintenance
- Minimizes energy cost



Classic Conflicts of Efficiency and Quality

- **Glare control** negatively affects efficiency
- **Color quality** negatively affects efficacy
- Application efficiency \neq efficacy or luminaire efficiency



Emerging Conflicts of Efficiency and Quality

- Light color tuning may negatively affect efficacy
- Mitigation of temporal artifacts may negatively affect efficacy
- Lighting for non-visual benefits may periodically require significantly higher light levels and luminances.



Glare





Glare

- The excessive ratio of luminances
- Absolute luminance
- Spectrum
- At extremes it causes the glare aversion reflex
- Excessive 450 nm blue increases the glare reflex



Glare and LED's

- The luminance of the Sun is about 1.5 billion cd/m^2 (nits)
- The luminance of a high power LED package is as high as about 150 million nits (**0.1 suns**)
- The maximum comfortable luminance is about 50,000 nits (**.000033 suns**)





Softening Glare

- Indirect lighting
- Larger area sources (reduce contrast)
- Lower luminance sources
- Shielding
- Optics



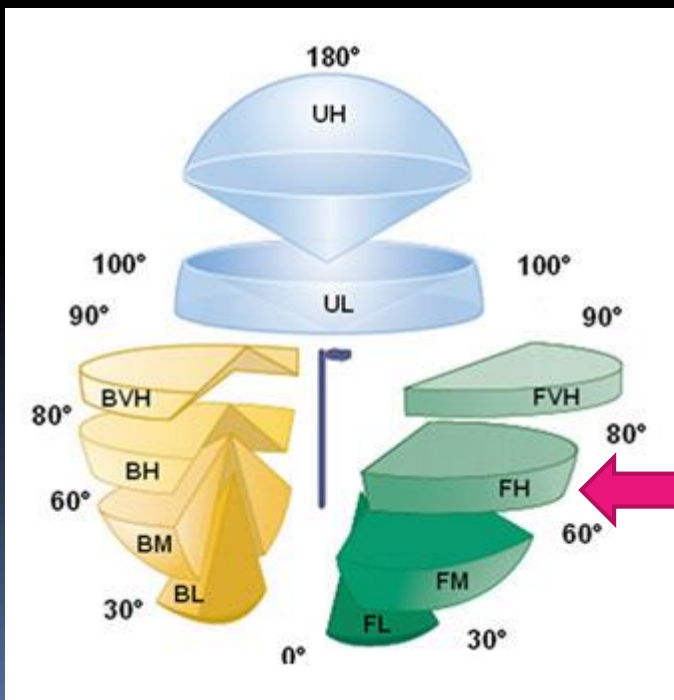
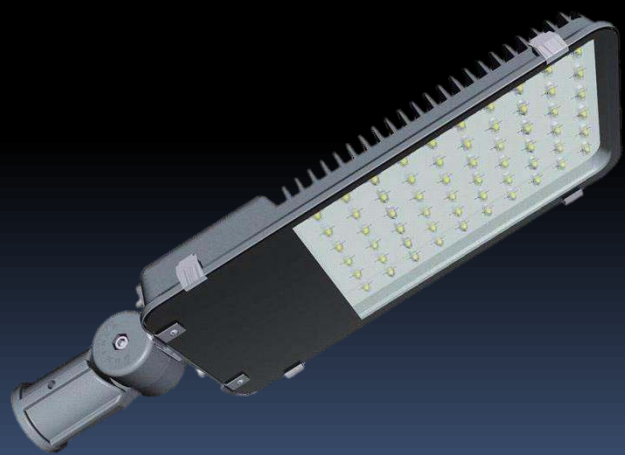


Emerging Issues of Glare

- Dramatic increases in efficacy continue now over 210 LPW
- Size of LED packages getting smaller
- LED laser technology
- Increasing demand for highest optical and photometric efficiency
- Pixelated glare



All of these luminaires are seen in the FH or FVH zones





Proper Light Levels





Light Levels and Retrofits

Underlit

1. Older population
2. General lighting <200 lux
3. Limited task lighting
4. No daylight

Properly Lit

1. Average age population
2. General lighting at least 300 lux
3. Task lighting where needed
4. Ordinary daylight

Overlit

1. Youthful population
2. General lighting at least 300 lux
3. Task lighting more than needed
4. Abundant daylight



Light Levels and Retrofits

Example: “Type A” 4’ T8 TLED lamp

- 3,570 Products listed on the QPL on 7/30/16
- 874 Products <4100K (24.5%)
- 248 products at least 2200 lumens on a standard ballast factor fluorescent ballast (6.9%)

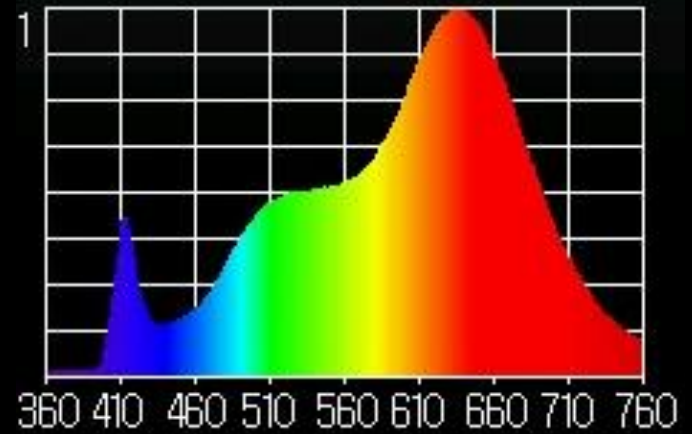


Emerging Issues of Light Levels

- Aging vision
- Impaired vision
- Glare counteracts visibility
- Uniformity possibly less important
- Variable light levels may be good
- High light levels needed to stimulate the Circadian system
- Location of light source



Proper Spectrum





Classic Metrics

- Correlated Color Temperature (CCT)
- Color Rendering Index (R_a)



Modern Metrics

- CRI_{1-15}
- CQS
- λ_p
- λ_D
- CIE x, y and u', v'
- Purity
- C78.377-2008
- IEC-SDCM
- D_{uv}
- S/P ratio
- M/P ratio
- TM-30-15





Applications

Classic White Light

- Generally best using Kruithof's curve of increasing CCT with increasing light levels
- Normal workspace levels best at 3500-4100K

CCT Color Tuning

- Many Applications
- User choice 2700K through 6500K \pm
- "Human centric" and circadian applications

Tuned Spectrum

- Medical
- Industrial
- Agricultural



Emerging Issues of Spectrum

- Added costs of color variability
 - RGB, RGBA, RGBAW, etc.
 - White tuning
- Decreased lumens per watt in color variability
- Importance of certain spectra relative to Circadian System

June 14, 2016

AMA Adopts Community Guidance to Reduce the Harmful Human and Environmental Effects of High Intensity Street Lighting

For immediate release:

June 14, 2016

CHICAGO - Strong arguments exist for overhauling the lighting systems on U.S. roadways with light emitting diodes (LED), but conversions to improper LED technology can have adverse consequences. In response, physicians at the Annual Meeting of the American Medical Association (AMA) today adopted guidance for communities on selecting among LED lighting options to minimize potential harmful human and environmental effects.

Converting conventional street light to energy efficient LED lighting leads to cost and energy savings, and a lower reliance on fossil-based fuels. Approximately 10 percent of existing U.S. street lighting has been converted to solid state LED technology, with efforts underway to accelerate this conversion.

"Despite the energy efficiency benefits, some LED lights are harmful when used as street lighting," AMA Board Member Maya A. Babu, M.D., M.B.A. "The new AMA guidance encourages proper attention to optimal design and engineering features when converting to LED lighting that minimize detrimental health and environmental effects."

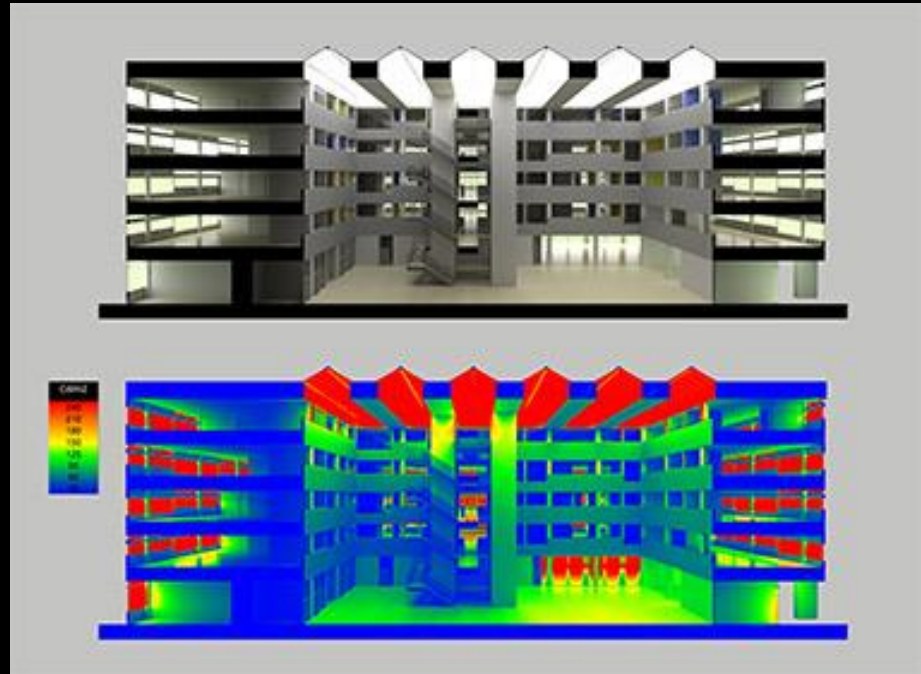
High-intensity LED lighting designs emit a large amount of blue light that appears white to the naked eye and create worse nighttime glare than conventional lighting. Discomfort and disability from intense, blue-rich LED lighting can decrease visual acuity and safety, resulting in concerns and creating a road hazard.

In addition to its impact on drivers, blue-rich LED streetlights operate at a wavelength that most adversely suppresses melatonin during night. It is estimated that white LED lamps have five times greater impact on circadian sleep rhythms than conventional street lamps. Recent large surveys found that brighter residential nighttime lighting is associated with reduced sleep times, dissatisfaction with sleep quality, excessive sleepiness, impaired daytime functioning and obesity.

The detrimental effects of high-intensity LED lighting are not limited to humans. Excessive outdoor lighting disrupts many species that need a dark environment. For instance, poorly designed LED lighting disorients some bird, insect, turtle and fish species, and U.S. national parks have adopted optimal lighting designs and practices that minimize the effects of light pollution on the environment.



Luminance



Veluxusa.com

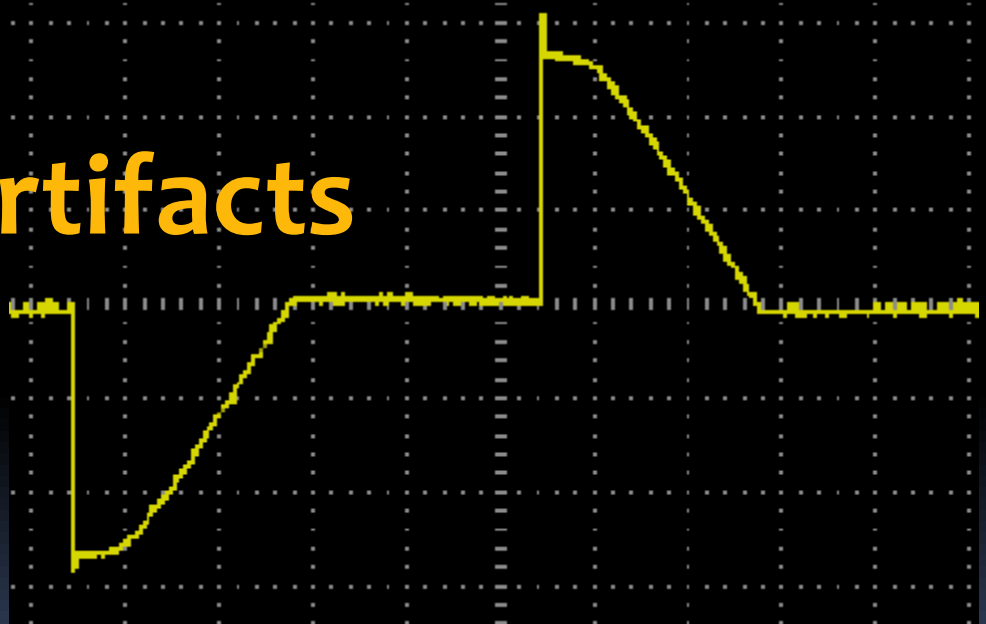


Luminance Based Design

- The future of architectural lighting design
- Intent: restrict luminance ratios to desired adaptation of the viewer



Temporal Artifacts

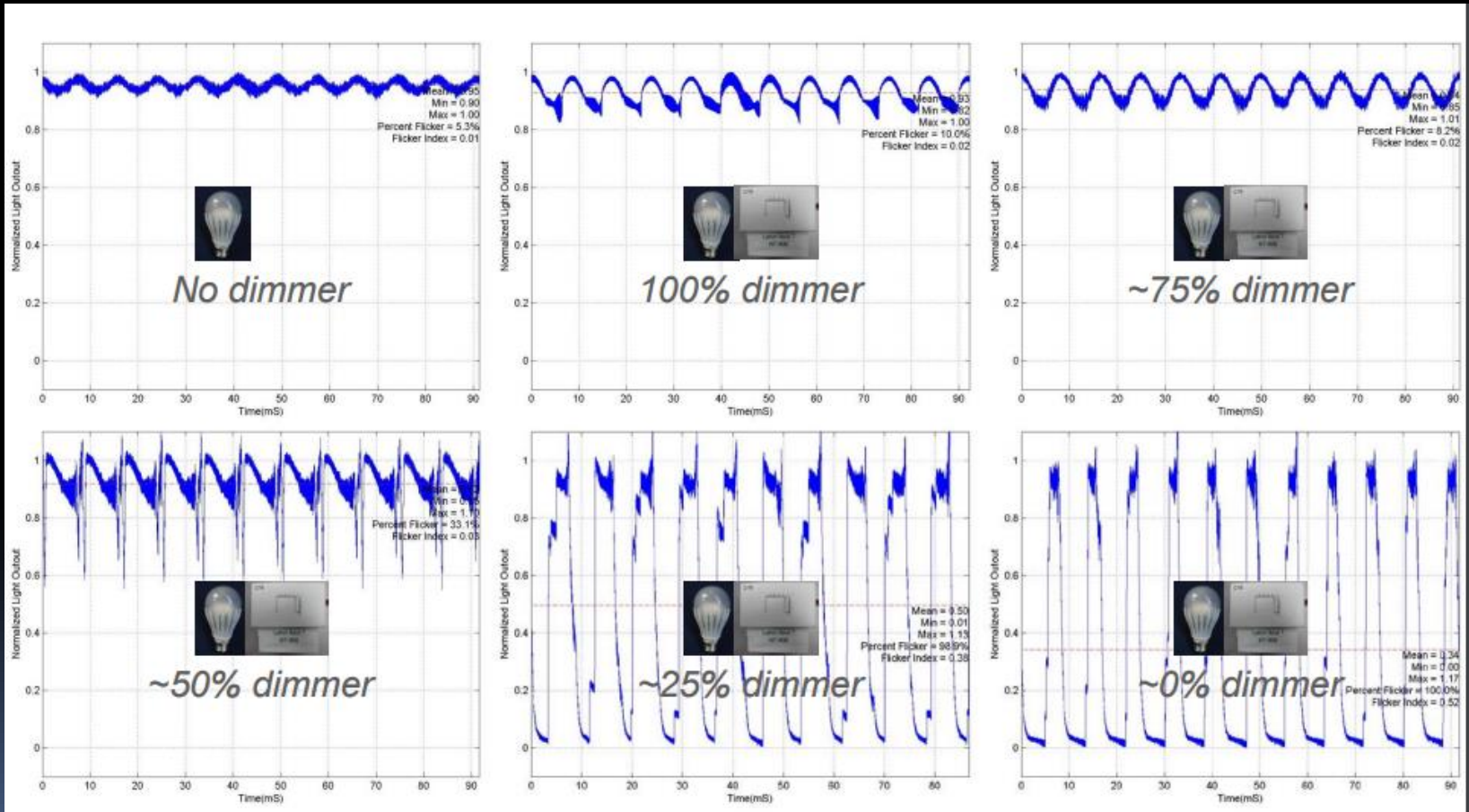




Temporal Artifacts

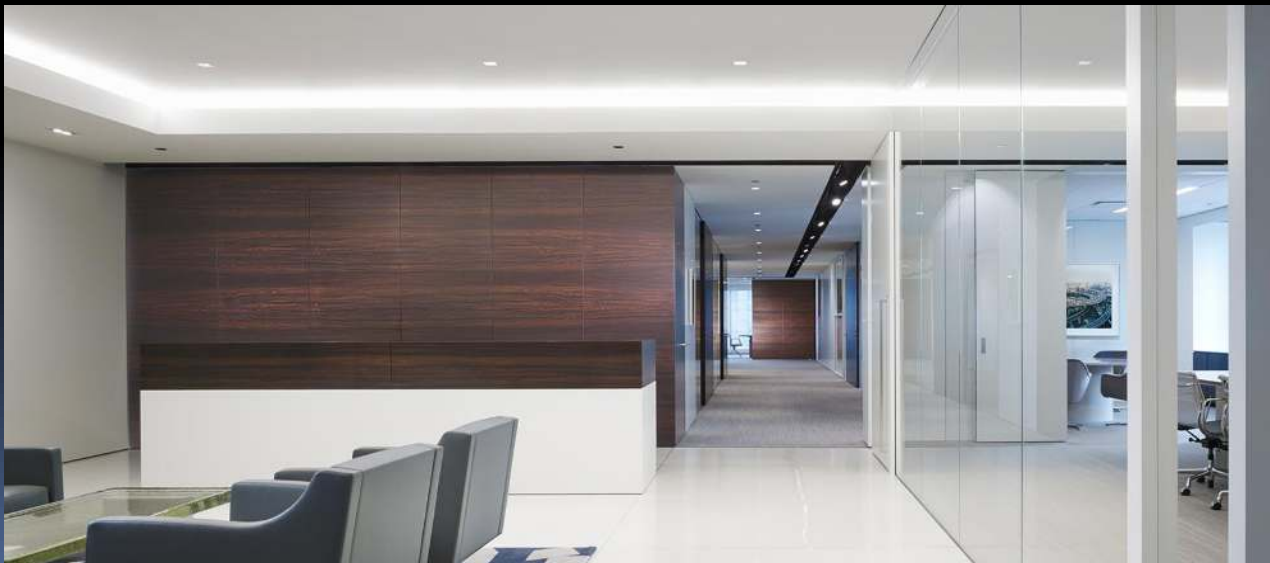
- Flicker
- Stroboscopy
- Instability

Flicker Compounded by Dimming





Architectural Style and Integration

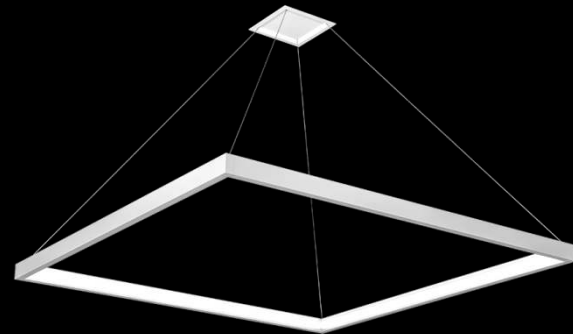


With Permission from Focal Point Lighting
Architect: Eastlake Studio
Photography: Steve Hall, Hedrich Blessing



Lighting Design Considerations

- Style
- Shape
- Location
- Detailing
- Ceiling





Emerging Issues of Design

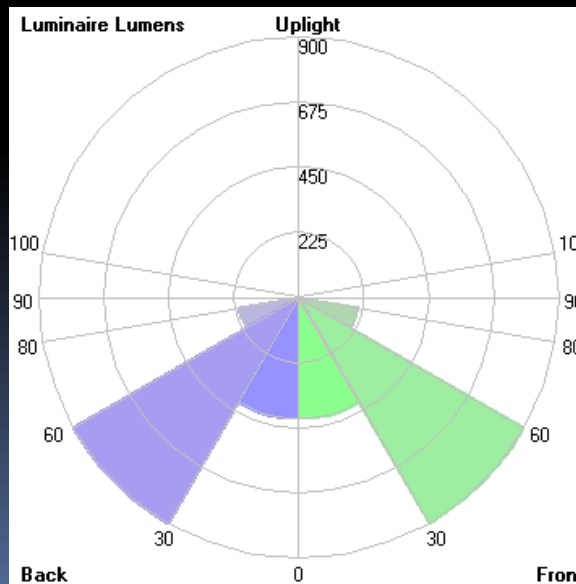
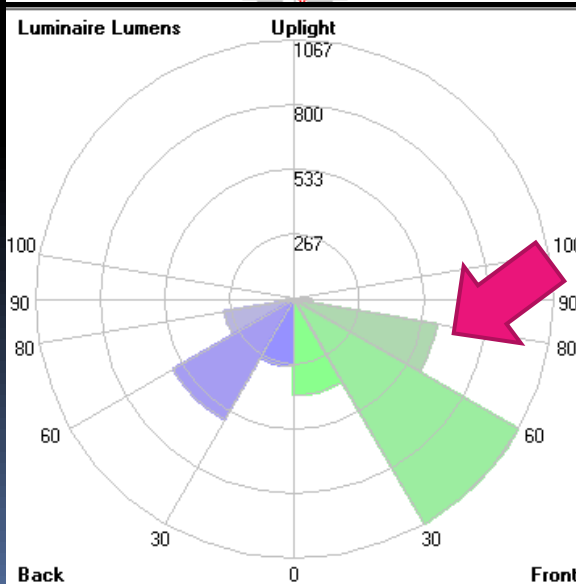
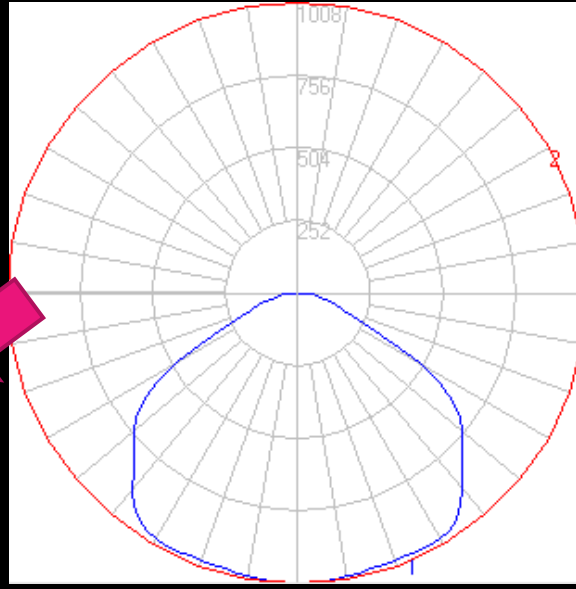
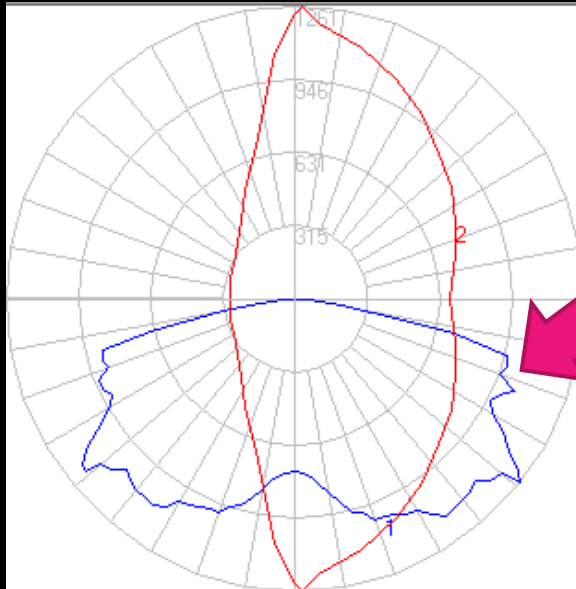
- Style often forces luminaire designs of reduced efficiency
- Appealing luminaires can't compete with efficient and super efficient luminaires
- Hard to make glare free super efficient luminaires



Efficiency, uniformity
Glare, pixelization

VS

Simplicity, softness, low glare
Pooling of light, non-directional





Results of Demonstration Project

- By day, the “barn light” system was preferred.
- By night, the “barn light” system was found to be less glaring, but the “cobrahead” system provided more uniform illumination
- The cobrahead system was dimmed until it was found have an “acceptable” level of glare.
- City Council chose the cobrahead system because it was already part of the city-wide LED conversion project and the less expensive barn lights would have added more cost.



Controllability





Controls Options

Switch or Dimmer

- No connectivity
- Limited automatic functions
- Highest reliability
- Typically intuitive and self teaching

Interactive Devices

- Some connectivity
- Limited automatic functions
- High reliability
- Mostly intuitive and self teaching but require commissioning

Lighting Network

- System wide connectivity
- All automatic functions
- Fair to high reliability
- Seldom intuitive nor self teaching and require commissioning



Classic Issues

- Flicker
- Fade rate
- Limited “smart” features
- Cost effectiveness
- Relatively high installation and wiring costs proportionate to features



Emerging Issues

- Flicker and stroboscopy
- Color changing or tuning
- Useful “smart” features
- Cost effectiveness
- Relatively high commissioning and programming costs proportionate to features



What Does All This have to do with Lumens?



Era of Rapid Change

- Revolution of light sources and controls
- Loss of distinct industry standards and leadership
- Authorities can't or won't keep up
- Persisting issues of quality
- International marketplace
- Emerging issues and conflicts
- Over-arching race to efficiency



Very Little Remains from the Past

- Classical and practical physics
- Principles of Photometry
- Basics of Electricity
- Principles of Codes and Standards
- Necessity for CIE, IES, NEMA and other organizations



Lumens Are Also Evolving

- “Scotopic” lumens and S/P ratio
- “Melanopic” lumens and M/P ratio
- New discoveries in the dynamics of human vision
- Unique spectra for other living beings and environments.



As an Industry, we must...


1. Dramatically increase the amount and rate of basic research
2. Coordinate better with other scientists to thoroughly vet emerging concepts
3. Slow down and stop jumping to conclusions from limited research
4. Rely on our classical principles to provide successful lighting with ever-decreasing energy use, changing more slowly to ensure that changes to our core science and principles are correct.



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