

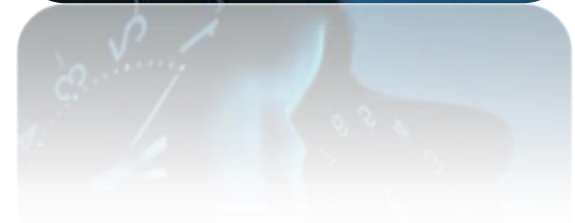


# LED Lighting Technology and Health

Robert Soler, Director of Lighting Research

# The Circadian System

- Circadian Rhythms are a daily rhythm our bodies go through
  - Hormone secretion
  - Cognition
  - Alertness
  - Productivity
  - Vigilance
  - Digestion
  - Bladder activity
  - Enzyme activity
  - Cell proliferation
- Light is the strongest time cue for circadian entrainment

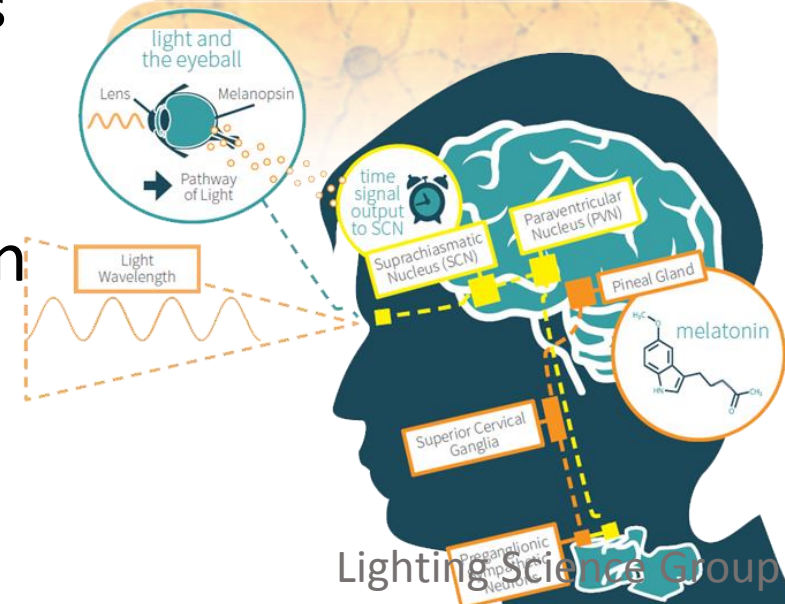
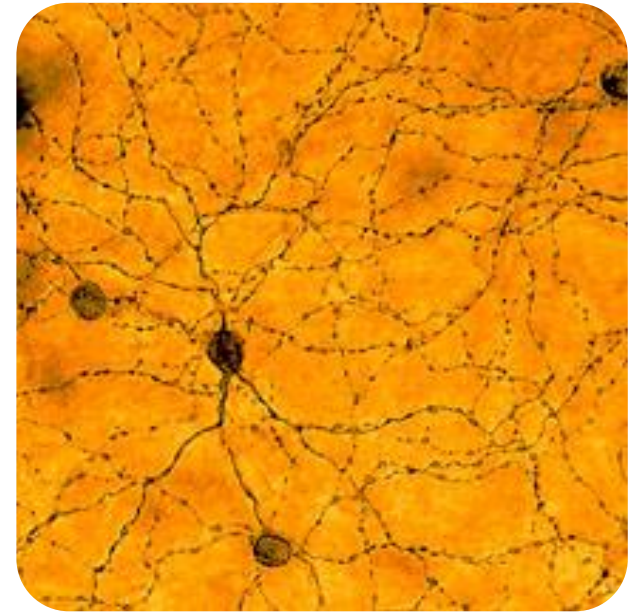


# New Photoreceptor

In 2001, scientists discovered a photoreceptor that links to Suprachiasmatic Nucleus (SCN) where our master clock resides.

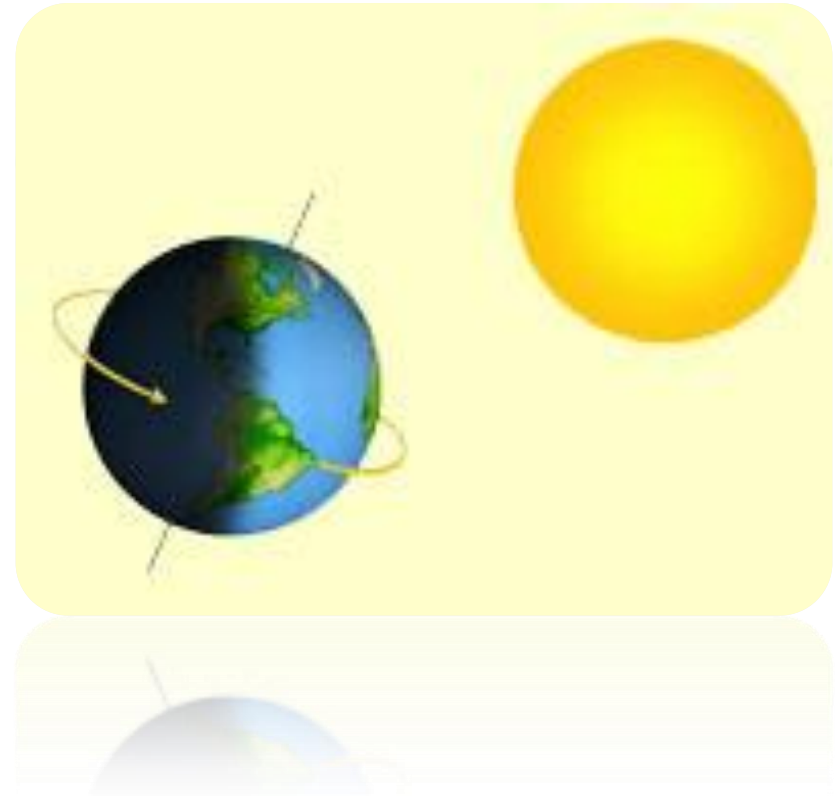
- Does not go to the visual cortex of the brain, like standard rods and cones
- Most sensitive to specific frequencies of blue light

More than 20% of gene expression in a given tissue has been estimated to be under circadian regulation (Reddy et al)



# 24 hour cycle

- Humans have a free running clock from 24.2-24.7 hours
- 24 hour light/dark cycle entrains our circadian clocks to 24 hours
- Electric lighting has created biological confusion in our circadian systems
  - Muddied the light/dark cycle
- Discovery of melanopsin has allowed us to mitigate this problem



# Modern Society's Clock

Light levels we see indoors fall into the twilight range

- 50 to 300 lux is what we have indoors, equivalent to what's available at twilight
  - Not enough during the day
  - Too much at night

**90% of time is spent indoors**

- **People in western region of time zone are more prone to circadian problems (such as SAD)**
- Increased chance of waking up in darkness
- Shows the importance of early morning biological light

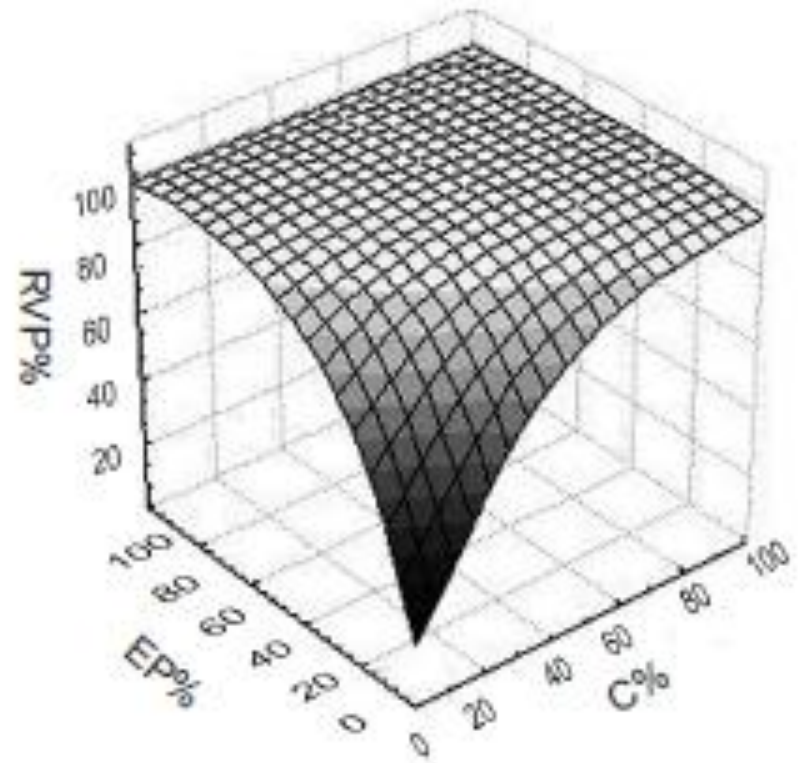


# Visual Performance

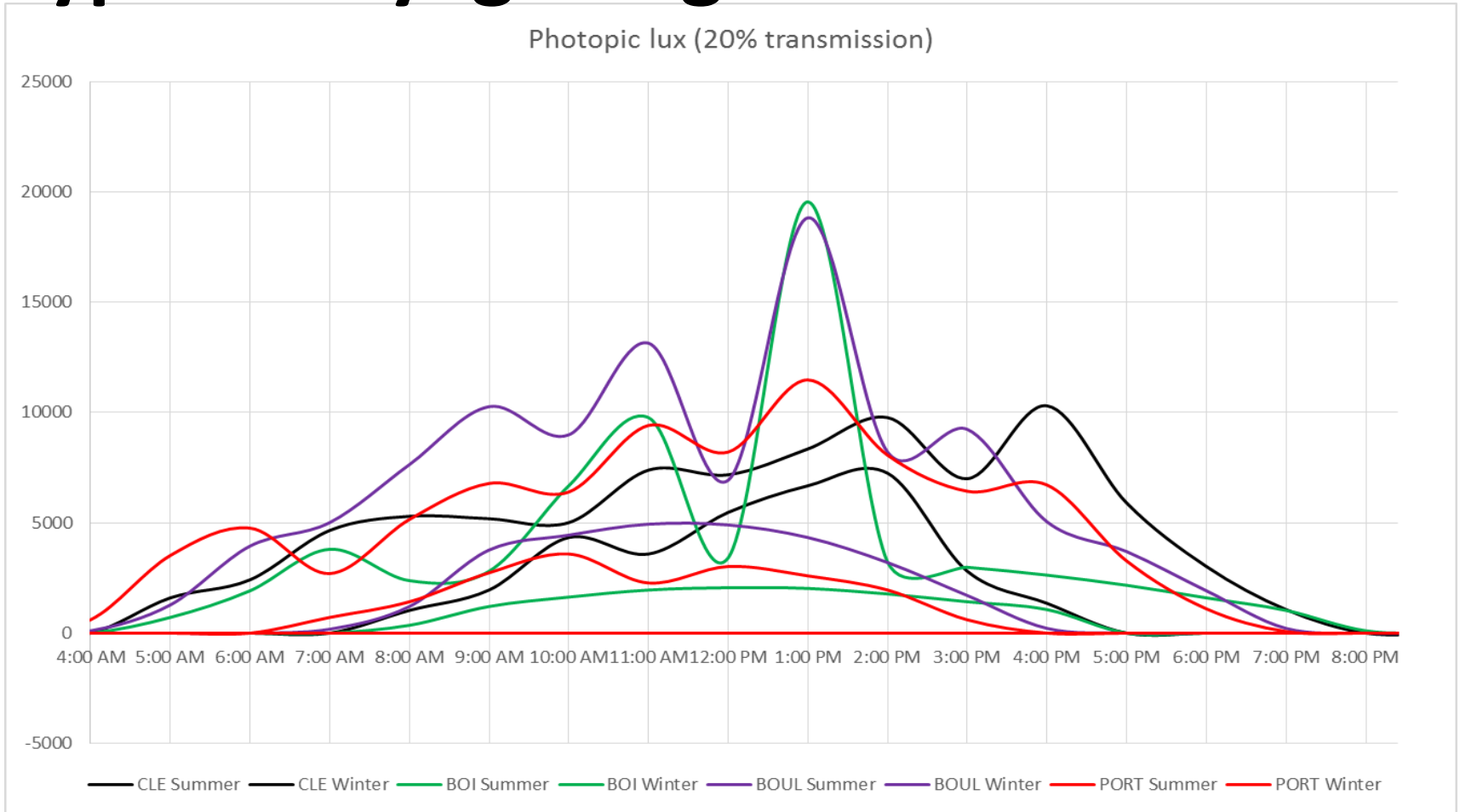
Light levels were designed without biology in mind

- Lighting Standards were built around visual performance
  - Saturation is in 100s of lux.
- Additional light would be a waste of energy

0 deg - 40 cd/m<sup>2</sup> - 83. 10<sup>-6</sup> sr



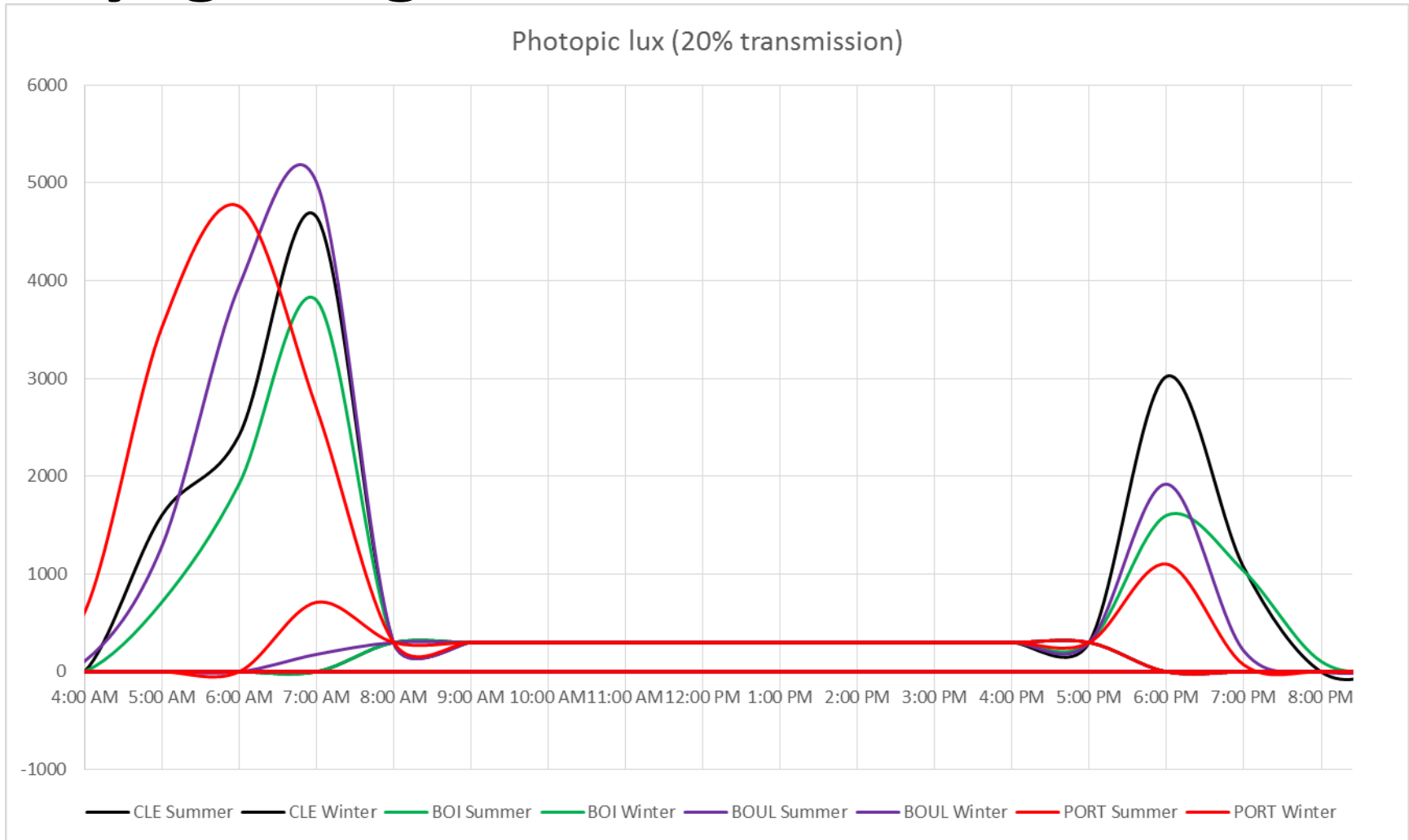
# Typical Daylight Signal



## NREL Outdoor signal throughout the day summer and winter in Cleveland, Boise, Boulder, and Portland (ME)

\*Assumes sunglasses are worn when outside: 20% transmission

# Daylight Signal for the Workforce



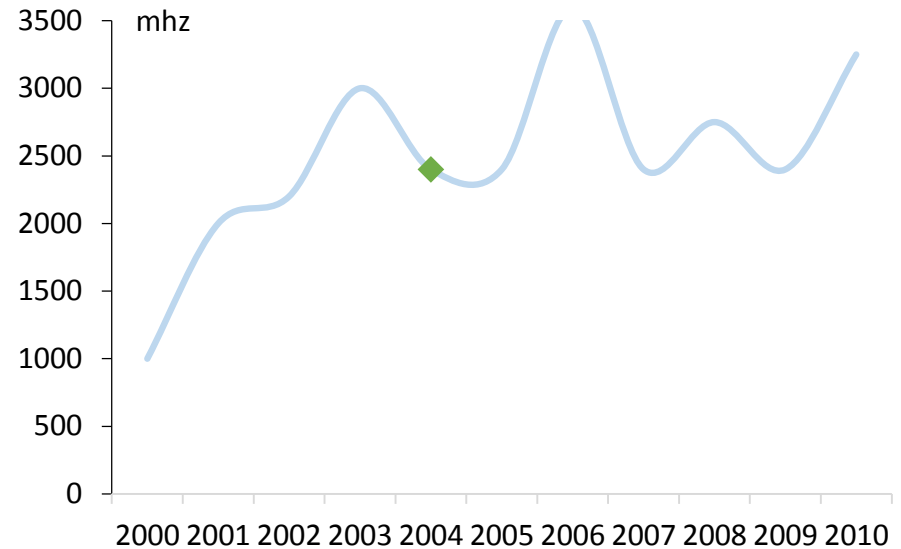
**Typical light signal throughout a worker's day (8am-5pm)**





# Processor Efficiency Hit a Peak

- Moore's law hit a theoretical peak in 2004
- Processing power became trivial
- Opened opportunities to do more with the technology



## The Processing Peak



2007 iPhone



2008 Cloud



2010 iPad



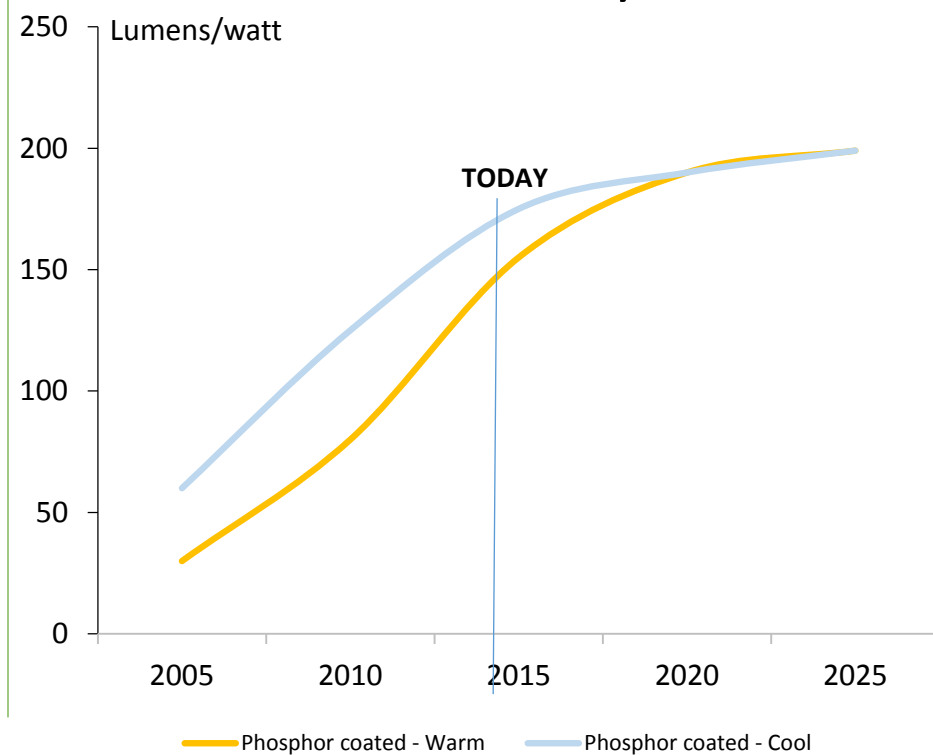
2013 Google Glass

# LED Efficiency Approaching Peak

## The Processing Peak

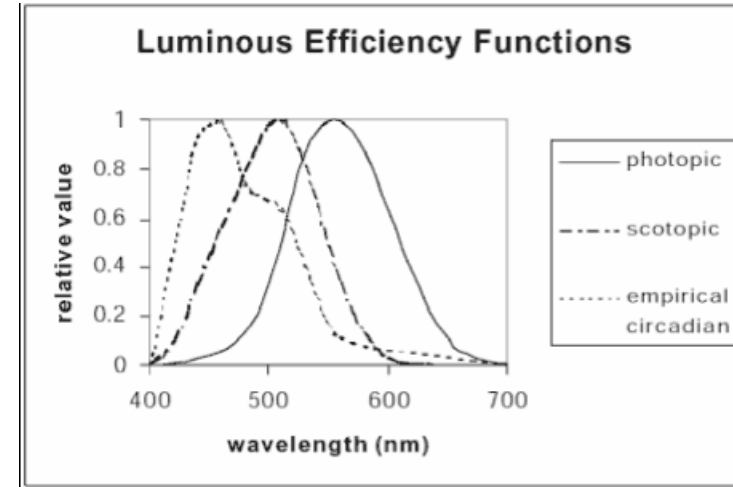


## The Efficiency Peak

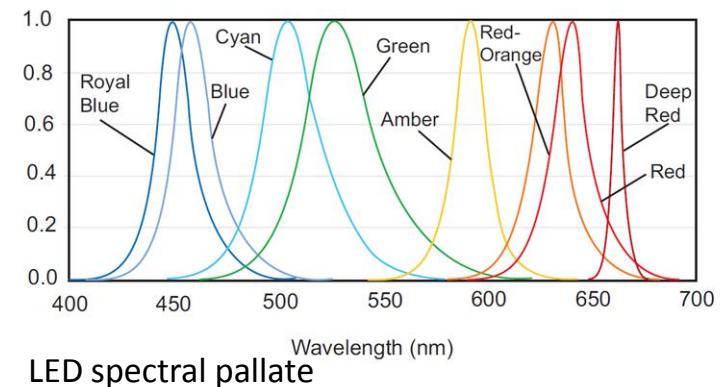


# Biological Light

- By understanding peak sensitivities of the biological systems we can maximize efficiency
- LED can be spectrally dialed in
  - Focus the energy used on the biological effect

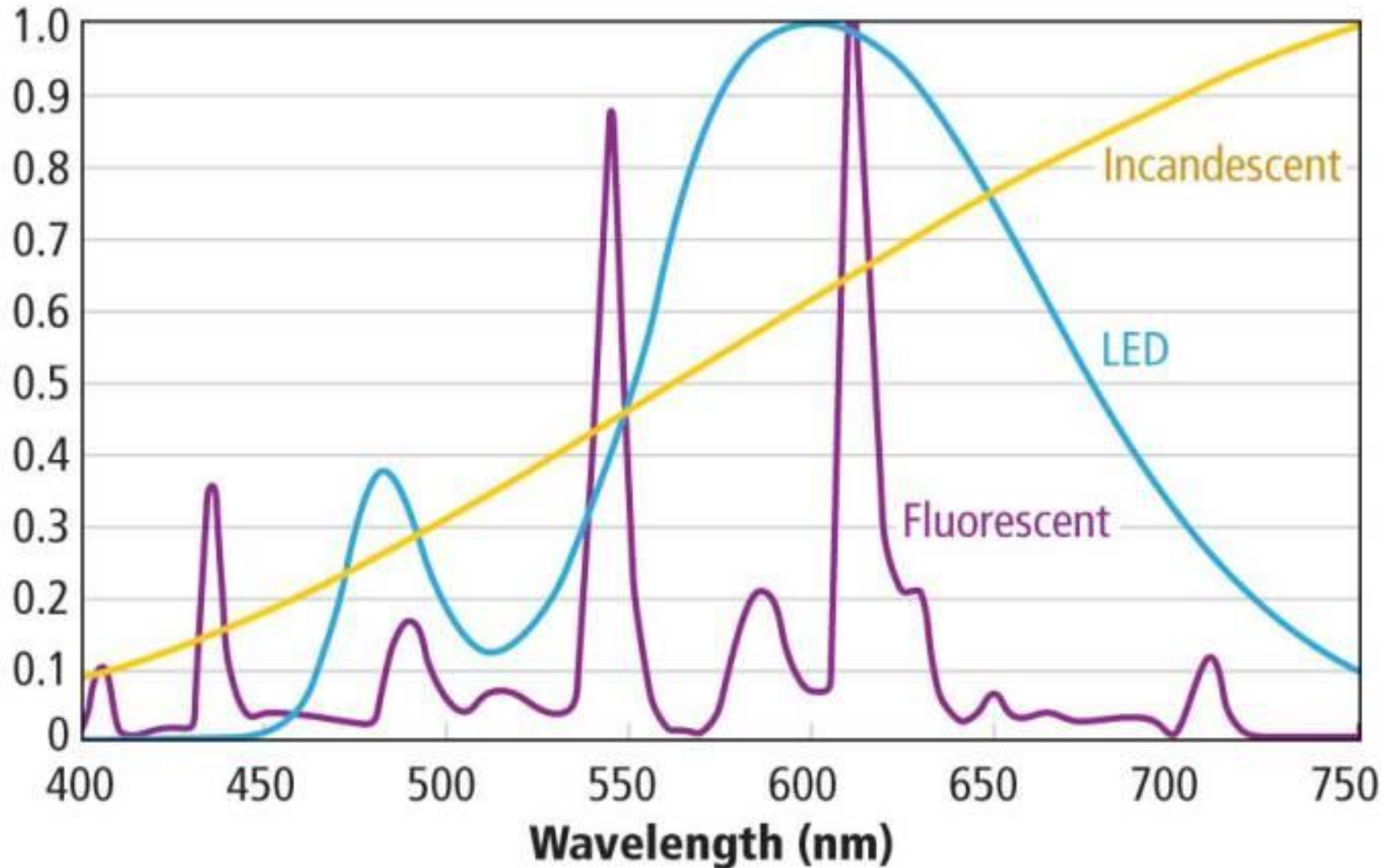


Sensitivity



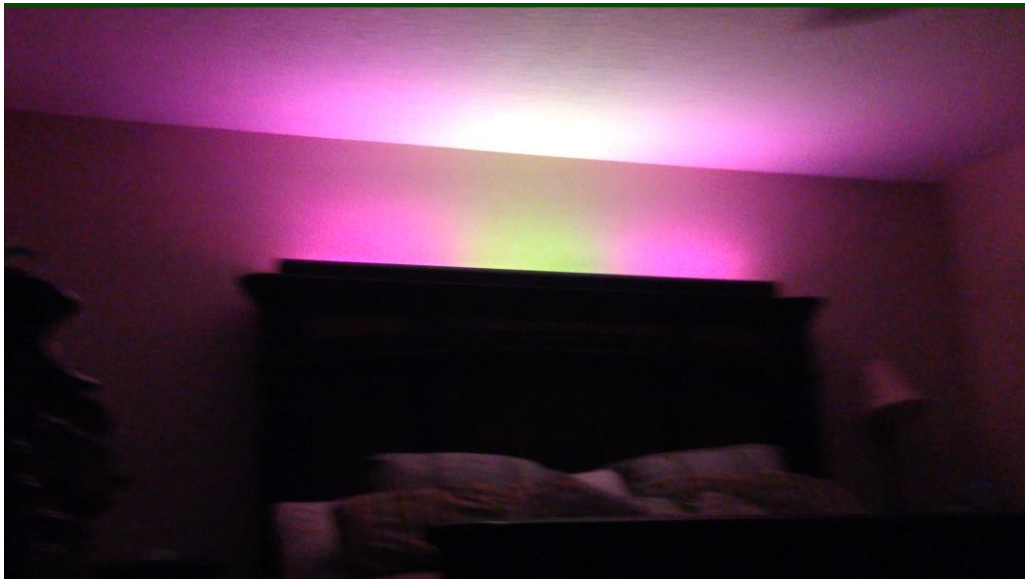
LED spectral palette

# Metamers - Demonstration



# Spectral Timing

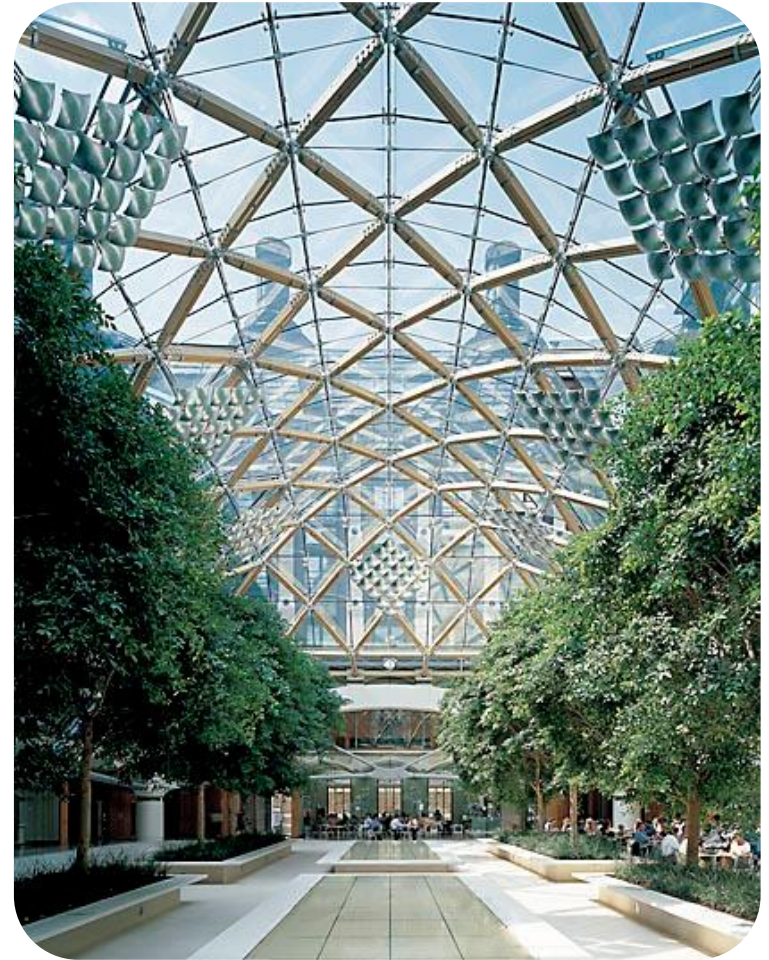
- Studies show Blue enriched light is most effective in the morning
- Simulated dawn (slow ramping of light) has a better effect than early morning bright light
- Red before blue light is better than blue light alone



Note: Light levels go from 25lux to 250lux (Camera is correcting)

# Bringing in the Daylight

- Using LED lighting, we can bring in the biologically significant daylight spectrums





# Thank You

Questions or more information

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