Can LEDs be Seen in Fog as Well as Incandescent Lamps?

John D. Bullough, Ph.D.
Lighting Research Center, Rensselaer Polytechnic Institute

2014 FAA Worldwide Airport Technology Transfer Conference

Galloway, NJ – August 5-7, 2014

Lighting Research Center

Rensselaer

LRC and Aviation Lighting Research

Aviation Lighting Research at the LRC

Human Factors

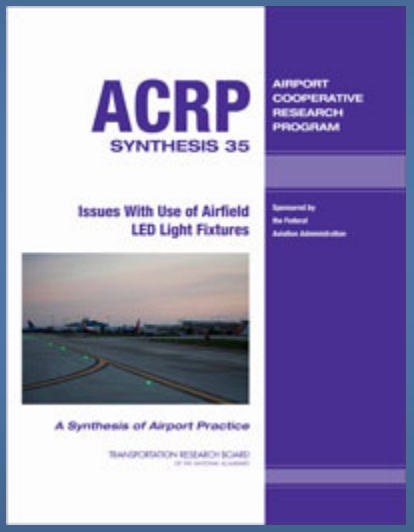
Color Vision Status and LED Identification
Signal Light Brightness
Perception of Linear Lighting
Effective Intensity of Flashing Lights
Stroboscopic Effect Perception
Requirements for LED Runway Guard Lights
Specifications for Remote Airfield Lighting

Solid State Lighting Technology

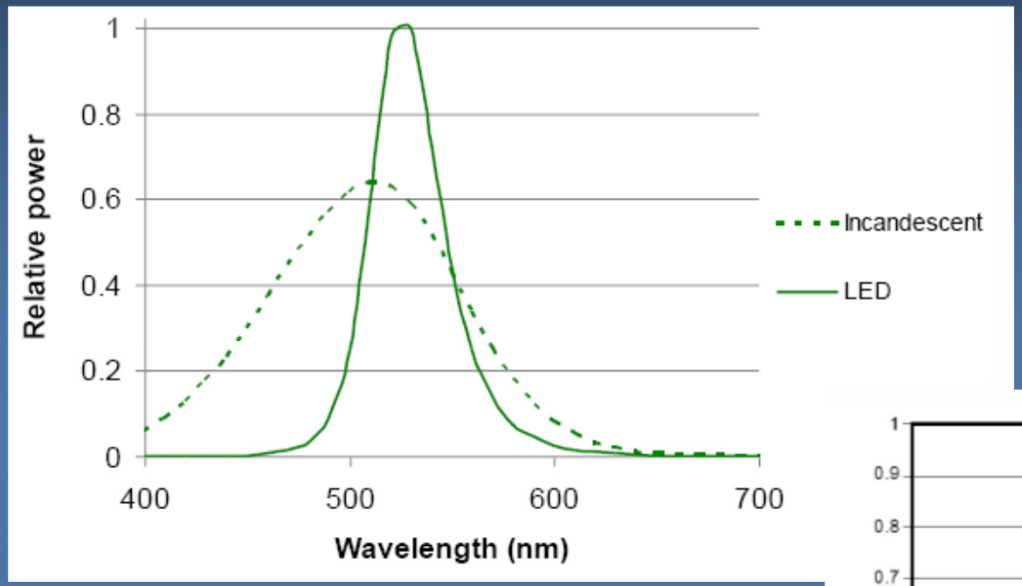
Heat Transfer in Taxiway Edge Lights
Life Testing for Airfield Lighting Fixtures
Solar-Powered LED Fixtures
Volatile Organic Compound Effects in LEDs
LED Driving Circuitry and Flicker
Photometric Testing for LED Fixtures
Electrical Infrastructure Research Team Support
Phosphor-Converted Amber LEDs
Junction Temperature Estimation for AC LEDs
LED Electrical and Thermal Parameters Under Stress

Background

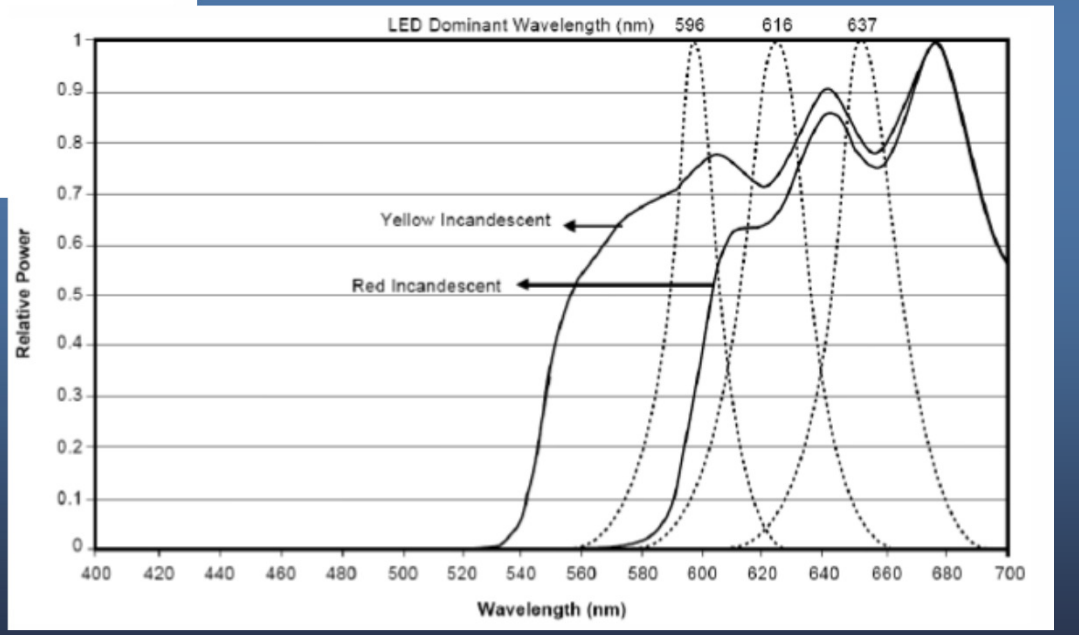
- LED lighting technology is increasing in use for airfield lighting
  - Potential for maintenance and energy benefits
- LEDs differ from incandescent sources in several important ways:
  - Spectral (color)
  - Temporal (onset/offset times)
- Are there issues with perception of LEDs in fog/haze conditions?



Spectral Distributions of LED and Incandescent Signal Lights



Green



Yellow and Red

Color Identification

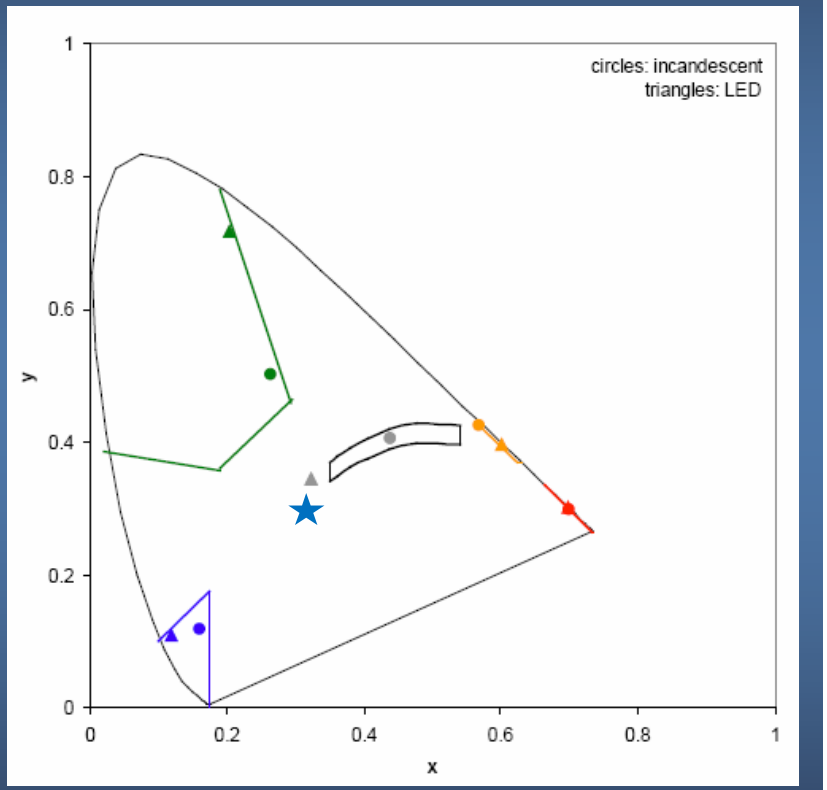
- LEDs tend to produce more saturated colors and higher correlated color temperatures (CCT) than filtered incandescent sources
  - Generally beneficial for identification in clear conditions (*Technical Note DOT/FAA/TC-TN12/61*)
- What about non-clear conditions?
  - Fog
  - Haze

Color Identification in Fog

- Fog scatters light and thus reduces the apparent intensity of a signal light, overlaying scattered light from other sources over the signal image
  - Scatter is wavelength-independent (Arnulf et al. 1957)
  - Fog particles are large relative to visible wavelengths (Middleton 1952)

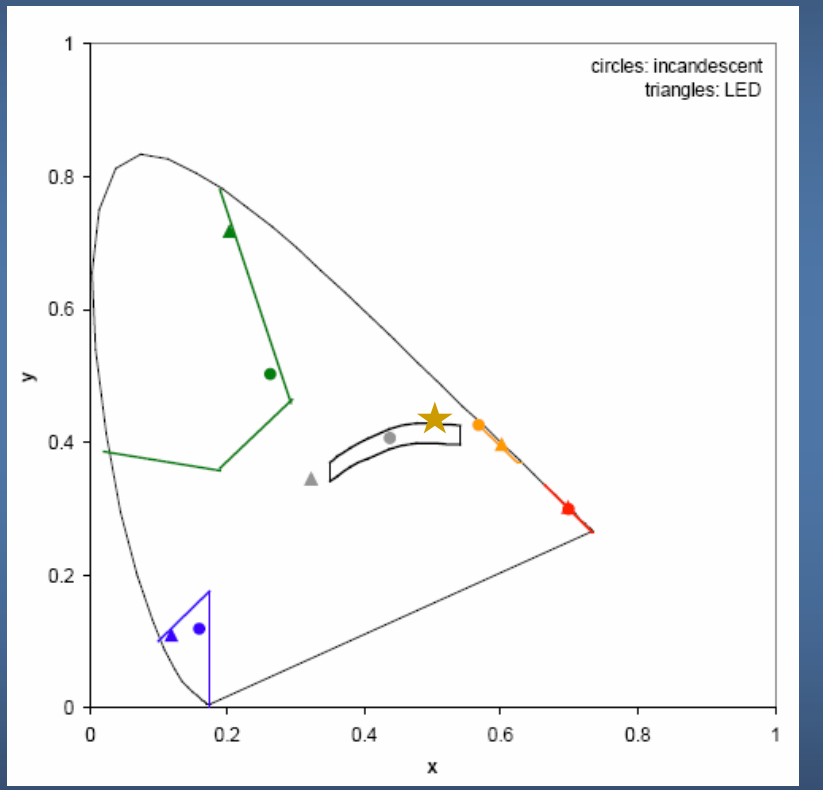
Color Identification in Fog: Daytime

- In daytime, scatter overlaying the light is white (★), so fog will desaturate signal color
  - Desaturation of some incandescent colors (like green) will make them appear white (Bullough et al. 2012)
  - LED green signals start out more saturated in color so the same amount of fog will have a smaller impact on LED color than on incandescent color



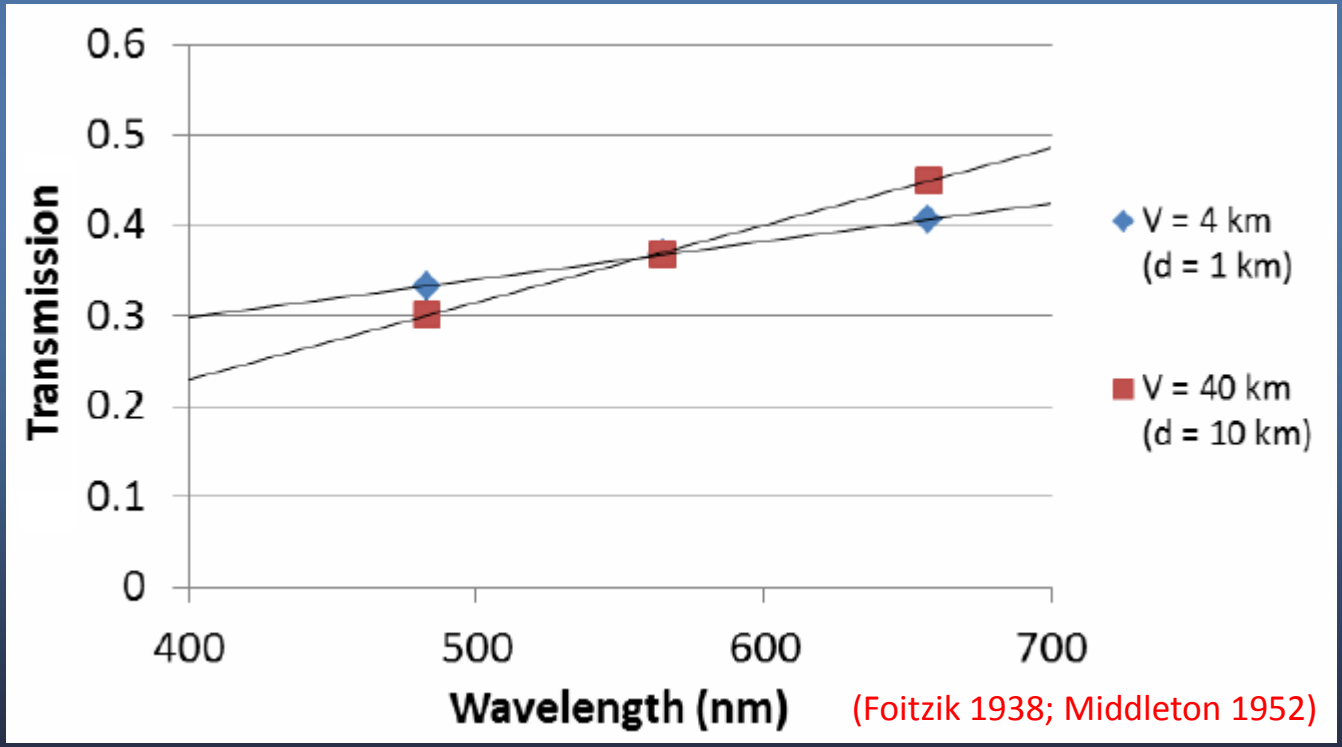
Color Identification in Fog: Nighttime

- At night, the color of scattered light depends upon the predominant nighttime light source
  - In urban areas, likely to be high pressure sodium [yellowish light] (★)
  - In rural areas, likely to be a mixture of signal light colors on the airfield
  - Central tendency likely to be "whitish" but chromaticity shift likely to be smaller



Color Identification in Haze

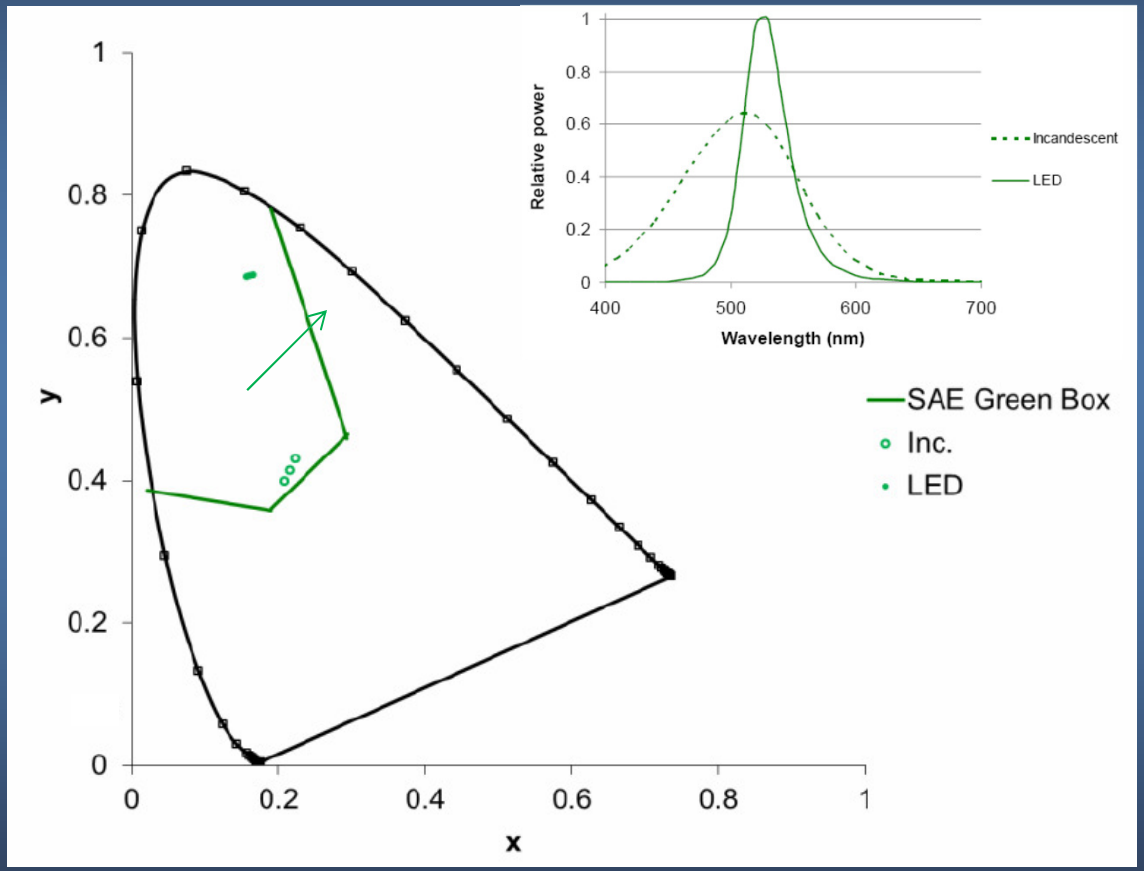
- Daytime issues similar to those of fog
- Haze selectively transmits light of different wavelengths
  - Smaller particle sizes (Arnulf et al. 1957)



(Foitzik 1938; Middleton 1952)

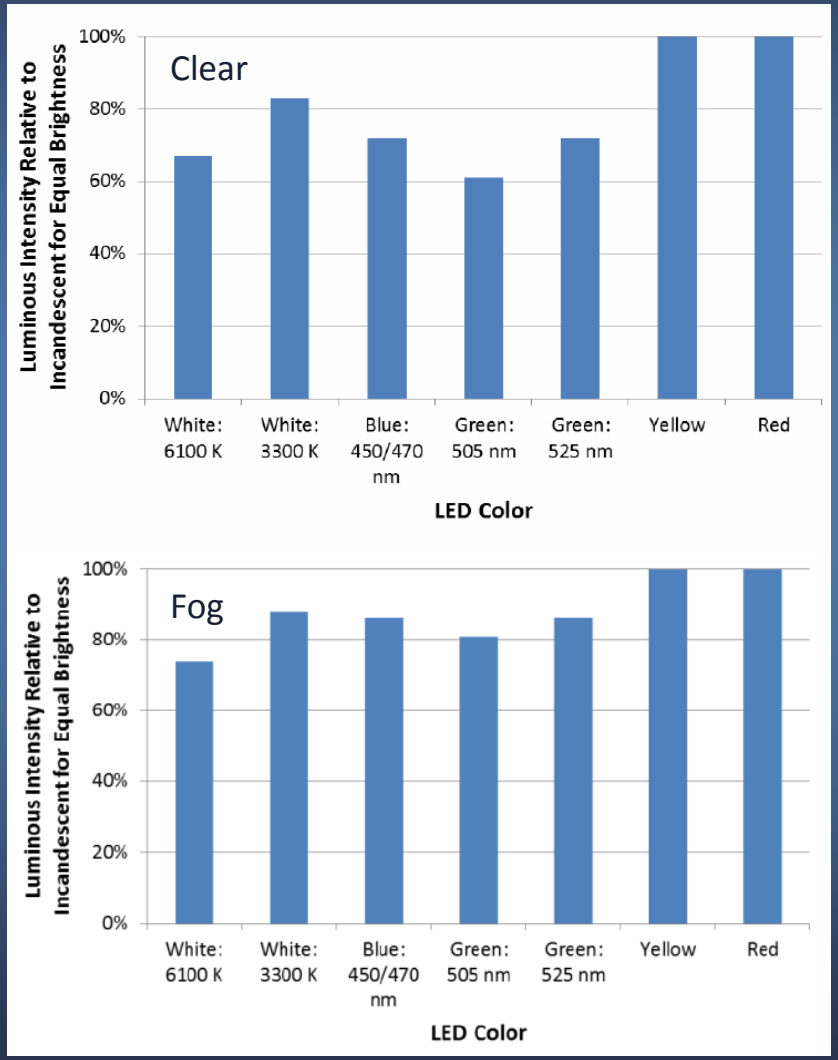
Color Identification in Haze (cont'd.)

- Shorter wavelengths are scattered more in haze
- Narrower spectral distribution is more "resistant" to chromaticity shifts



Brightness Appearance in Fog

- Higher saturation and CCT of LED signals results in brighter appearance relative to incandescent of the same luminous intensity
  (Bullough et al. 2007)
- Scattered light from fog is superimposed over signal light images, reducing the relative brightness enhancement of LEDs over incandescent



Flashing Light Detection

- To achieve equivalent response times and ratings of noticeability in clear conditions, simulated flashing incandescent runway guard lights (RGLs) needed to have ~4 times higher intensity than flashing LED RGLs (Radetsky et al. 2009)
- The presence of fog increased the necessary intensity by a factor of ten to achieve equivalent visibility, for both incandescent and LED RGLs
  - To achieve equivalent response times and ratings of noticeability under fog conditions, simulated flashing incandescent runway guard lights (RGLs) needed to have ~4 times higher intensity than flashing LED RGLs (Radetsky et al. 2009)
  - Fog did not seem to impact detection of LED signals with shorter onset times any more than incandescent sources, with longer onset times

Summary

- "Can LEDs be seen in fog as well as incandescent lamps?"
  - Yes
  - LEDs are resistant to color shifts from haze at night
  - Daytime fog and haze diminish, but do not reverse, advantages for color identification and brightness
  - Fog does not affect relative conspicuity benefit of shorter onset times of LEDs in RGL applications

Thank you!

- Acknowledgments:
  - Donald Gallagher and Nelda Milburn, FAA
  - Andrew Bierman, Jean Paul Freyssinier, N. Narendran, Conan O'Rourke, Leora Radetsky, Nicholas Skinner, Rachel Taranta