Achieving Excellence in Backlit Decorated Plastics

Paul Uglum

Uglum Consulting, LLC

UGLUM
CONSULTING LLC

Backlighting Decorated Plastics: Design, Technology and Risks

Why Backlighting?

Basics of Color and Light

Backlighting Design and Issues

How to Measure and Specify Backlighting

Technologies to produce Backlit Decorated Parts

Backlighting Risks

UGLUM
CONSULTING LLC

Why Backlighting?

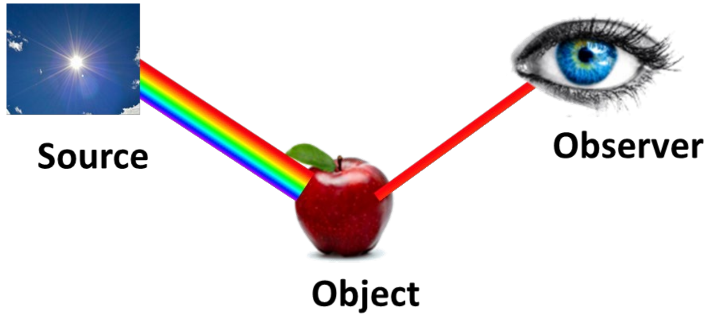
Because it adds value to the product

Aesthetic
Decorative
Ambient

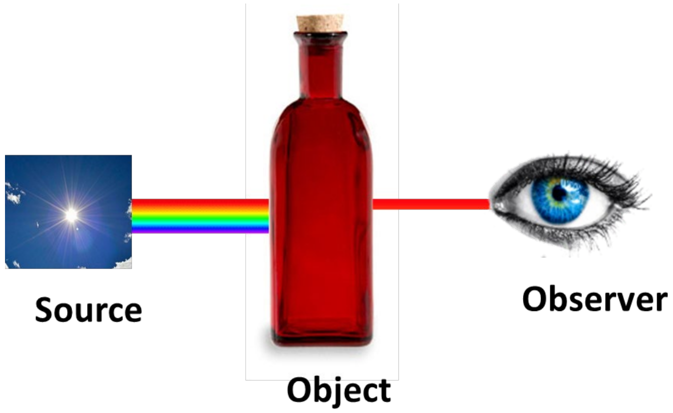
Functional
Informative

UGLUM CONSULTING LLC

We are all familiar with color and appearance when the light is reflected



We are less familiar with color and appearance when the light is emitted



Choose the source and manage the distribution of the light

UGLUM CONSULTING LLC

Structure of a Backlit Product

Light Source → **Light Delivery System** → **Decorated Plastic Part**

Light Source
- Available Color
- Available Intensity

Light Delivery System
- Moves light to part
- Distributes light evenly
- Modifies color
- Modifies intensity

Decorated Plastic Part
- Defines Lit Feature
- Distributes light evenly
- Hides non-lit portion
- Modifies color
- Modifies intensity

UGLUM CONSULTING LLC

Design of a Backlit Product

In addition to the part itself the operating environment and design intent must be considered

How bright must it be to be seen and not be a distraction

The Foundation of Design is Knowing the Requirements

UGLUM
CONSULTING LLC

How much light to you need?

What are the requirements?

What is the intended use of the product?

Safety related ?

Defined by regulation?

Is the image / feature visible when not lit?

Is diming or “movement” needed?

What are the package size limitations?

Backlit Brightness Levels

Luminance Levels Various Products

Laptop	200 Cd/m2
Cell Phone	500 – 700 Cd/m2
Rugged Laptop	1500 Cd/m2
TV	450-1500 Cd/m2
Display in Sun	1000 Cd/m2
Car Headlights	10200 Cd/m2
Car tail Lights	4300 Cd/m2
Car button at night	8 Cd/m2

UGLUM
CONSULTING LLC

Light Sources

The Foundation of Backlit Systems is the Light Source

Incandescent

Electro luminescent

Cold Cathode Gas Discharge - Neon

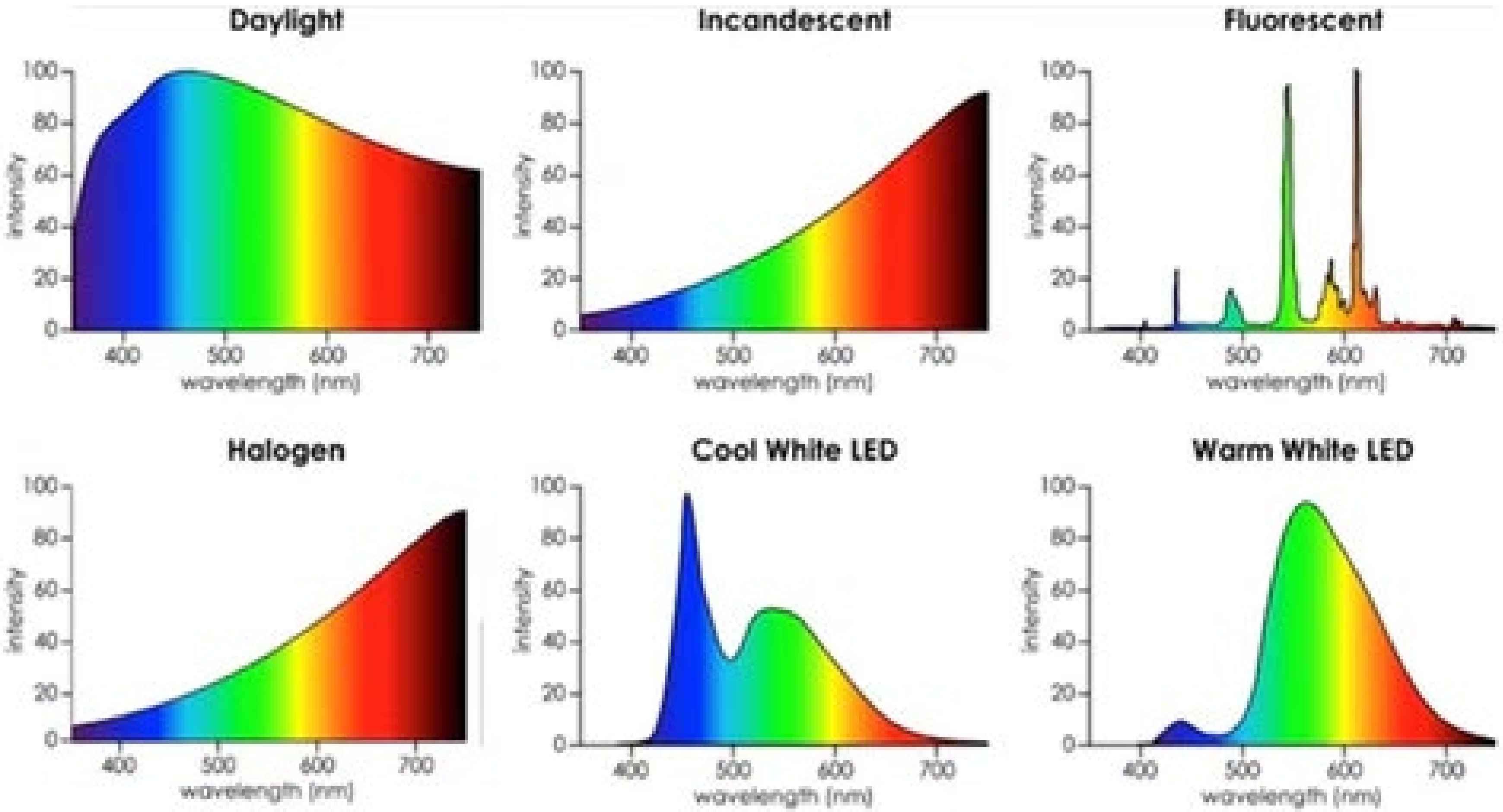
Fluorescent

Light Emitting Diodes

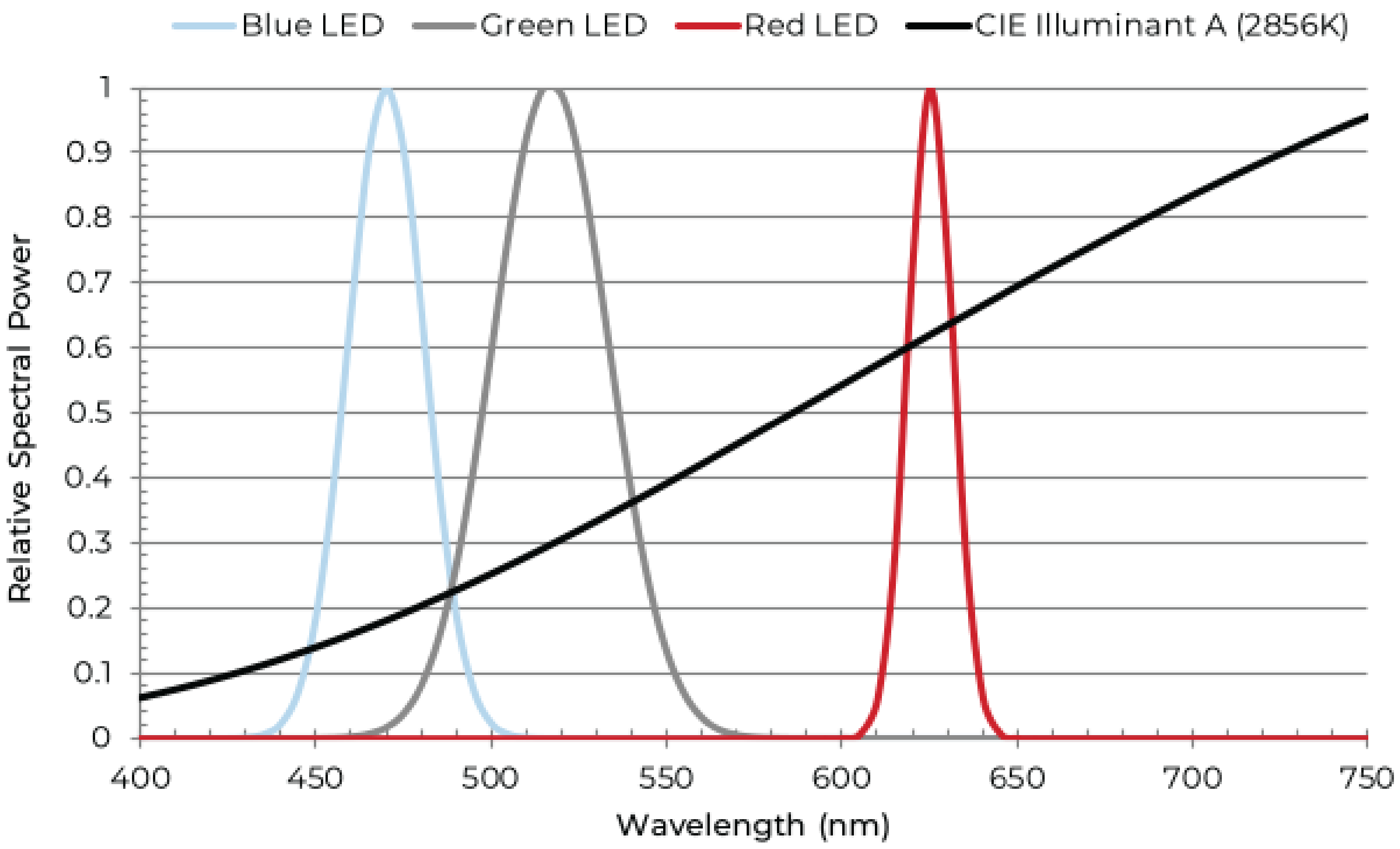
Organic Light Emitting Diodes

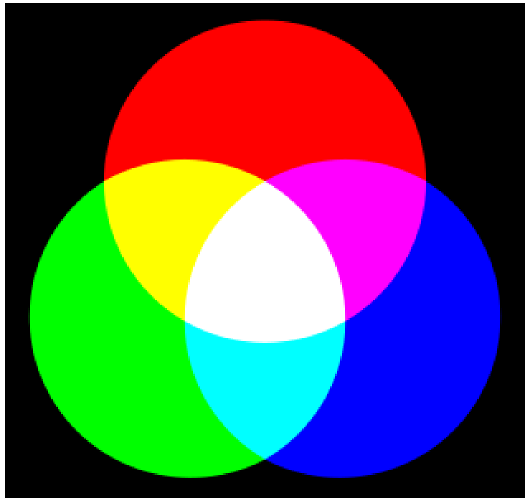
UGLUM
CONSULTING LLC

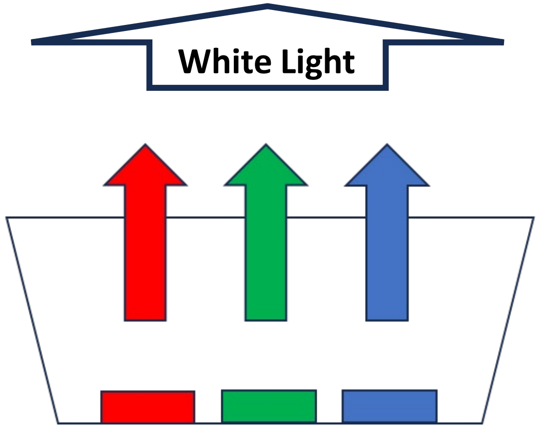
Color Content of Light Sources



Color Mixing



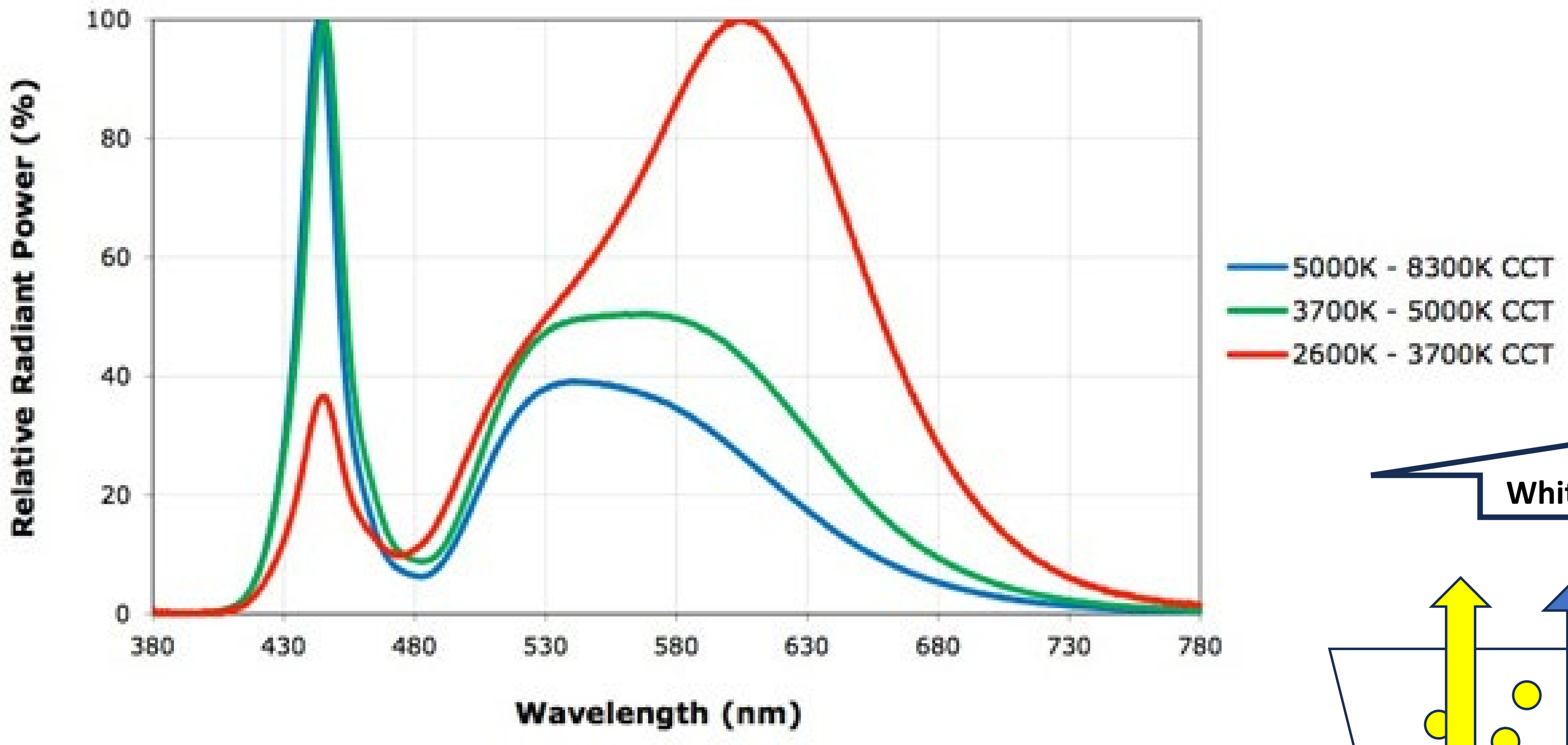


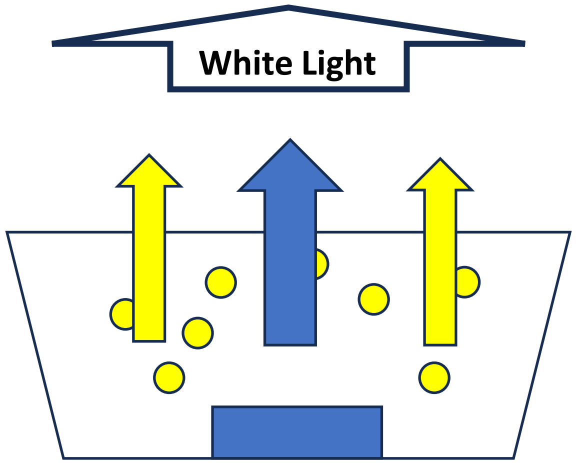


A white light appearance as well as other colors can be obtained by mixing red, blue and green light from LEDs

UGLUM
CONSULTING LLC

"White" LED's

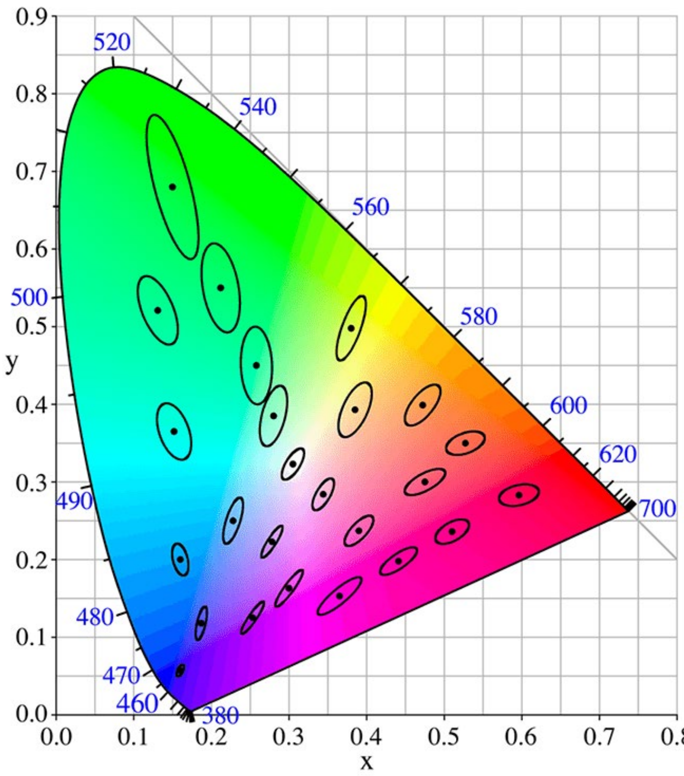


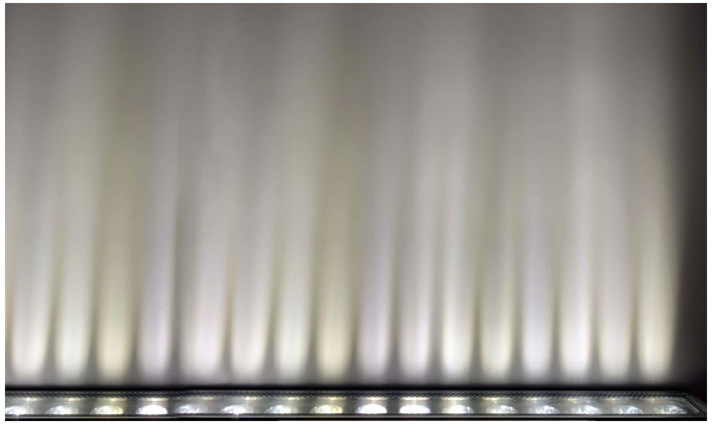


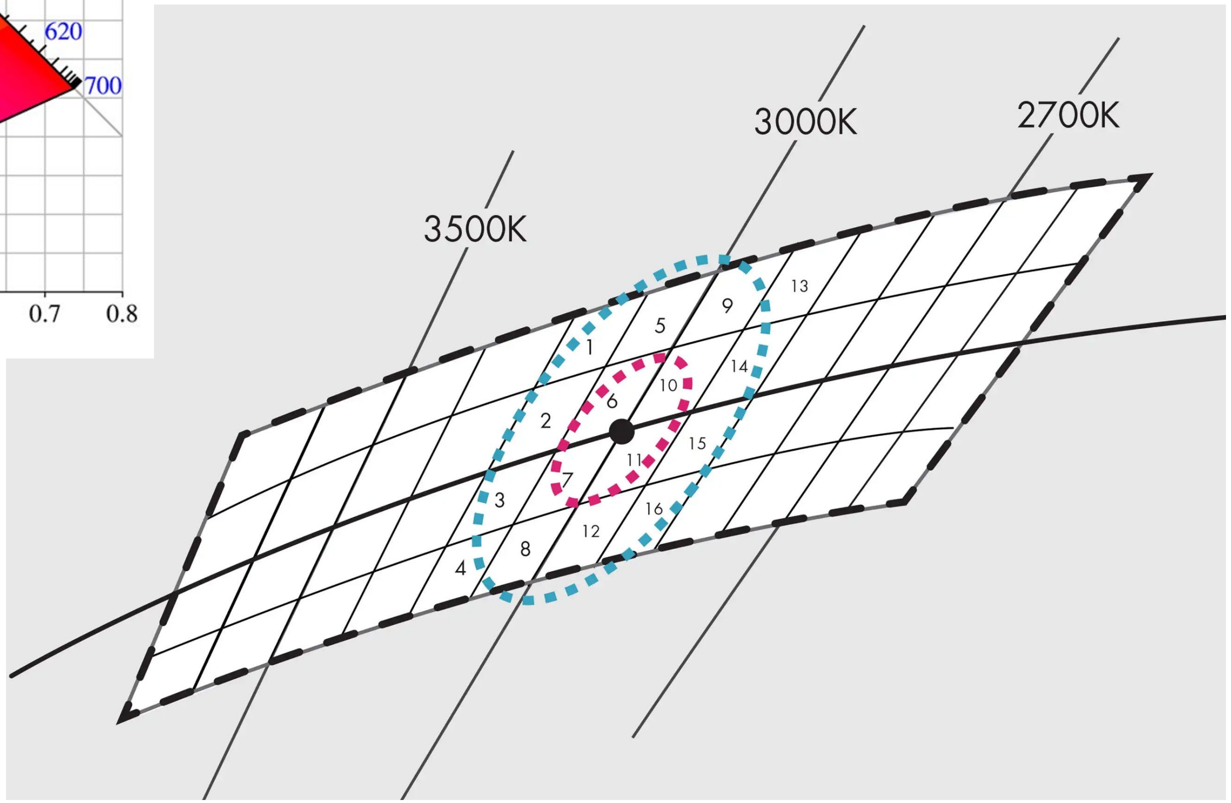
Blue light from the blue die and yellow light from the phosphors combine to appear as white light

UGLUM
CONSULTING LLC

LED binning and issues





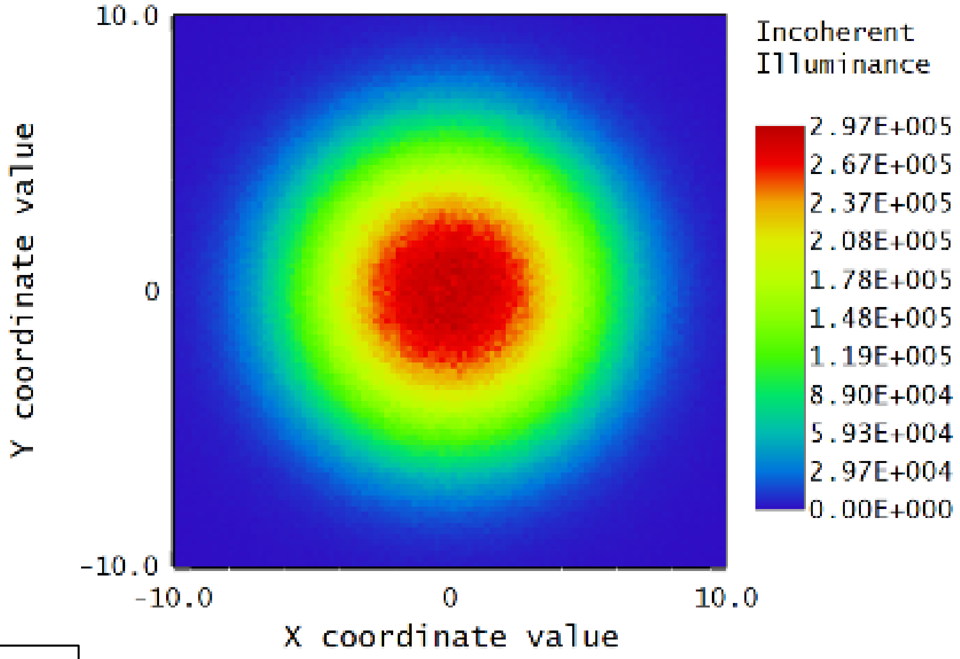


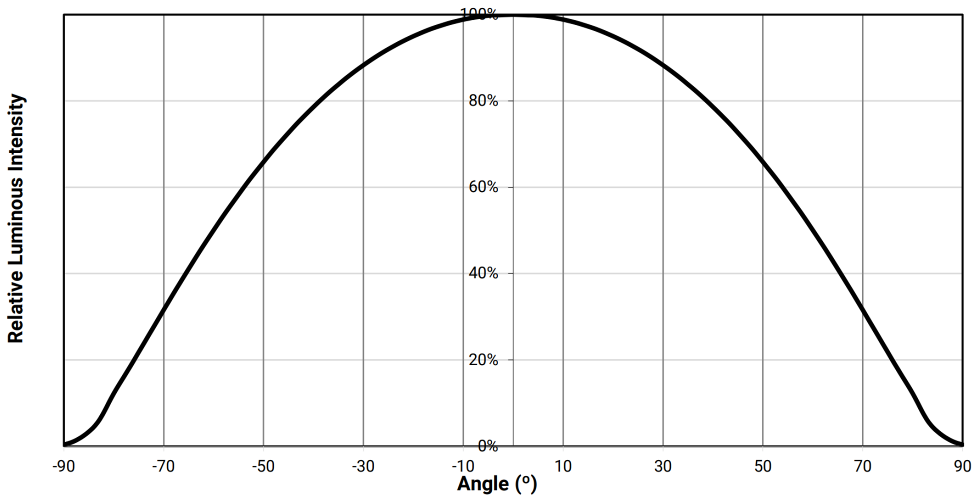
LED Light Distribution

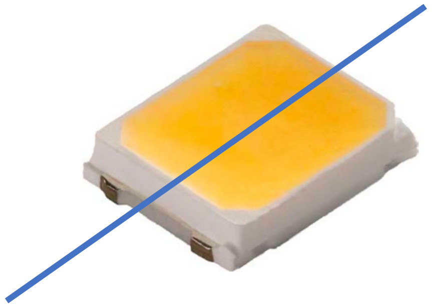
Outputs are:

Light

Heat



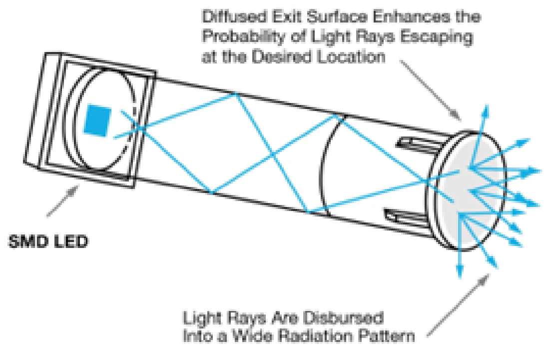




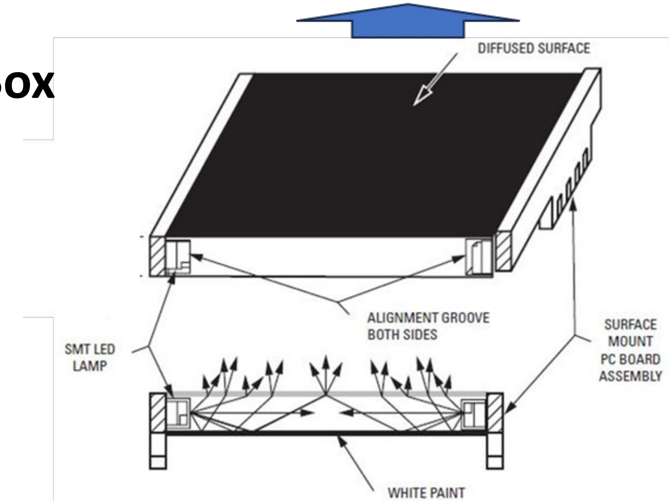
UGLUM
CONSULTING LLC

Light Transfer Techniques

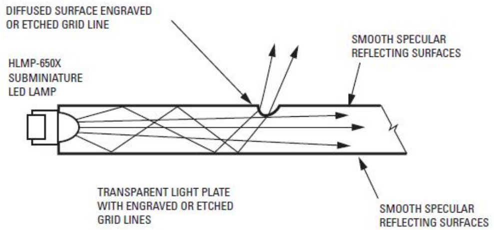
Direct LED Lighting



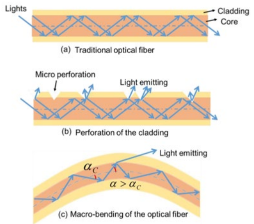
Light Box



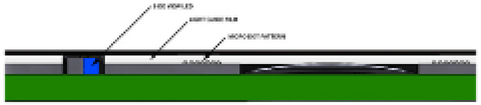
Light Pipe



Fiber Optics & Fiber Optic Mats



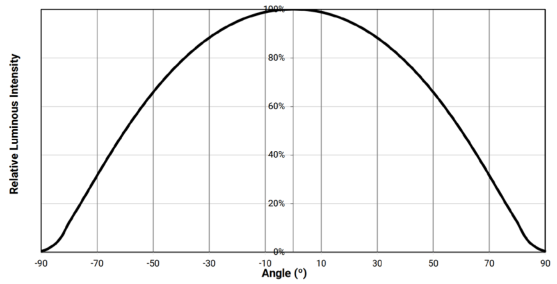
Light Guide Films

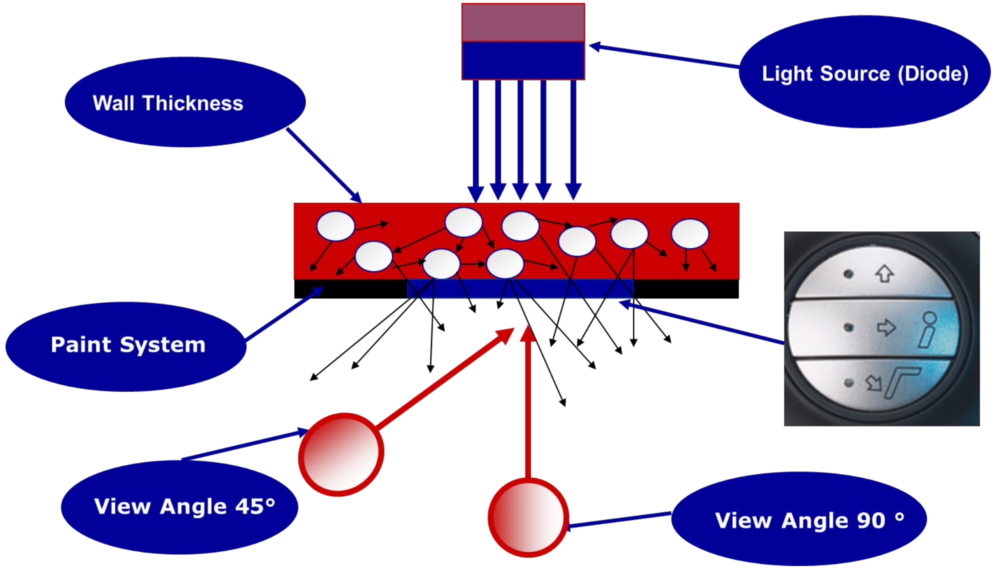


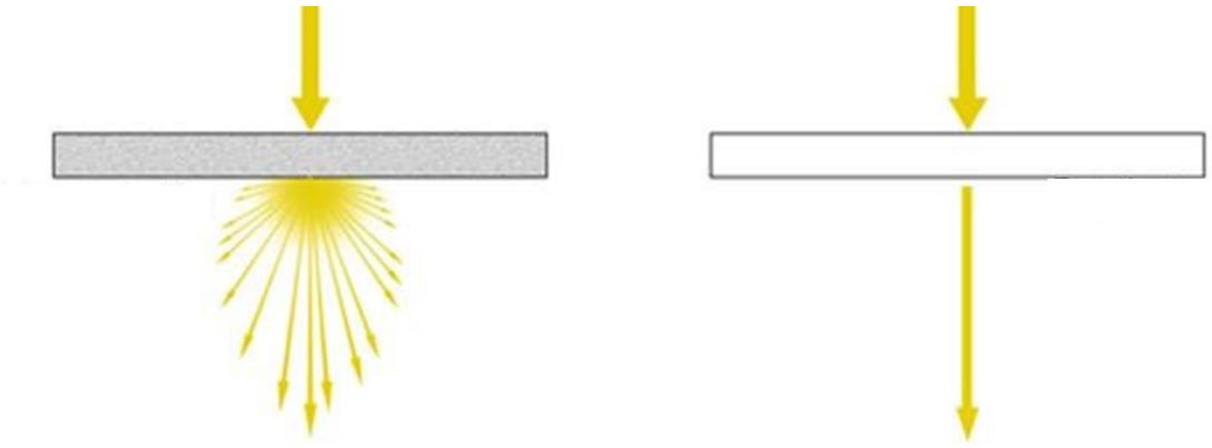
Light Source → Light Delivery System → Decorated Plastic Part

UGLUM CONSULTING LLC

Bright Spots and Light Scattering

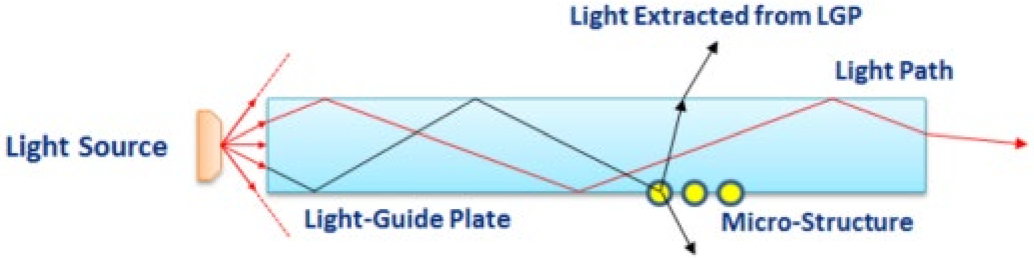






Light Pickup and Internal Reflections

Snell's Law

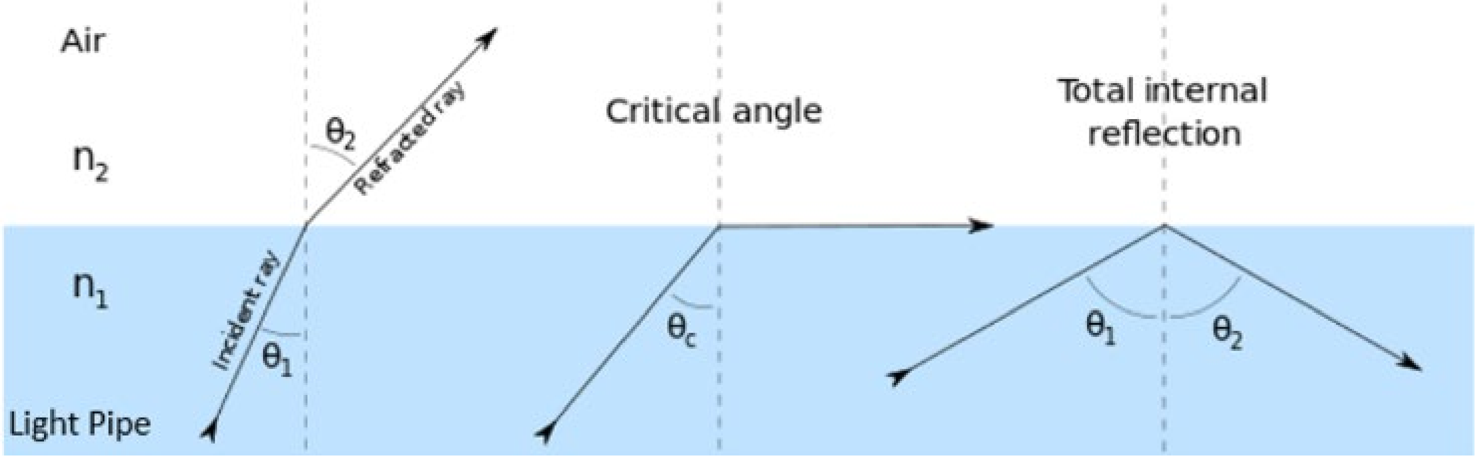


Refractive Index

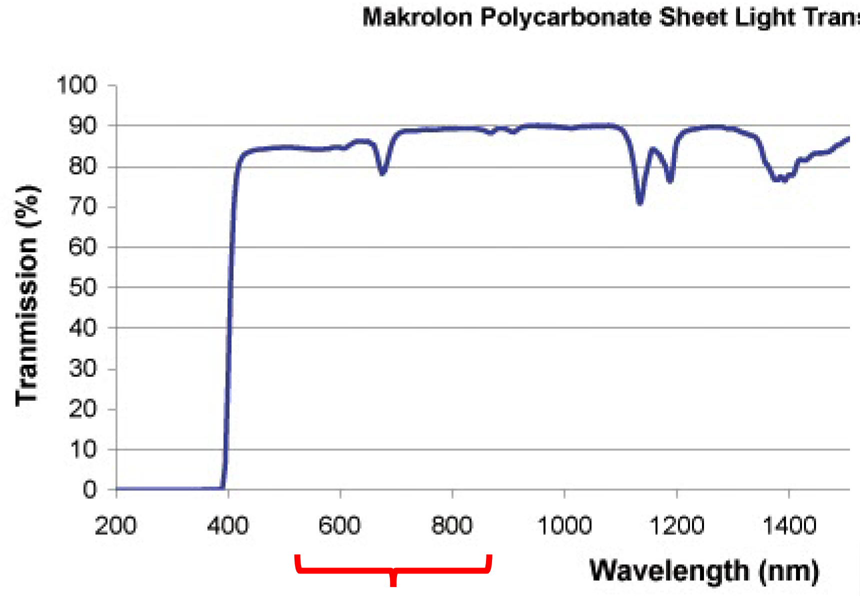
Polycarbonate = 1.58

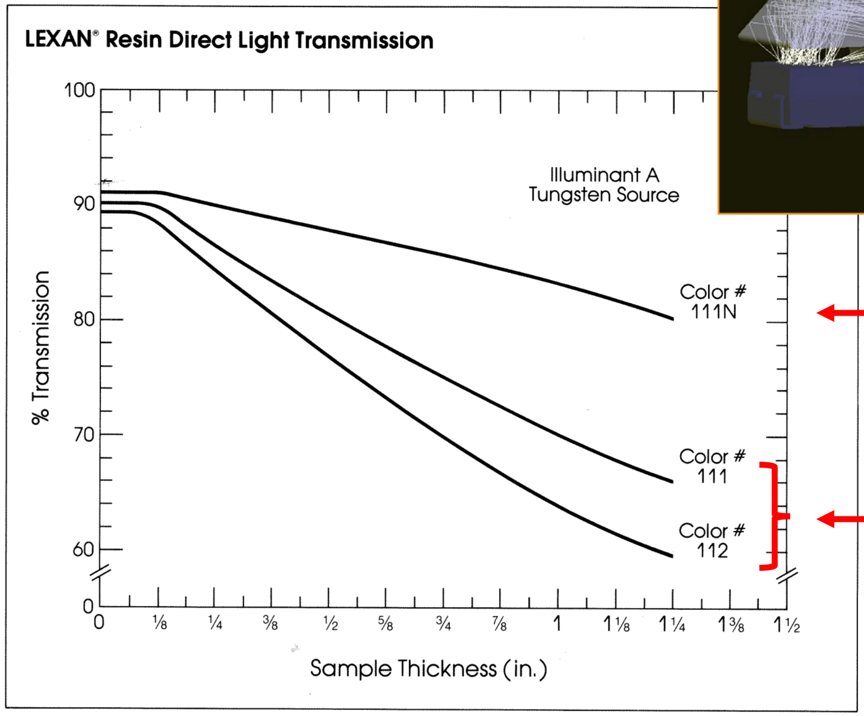
Acrylic = 1.49

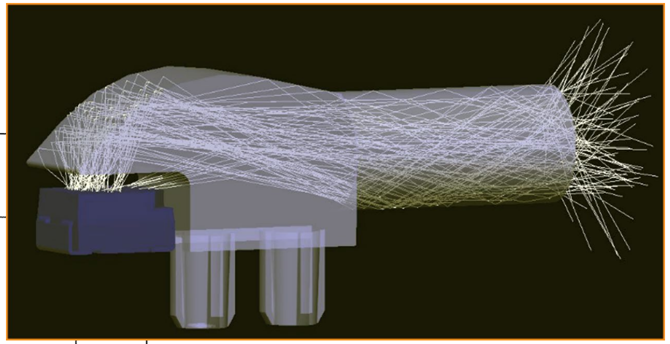
Light pipes work by total internal reflection which occurs when the incident angle is greater than the critical angle. $n_1 \sin \theta_1 = n_2 \sin \theta_2$.



Selective Absorption of Color in "Clear" Plastic







No Dye

Blue Dye

Lambert's law suggests that a sample's absorbance is proportional to the path length of light passing through it.

Mathematically it can be stated as $A \propto l$

UGLUM CONSULTING LLC

Brightness Loss due to Air Gaps

Intensity loss due to differences in refractive index

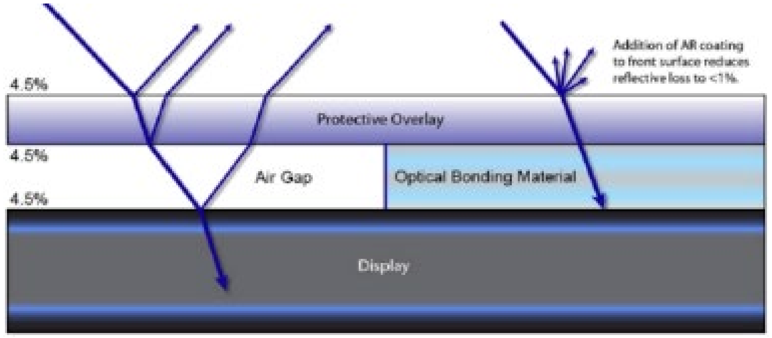
The specular reflectance (R_S) of an interface between two non-absorbing media of refractive indices n_1 and n_2 is given by

$$R_S = [(n_1 - n_2)/(n_1 + n_2)]^2 .$$

Fresnel Equation

For a plastic(n_1 = 1.49–1.59) and air (n_2 = 1.0) interface, R_S is ~ 4.0–4.25%.

Every time light enters of leaves a plastic surface about 4.5 % of the light intensity is lost



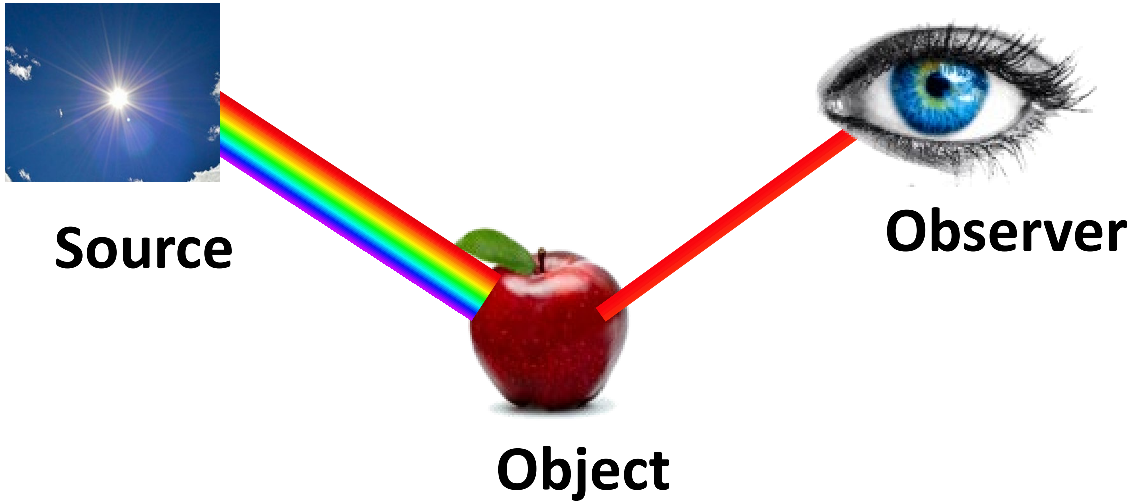
UGLUM CONSULTING LLC

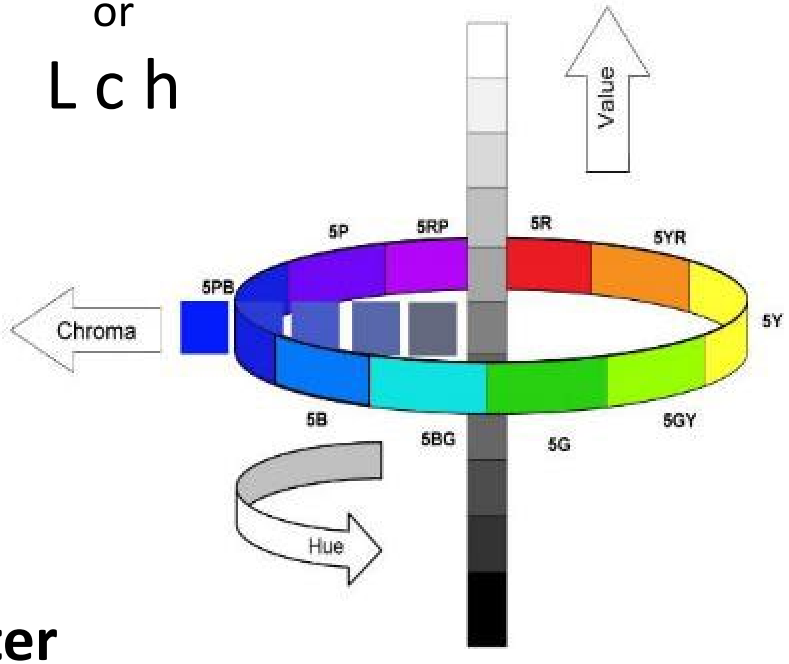
Reflected Color

L*a*b*

or

L c h





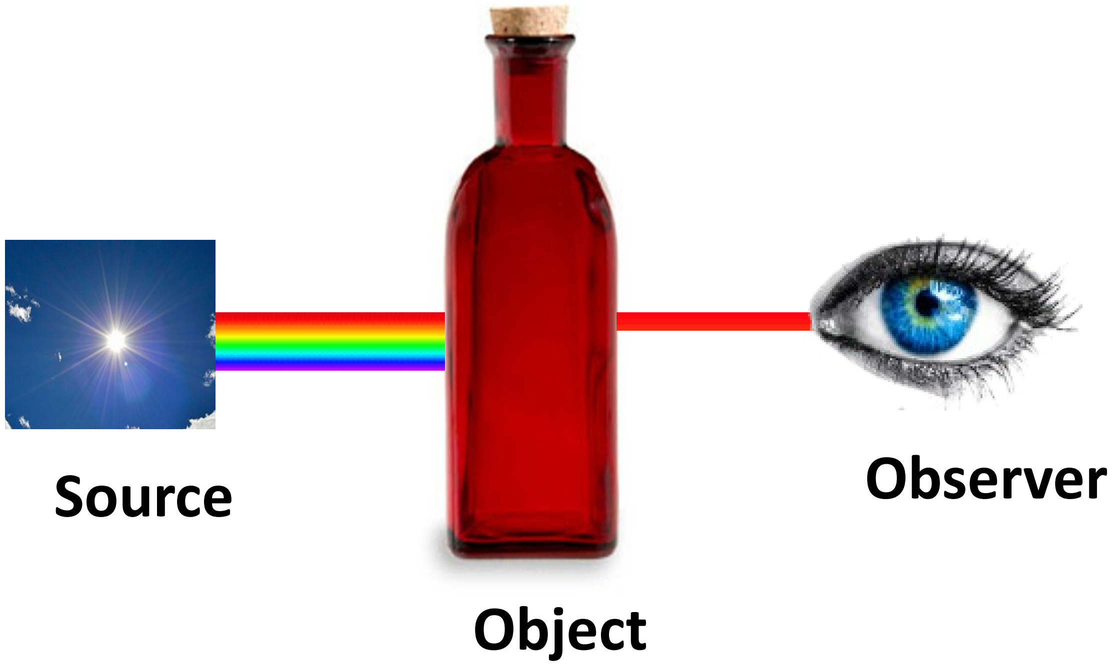
Spectrometer

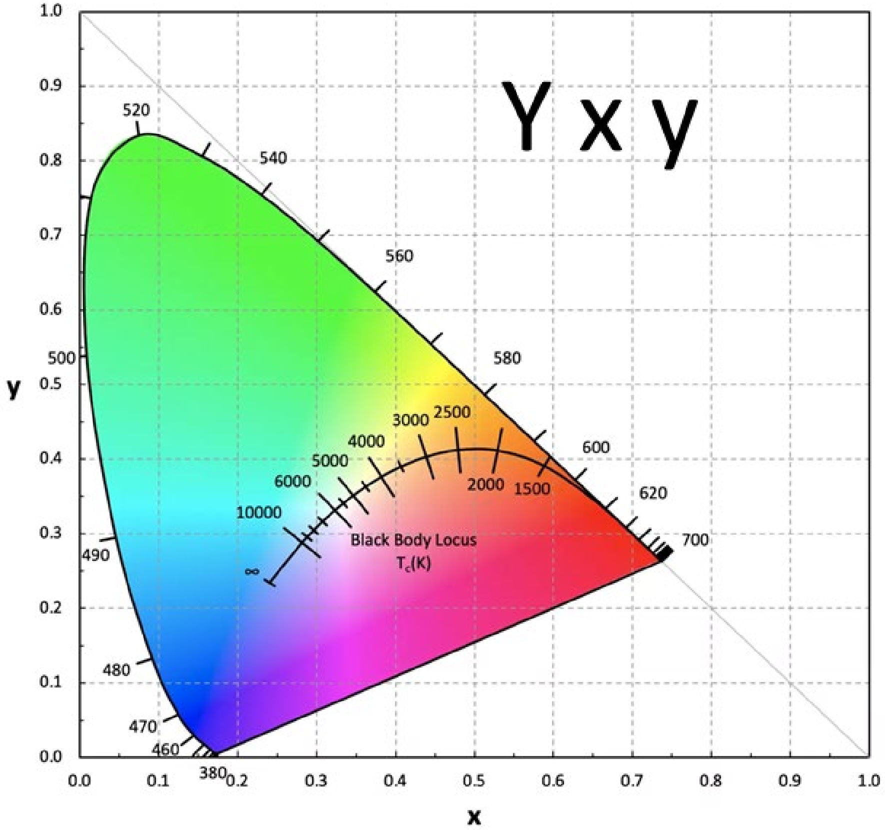
Munsell Color System

Reflected Color requires a light source, an object and an observer

UGLUM
CONSULTING LLC

Emitted Color and Intensity



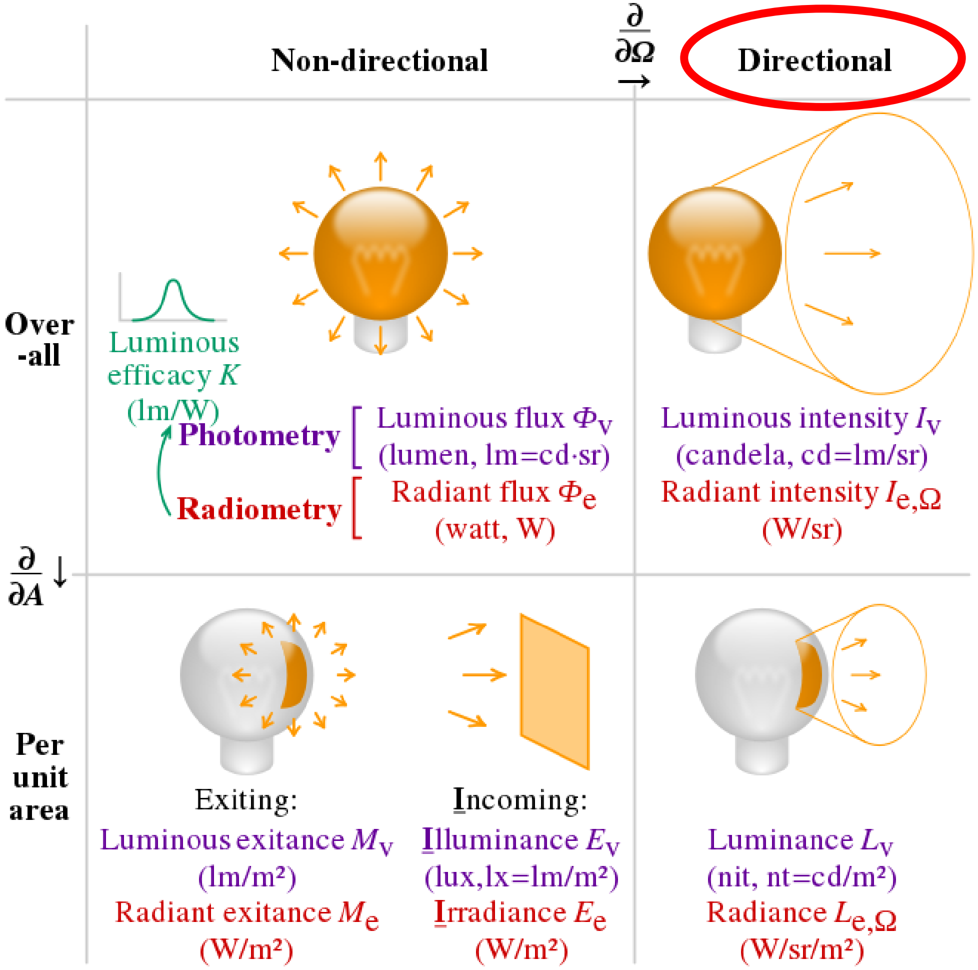


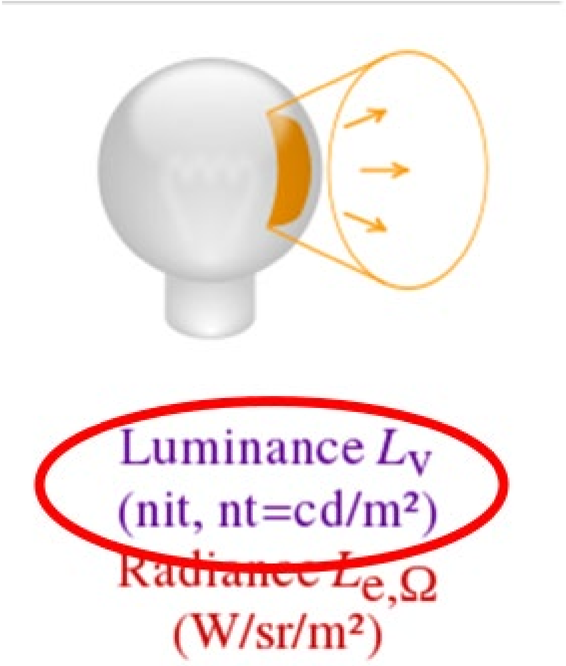
Spectrophotometer or Spectroradiometer

Color and Luminance (Brightness) should be reported using CIE 1931 Color space

Measuring Light Color and Luminance (Intensity)

UGLUM CONSULTING LLC



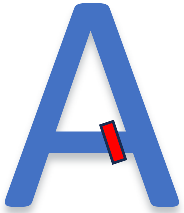


Numerical values alone do not describe the observed apparent brightness.

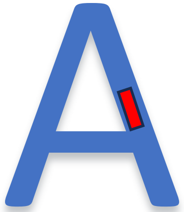
Larger back lit areas of the same intensity will appear brighter to the observer

UGLUM
CONSULTING LLC

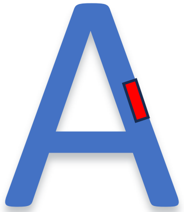
Measuring Light Color and Luminance (Intensity)



INCORRECT

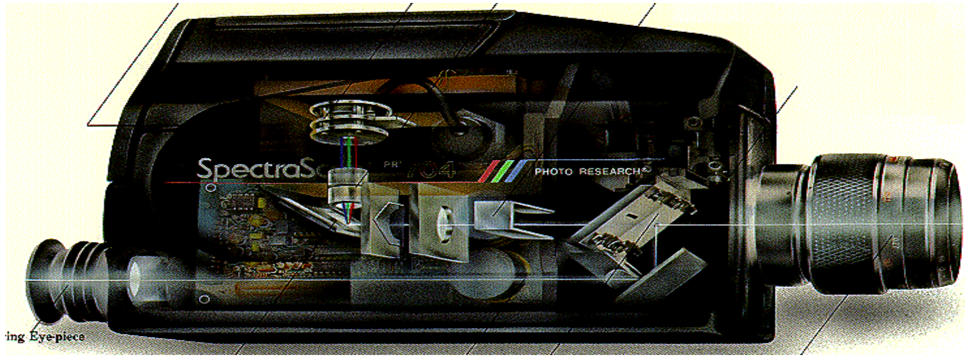


CORRECT



INCORRECT

- Entire aperture image contained within the lighted area of graphic
- Flaws (pinholes, etc.) should not be included in the aperture area.
- Measured area perpendicular to the lens tube
- Make multiple measurements at uniformly distributed points (location and apparent brightness)
- Subjectively (visually) evaluate part/assembly to be measured
- Measure in dark room



UGLUM CONSULTING LLC

With Plastic Decorating There are Many Technical Solutions

- Paint and Coatings
  - Decorative Coatings (Paint and Ink)
  - Functional Coatings (Hard coat)
- In-Mold
  - In-Mold Labeling
  - In-Mold Decorating (Ink Transfer)
  - In-Mold Materials
- Physical Vapor Deposition
- Plating (Galvanic Process)
- Pad Printing
- Hydrographics
- Thermal Transfers
- Hot Stamping
- Gravure Printing
- Flexographic Printing
- Digital Printing (Ink Jet)
- Dye Sublimation
- Screen Printing
- Flocking
- Laser Texturing
- Laser Ablation
- Laser Marking
- Applied Materials
  - Applied Metal
  - Leather Wrap
  - Three Dimensional Overlay
- Direct Dispense
- Combined Processes
- Associated Technologies
  - Surface Preparation
  - Measurement and Testing

UGLUM
CONSULTING LLC

Light is the "New Chrome"

You Can Have Both

Back Lit Metal over Plastic

Conventional Paint and Laser with PVD

Back Lit Plated Plastic
Two Shot or Modified Process with Lasering

Selective Backlighting through PVD

UGLUM CONSULTING LLC

Hidden Until Lit

HiddenIcon, Shy Tech

Light-OFF

Light-ON

Hidden til Lit PVD Trim

Hidden Until Lit features greatly enhance the appearance and usefulness of backlit plastics.

UGLUM
CONSULTING LLC

IMD is the Near Ideal Solution for Hidden Until Lit

Hidden Until Lit features greatly enhance the appearance and usefulness of backlit plastics.

UGLUM
CONSULTING LLC

Displays and Integrated Electronics

Functional circuitry can be integrated into IMD parts creating smart surfaces

UGLUM
CONSULTING LLC

With Back Lit Decorated Plastic There are Additional Risks

Light Leaks

- Source Isolation
- Pigment Distribution (Galaxy Effect)
- Poor Hiding Power of Opaque Layer
- Bubbles or Voids
- Laser Damage of Surface
- Susceptibility to physical damage
  - during manufacturing
  - during use

Uneven Lighting

- Pigment Distribution in coating (Cloud Effect)
- Poor light diffusion (distribution)
- Directional Lighting
- Shadowing Effects

Uneven Color

- Cross talk from sources or selective absorption

UGLUM
CONSULTING LLC

Cross Talk and Lighting Isolation

Small Lit Segments in Buttons

Pad Print to Increase Light Capture

UGLUM
CONSULTING LLC

Contact Information

Paul Uglum

Uglum Consulting, LLC

paul.a.uglum@gmail.com

(+1) 317 417 5596

UGLUM CONSULTING LLC

Reference

The Light Measurement Handbook
Alex Ryer

UGLUM
CONSULTING LLC