International Color Consortium

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Measurement and Profiling of Paper with Optical Brighteners

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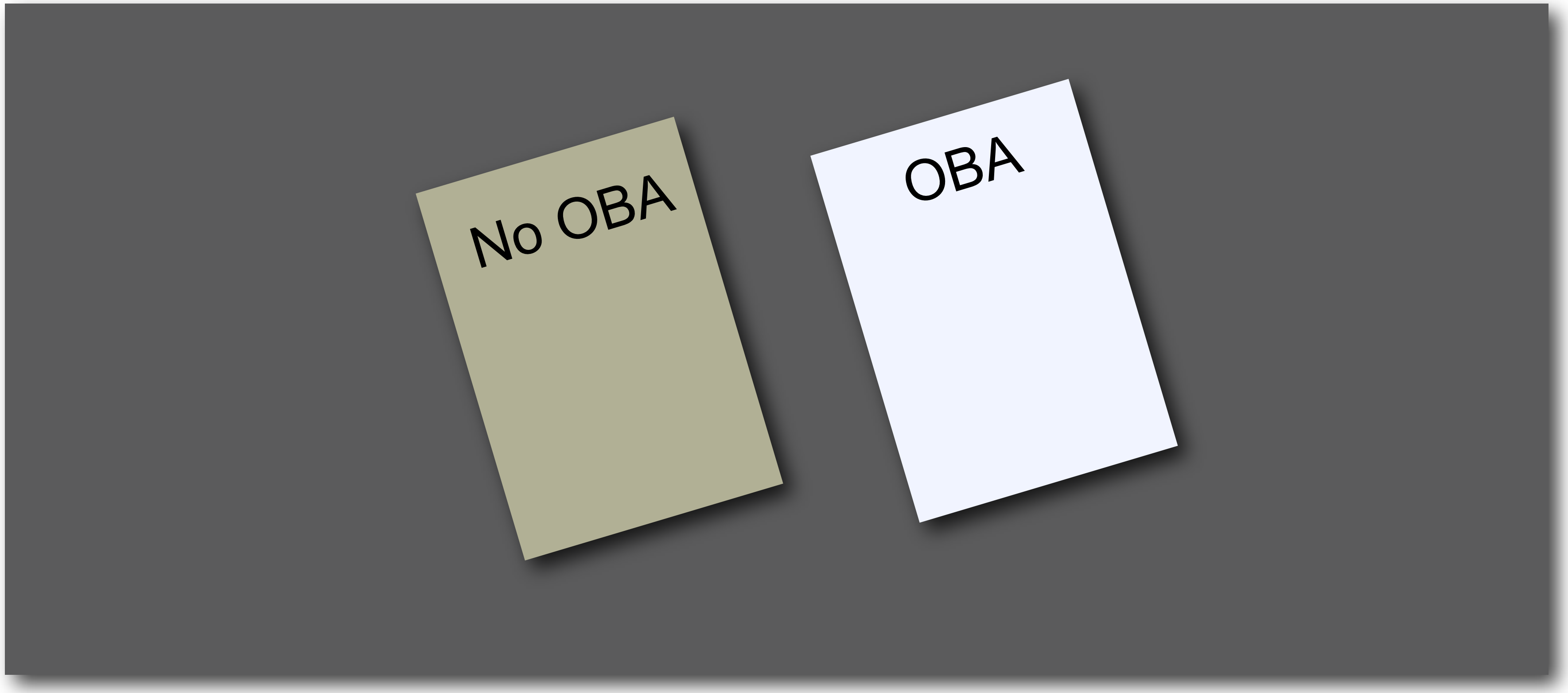
What's the Problem?

- **Accurate ICC profiles require accurate measurements**
- **A very large percentage of papers contain optical brightening agents (OBAs)**
- **OBAs fluoresces under UV light. UV light causes OBAs to emit blue light**
- **Viewing conditions have a very wide range of UV light**
- **Measurement instruments contain some level (or levels) of UV light**
- **An accurate measurement requires that the measurement match the level of UV in the viewing environment**
  - How to measure UV in the environment?
  - How to measure colors based on the environmental UV level

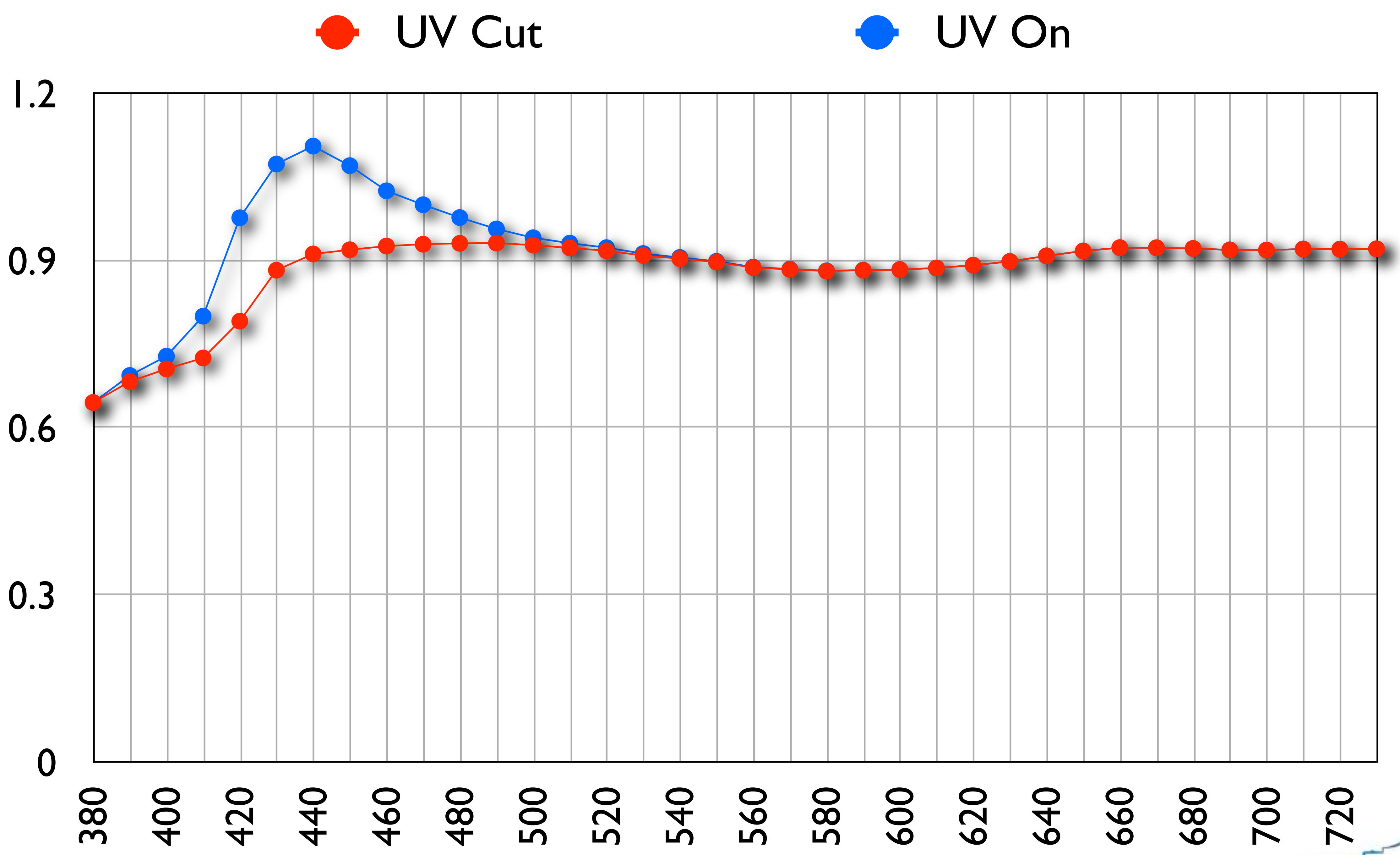
Optical Brightening Agents

- OBAs convert ultraviolet light to blue light.
  - They can make paper appear brighter and less yellow



- **Not the only source of Fluorescence, but the most important**

Paper Reflectance with and without UV



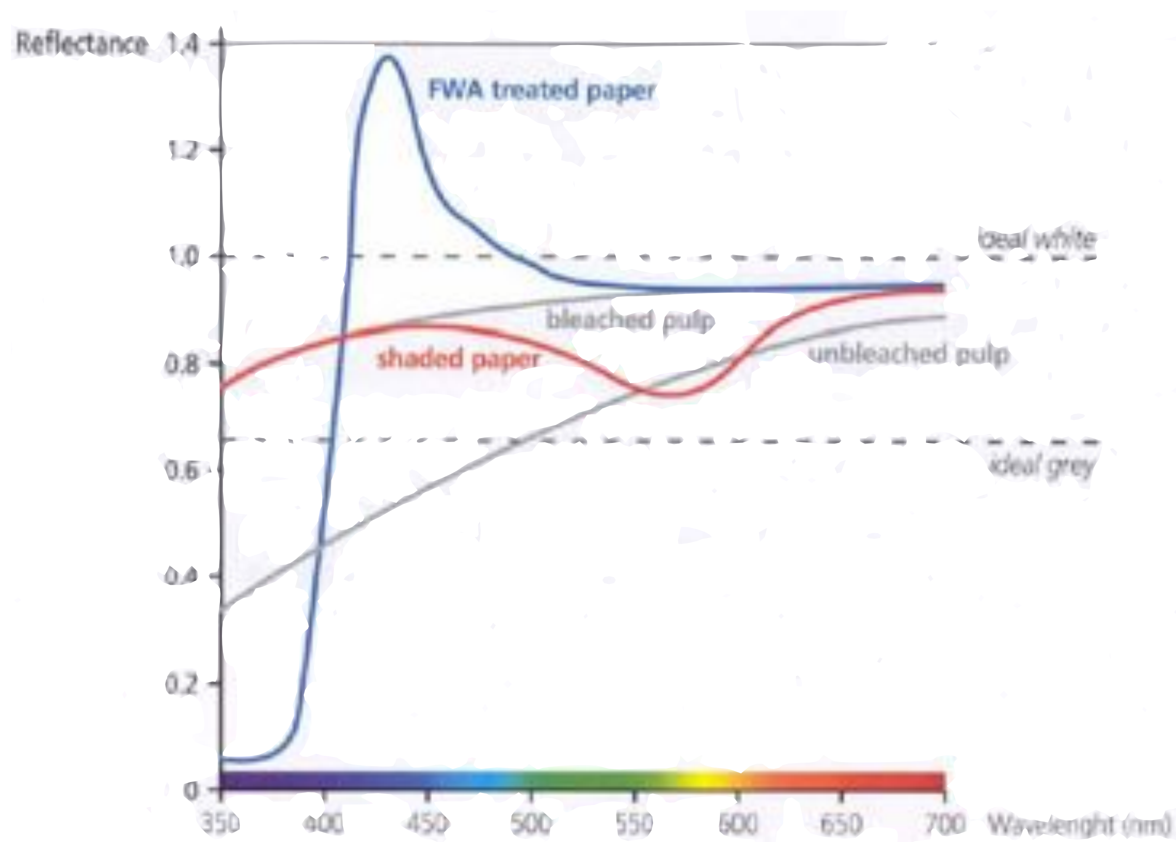
OBAs are very common

- Found in 90% of graphics arts samples
  - –Can be found in paper made from recycled paper
    - Optical brightener quenchers are used to negate the OPB

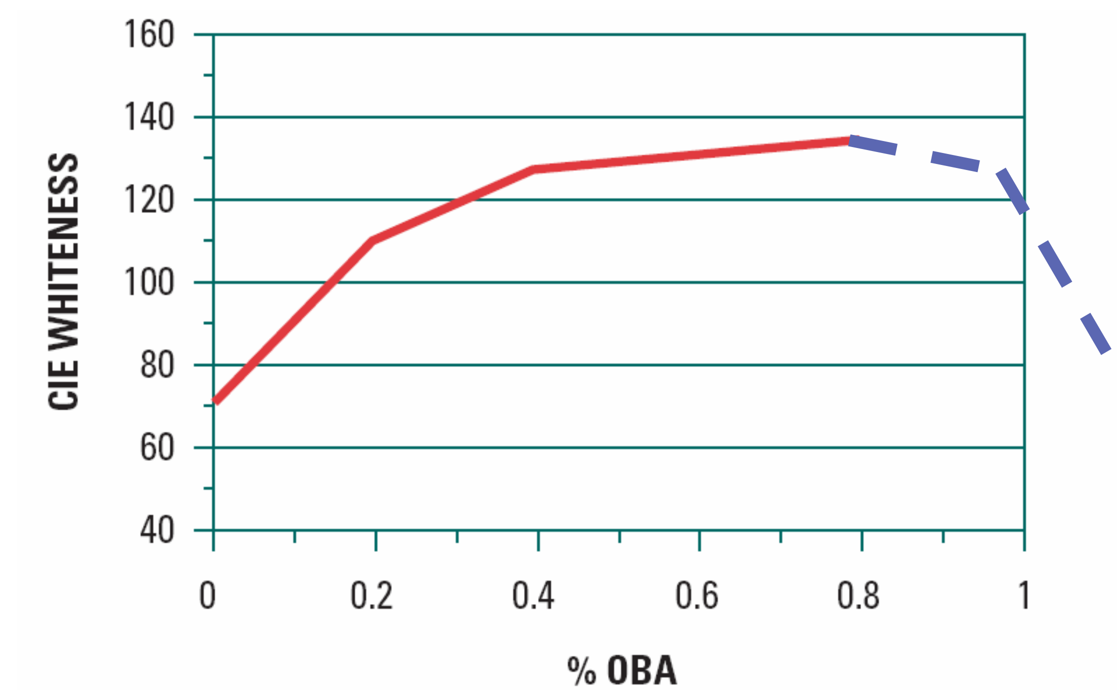
Benefits of OBAs in Paper

- Provides an inexpensive way to brighten paper
  - Brighter
  - Less yellowish appearance
- Expands the gamut volume of paper

Inexpensive and Effective way to Increase CIE Whiteness

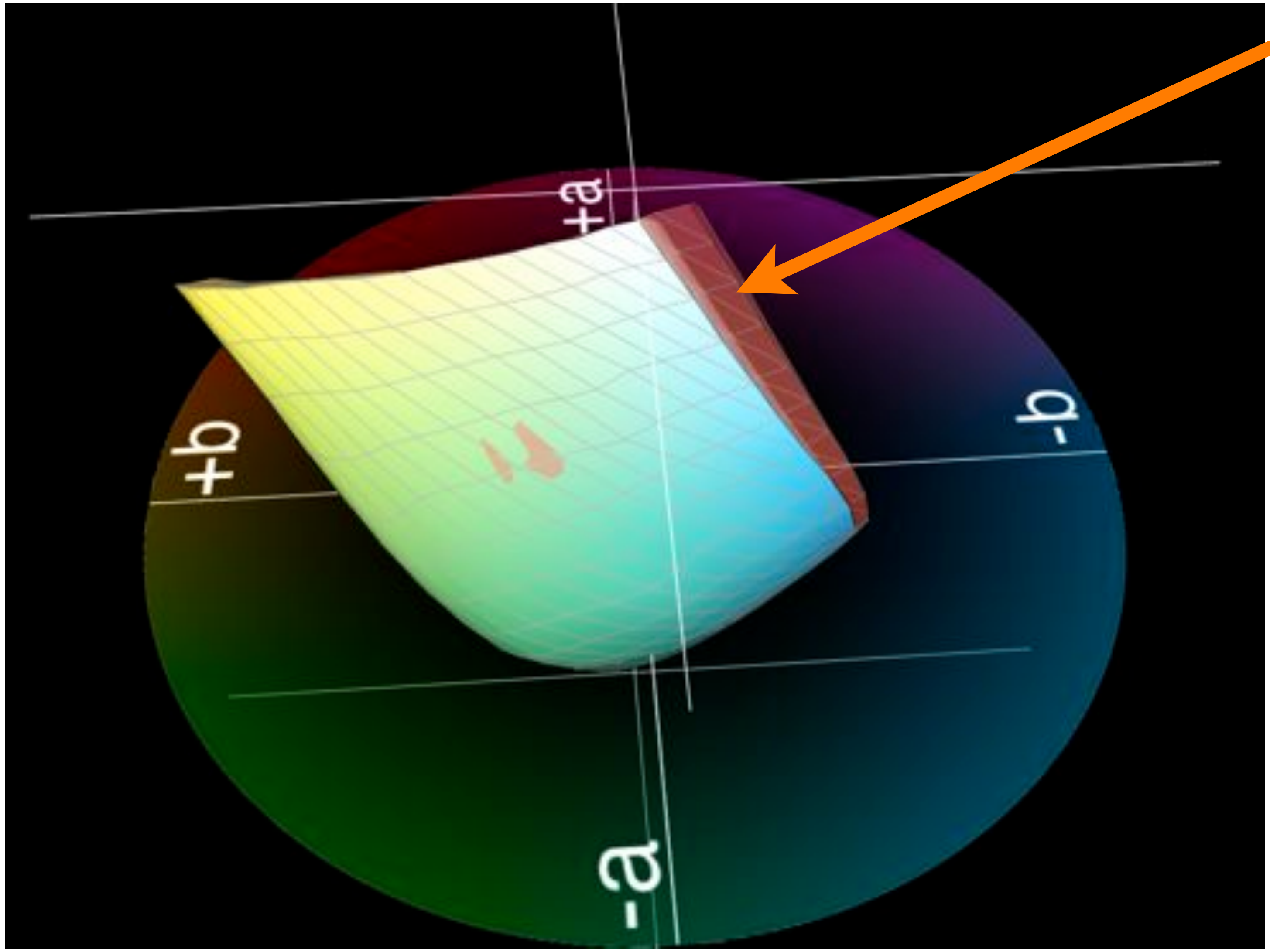


Source: Ciba SC



–Especially important for low-cost printing

OBAs Expands the Gamut Volume



Volume gained from fluorescence

	Gamut-Volume
UV Cut	744340
UV Included	777126

OBA Drawbacks

- Difficult to characterize
  - –Causes difference between measurement of color and perception of color
  - –Inter-instrument agreement is poor
  - –Color management fails
- Changes appearance under different illuminates
- Optical brighteners are susceptible to environmental influences
  - –Paper with OBAs can yellow over time

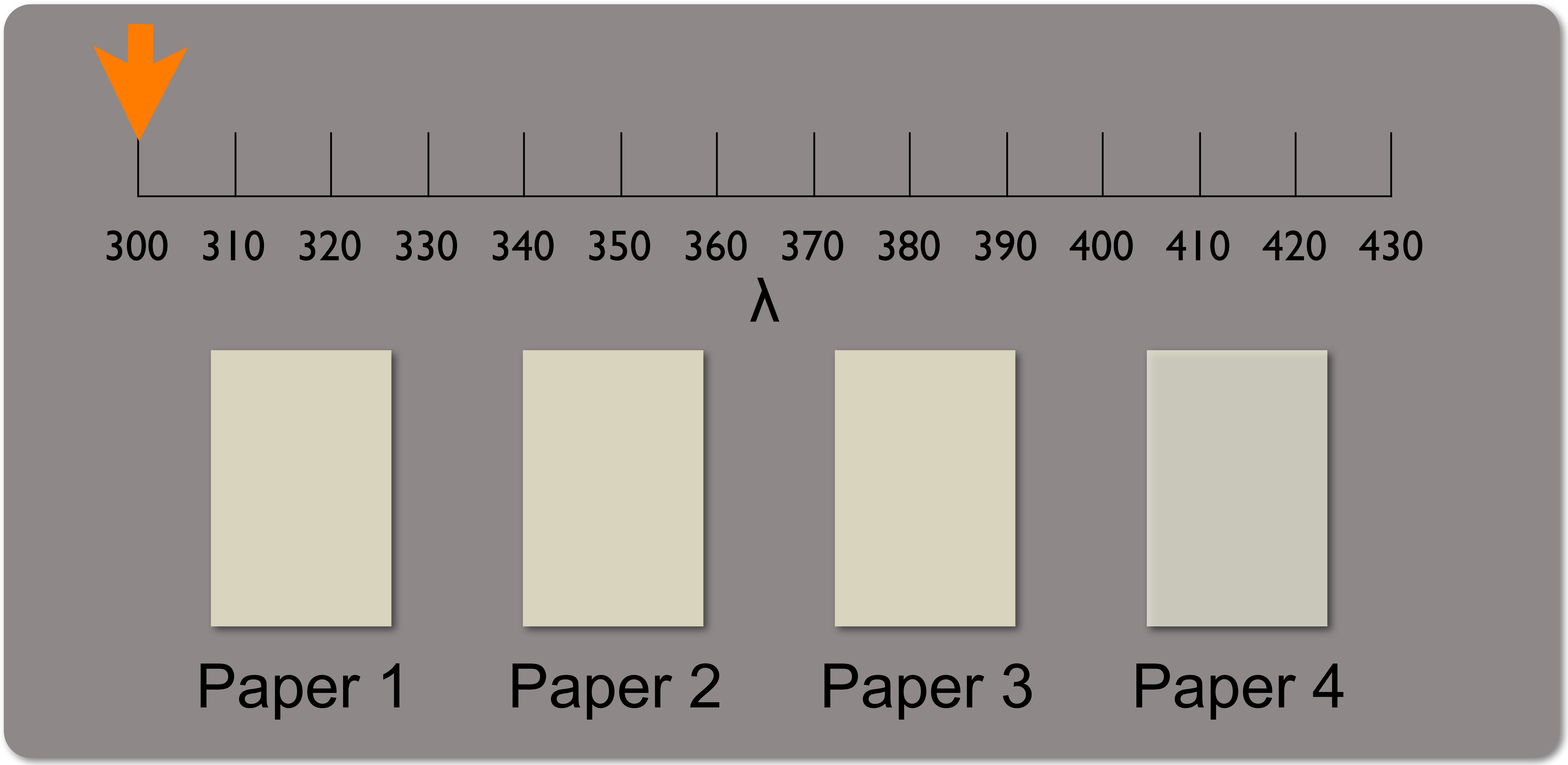
3 Factors Contribute to Errors

- **Variations in media**
  - —Different levels of OBAs in the substrate
  - —Different UV absorption of the inks
  - —Coatings also absorb UV
- **Measurement Device Differences**
  - —Most devices are M0 or M2
- **Viewing Environment Differences**
  - — D50 viewing booths have a wide range of UV

Media Related Variables

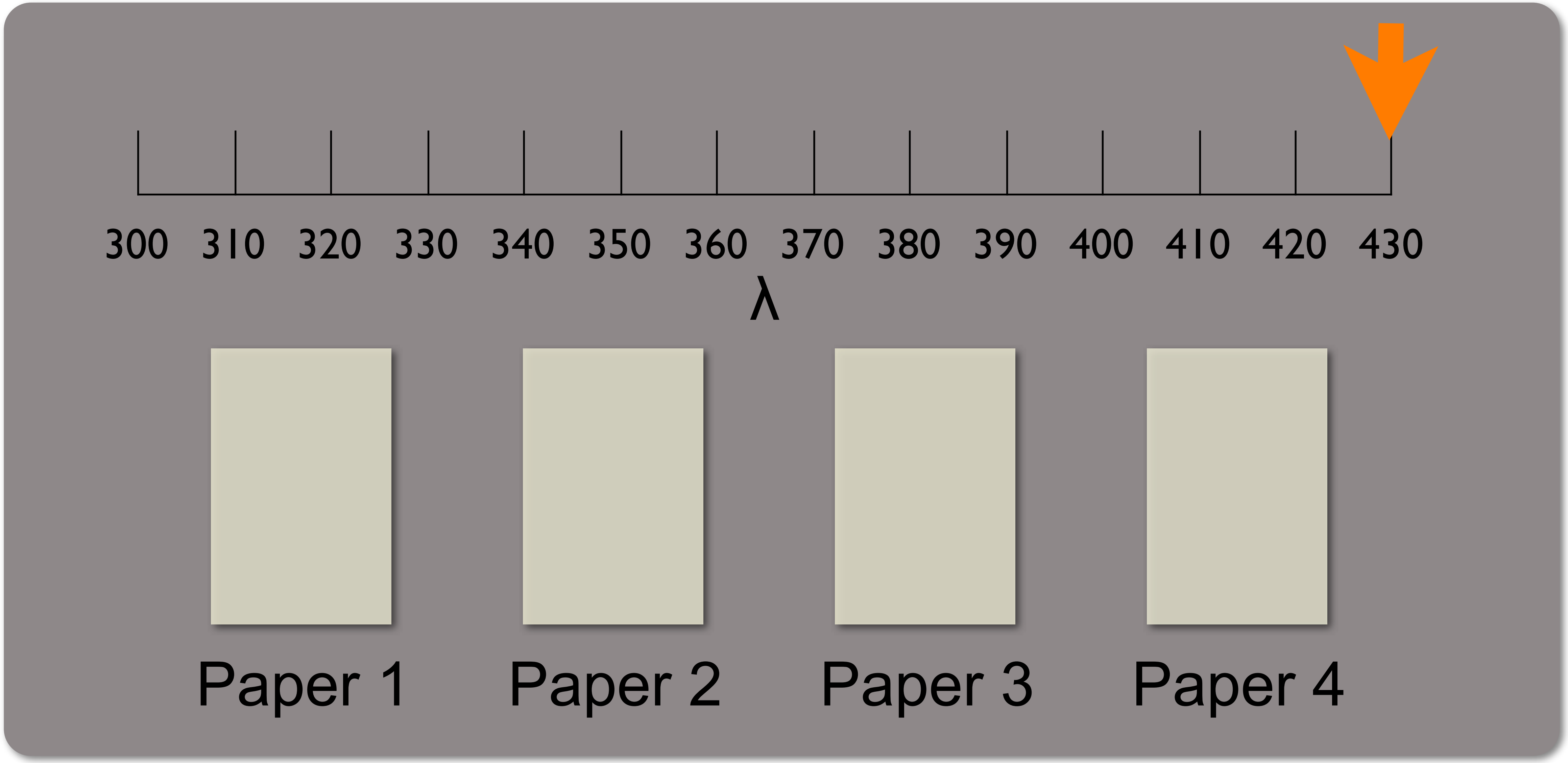
- **UV Absorption by Inks**
  - Inks have different UV absorption characteristics that don't extrapolate well from visible range absorption characteristics
- **Brightener efficiency is a function of wavelegth**

Brightener Efficiency



OBA efficiency as a function of illuminant wavelength
(some papers illustrated here are atypical)

Brightener Efficiency



OBA efficiency as a function of illuminant wavelength
(some papers illustrated here are atypical)

Measurement Device Have Different Levels of UV

- **Many spectrophotometers have historically used incandescent lamps that have a spectral power distribution close to illuminant A**
  - —Measurement Condition M0 (ISO 13655)
  - —M0 does not specify UV content
    - –Inconsistent UV content causes differences in measurement between devices

- **Need to minimize measurement differences between devices due to fluorescence resulted in the introduction of M1 & M2 measurement conditions**

M2 Measurement Condition

- UV Cut
- Attempts to eliminate the effects of fluorescence by eliminating light that excites the OBAs
- OBAs are excited by UV light in the range of 300nm to 410nm
- Human vision is sensitive to light below 410
- A tradeoff has to be found between suppressing fluorescence and achieving a reasonable signal-to-noise ratio for the measurement

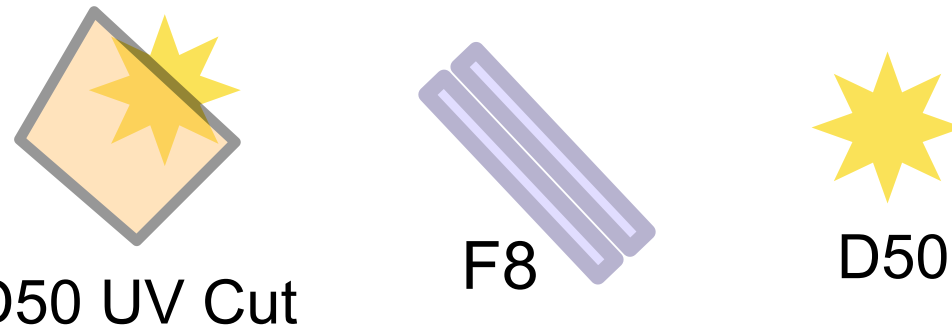
M1 Measurement Condition

- **D50 Source**
- **Minimize measurement differences between devices by specifying that the spectral power distribution of the light source match D50**
- **Conformance can be achieved with two methods**
  1. The spectral power distribution should match CIE illuminant D50
  2. A compensation method that is able to control the amount of UV
     - Conformance is judged by measuring a set of certified reference materials

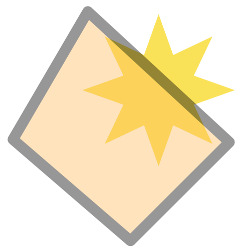
Viewing Booths have Variable Levels of UV

- **Measurements of Viewing Booths..........**

Change In Appearance For Different UV Levels



Change In Appearance For Different UV Levels



D50 UV Cut

Change In Appearance For Different UV Levels

F8

Change In Appearance For Different UV Levels

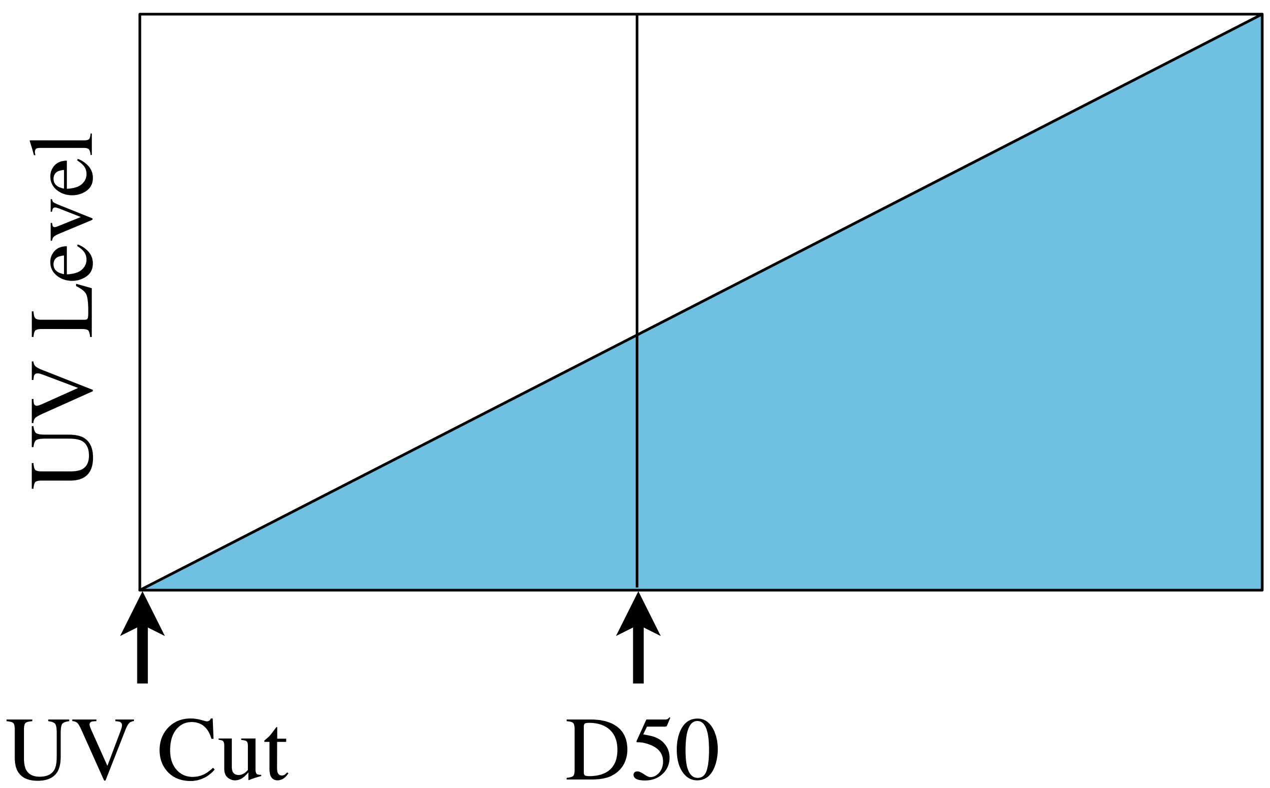
D50

ISO 3664:2009

- **ISO 3664:2009 specifies a standard viewing booth that will provide consistent results**
- **The UV content of a viewing booth is specified to be that of D50**
  - Matches the M1 measurement condition
- **A UV blocking filter is permitted for the matching of the M2 measurement condition**

Viewing Conditions Other Than D50 and UV Cut?

- **ISO 13655 & ISO 3664 specify measurement conditions and viewing booths that will reduce differences due to OBAs**
- **Unfortunately UV Cut and D50 specify only two levels of UV illumination**
  - —Viewing conditions where prints are viewed can have a wide range of UV illumination



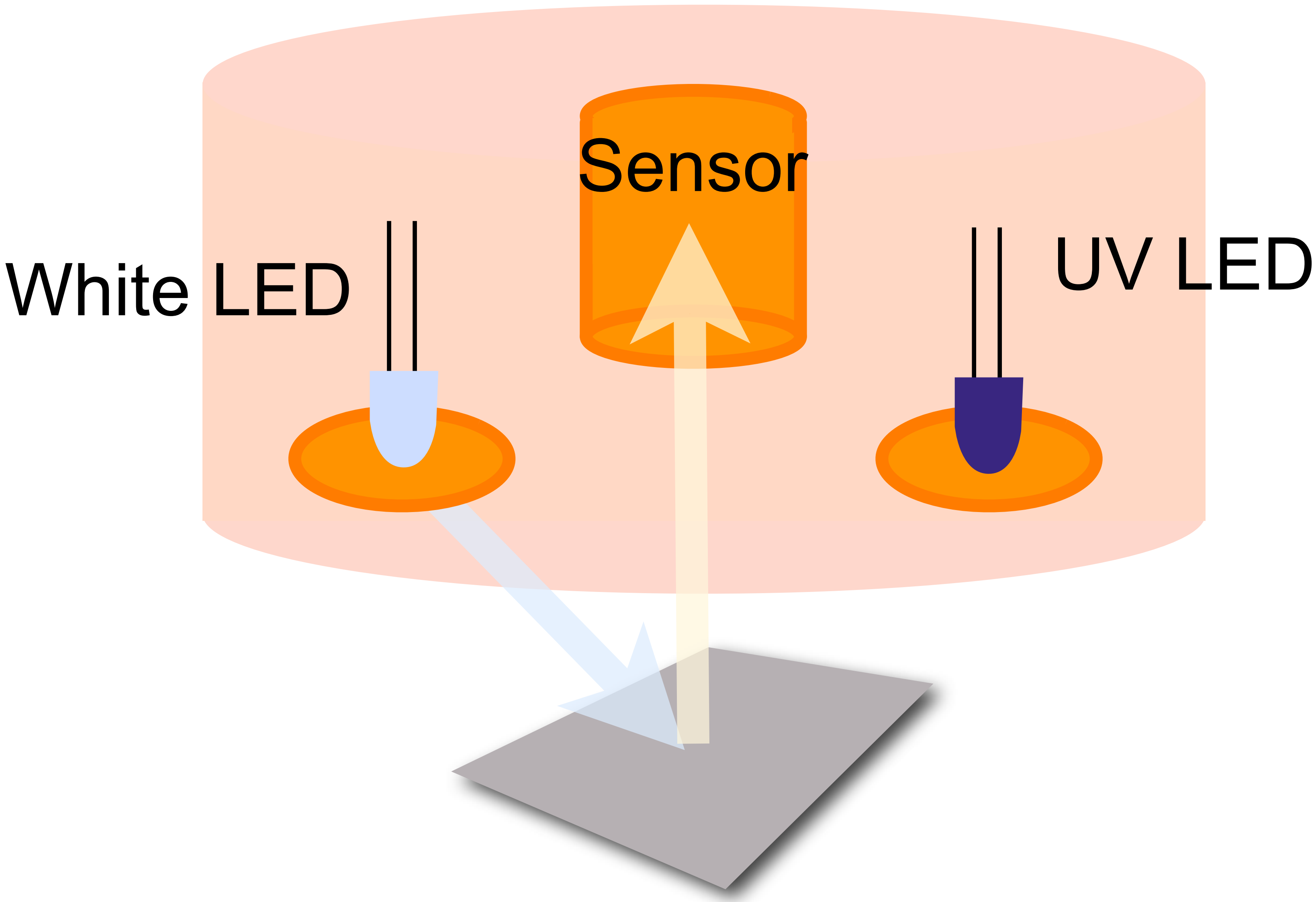
Need a Solution that Works in All Viewing Conditions

1. **For an arbitrary viewing condition, some kind of measurement must be made for that viewing condition**
   - Can measure the UV content of the light source
   - Instruments that can perform this measurement are not readily available
2. **The information about the UV content of the light source needs to be used to get the measurement data**
   - Could adjust the UV level of the instrument to match viewing conditions
   - Could make measurements at two or more UV levels and combine the measurements based on the viewing conditions

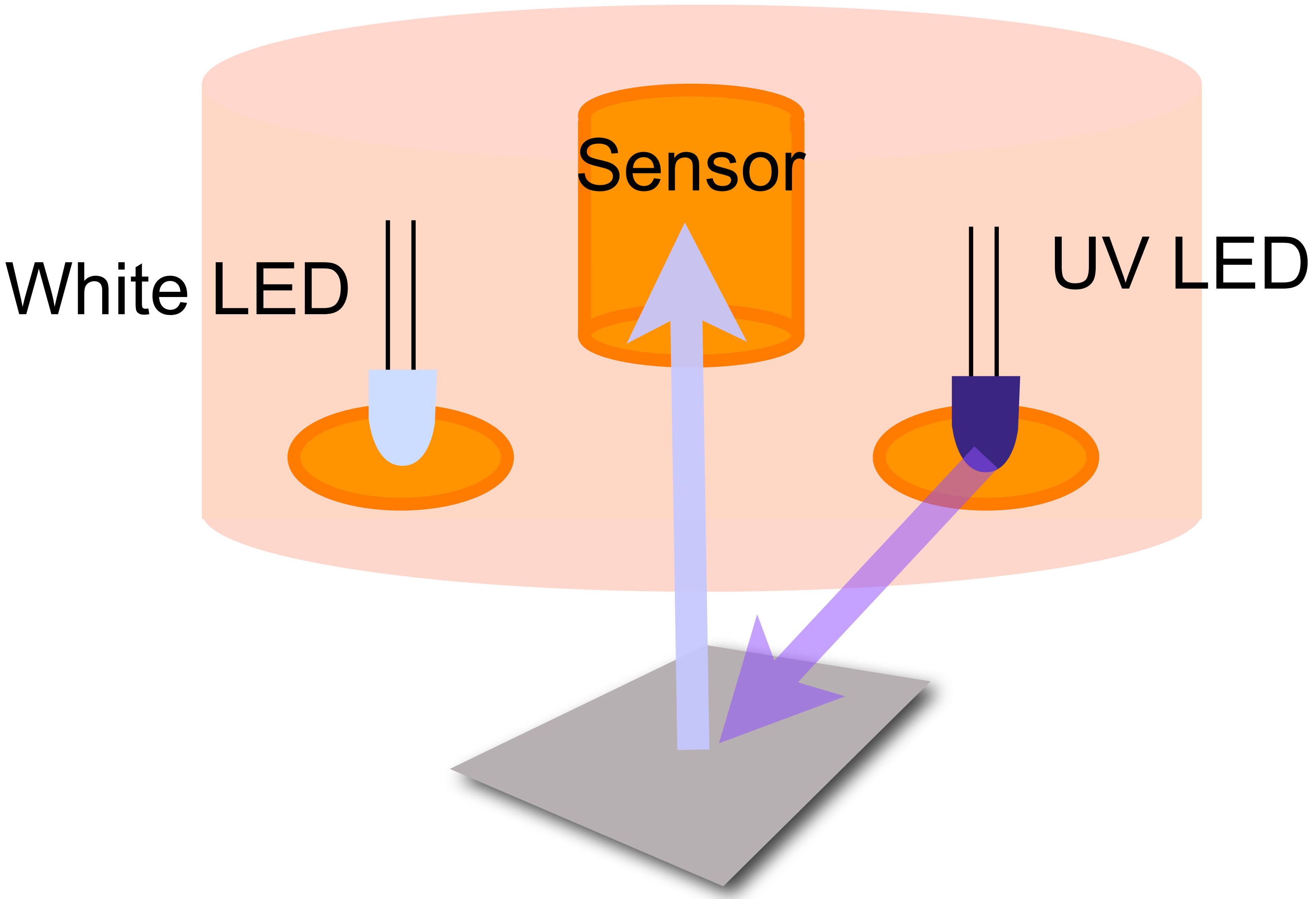
The iSis Uses a Dual Measurement Solution

- The iSis uses LED illumination
  - –White LED provides visible range illumination
  - –UV LED provides UV illumination

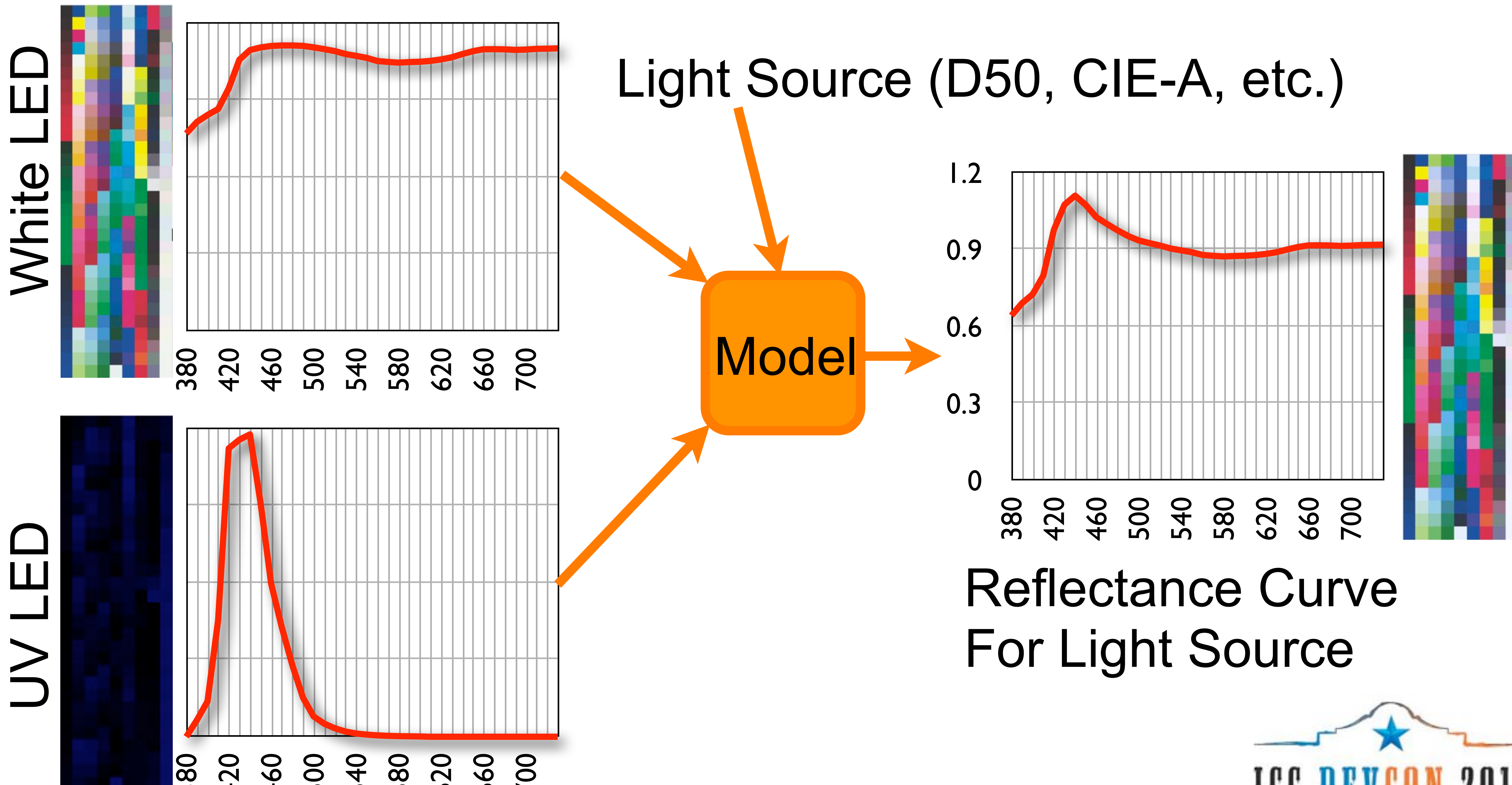
Simplified Diagram of iSis



Simplified Diagram of iSis



Combine Dual Measurements to Get Result for Arbitrary Light Source



How to Get UV Level of Viewing Environment?

- **Get the UV level by doing a visual match**
- **Match a printed color to a non-fluorescing reference color in the viewing environment**
- **Create a chart with colors that match the reference color for different levels of OBA fluorescence excitation**
  - Dual spectral measurements are combined to simulate different levels of excitation
  - Choose a range of excitation and match the reference color at each level of excitation

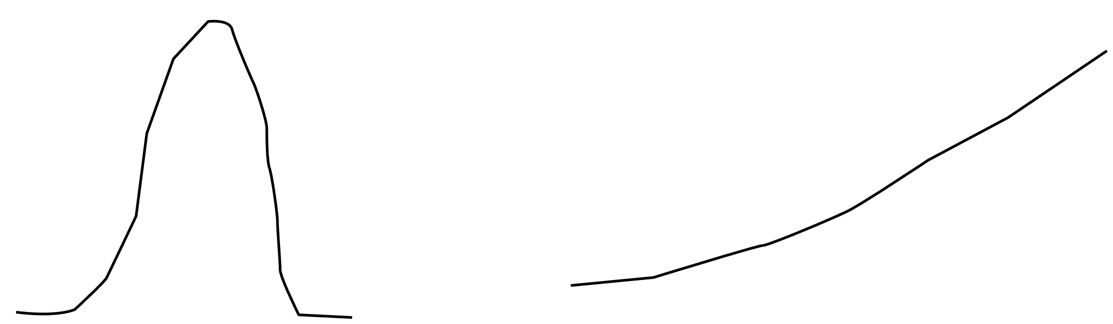
The OBC Matching Process

- Match at different gray levels to compensate for UV absorption by the inks
- Different gloss levels of reference colors allow comparisons to be made with more similar surface properties

OBC Demo

Benefits of Doing a Visual Match

- **Visual matching determines the level of OBA fluorescence excitation for the viewing environment**
- **A mismatch of UV content of the measuring instrument and the viewing environment could result in errors due to the brightener efficiency and UV absorption characteristics of the ink**



- **Errors may result unless the instrument can reproduce the UV content of the viewing environment to a sufficient level of accuracy**

Building a Profile Demo

Conclusion

- OBAs make accurate measurements difficult
- M1 & M2 solve the problem of getting consistent measurements with different devices possible
- Standardized light booths can be combined with M1 or M2 to get predictable output with ICC profiles
- Non-standard viewing conditions can be characterized by the OBC process