



# Replicating Daylight

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September 26, 2016



More Value , More Innovation

To be the global leader of the intelligent and sustainable electric-powered vehicle, combined with solid automotive technology and creative innovation.



# Outline

- Introduction
- Experiencing light
- Replication
- Why go beyond RGB?
- Collecting Data
- Sky shots
- Summary



- Founded 2007 – Silicon Valley, CA
- Purpose – create any light for human consumption
  - Products/services to create/playback light
- Privately owned
- Current products:
  - Light Replicator (16 color light player)
  - Penta, Octa (5, 8 color light players)
  - Light Recorder (spectrometer)
  - LumenScripts (content)
    - Recordings, created, composed digital data

# Target Applications for Researchers

- Consumer/Home – daylight experience indoors, better circadian cycle
- Retail – make products more appealing
- Healthcare – faster healing, wake/sleep
- Workplace – increase productivity
- Sensors – time varying spectrum
- Movie, TV – outdoor scene or filter replication

# Two ways of experiencing light

## Illumination

- Look at people, objects
- Less saturated colors
- Changes slowly
- Low spatial density
- High spectral density
- CRI – important, RGBWA
- Collimated, Diffuse
  
- Electric lights, Daylight
  - RGB is NOT sufficient

## Infotainment

- Look at the light
- Saturated colors
- Changes fast
- High spatial density
- Low spectral density
- CRI – don't care, RGB
- Collimated, Diffuse
  
- Computer Display, TV, Rock Concert
  - RGB is sufficient

The sky is a special case. It fits into both categories.

# Underlying Philosophy

- There is no one or a few ideal light sources.
- There are many, many useful sources, including ones we don't even know we want.
- Spectrum and time are key attributes of light.
- CCT and chromaticity are inadequate substitutes for SPD.
  
- So, where do we start?

# Accurate Replication Is a Good Thing

## Historical Success Factor – Replication

Replicator	Intention: 2x	Realization: 1,000x!
Printing Press	Sacred Book	Books and Newspapers
Camera	Formal Portraits	Casual Snapshots
Phonograph	Historic Oratory	Pop Music
Xerox copier	Replace carbon paper	Copy/print everywhere
Betamax	Studio Tape Deck	Personal TV/Movie library
MP3	Smaller, cheaper	Every song in your pocket
WWW	Office File sharing	Everyone, Everything
Light	Standard Illuminants	Skylight and beyond, at will



# Underlying Philosophy

Daylight is the gold standard for illumination.  
Firelight is the silver standard.

Electronic illumination should over time be able to do everything daylight and firelight can do.

There is more to illumination but the above is key.  
- Saturated, de-saturated colors



# Daylight and the sky

Intense collimated light that moves across the space, sharp shadows (south, 80%\*)


Large, diffuse, low glare light (north, 20%\*)

Changing spectrum, changing time

\* Depending on clouds and other atmospheric conditions



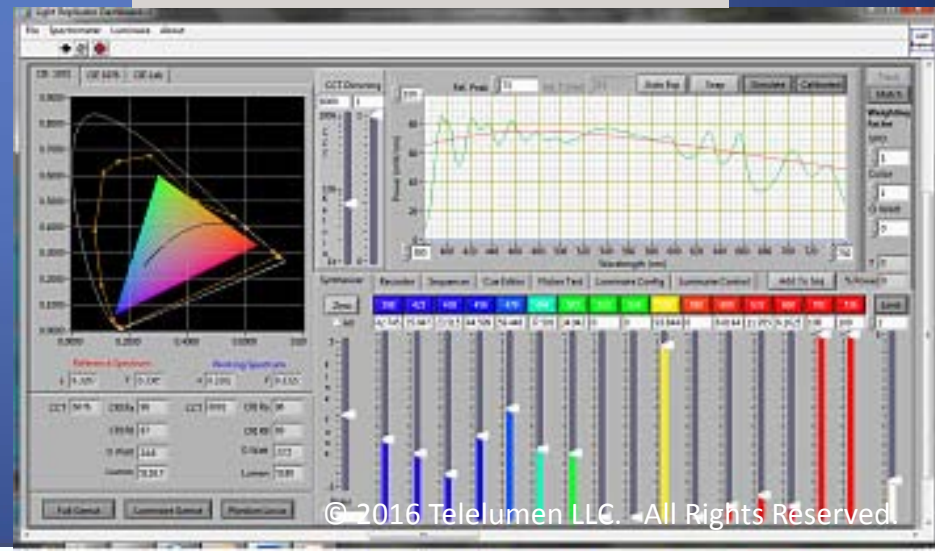
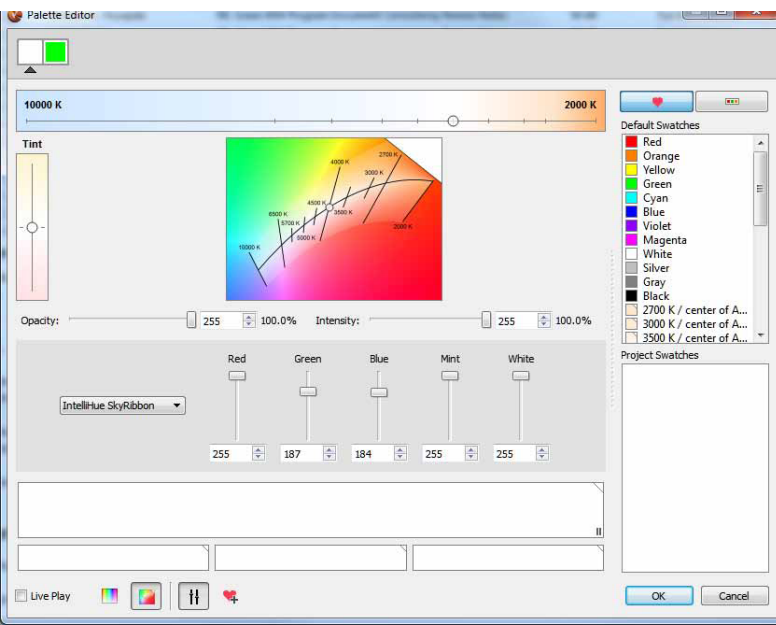
Brooklyn, N. Y. Dec 1910  
*Mr. J. J. ...*



The BROOKLYN CALCIUM LIGHT CO. Dr.  
**PURE OXYGEN GAS AND CALCIUM LIGHTS**  
FOR ALL OCCASIONS  
TELEPHONE, 3165 MAIN      LABORATORY: 112 FRONT STREET.



# RGB and beyond







CoeLux



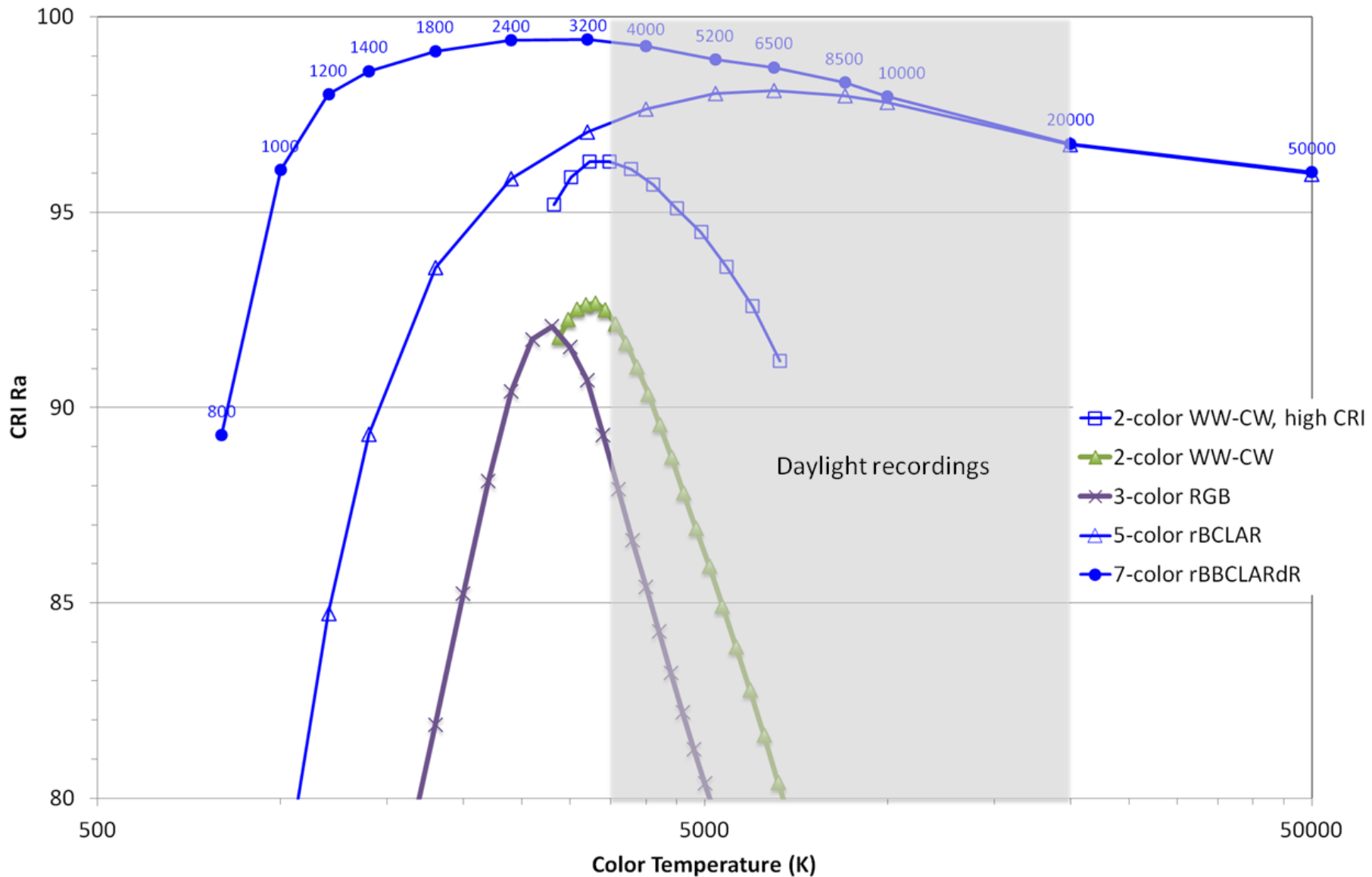
Fraunhofer



# Why go beyond RGB

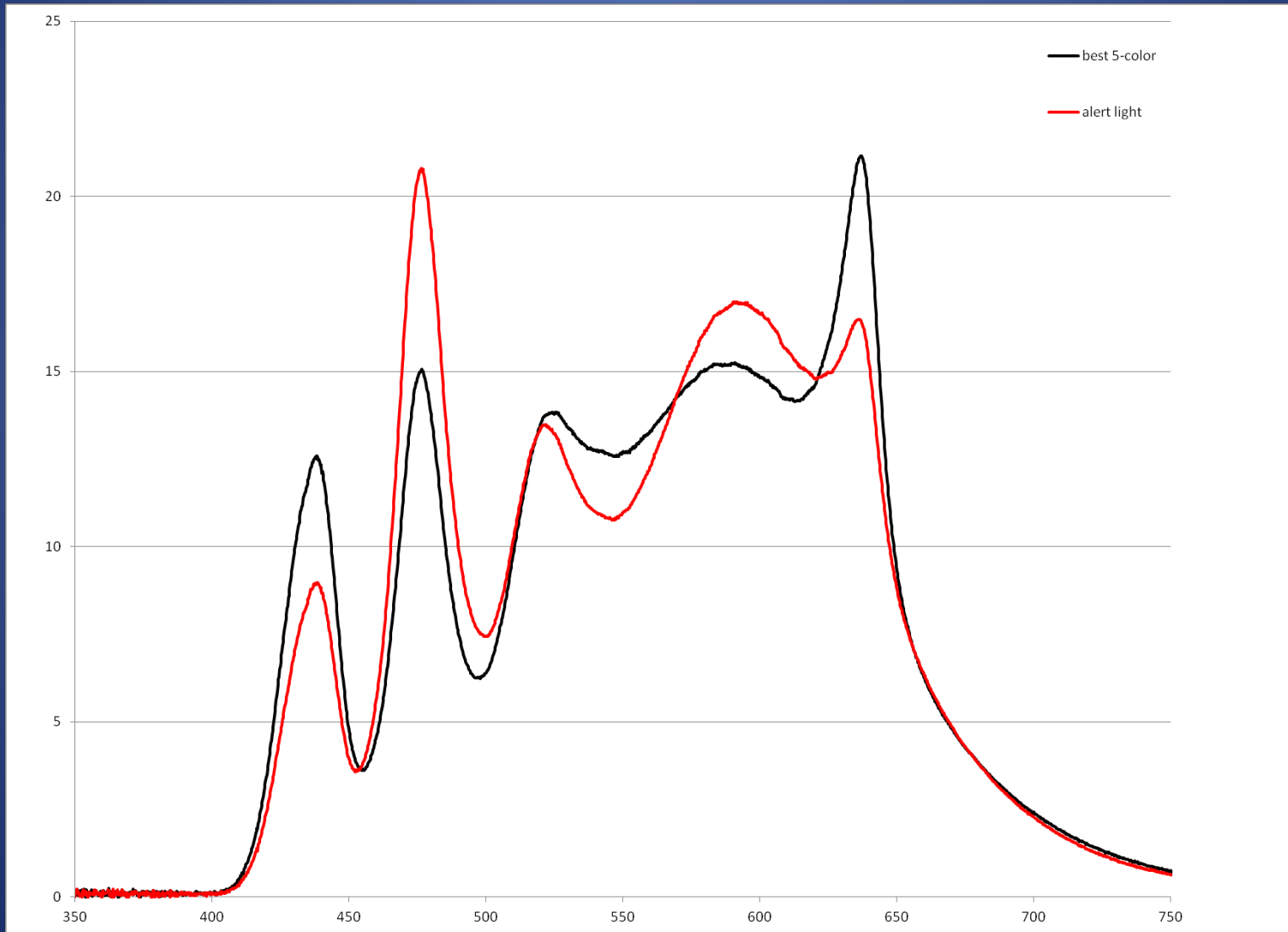
- Broader CCT range at higher color quality
  - Improved replication of arbitrary SPD
- Multiple solutions for a given chromaticity
  - More degrees of freedom
- Larger gamut area
  - Allow increased saturation

# Value of more color channels



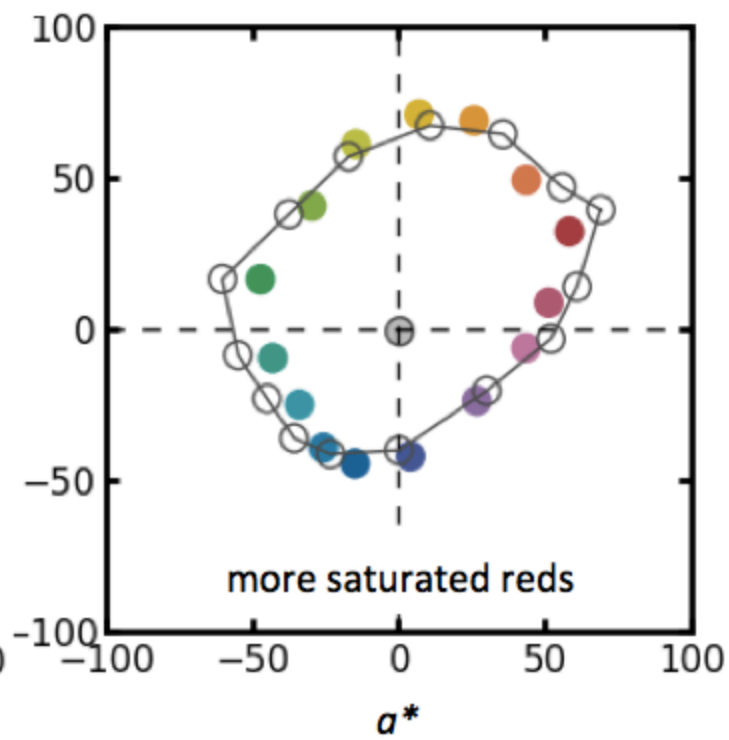
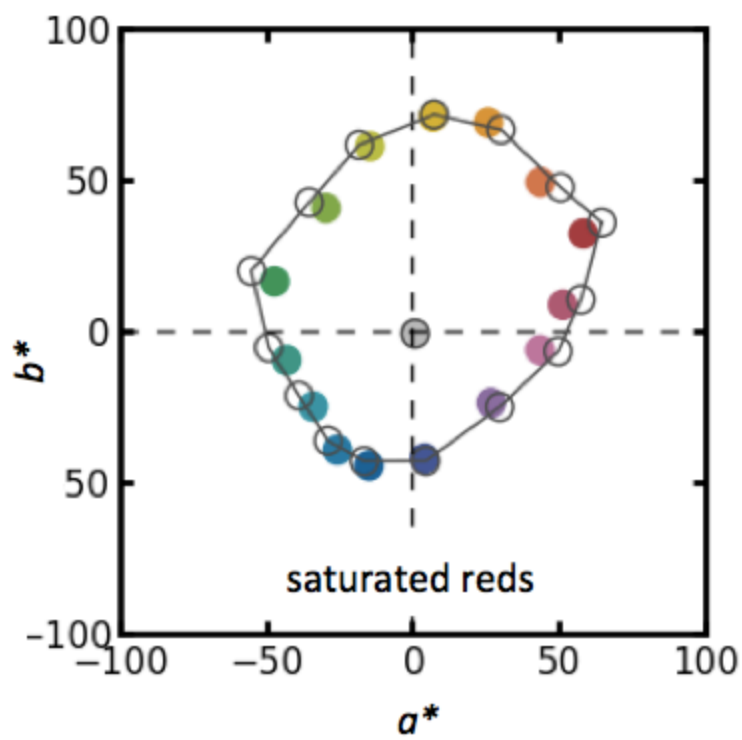
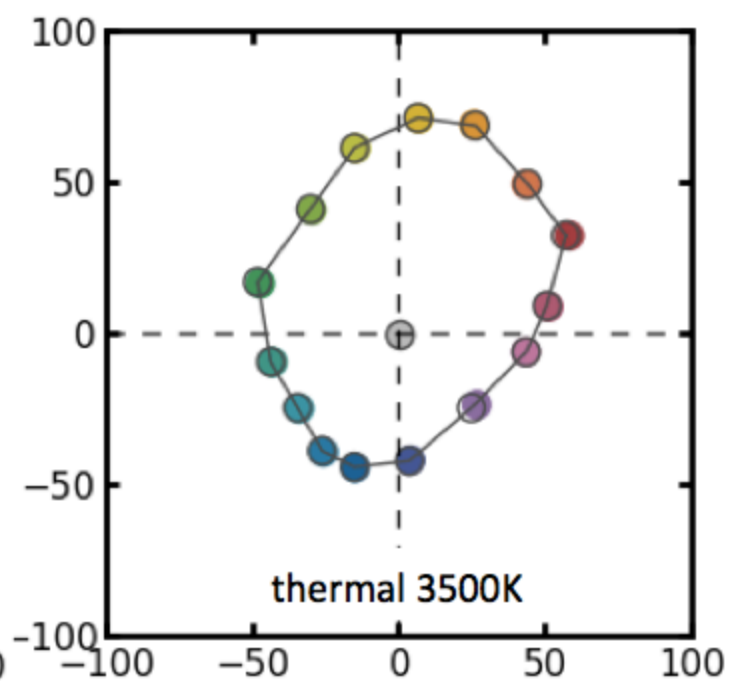
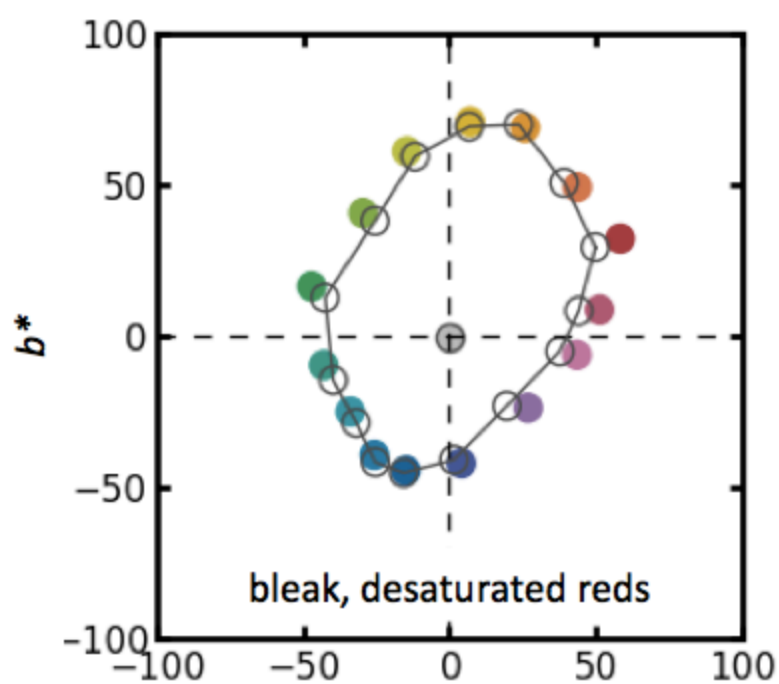


# Multiple 4000K, high CRI solutions – 5-color

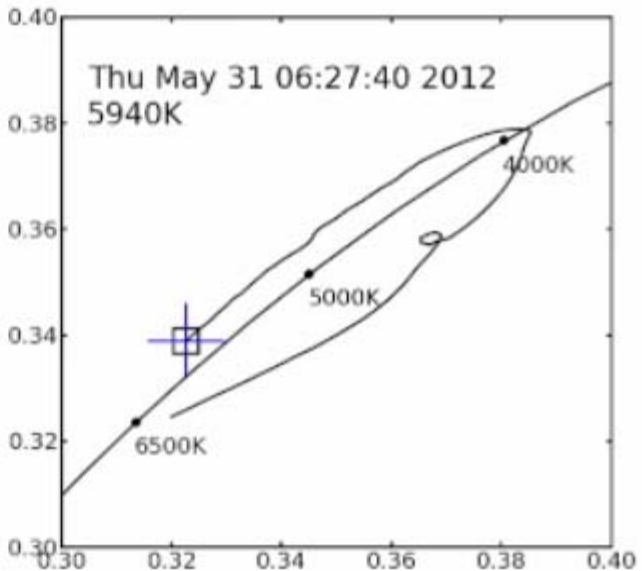
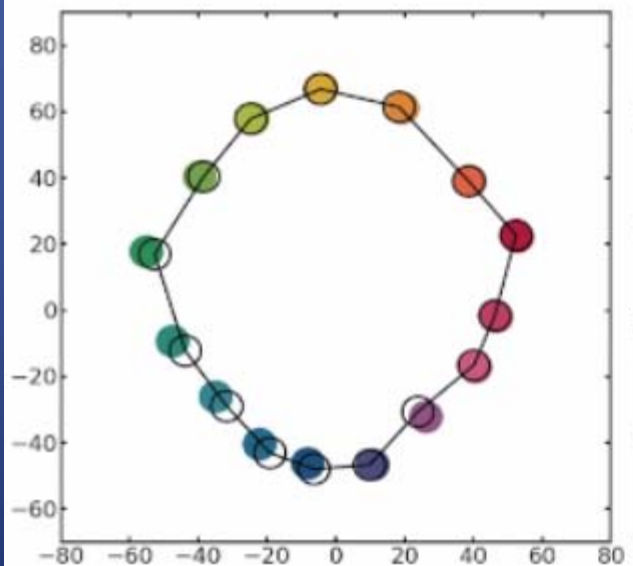
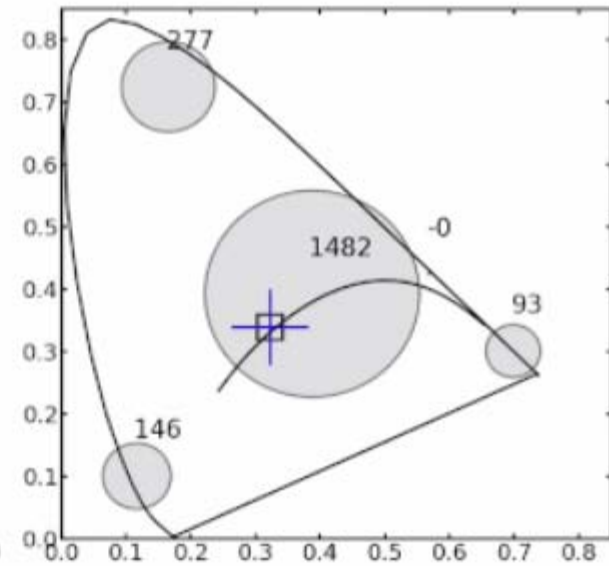
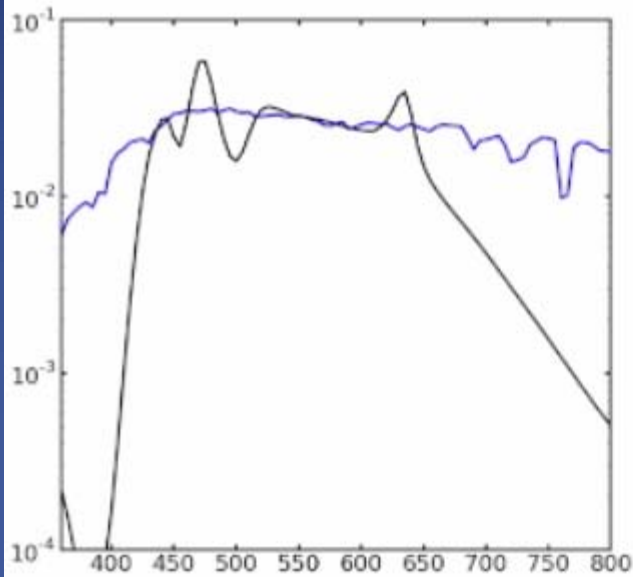


# Multiple Solutions Example

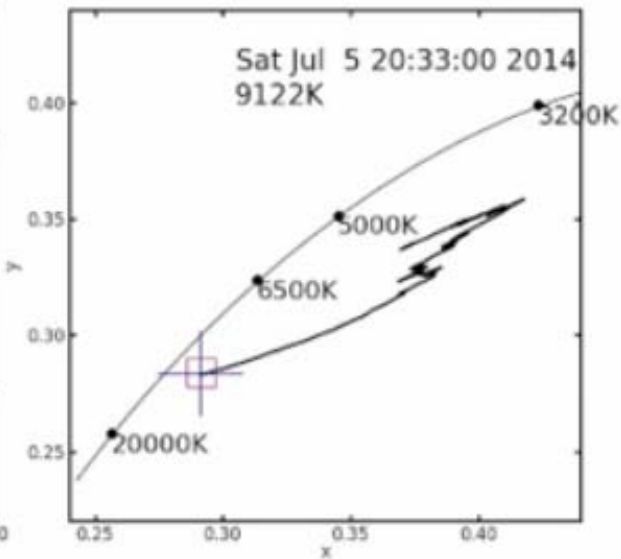
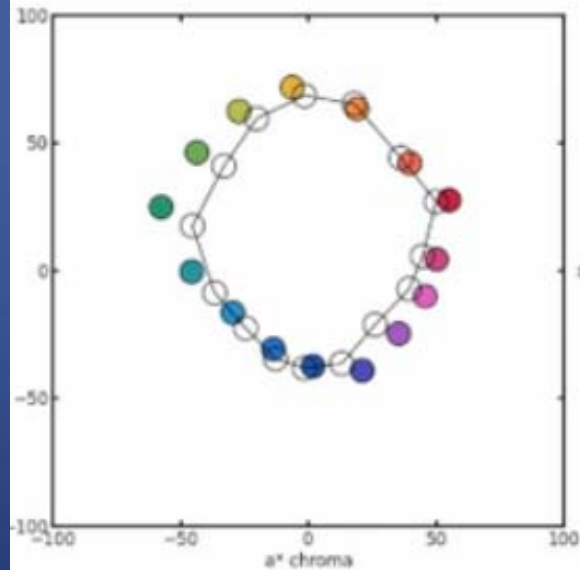
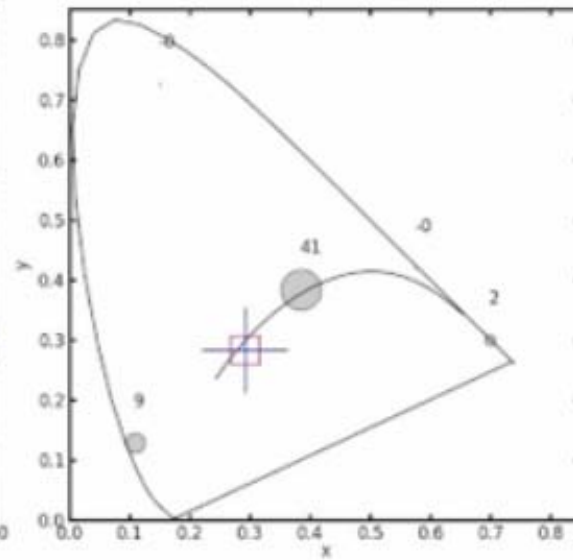
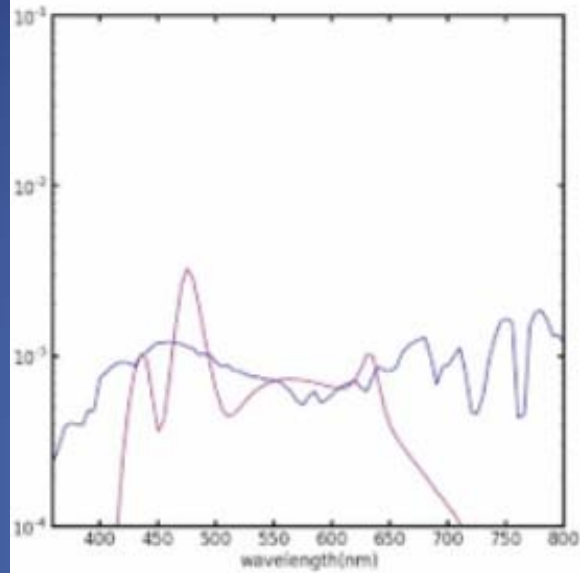
- 5-channel system producing 3500K with a progression from de-saturated reds to a thermal radiator to saturated reds
- In general more saturated reds and greens are more appealing.
- More saturated blues and yellows are less appealing.



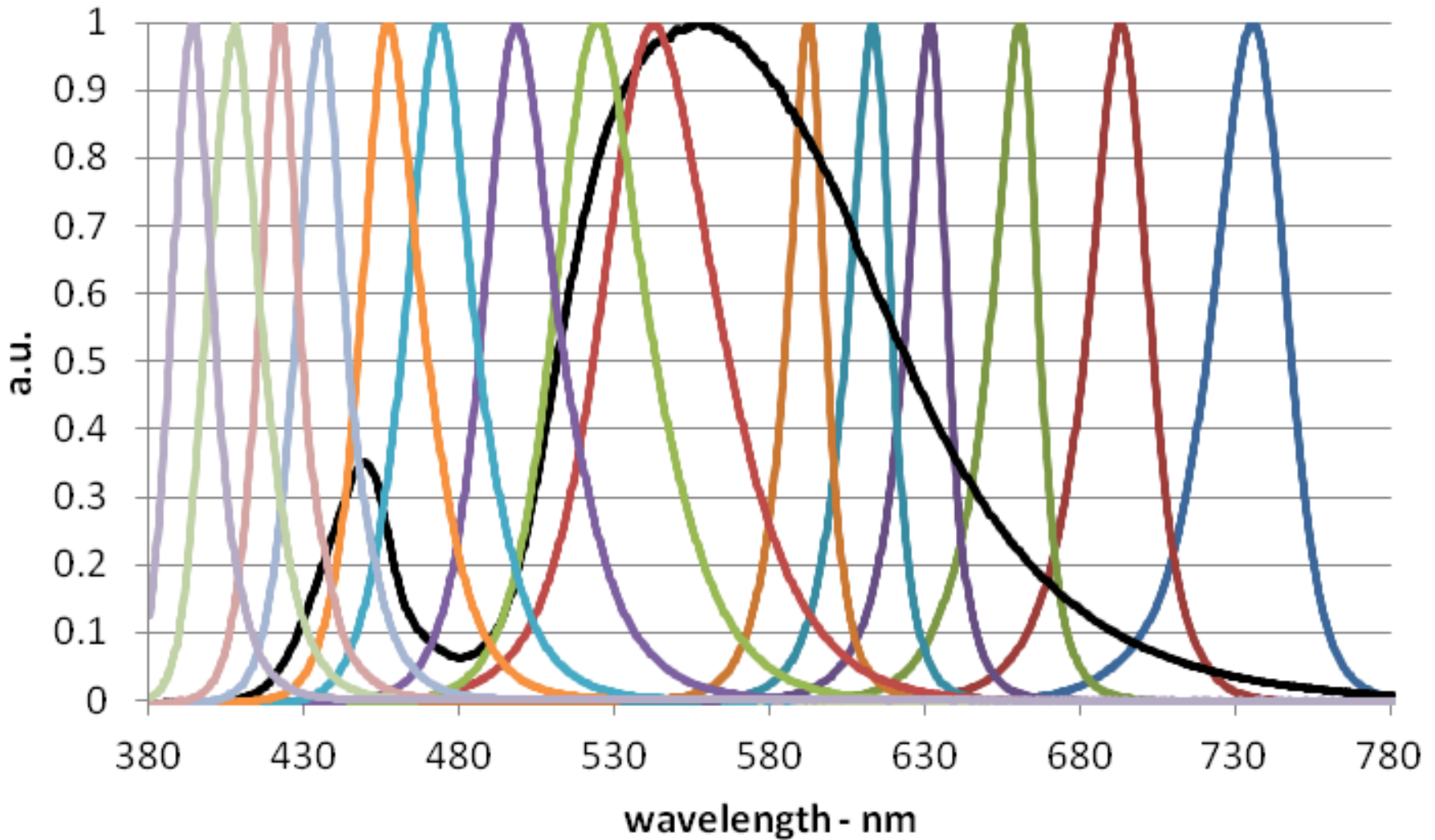
# Valley of Fire sunrise, USA



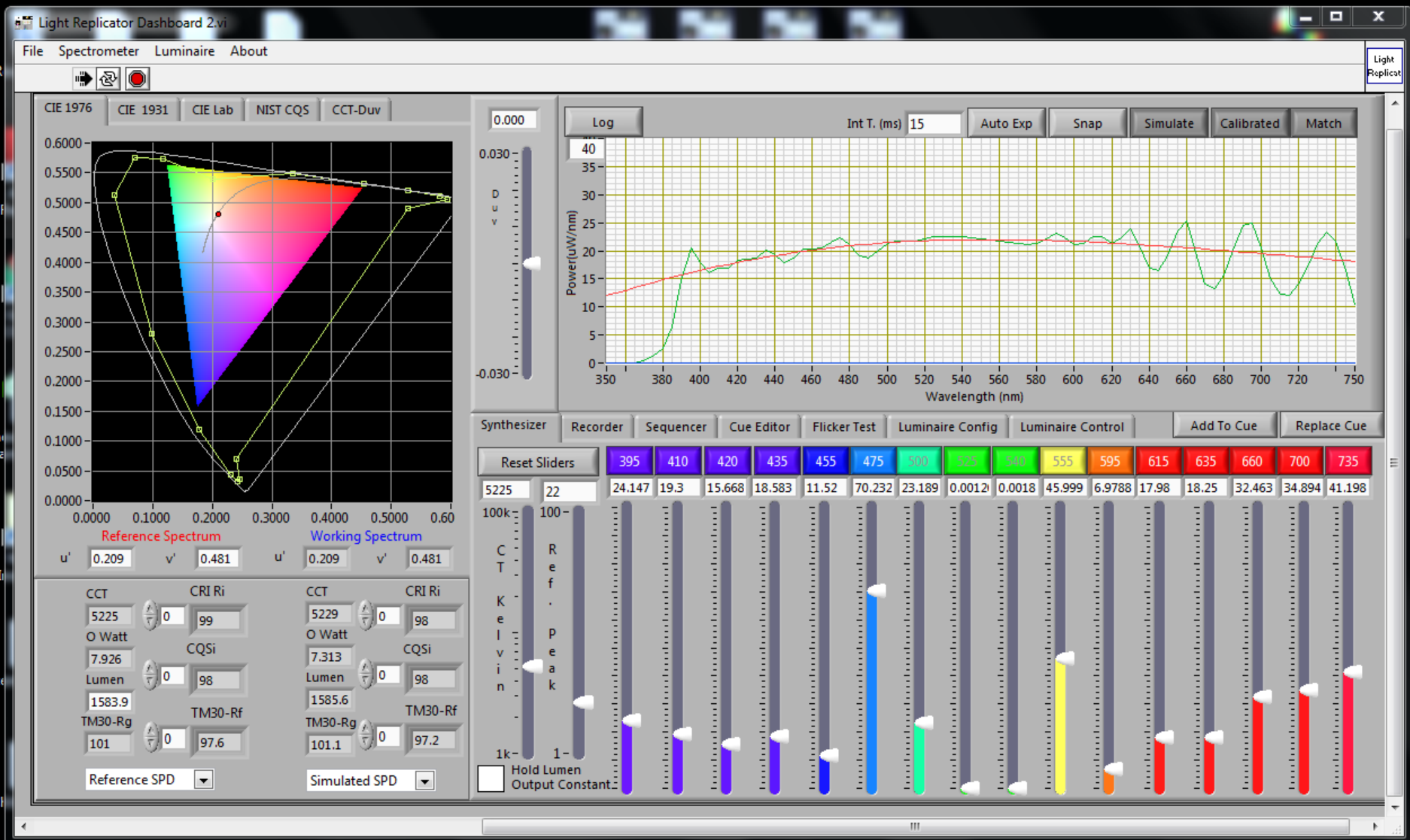
# Santa Cruz sunset, USA



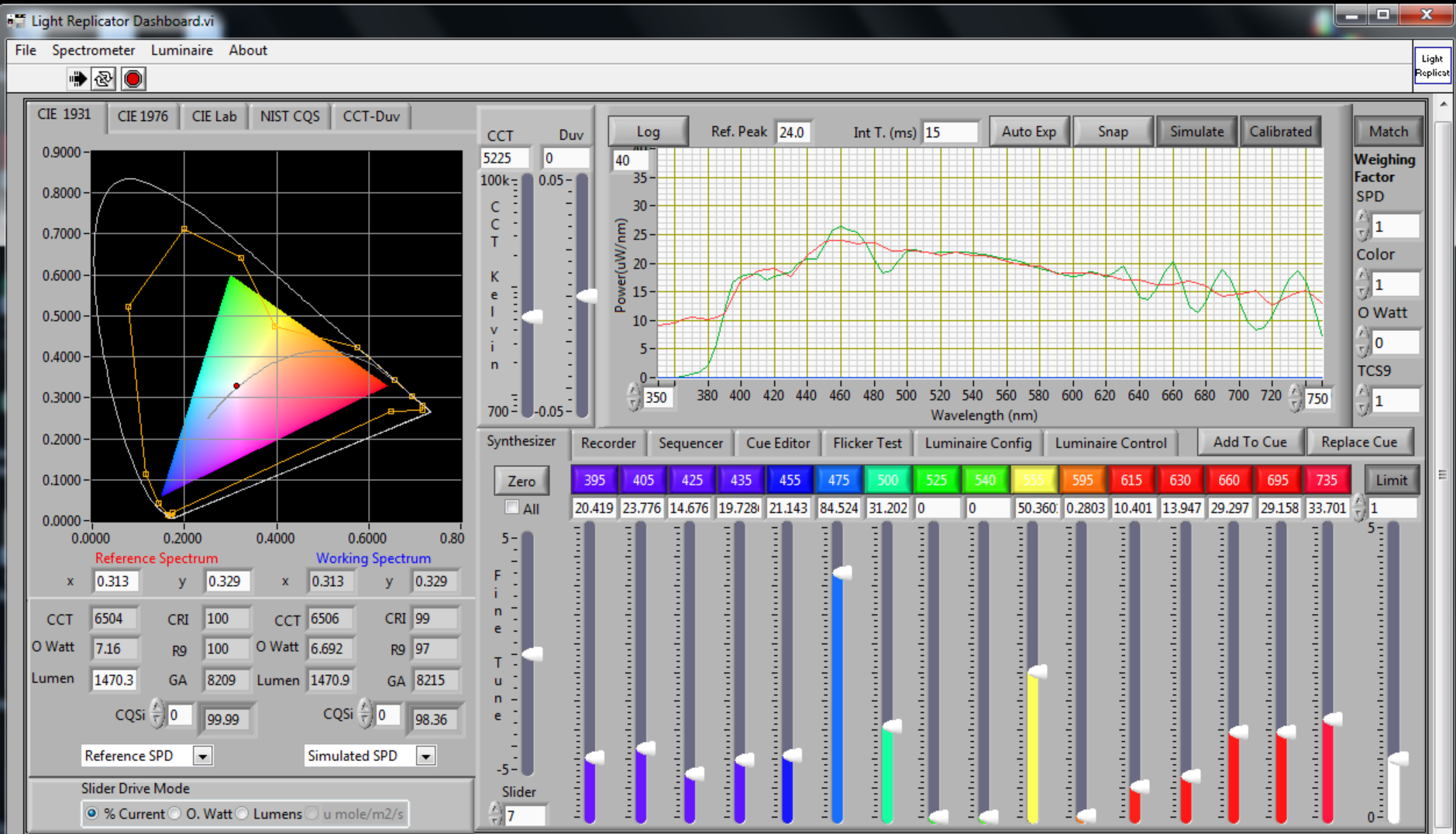
# Telelumen Light Replicator



# Light Replicator – 5225K

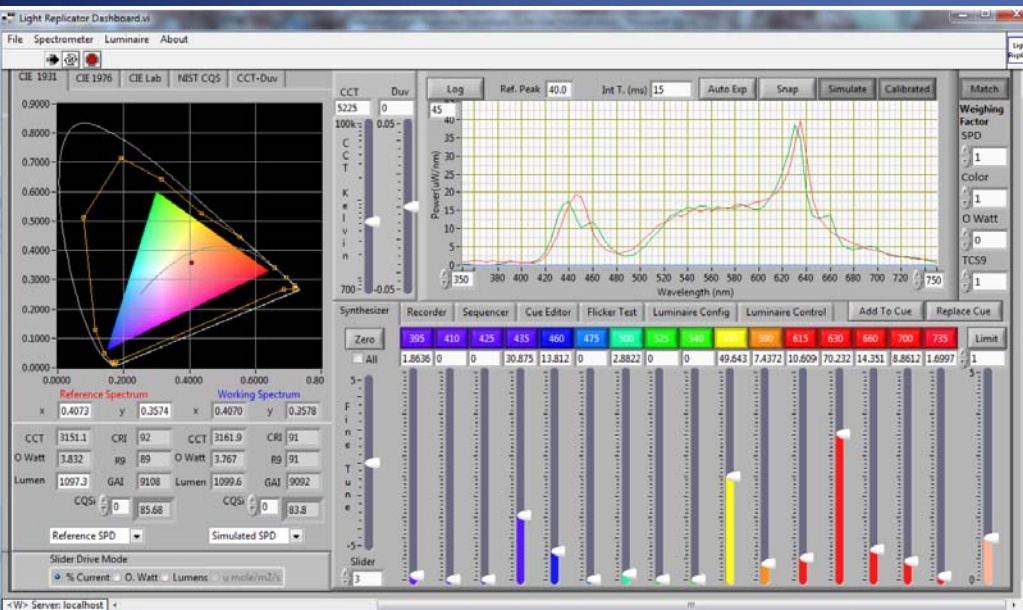


# D65 match – 16-channel





# Create/Record, Edit, Playback GUI Example



This screenshot shows the 'Recorder' tab of the software. It features a 'Spectrometer' status indicator (On Line) and a 'Monitor' checkbox. Recording parameters include 'No of Frames' (1), 'Scan Interval' (100 Milli Seconds), 'Start Time' (13:00:00), 'Frame No.' (0), 'Save Interval' (10 Seconds), and 'Current Time' (13:00:00). There are also checkboxes for 'High Speed Acquisition' and 'Correct for Elec. DarkAcquisition'. Playback controls include 'Frames to Add' (1), 'Load Spectrum', 'Save Spectrum', and 'Save Iso' buttons. A 'Meas. Offset' and 'Zero Recorder' button are also present. The 'Active Spectrometer' section shows a 'Serial Number' dropdown set to 'Simulation' and a 'Save Image' button. The 'Image File Type' is set to 'PNG' and 'Every Nth Frame' is set to 0. The 'Frame Time' is 199.

This screenshot shows the 'Luminaire Control' tab. It contains a table of color and power settings:

Color	Name	Watt	Fade Up	Hold	Fade Dn
Orange	2000K	0	10	0	1
Orange	3000K	0	1	4	6
Blue	20000	0	6	6	1
Blue	Blue Strobe	0	1	4	5
Pink	Pink	0	9	3	1
Orange	5225K 35 Peak	0	1	4	10
Orange	Precandle	0	10	8	0.01
Grey		0	0	0	0

Below the table is a 'GoTo Cue' section with a 'Cue Pair' dropdown set to '11, 12, 13, 14'. A graph shows 'Amplitude (%)' on the y-axis (0 to 120) and 'Time (second)' on the x-axis (0 to 23). The graph displays a dashed line for the selected cue pair. 'Clear Cue', 'Load Cue', and 'Save Cue Iso' buttons are located below the graph. At the bottom, there are radio buttons for 'Load Native Data (slider)' and 'Load Generic Data (SPD)'.

This screenshot shows the 'Sequencer' tab. It includes 'Record time' (00:00:00) and 'Current time' (12:25:05) fields. A 'File Name to Receive/Delete' field is present. Below these are playback controls: '<< 1 >> 3', '<<< 4 || 5 >>> 6', 'A/B 7 Stop 8 Fav 9', 'DN DIM # 0 UP RST', 'Bright -', and 'Bright +'. A table lists tracks with serial numbers and file names:

Track	Serial Number/File Name
	4311417438385430066F0035
1	Black.Iso
2	Channel Scan Equal Optical Watt 2s.Iso
3	Channel Add Subtract Equal Optical Watt 1s.Iso
4	1000K.Iso
5	2000K.Iso
6	3000K.Iso
7	4000K.Iso
8	5225K.Iso
9	6500K.Iso
10	8000K.Iso
11	10000K.Iso
12	100000K.Iso

On the right side, there are buttons for 'List Directory', 'Send File to Luminaire', 'Receive File to Disk', 'Receive File', 'Delete File', 'Get Luminaire Info', 'All Dark', 'Clear Screen', 'Reset Luminaire', 'Update Firmware', and 'Format SD Card'.



LED



Metal  
Halide



**Metal Halide**  
**4000K ~65 CRI**  
**R9 <0**



**LED**  
**5000K 90+ CRI**  
**R9 50+**



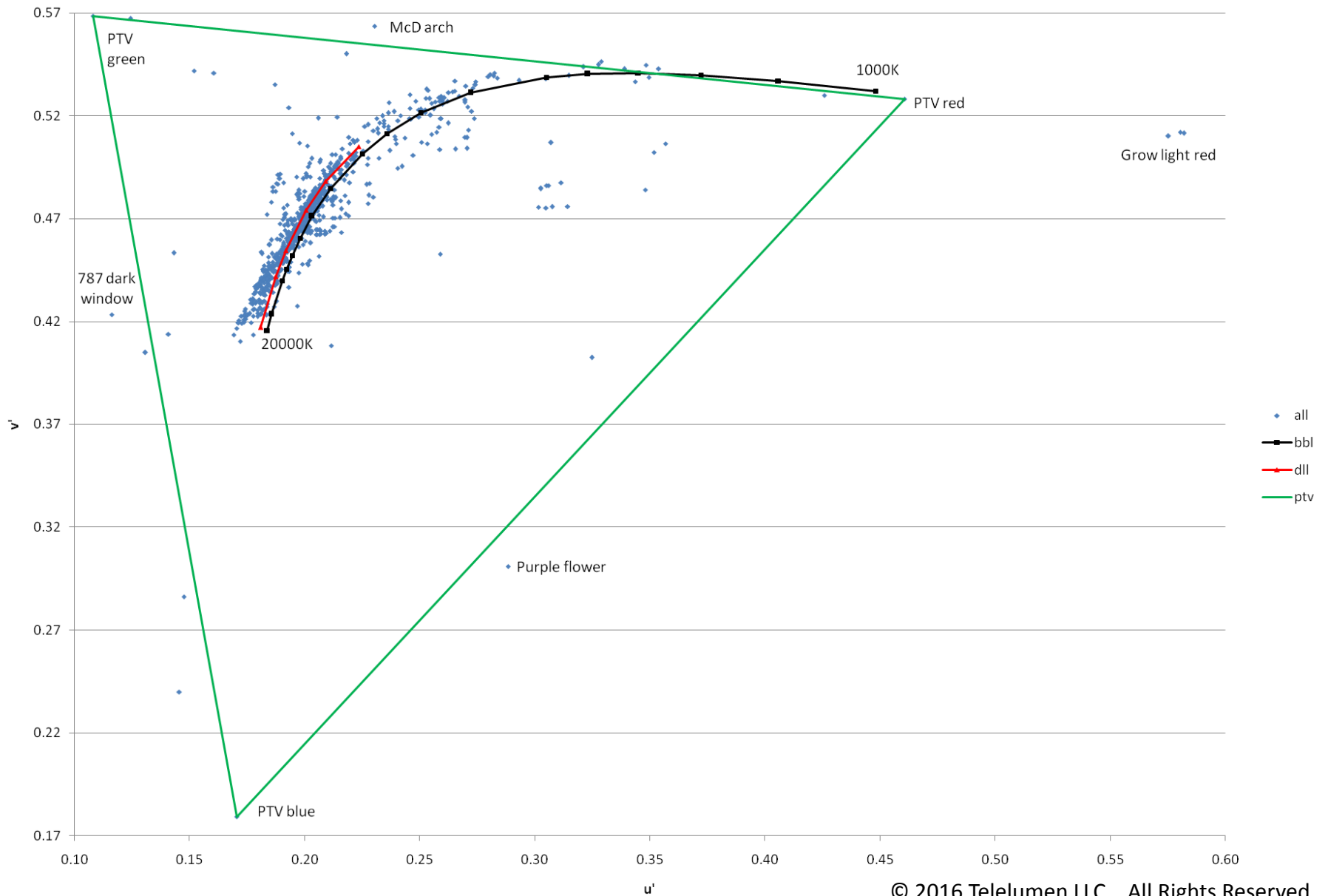
# Collecting Daylight Data

- Spectrometer
- Camera with fish-eye lens

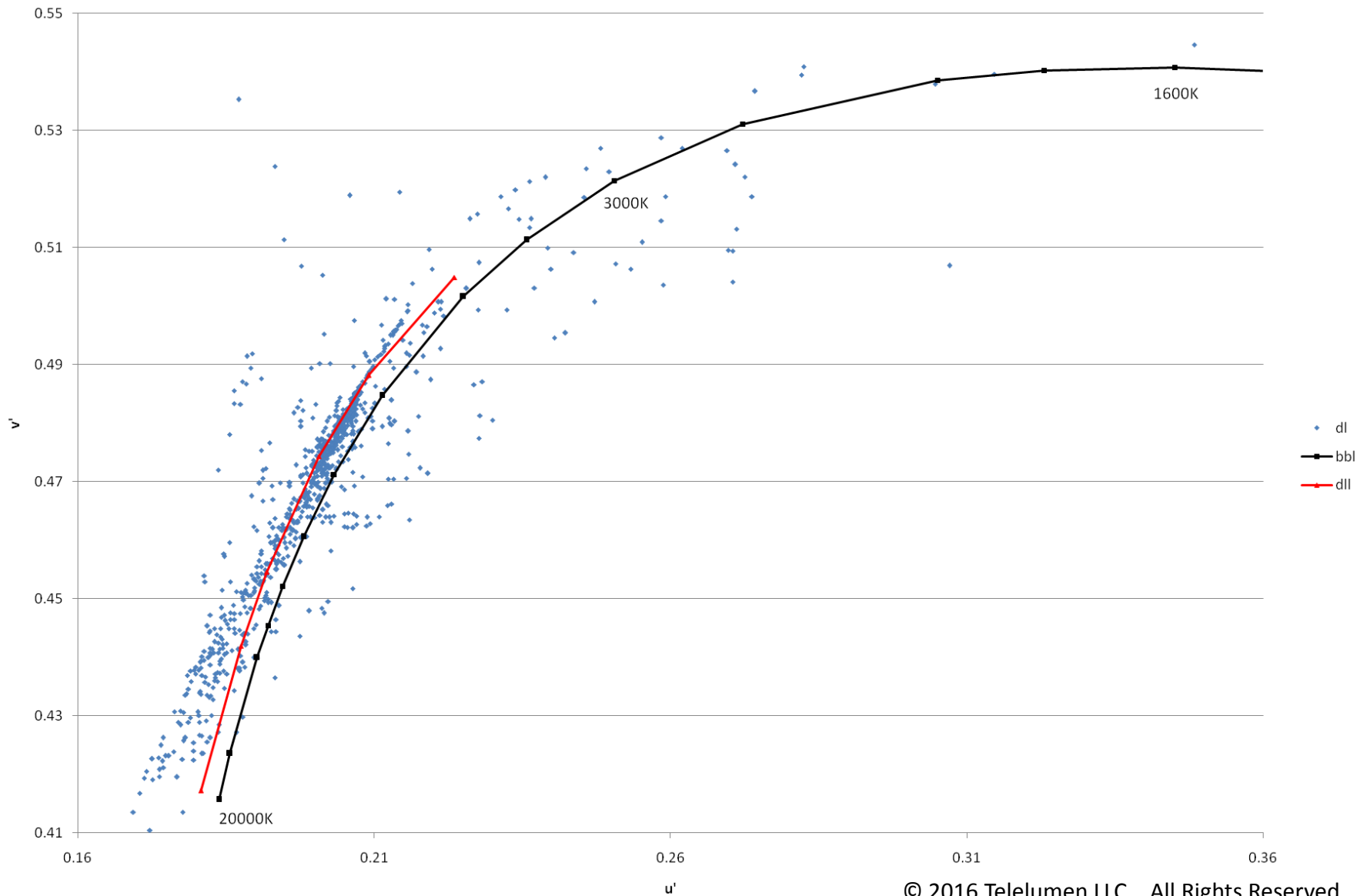
# Portable Spectrometer for Light Recording



# Spectrometer recordings

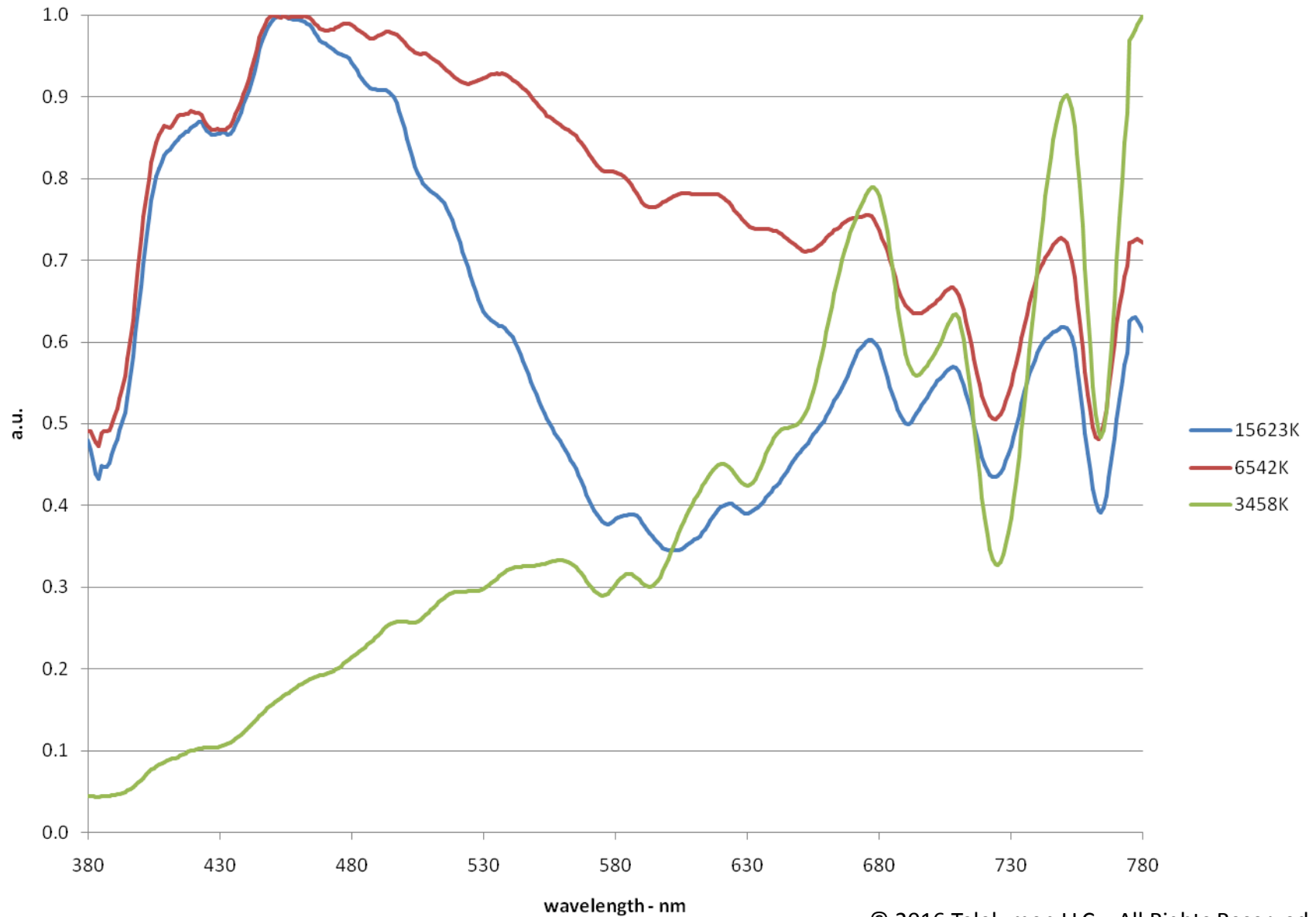


# Daylight recordings

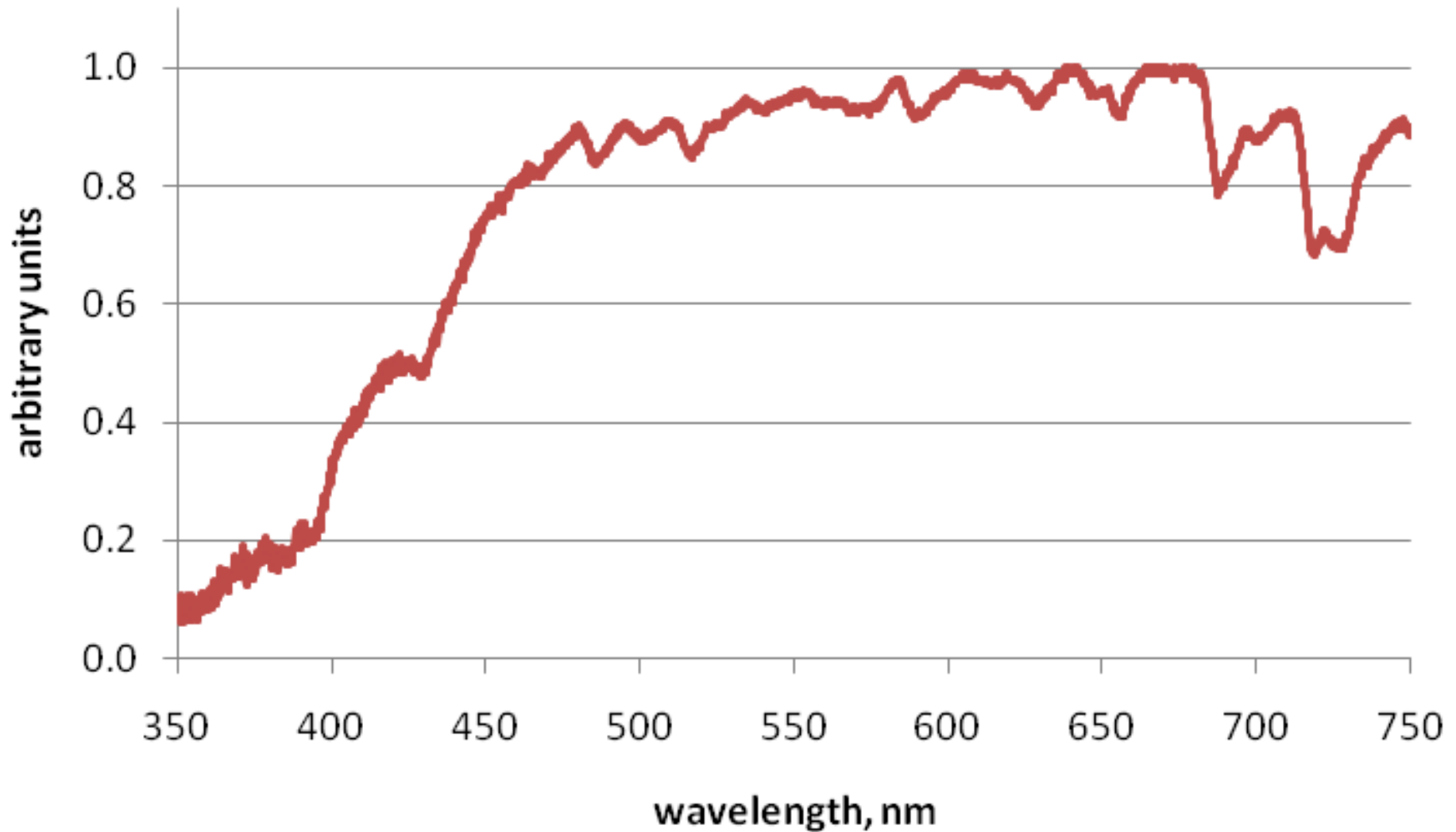




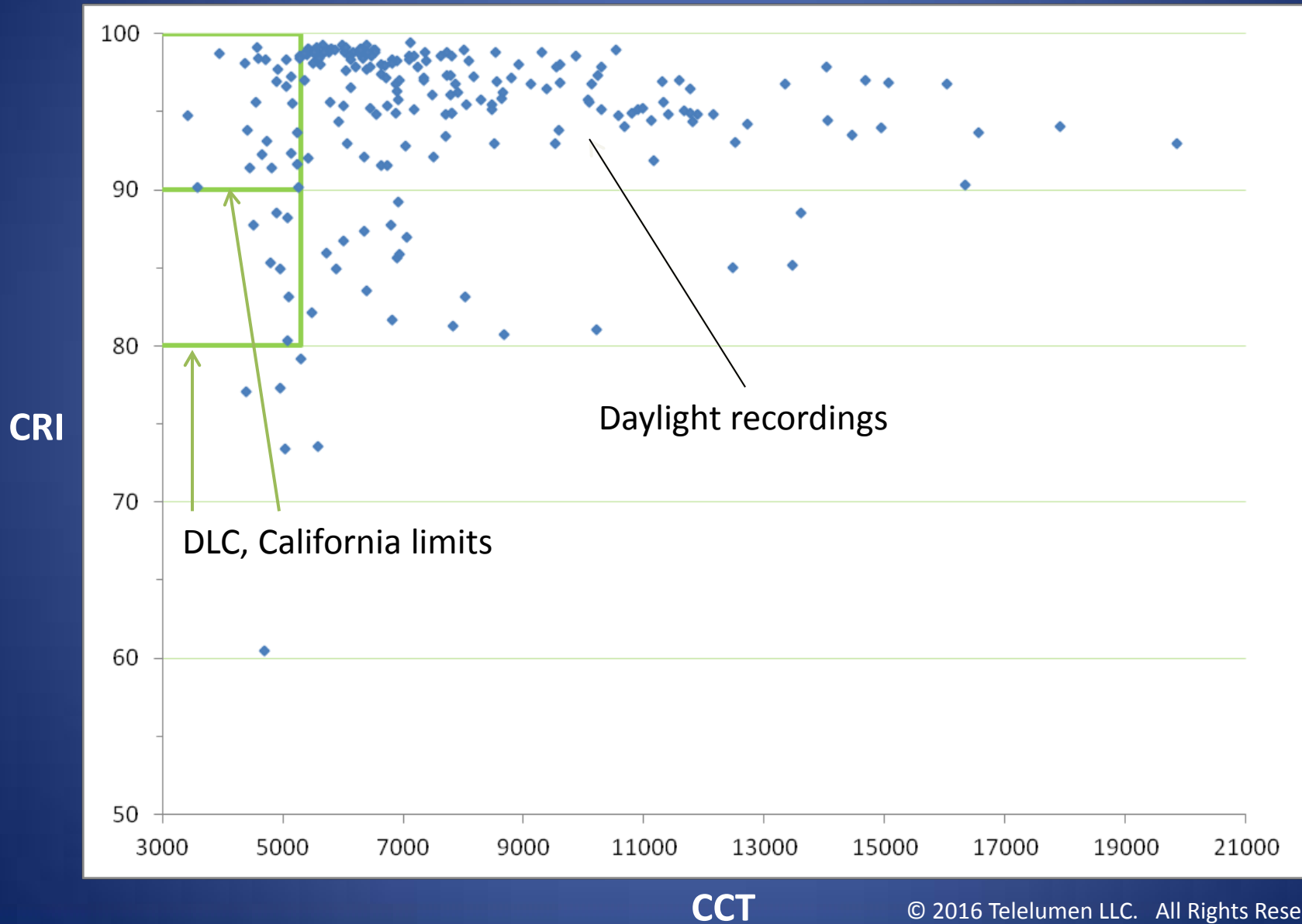
# Daylight recordings



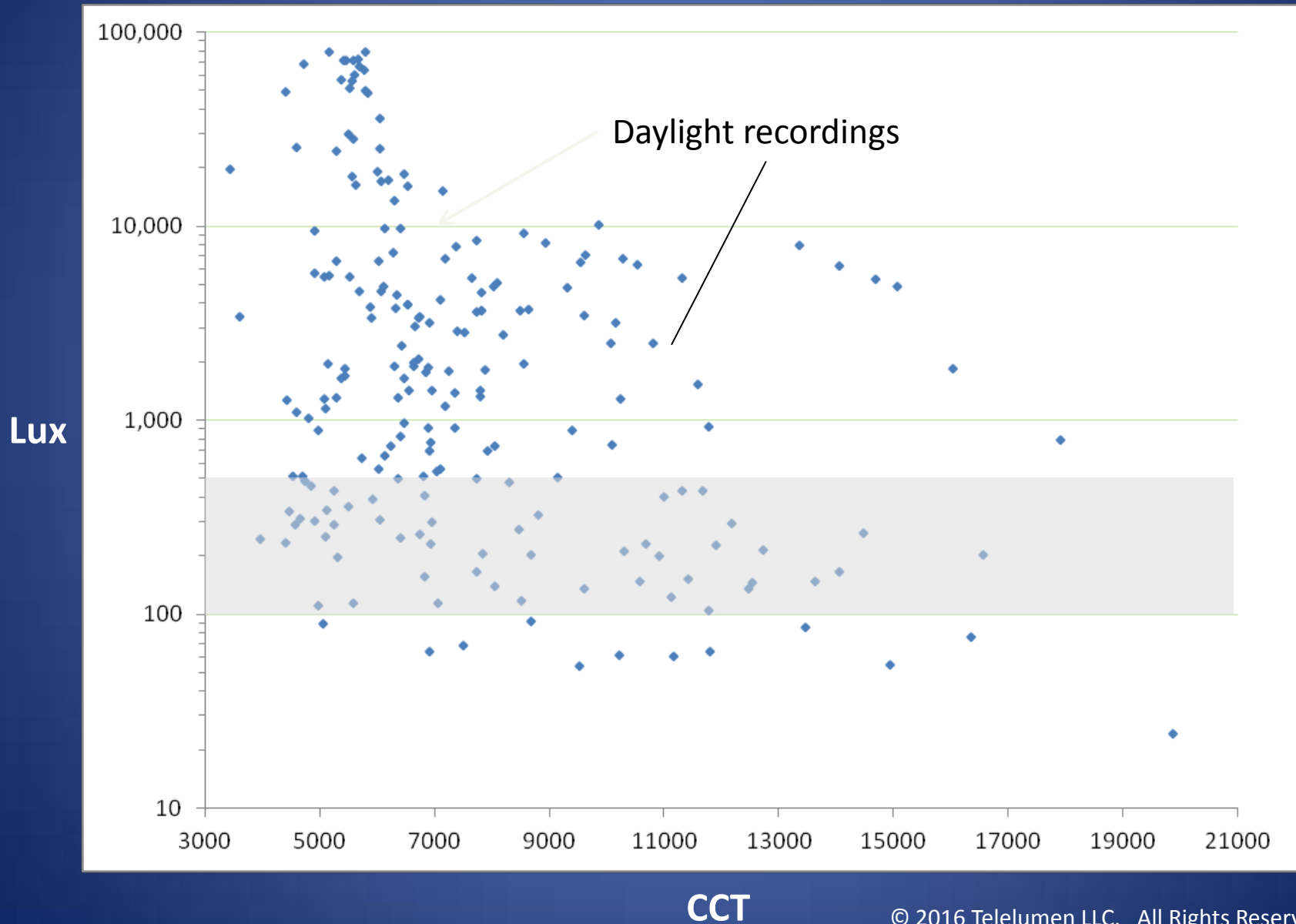
Moonlight at 3:20am, clear sky.  
Recorded 22feb14 in Sunnyvale, CA USA  
Approximately 0.7 lux, 4,700K, 98 CRI



# CRI vs. CCT



# Illuminance vs. CCT



# Sky Shots





















CITTANE















LUXURY BRAND SHOP  
Japan-free Tax Shop

MEX  
24h OPEN  
DISCOUNT  
WARRANTY  
CASH  
CASH  
CASH

BEER  
OPEN  
24h OPEN  
DISCOUNT  
WARRANTY  
CASH  
CASH  
CASH

















W  
KUALA LUMPUR





















# Beyond Replication

- “Fix” a cloudy day – fill in filtered daylight
- Augment real time
  - Stretch, compress, shift
- Designer spectrum – purposeful distortion
  - Example: Make products look better – increase sales
- Design from scratch
  - Health
  - Productivity
  - Enjoyment

# Summary

- The blackbody locus is only a convenience
- Daylight is a model for electronic illumination
- Move beyond CCT and a few references
- Controlling the spectrum is key
- Clock, calendar, location, are also important
- Light Players provide a simple control interface
  - Professional content from playlist



谢谢

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