



Illumination content for color tunable luminaires

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Smart Lighting 2015

Connected Lighting

May 20 & 21 2015 - Berlin, Germany

Agenda

- Introduction
- Illumination vs. Infotainment
- Illumination – What do we want? Gold.
- Light recording, playback, content
- Controls – User experience
- Conclusion

Telelumen

- 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 (5 color light player)
 - Light Recorder (spectrometer)
 - LumenScripts (content)
 - Recordings, created, composed digital data

Applications

- Consumer/Home – daylight experience indoors, better circadian cycle
- Retail – make products more appealing
- Healthcare – faster healing, wake/sleep
- Workplace – increase productivity
- Movie, TV – outdoor filming, filter replication
- Experimental – control of the spectrum

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

Illumination “knobs and levers”

- Quantity of light – flux
- Spectrum – SPD, color channels
- Time – clock, continuous change
- Space – location(s)
- Dispersion – degree of collimation, direction

- **The more dimensions we control**
– **the more powerful the experience**

What do “we” want?

- High color quality – skin, food, wood, flowers
- Dynamic – clock, subtle continuous change
- Easy to use – home theater, music player: content, volume
- Beam control – 1 to 180 deg
- Source area – 1 sq-cm – 50 sq-m
- Movement – aiming, processional
- Glare abatement
- Huge dynamic range – black to blinding (million to one)
- Multiple sources – multi-channel playback (home theater)
- Aesthetically pleasing when turned off
- Low energy use – 90% of the time

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.

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

The basics of illumination matching – 1

- Chromaticity and flux may be matched by a 3-channel light source but colors of objects will not match in most cases.
- Perceived color of an object is determined by the spectrum of the incident light and by the spectral reflectance of the object.
- The optimization goal is to minimize the RMS difference between the tristimulus values of target light and synthesized light reflected by reference color palette.

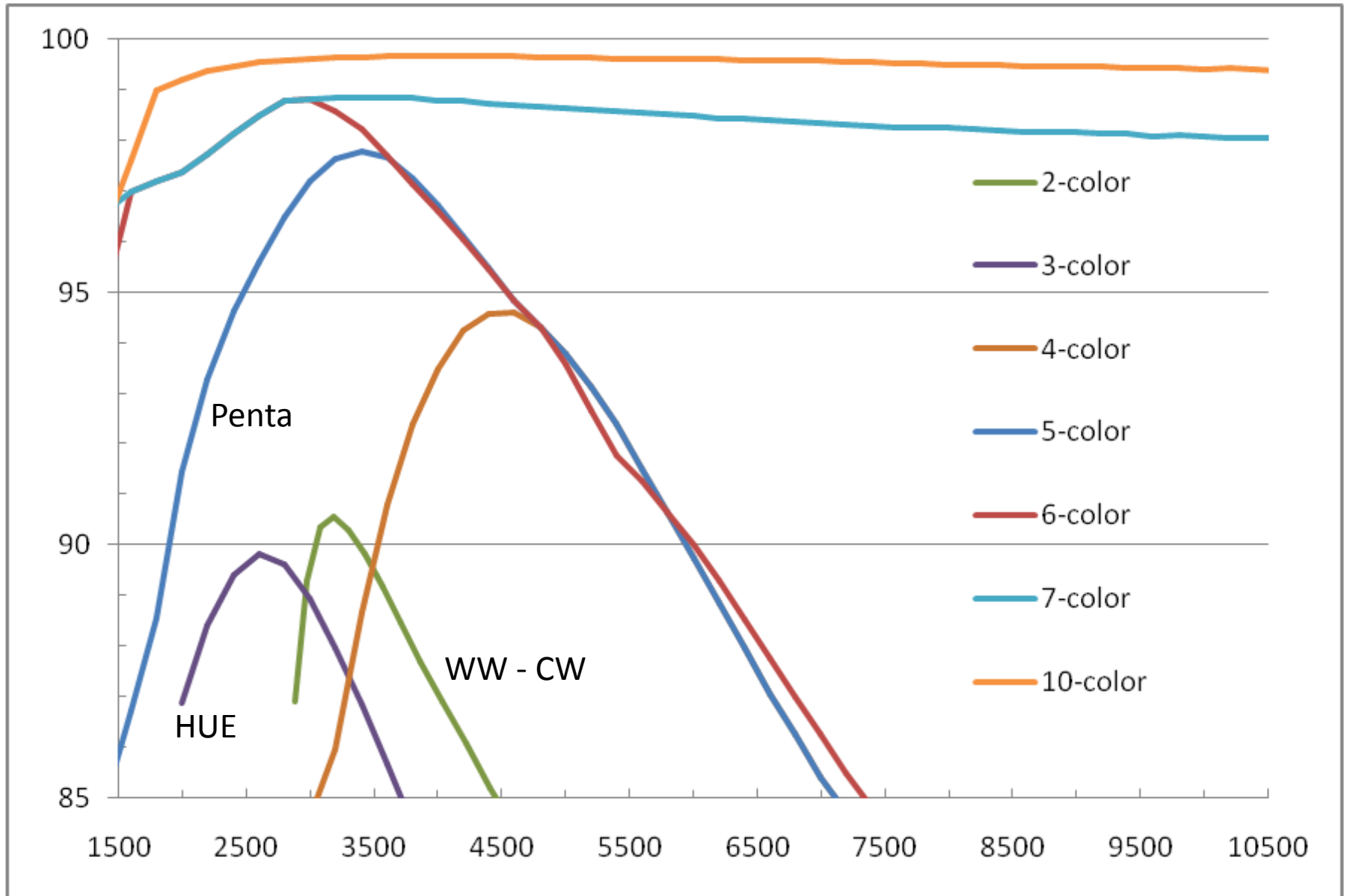
The basics of illumination matching – 2

- Additional degrees of freedom provided by a greater number of light channels (beyond 3) are required for correct reproduction.
- Some illumination sources are not on the black body locus such as sunrise and sunset that are desirable to reproduce with high fidelity on electronic illumination systems.

The value of more color channels

- Wider CCT or gamut area at higher color accuracy or preference
- More degrees of freedom
 - With many solutions for a given chromaticity come options to choose the best solution for given application: CRI, color contrast, circadian, etc.

Multi-color – CQS vs. CCT



Choosing color channels

- Widest possible gamut or
- Maximizing luminous efficiency or
- Widest range in CCT with “good” CRI or
- “Do no harm” museum light (subtract short wavelengths) or
- Induce fluorescence (add short wavelengths) or
- Inspection light (flattest spectrum) or
- Some combination of the above or other special cases

Consistent output

- Multi-channel luminaires are "forgiving" in that they do not require tightly binned components. Luminaire matrices are measured once at the factory.
- Two luminaires may have quite different component LEDs both in terms of number and make-up of channels but will maintain the same chromaticity over their operating range.
- In general, changes in flux are the primary reason for changes in chromaticity.

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



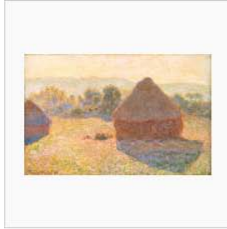
Claude Monet – “Haystacks”

The series shows differences in perception of light across various times of day, seasons, and types of weather.

1890-1891 series [\[edit\]](#)



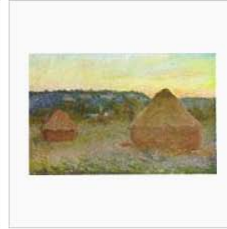
Grainstacks in the Sunlight, Morning Effect, 1890. Oil on canvas. Private collection.



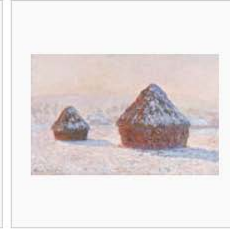
Haystacks, (Midday), 1890-91, National Gallery of Australia



Wheatstacks (End of Summer), 1890-91. Oil on canvas. Art Institute of Chicago



Wheatstacks, 1890-91. Oil on canvas. Art Institute of Chicago.



Wheatstacks, Snow Effect, Morning, 1891. Oil on canvas. J. Paul Getty Museum



Haystacks at the End of Summer, Morning Effect, 1891. Oil on canvas. Musée d'Orsay, Paris, France.



Haystacks on a Foggy Morning, 1891. Oil on canvas. Private collection.



Haystack, Morning Snow Effect (Meule, Effet de Neige, le Matin), 1891. Oil on canvas. Museum of Fine Arts, Boston.



Grainstacks Snow Effect, (Meules, effet de neige), 1891. Oil on canvas. National Gallery of Scotland, Edinburgh, Scotland



Wheatstacks (Sunset, Snow Effect), 1890-91. Oil on canvas. Art Institute of Chicago.



Wheatstack (Snow Effect, Overcast day) (Meule, effet de neige, temps couvert), 1890-91. Oil on canvas. Art Institute of Chicago.



Wheatstack, 1890-91. Oil on canvas. Art Institute of Chicago.



Wheatstack (Thaw, Sunset), 1890-91. Oil on canvas. Art Institute of Chicago.



Wheatstack (Sun in the Mist), 1891. Oil on canvas. Minneapolis Institute of Arts.



Grainstacks. (Snow effects; sunlight), 1890-91. Oil on canvas. National Gallery of Scotland, Edinburgh, Scotland.

Mt. Hamilton, San Jose, CA, USA



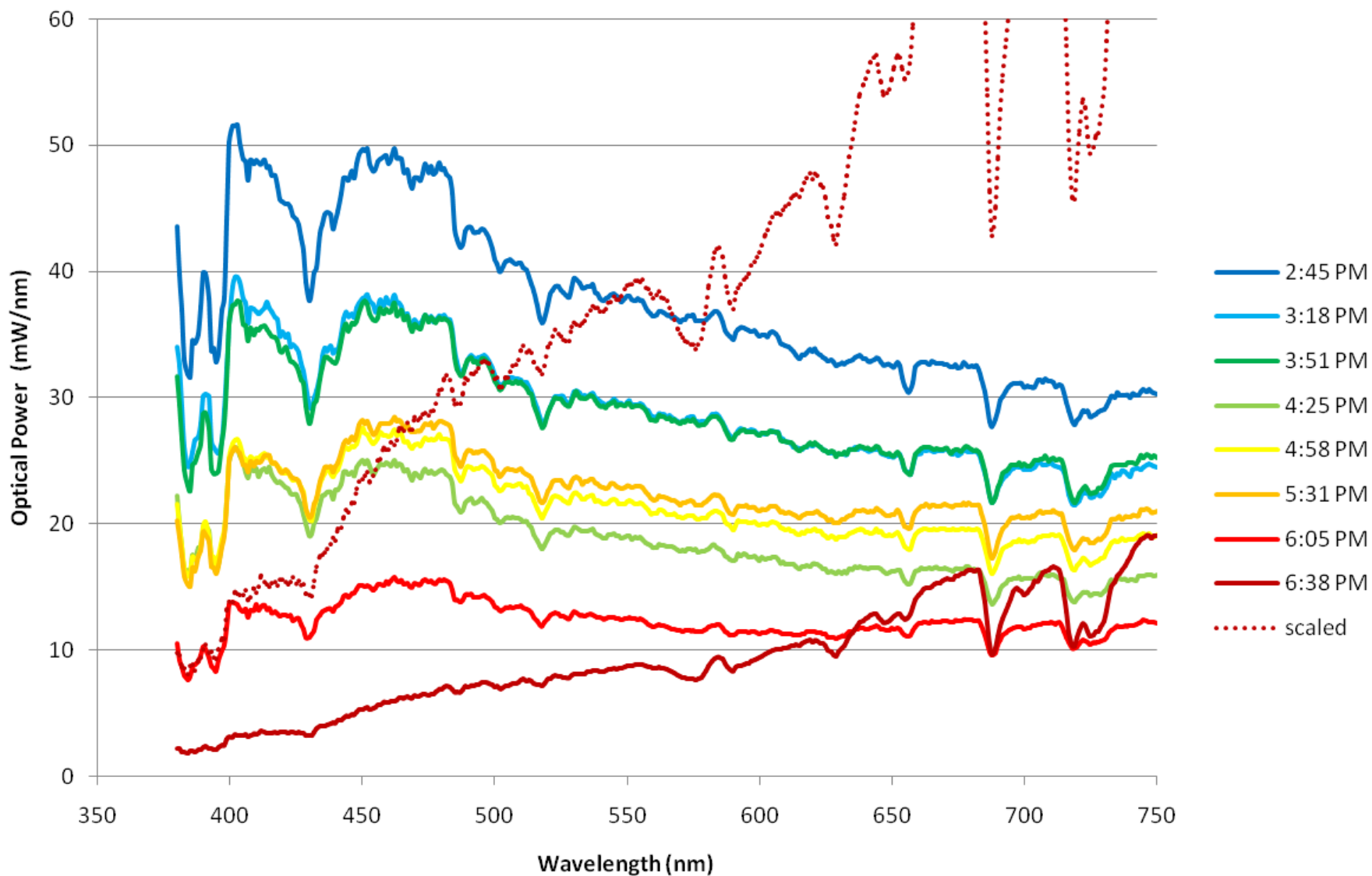








SPD Snapshots of Daylight Over 4-Hour Period



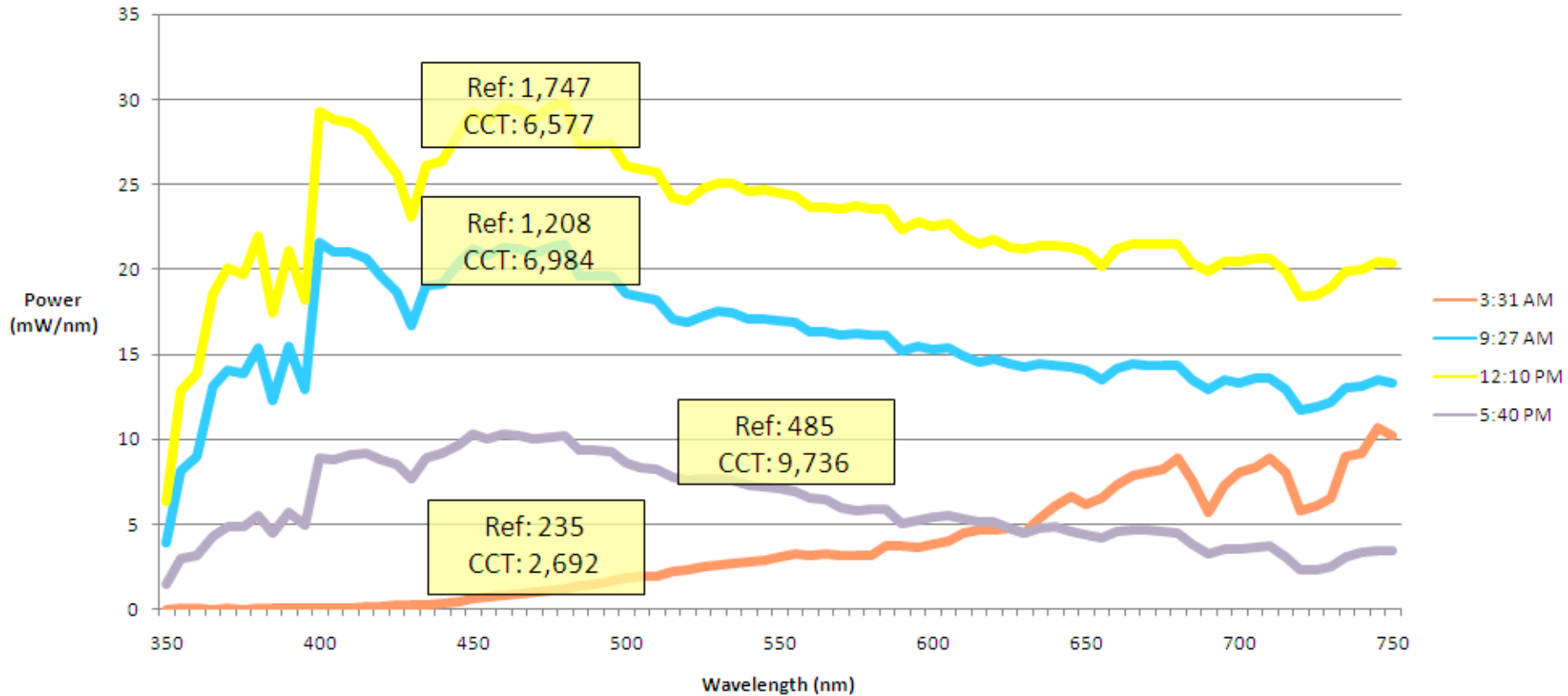


Steve Paolini – 8/1/2014

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Sunlight Snapshots

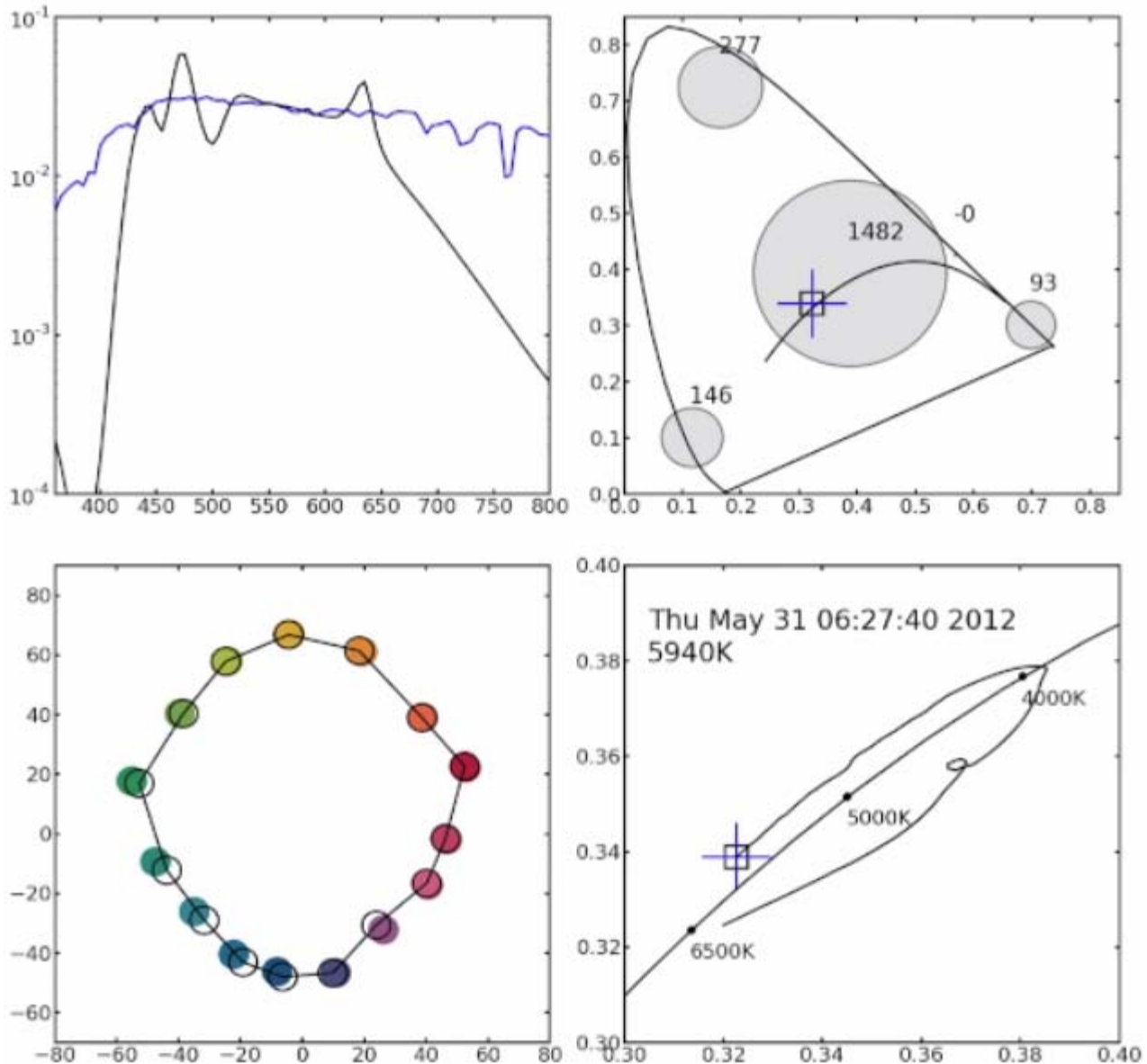
Mt. Fuji, Full Day, 7/14/2011



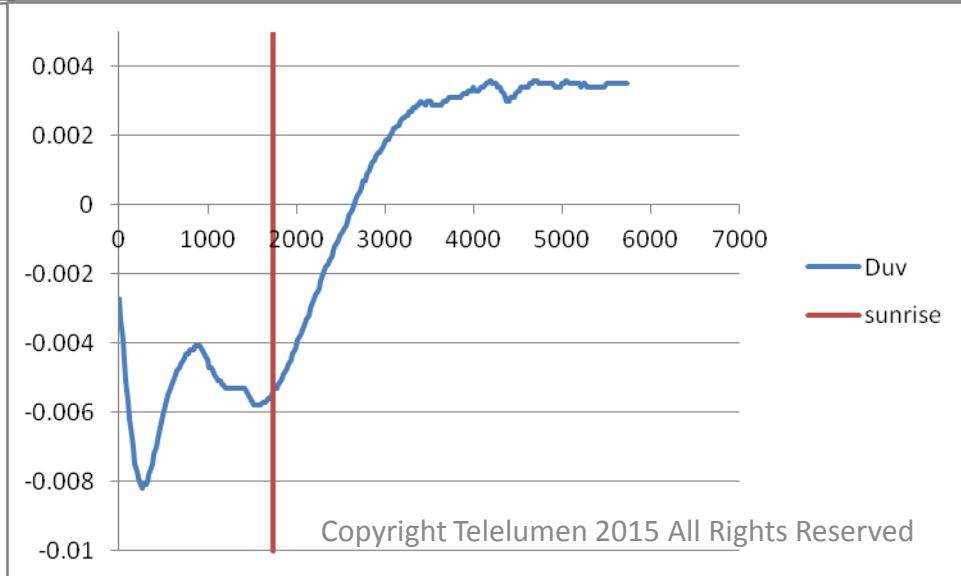
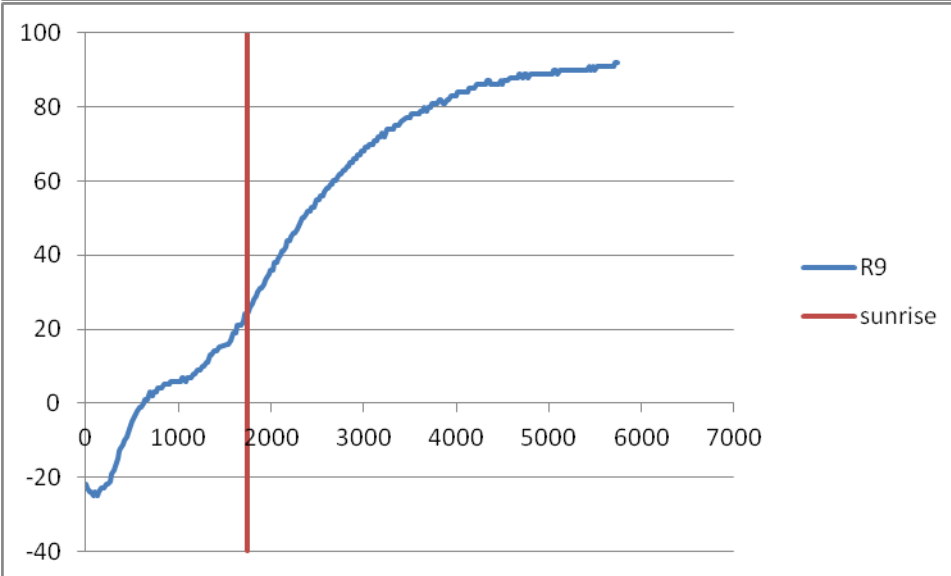
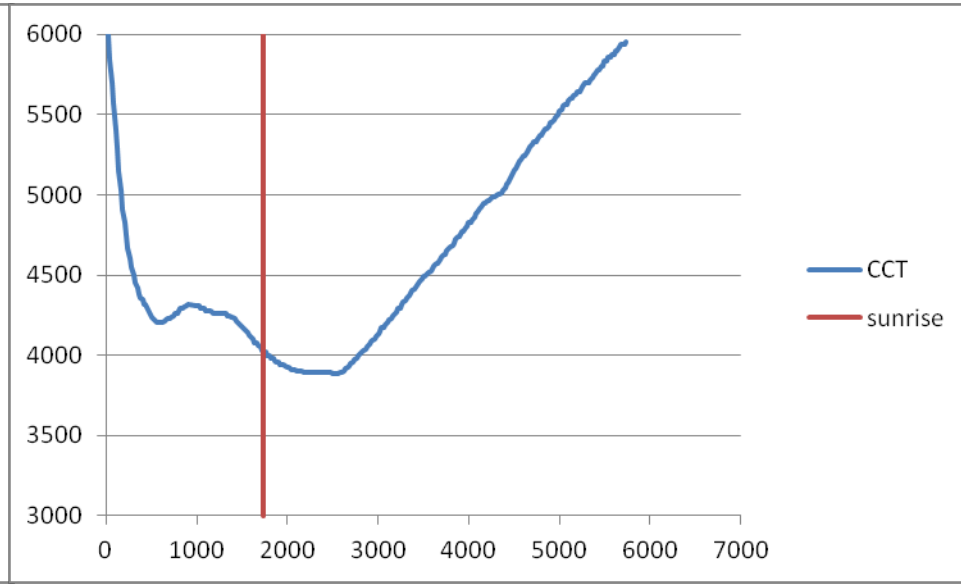
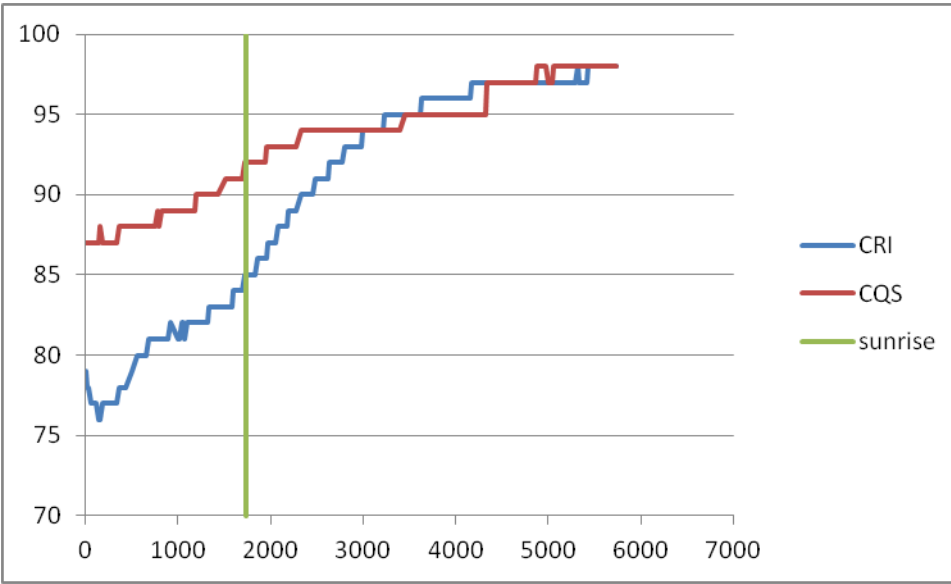
Valley of Fire, Nevada USA



Valley of Fire sunrise



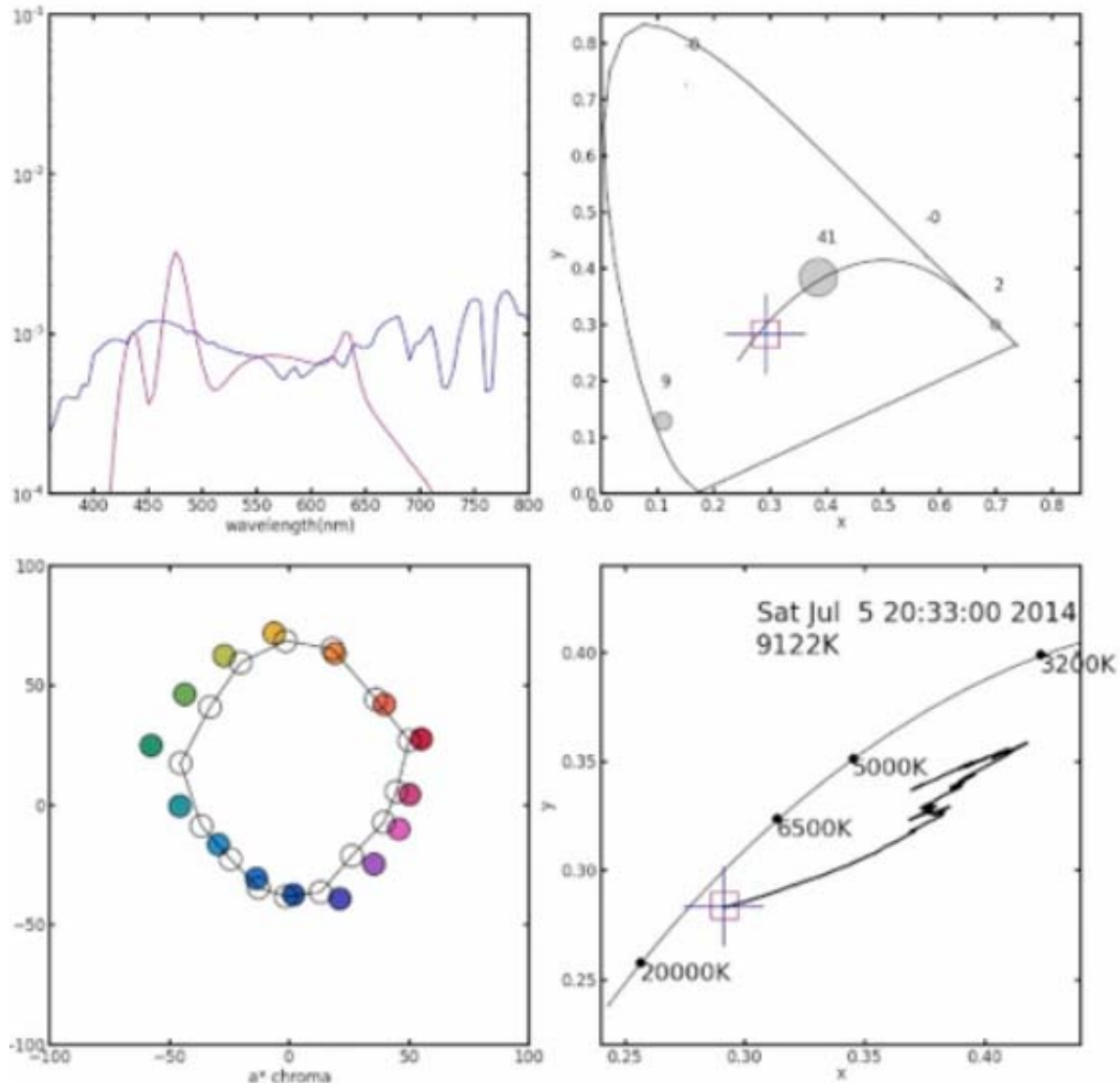
Valley Summary – there's a lot going on







Santa Cruz sunset, USA

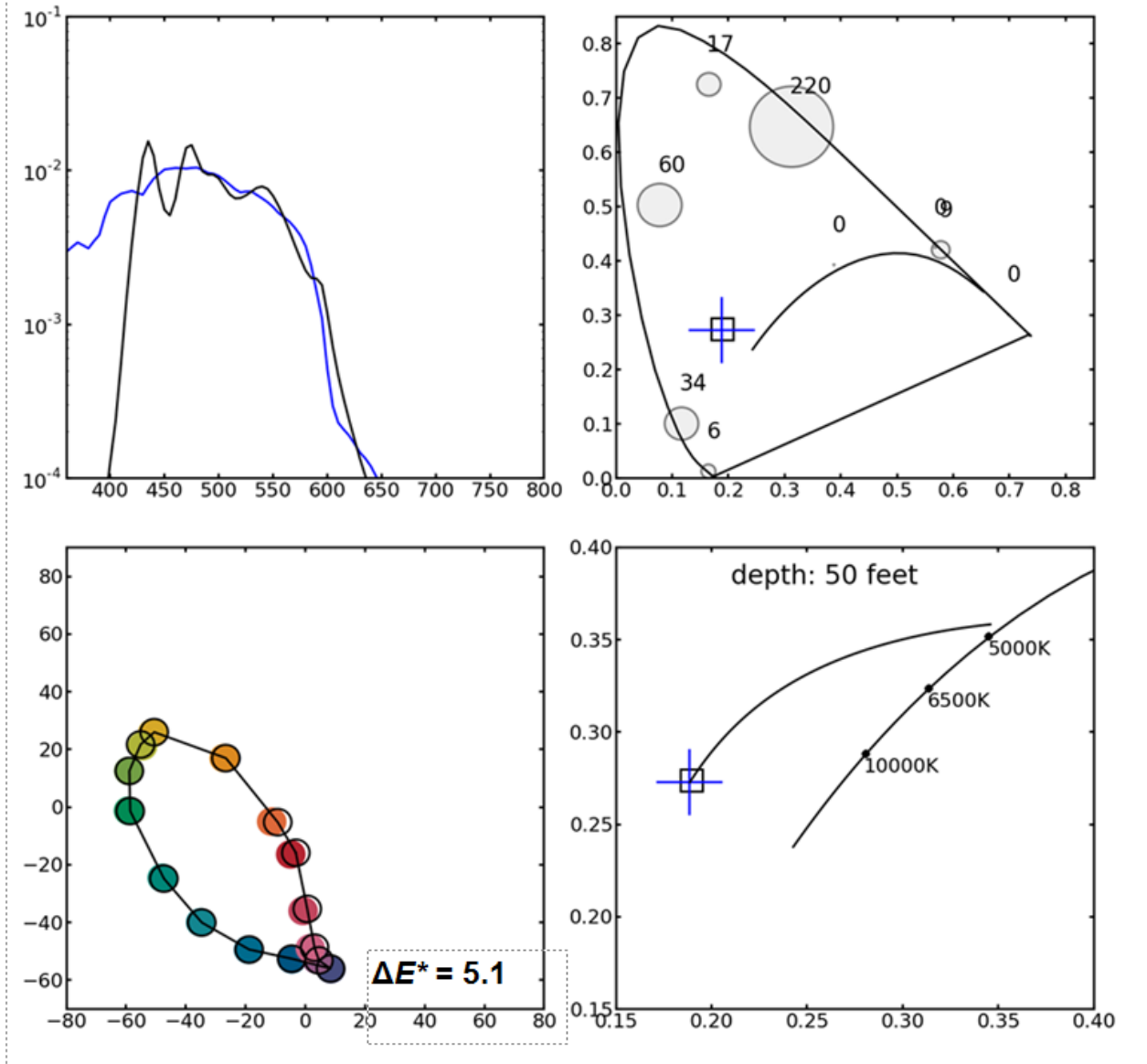




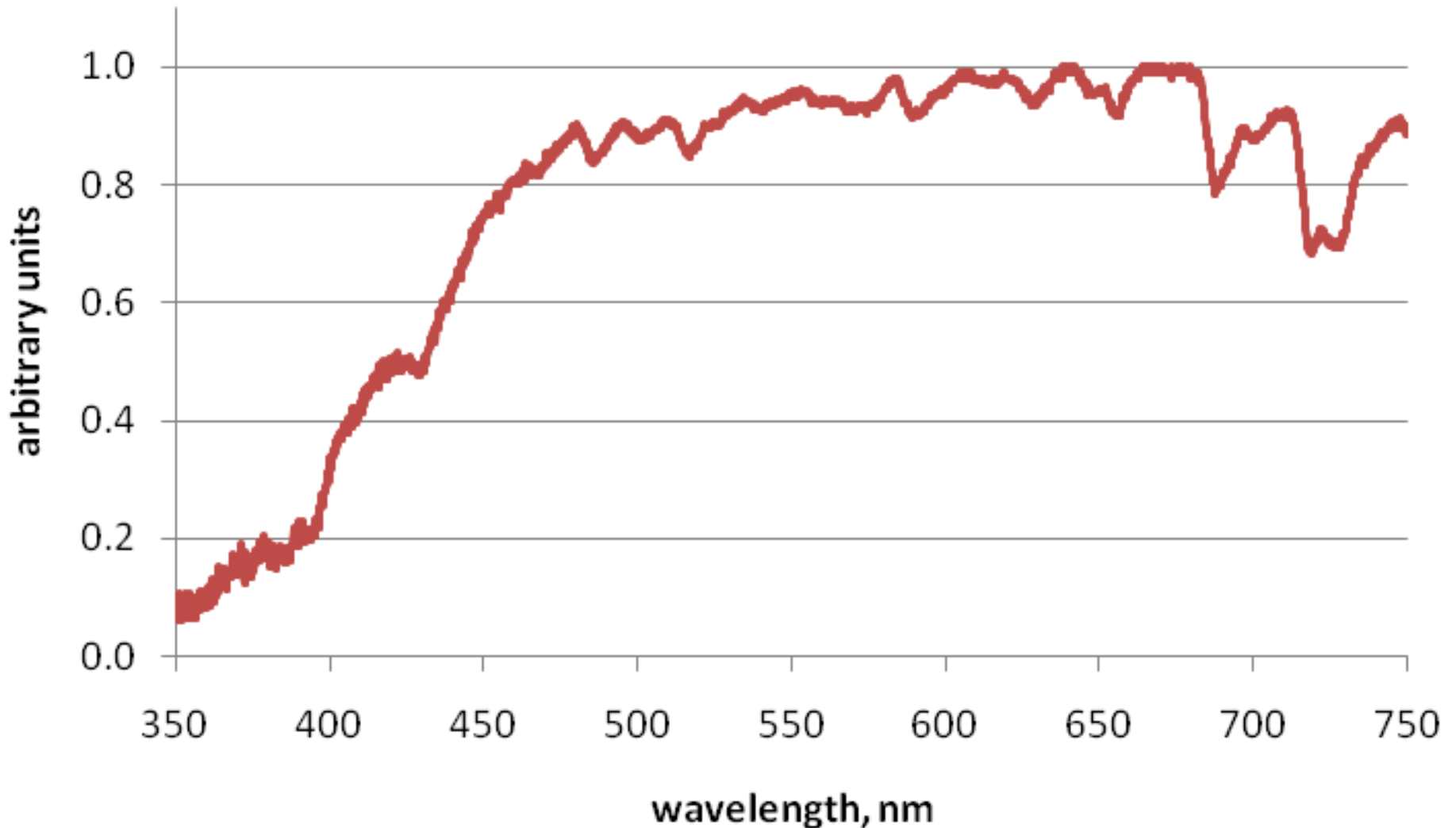




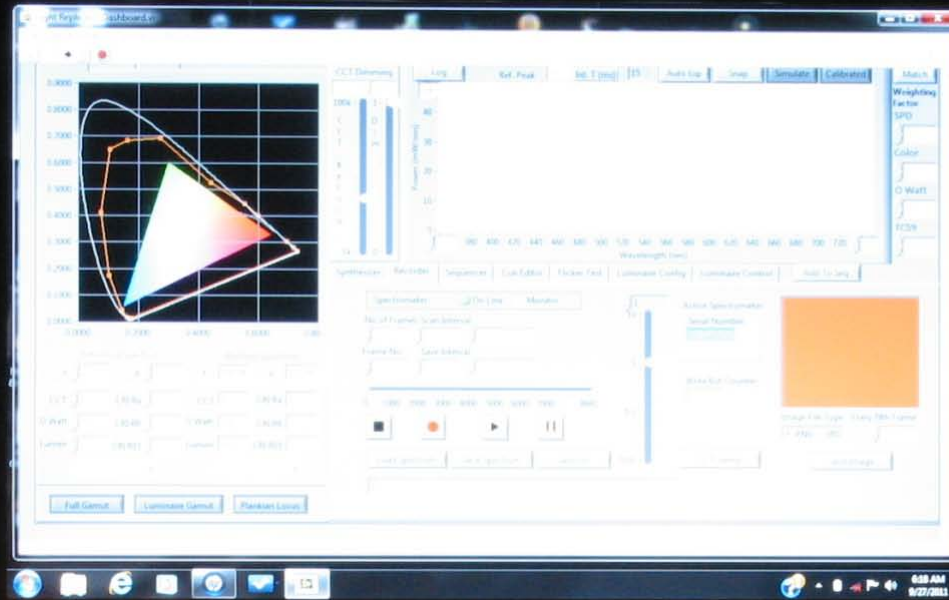
Underwater lighting synthesized by a 9-channel luminaire



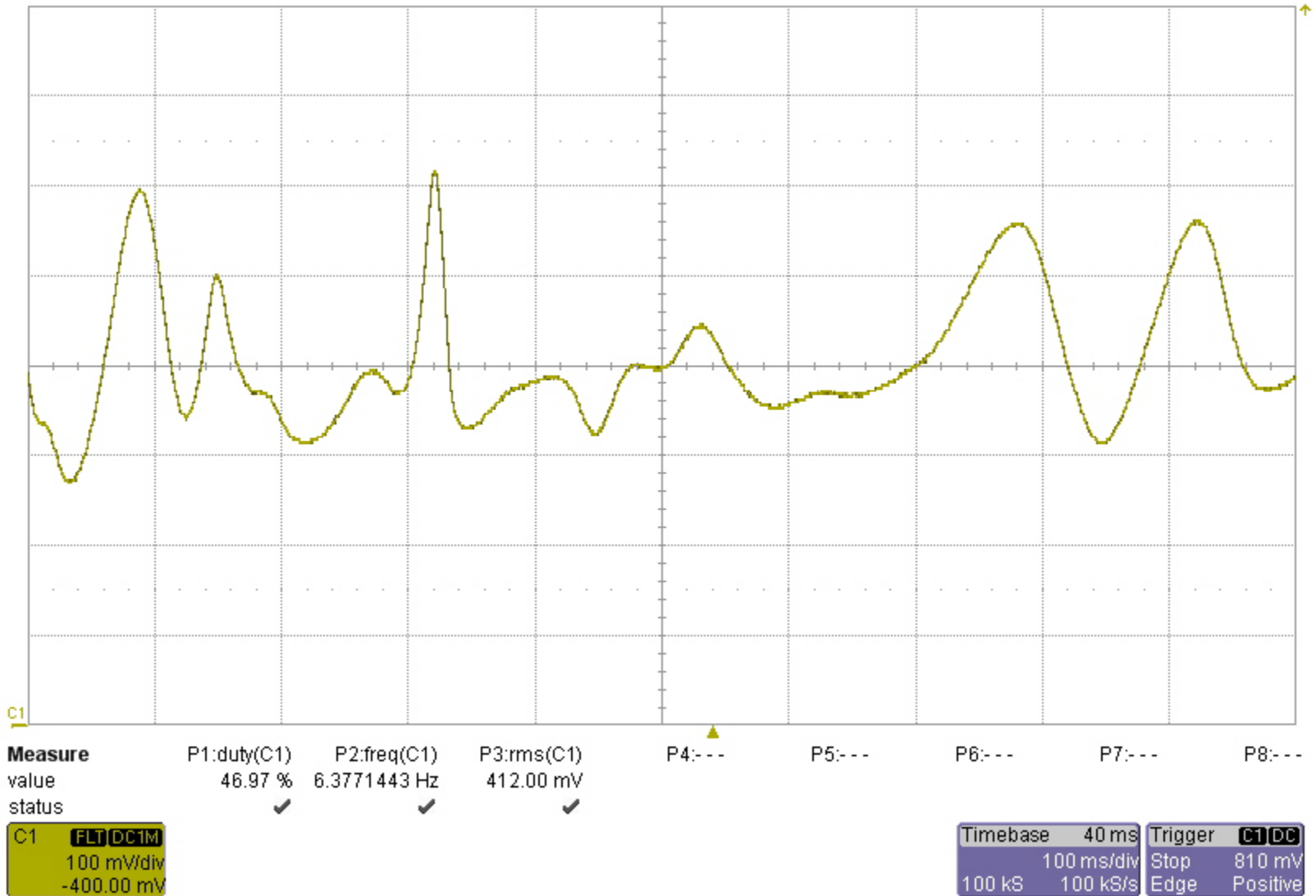
Moonlight at 3:20am, clear sky.
Recorded 22feb14 in Sunnyvale, CA USA
Approximately 0.7 lux, 4,700K, 98 CRI

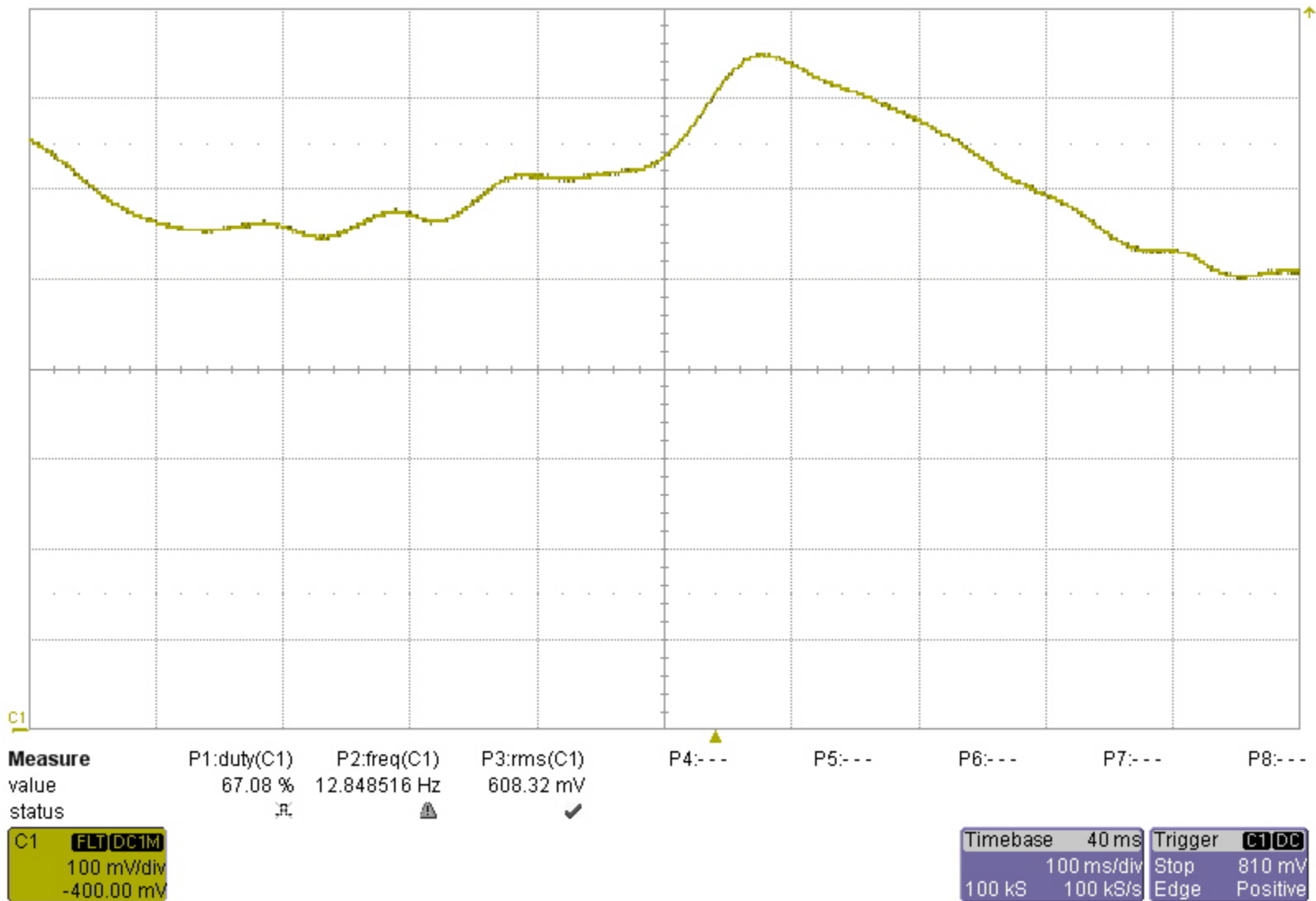


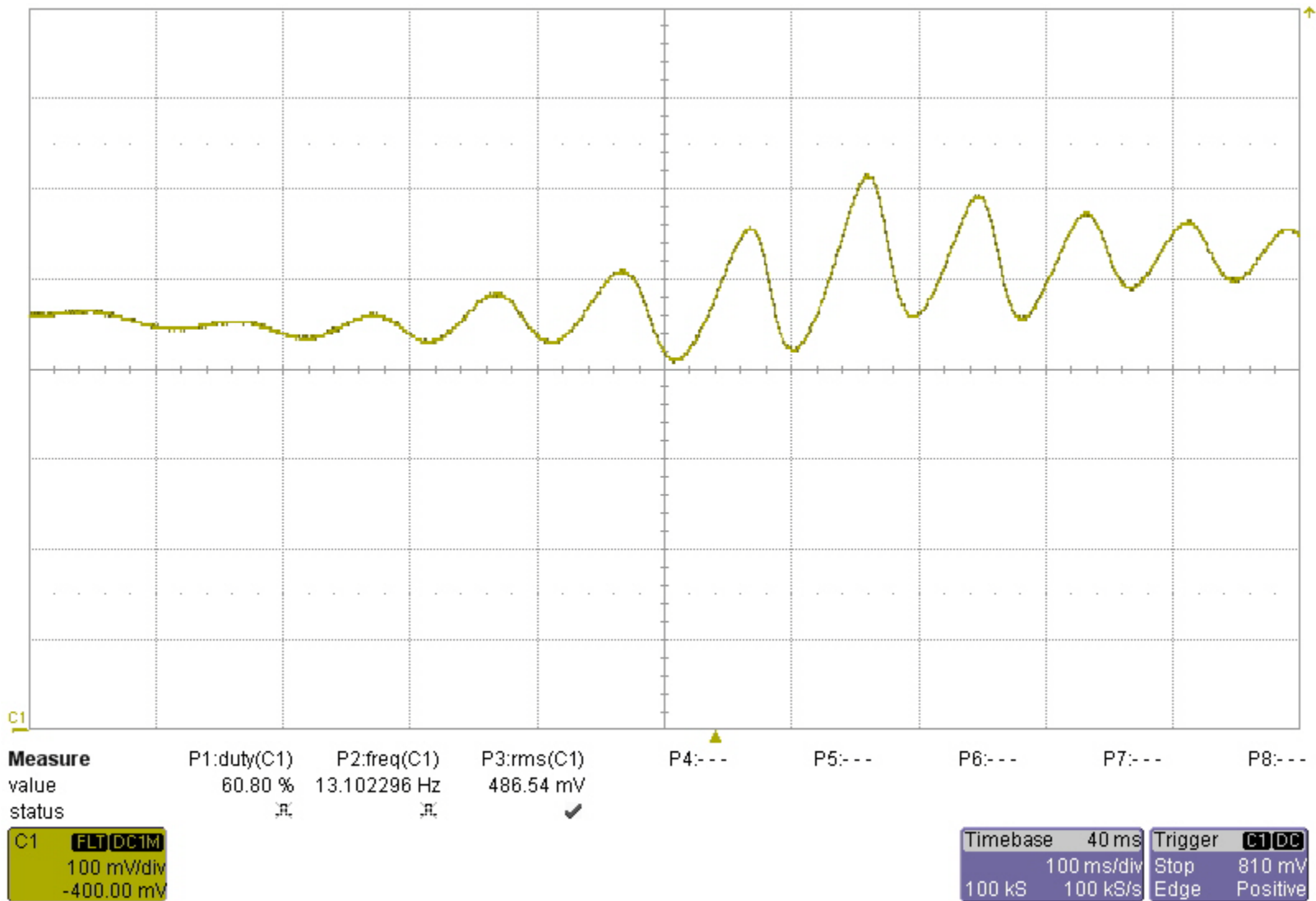
Light Recorder



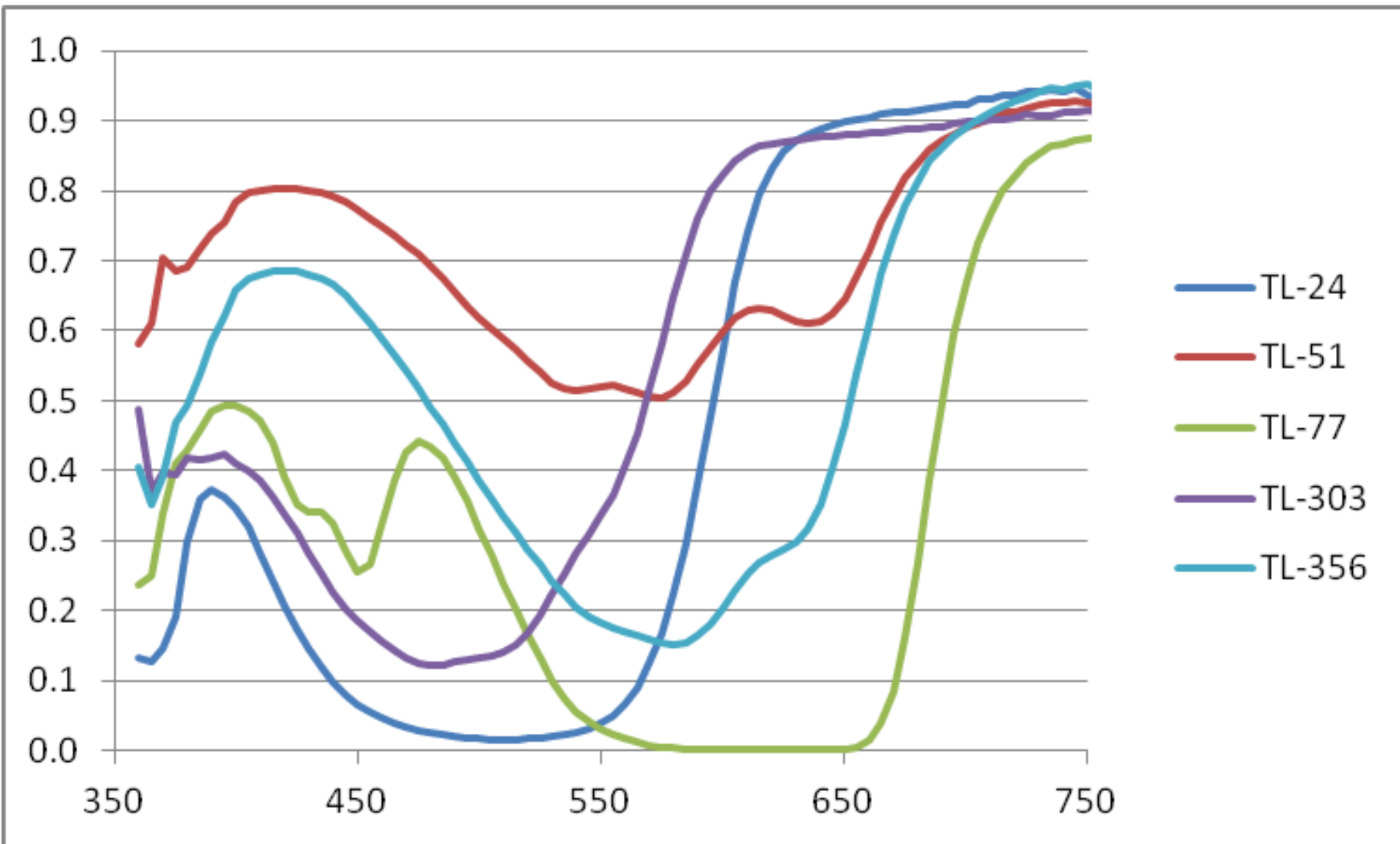
Candle Flame from Photometer – 1 sec



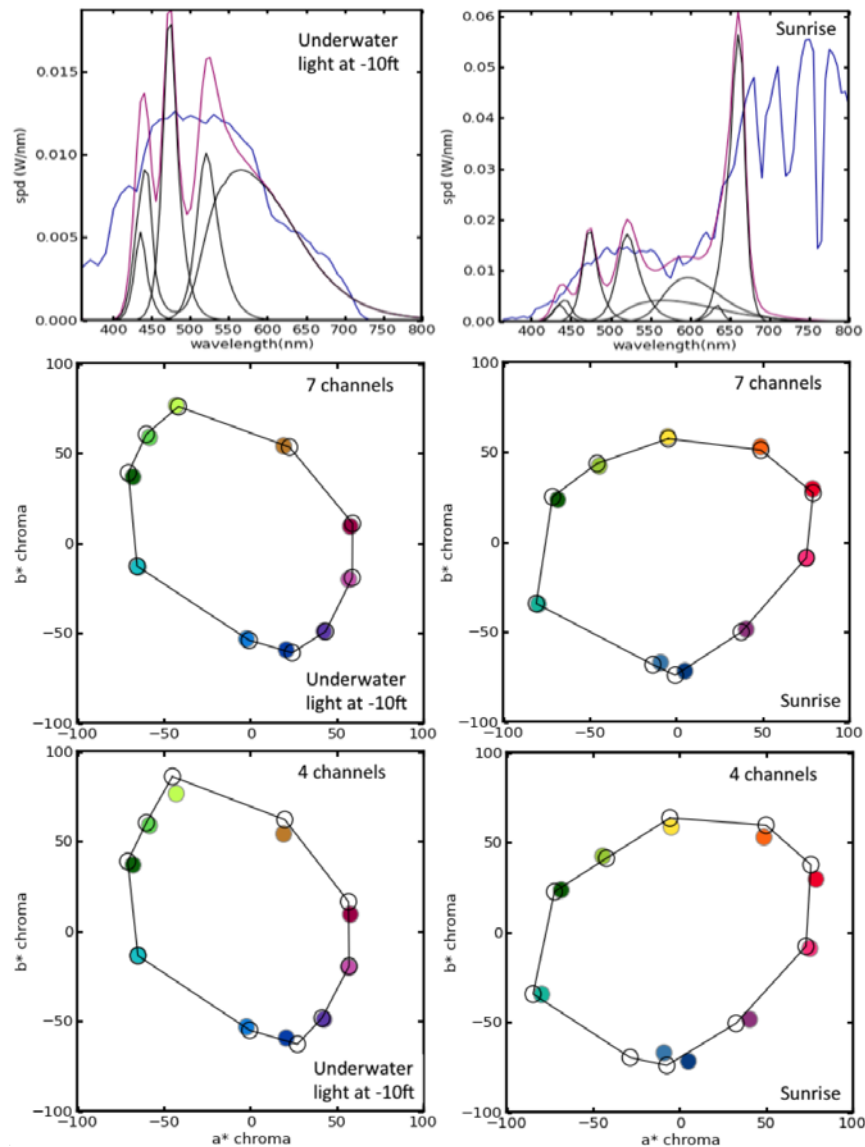




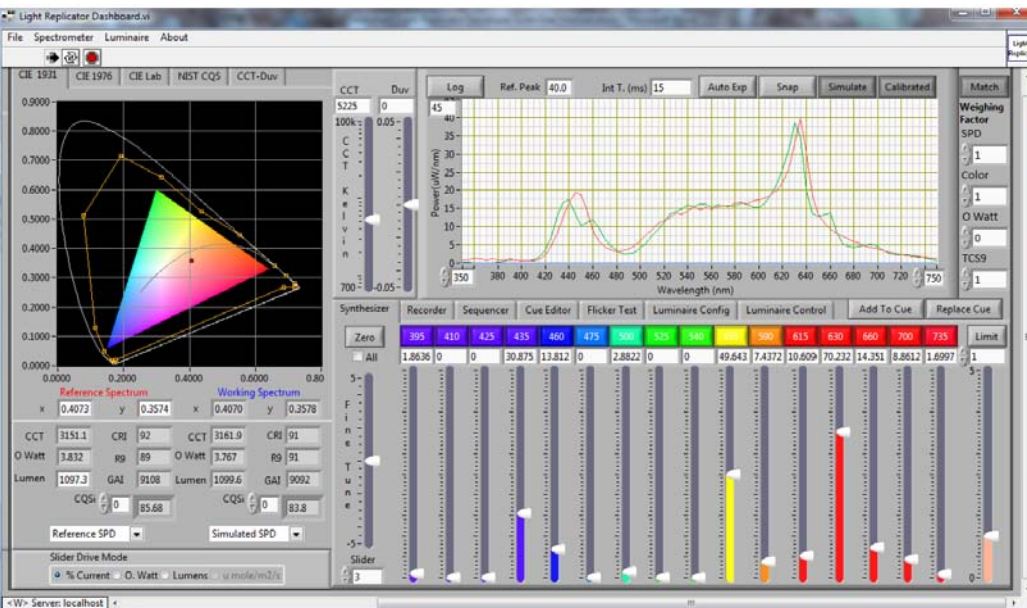
Theatrical Filters



Non-white illumination reproduction by 4 and 7-channel light sources evaluated with Rosco filters as a reference color palette



Create/Record, Edit, Playback GUI Example



This panel shows the 'Recorder' and 'Sequencer' sections of the software. The 'Recorder' section includes controls for 'Spectrometer' (On Line, Monitor, Replicate), 'No of Frames', 'Scan Interval', 'Start Time', 'Frame No.', 'Save Interval', and 'Current Time'. The 'Sequencer' section has a 'Frames to Add' control and playback buttons (Load Spectrum, Save Spectrum, Save Iso). On the right, there is an 'Active Spectrometer' list with 'Simulation' selected, and buttons for 'Reset Offset', 'Meas. Offset', and 'Zero Recorder'. A 'Frame Time' field is set to 199.

The 'Cue Editor' section displays a table of cues with columns for Color, Name, Wait, Fade Up, Hold, and Fade Dn. Below the table is a 'GoTo Cue' field set to 13 and a 'Cue Pair' field set to 11, 12, 13, 14. A graph shows 'Amplitude (%)' on the y-axis and 'Time (second)' on the x-axis, with a dashed line indicating a fade-in and a solid line indicating a fade-out. Buttons for 'Clear Cue', 'Load Cue', and 'Save Cue Iso' are present, along with radio buttons for 'Load Native Data (slider)' and 'Load Generic Data (SPD)'.

This panel shows the 'Sequencer' and 'Luminaire Control' sections. The 'Sequencer' section has 'Record time' (00:00:00) and 'Current time' (12:25:05) fields, a 'File Name to Receive/Delete' field, and a track list with 12 items. The 'Luminaire Control' section on the right includes 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'.

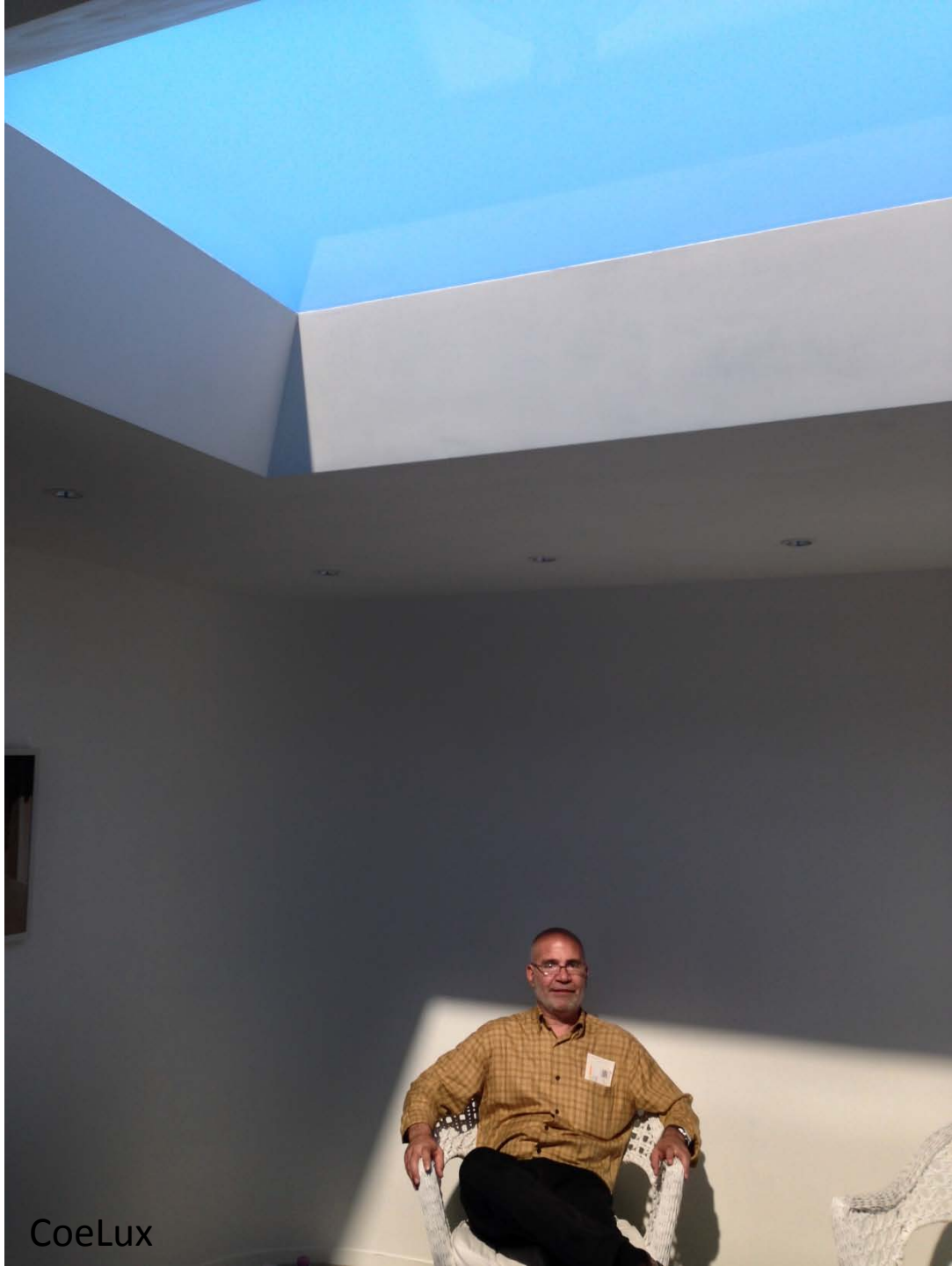


Fraunhofer





CoeLux



CoeLux

Beyond Replication

- “Fix” a cloudy day – fill in filtered daylight
- Augment real time
 - Stretch, compress, shift
- Designer spectrum – purposeful distortion
- Design from scratch
 - Health
 - Productivity
 - Enjoyment

Controls – looking ahead

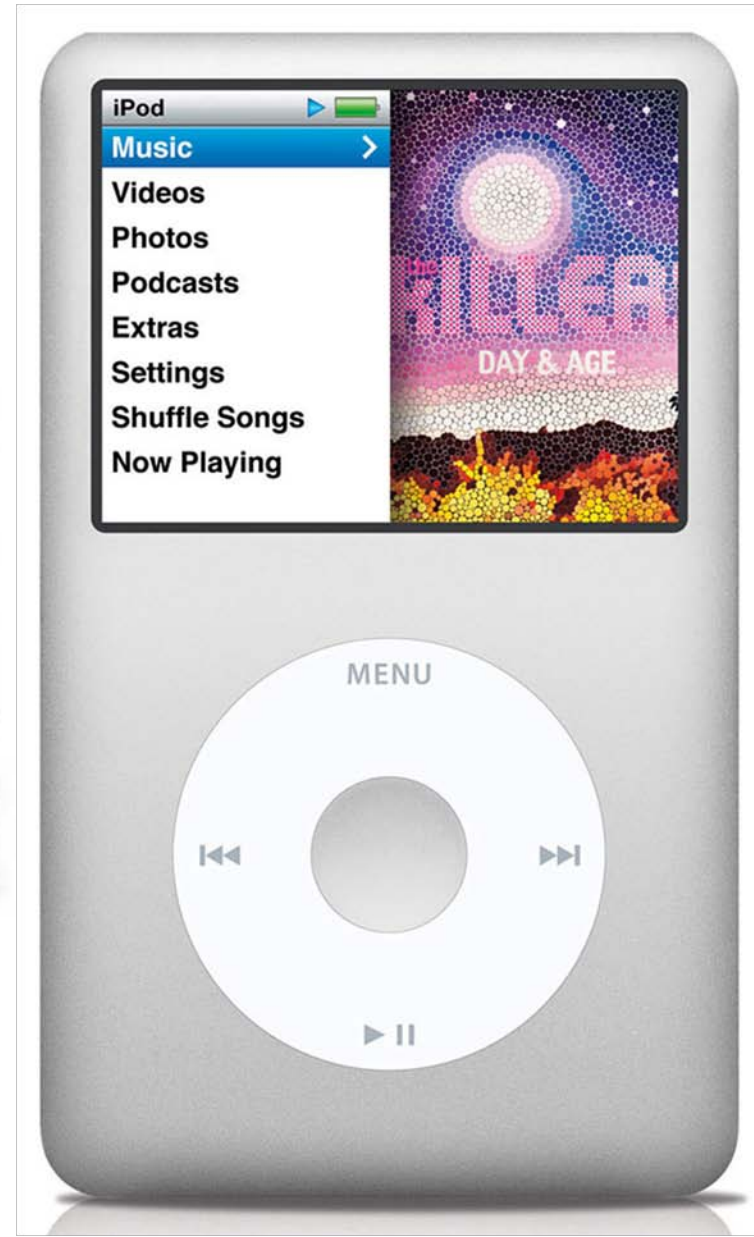
Most light consumers don't want to tinker with the details, nor do they have a professional to take care of them.

- They want to experience the energy
- With the ease of selecting a song or a movie
- Not composing a song or fiddling with a color wheel

Tinker with the Lights



Tinker with sound vs. Experience it



Controls – the legacy

Triac – stop now before its too late

0-10v – analog volume control, build a bridge

DALI – simple digital, build a bridge

EnOcean – self-powered wireless, build a bridge

DMX – powerful digital, build a bridge

MIDI – musical digital, worth a look

None are ideal for light players, in general build a bridge.

In the near future...

We believe lights will become light players.

Light songs (LumenScripts) may also have audio and video tracks.

- Movies started without sound
- Recorded music started without video

Light players will impact the smart home, enhance the retail experience, and improve the biological response.

**The more dimensions we control
– the more powerful the experience.**



Vielen Dank für Ihre Aufmerksamkeit
Thank You

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