



Don't Blink


**The Importance of Sampling Rate in
Monitoring UV LED Curing Applications**



March 10, 2020

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EIT Instrument Markets**



- Sampling Challenges and Rates
 - Radiometer Sample Rates
 - Broadband vs. LED sources
 - Irradiance Profiles
 - Readings From Digital Printers
- 

How often should I measure?

The measurement frequency should not be confused with the instrument sample rate

Considerations

- Type of product, process window and risk factors
- Value of product, line speed and risk tolerance
- Stability of the UV System/Process
- Human Error

30+ Years of Technology Changes

- Cell Phones
- Cameras
- Computers



Sampling Challenges

Political

- Dewey Defeats Truman November (1948)
- And the winner of the election is ... (November 2020)



Consumer Products

- New Coke taste (1985)

Personal

- Honest officer, my average speed was much less (Everyday)



Radiometer Sample Rates



**5-40
Samples/second**

**128-2048
Samples/second**

**Over sample, effective sample
rates of 128-2048 Samples/second**

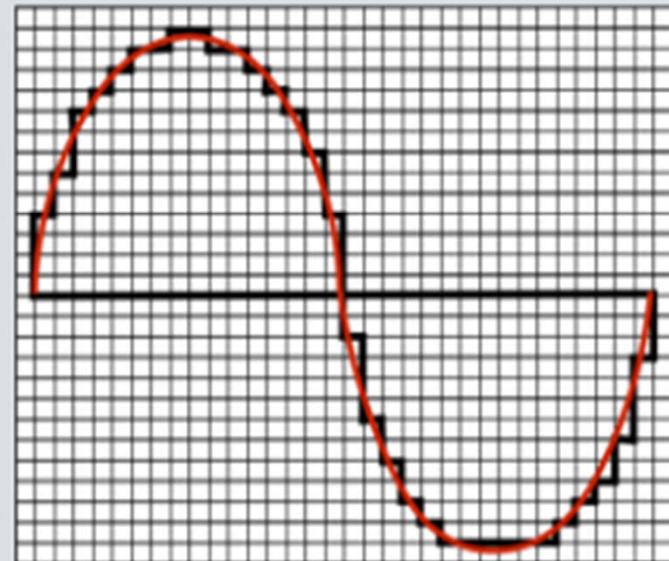
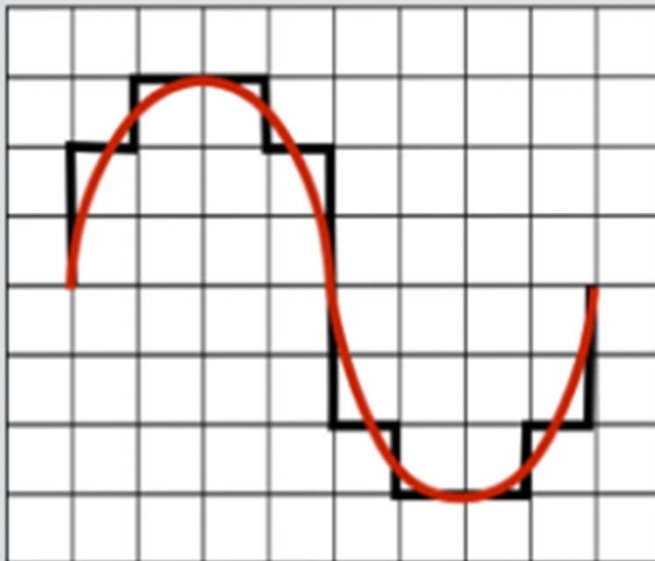
- Radiometer sample rates have changed over time
- Sample rate used a function of UV source and line speed
- What is needed for the future?



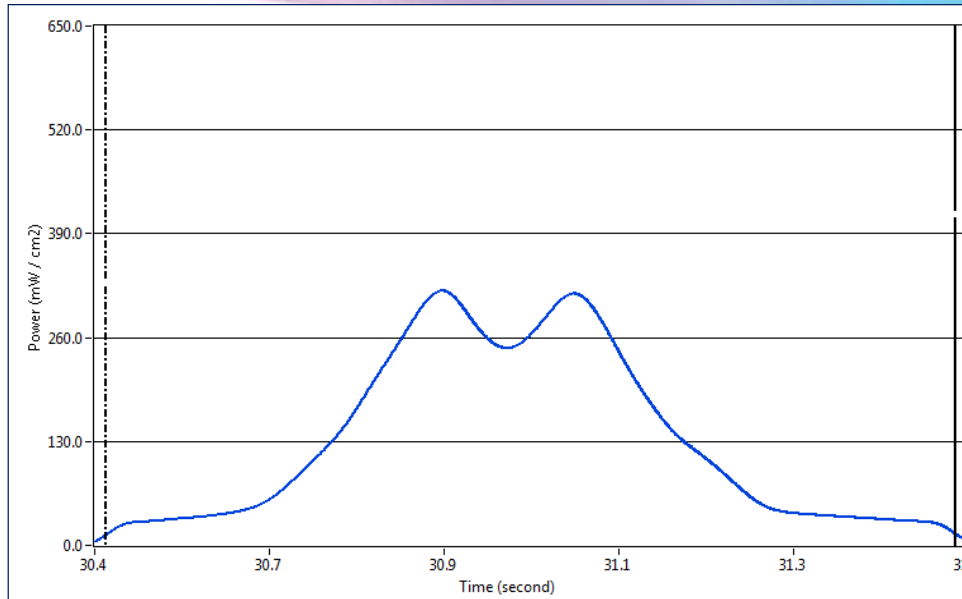
Low vs. High Sample Rate

A higher sample rate on the right better captures dynamic changes in the process

Low Sample Rate **VS** High Sample Rate

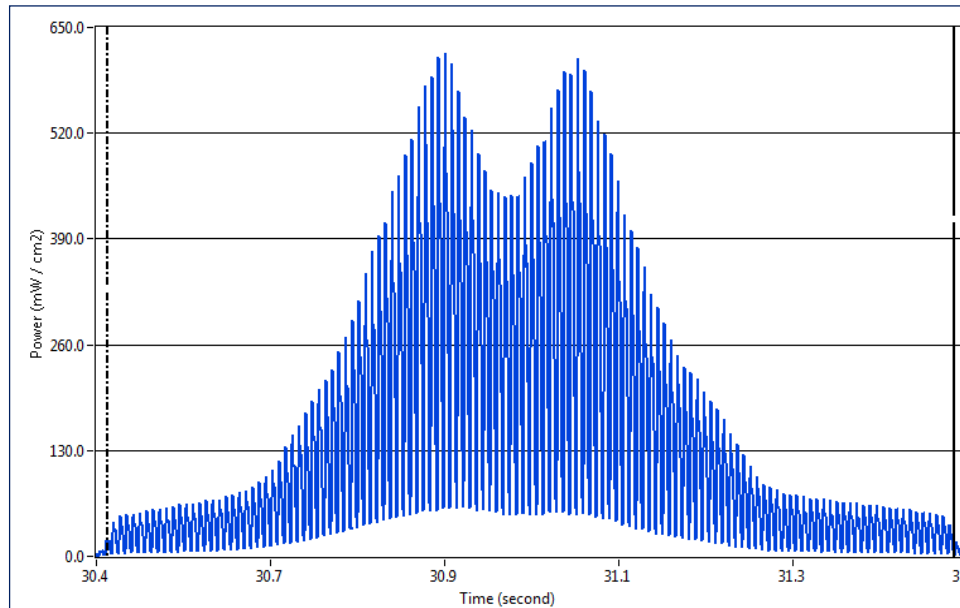


Radiometer Sample Rates



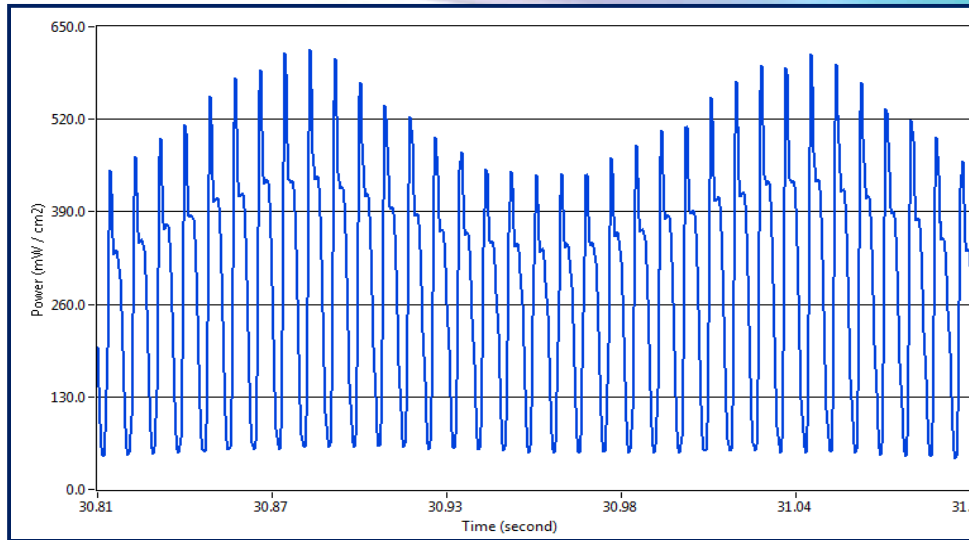
Peak irradiance is **318.3 mW/cm²** and the energy density is **139.9 mJ/cm²**

AC Versus DC Powered Lamps

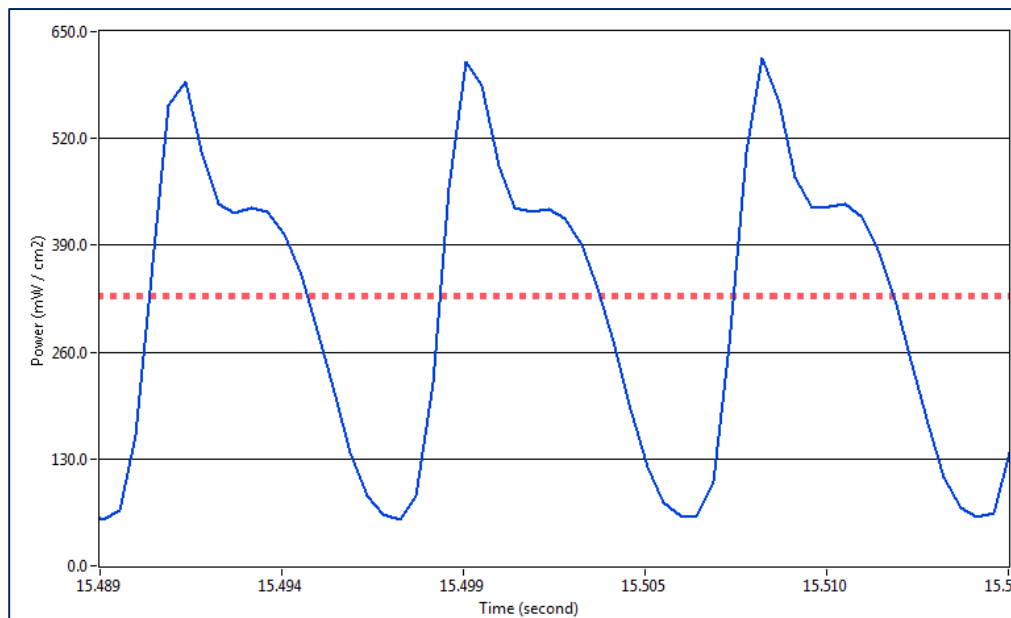


Peak irradiance is **618.0 mW/cm²** and the total energy density is **139.9 mJ/cm²**

Radiometer Sample Rates



Close up of irradiance profile

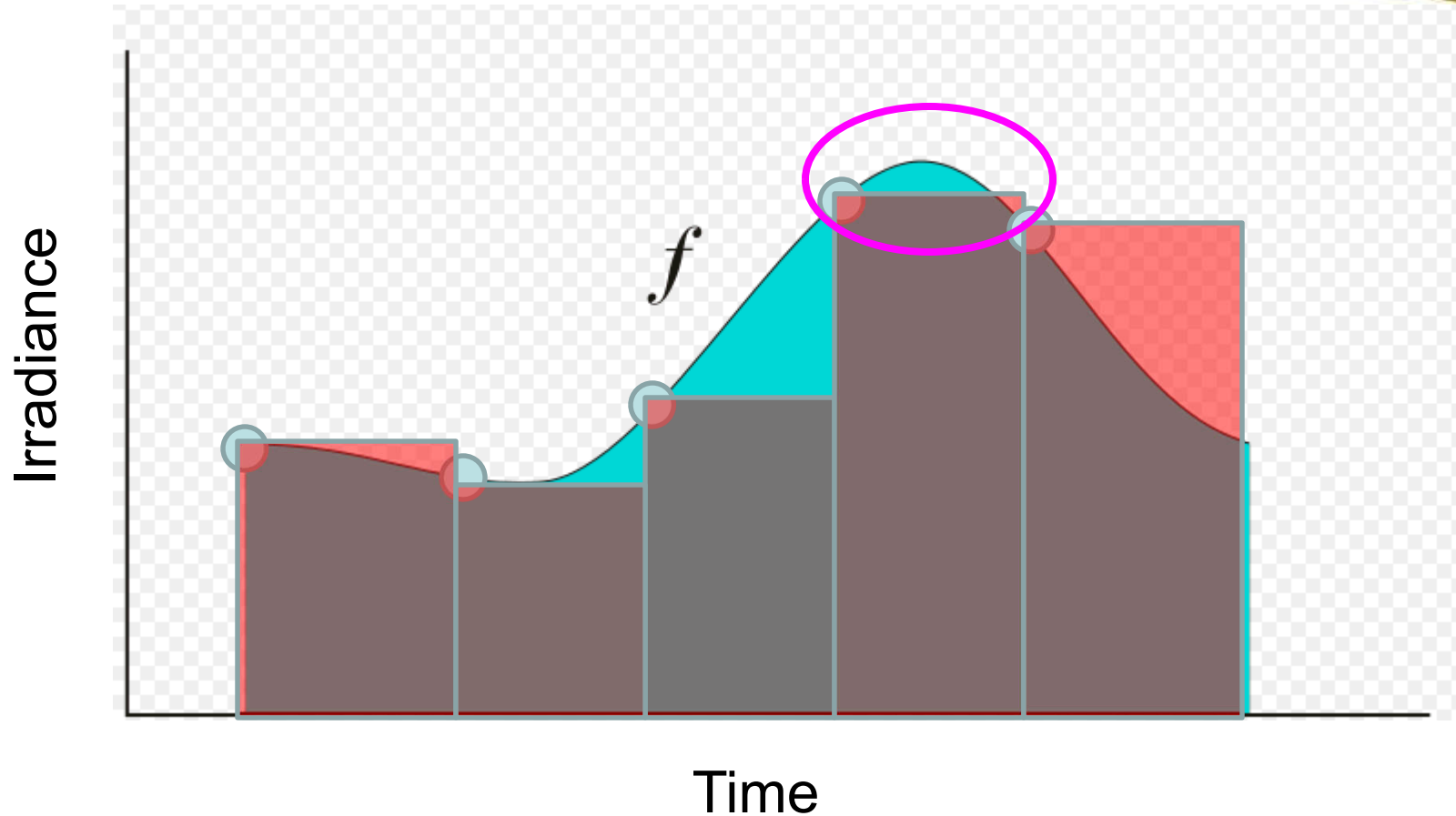


Blue trace shows showing AC cycling of the irradiance profile

Red trace shows RMS (average) irradiance profile

Radiometer Sample Rates

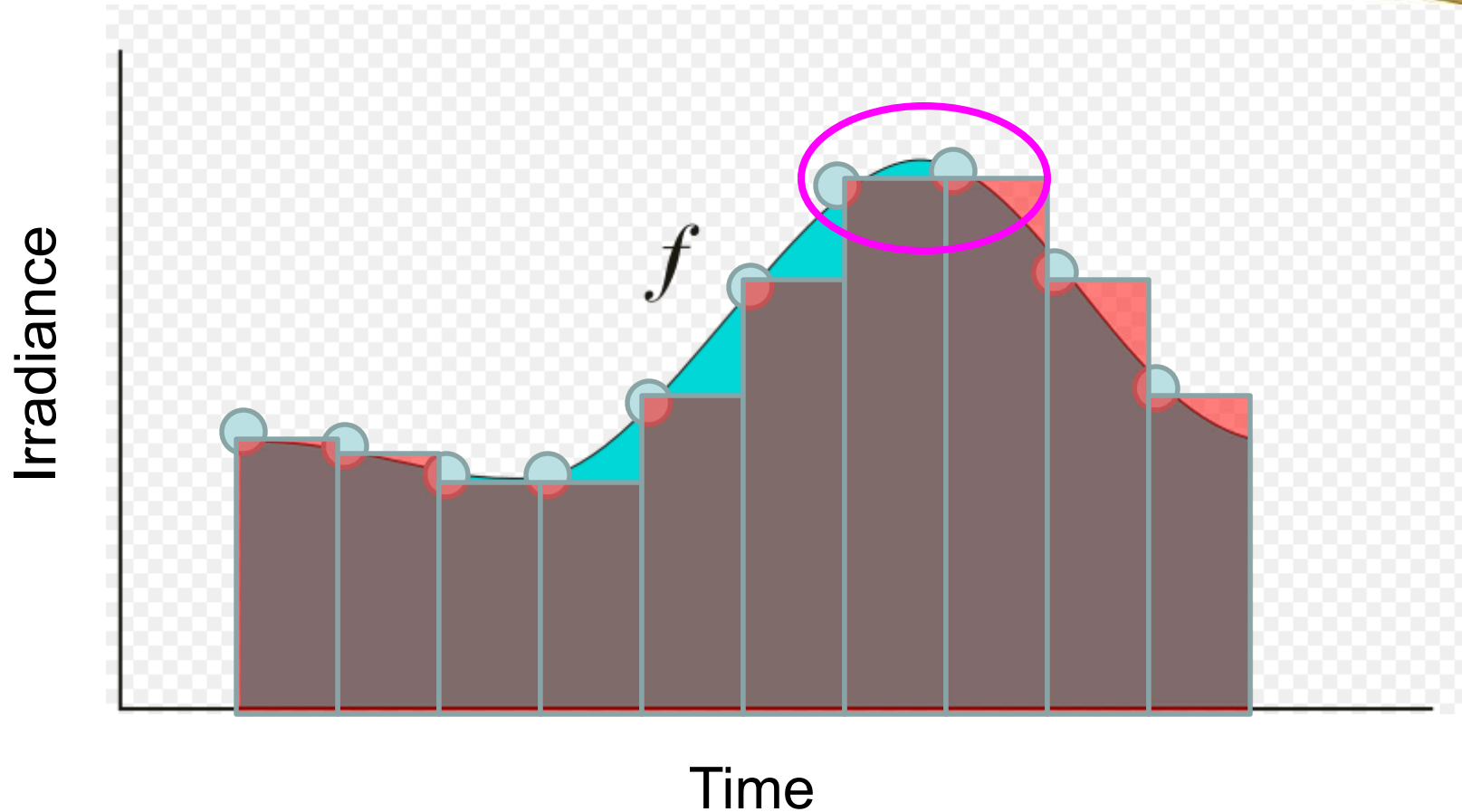
Sample Rate



“Missed” the peak irradiance value

Radiometer Sample Rates

Sample Rate



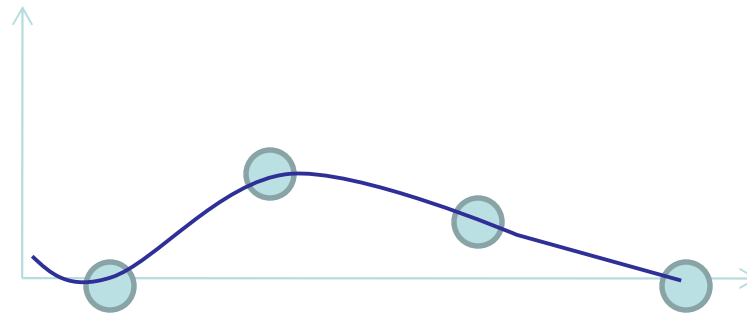
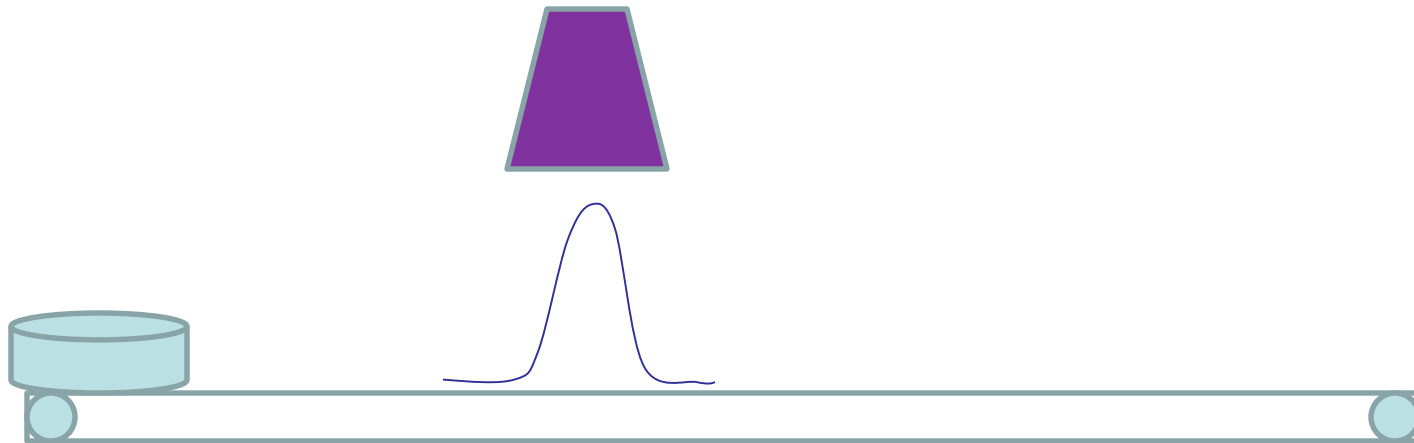
Better chance of "catching" the peak irradiance

Radiometer Sample Rates

Sample Rate

What works well at one-line speed...

Sample 2 Hz

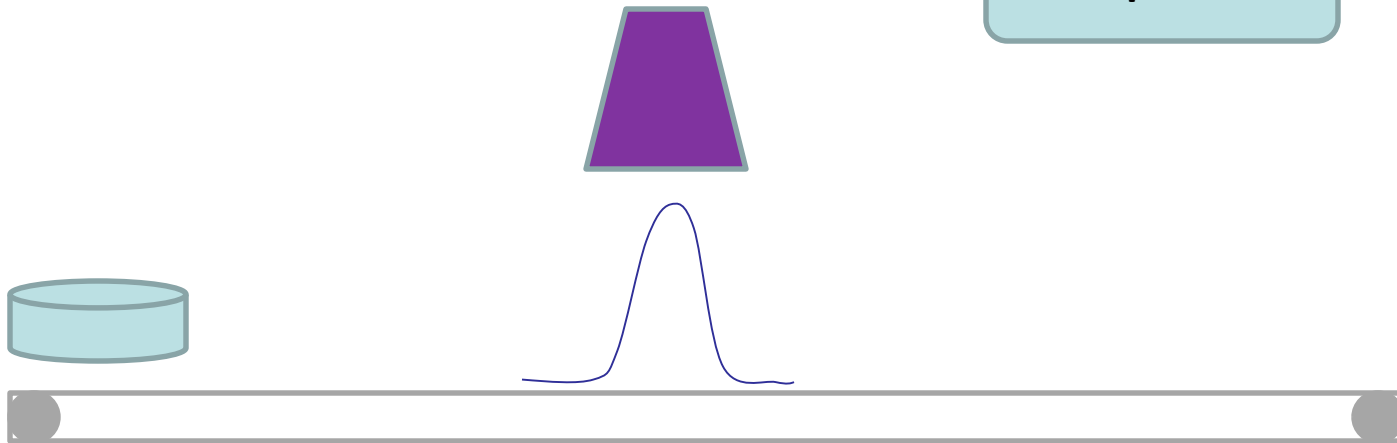


Radiometer Sample Rates

Sample Rate

May not work well at another.

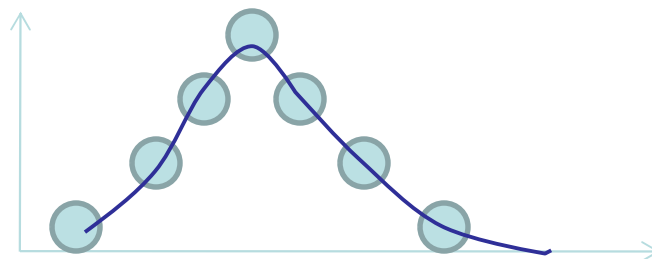
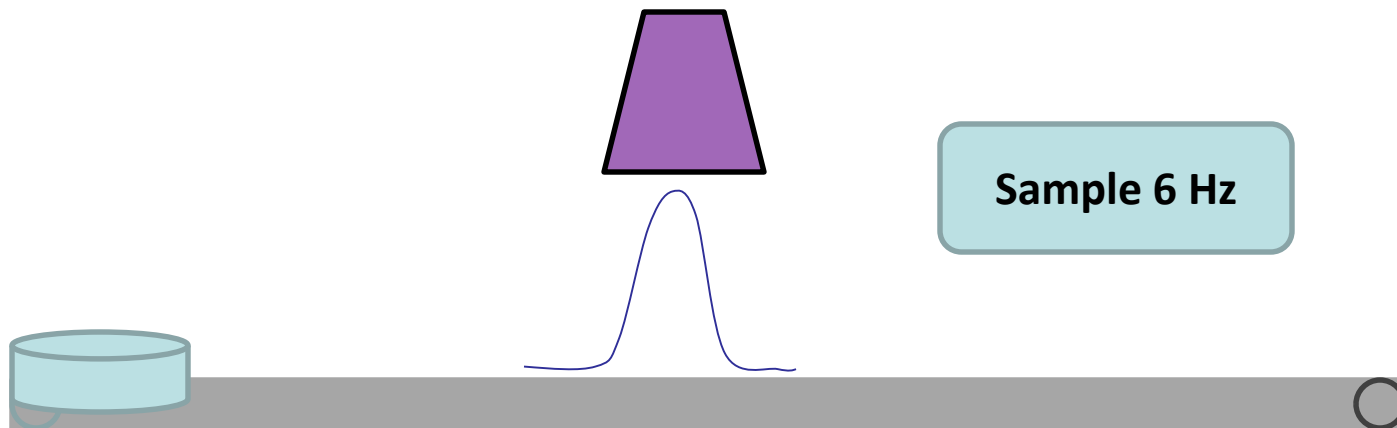
Sample 2 Hz



Radiometer Sample Rates

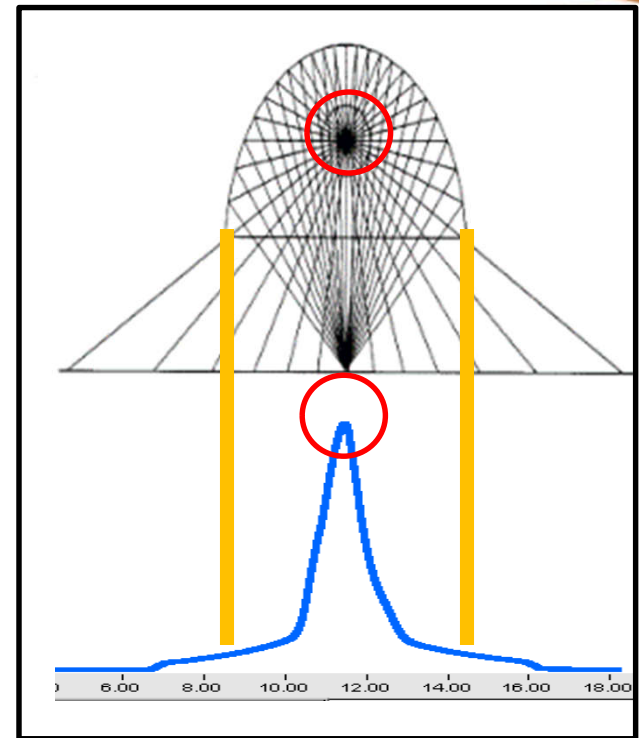
Sample Rate

- The sampling rate must be appropriate for the process.
- Rates can vary from 5 to 30,000 samples/second



Broadband Mercury Sources

- Broadband source that is focused may have a bulb diameter of 0.35-1.02" (9-26 mm).
- The overall distance from one side of the reflector to the other will vary based on the design of the lamp housing and reflector
- The peak irradiance corresponds to the diameter of the bulb **(Red)**
- The UV collected under the reflector is also shown. **(Orange)**



Broadband Mercury Sources

- Values based on a broadband mercury bulb, 0.75" diameter and 6" reflector
- Estimated samples at 128 Hz & 2048 Hz

Line Speed (Feet per Minute)	Instrument Sample Rate (Hz)	Estimated Number of Samples collected under the Reflector	Estimated Number of Samples collected under the Peak
25	128	154	19
50	128	77	9.6
100	128	38	4.8
200	128	19	2.4
400	128	9.6	1.2
25	2048	2458	307
50	2048	1229	154
100	2048	614	77
200	2048	307	38
400	2048	154	19

LED Sources

- The UV output area on an LED is generally smaller than the corresponding output area on a broadband source
- Common widths of the active “LED chip” area for LED sources can vary between 0.4-2.0” (10-50 mm)
- Most LEDs do not utilize reflectors
- Only direct under “chip” values
- Power Supply: DC driven



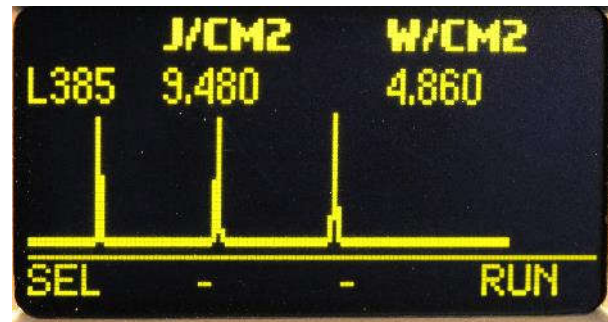
Photo Courtesy Excelitas

LED Sources

- Values based on a LED with 1" (25.4 mm) window
- Estimated samples at 128 Hz & 2048 Hz

Line Speed (Feet per Minute)	Instrument Sample Rate (Hz)	Estimated Number of Samples collected under the LED
25	128	25.6
50	128	12.8
100	128	6.4
200	128	3.2
400	128	1.6
25	2048	410
50	2048	205
100	2048	102
200	2048	51
400	2048	25.6

Sample Rates

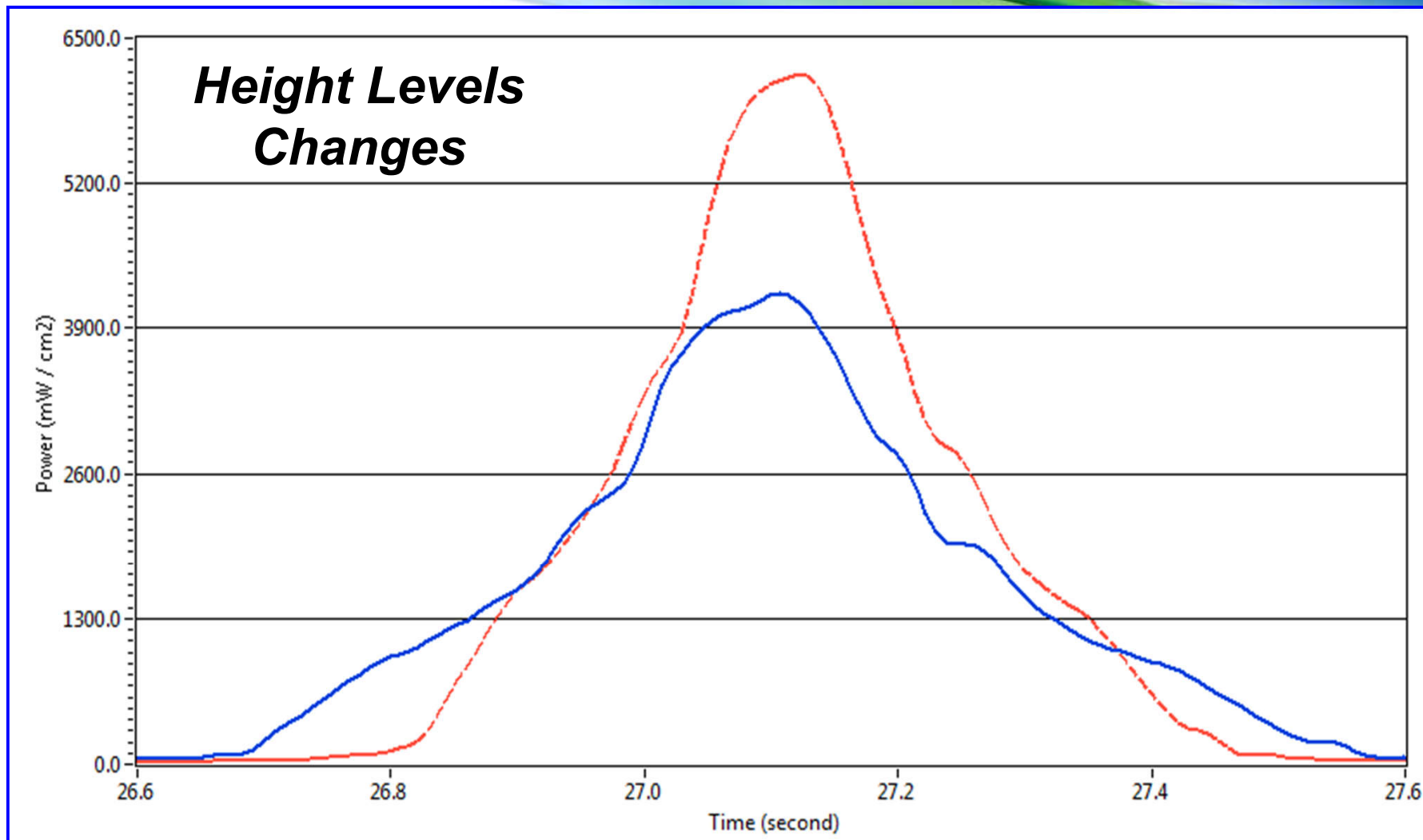


- Single L-Band (L365, L385, L395 or L405), Dynamic range of 40 W/cm²
- Standard (Display) or Profiler (Display and Computer) Versions
- Adjustable sample rate Choices (25-128-2048 Hz)
 - Smooth On: 25 Hz: **Stop using Smooth On!**
 - Smooth Profiler: 128 Hz: **Rate of data transfer to software**
 - Smooth Off: 2048 Hz: **Fastest, matches PowerMAP II & LEDMAP**

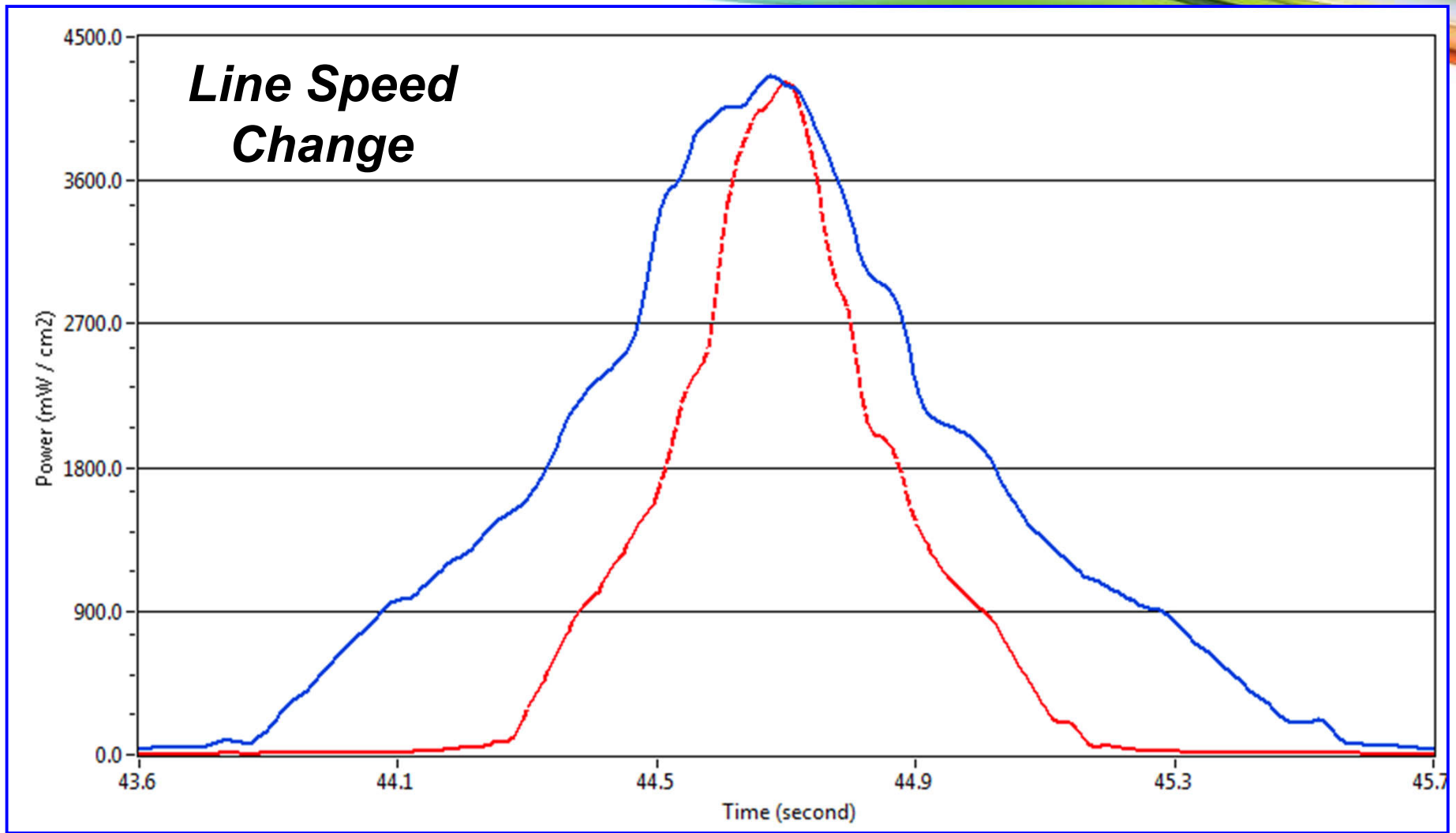
Profiling Radiometer

- Measure the peak irradiance and total energy density
- Profile the irradiance as a function of time
 - Some also profile temperature
- Software or Display
- Irradiance profiles useful to:
 - Analyze system changes over time
 - Compare multi-lamp systems
 - Trouble shoot lines
 - View lamp focus
 - Determine lamp type
 - Power supply analysis

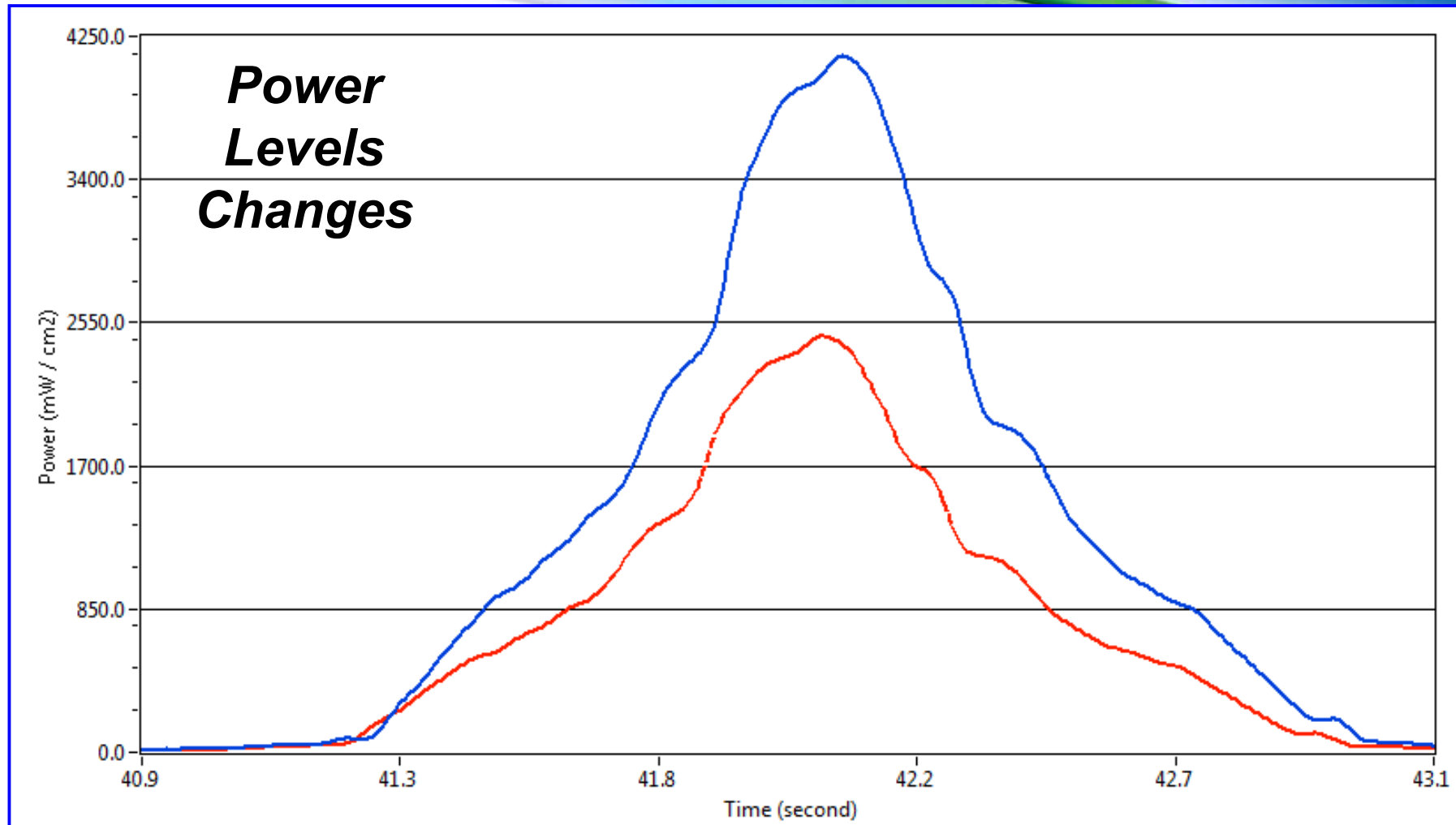
Profiling Radiometer



Profiling Radiometer

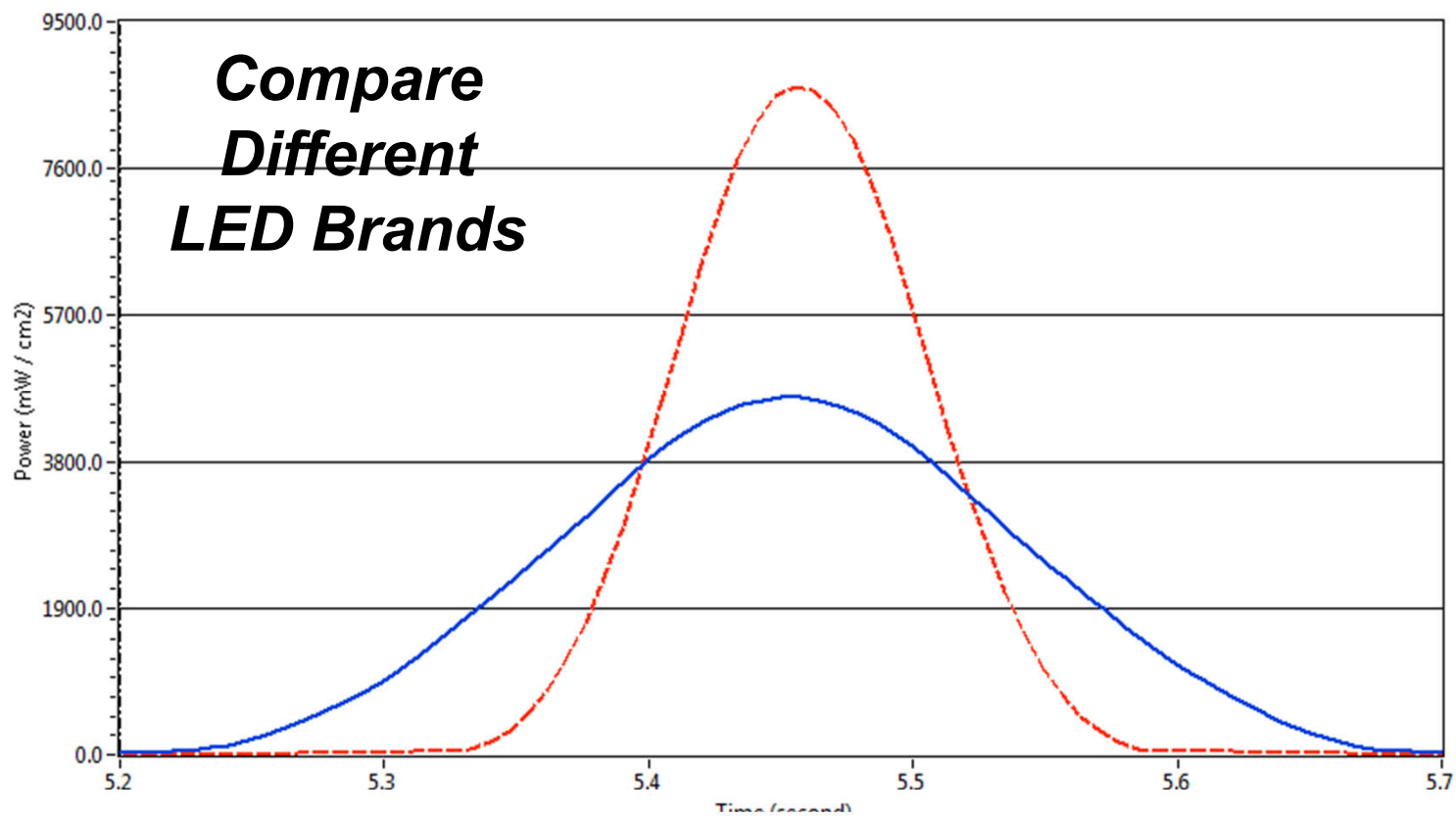


Profiling Radiometer



Profiling Radiometer

Compare Different LED Brands

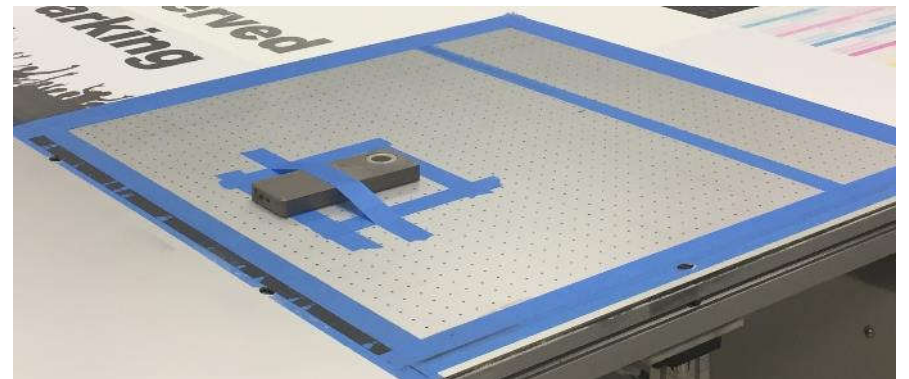


Summary By Table

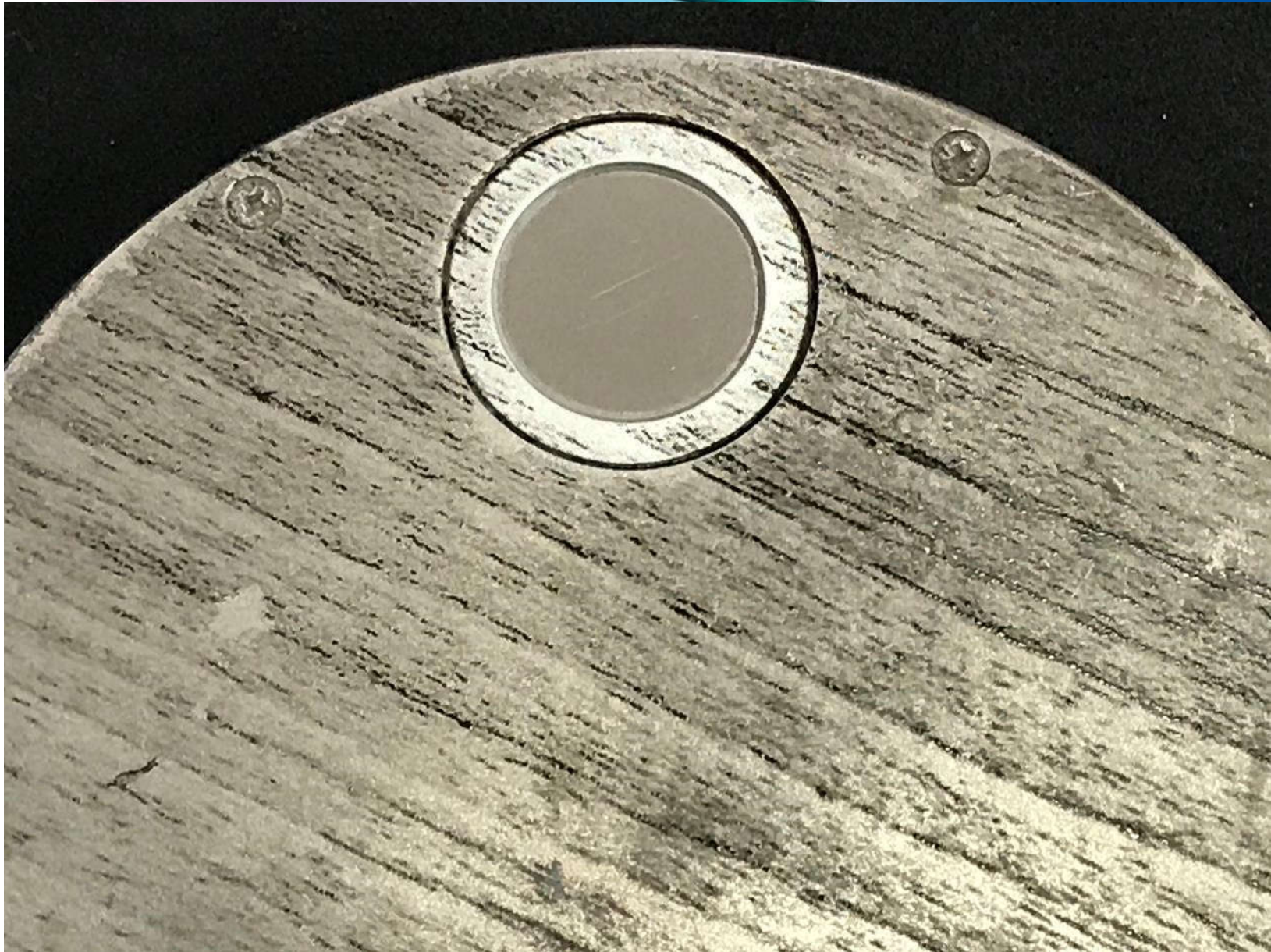
	Sample File	Reference File	Difference	%
L395- Power (mW/cm ²)	4625.233	8657.664	-4032.432	-46.6
L395- Energy (mJ/cm ²)	1104.068	1102.970	1.097	0.1
Enable cursors	ON			
Time	6.05			
Time - Ref	5.18			

Digital Printers

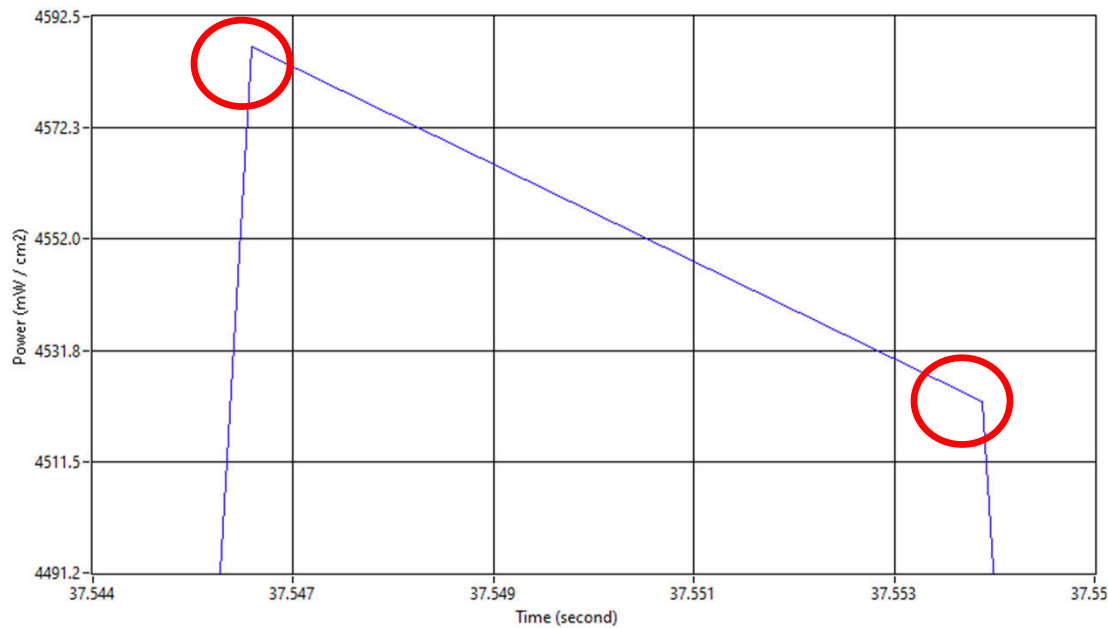
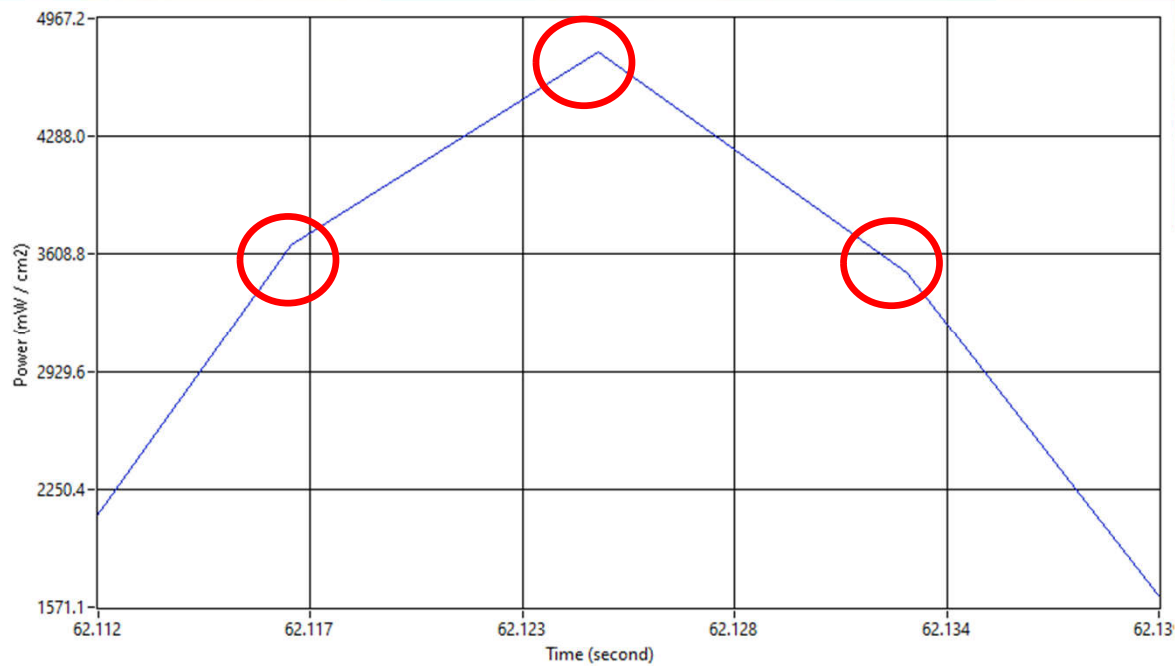
- LED source on either side of print head
- Increasing production speeds up to 400+ fpm
- Axis of motion:
 - Back and forth travel of print head
 - Print bed also moves
- Secure instrument to print bed
- Ways to measure
- Multiple passes
- Make sure inkjet is off



Digital Printers



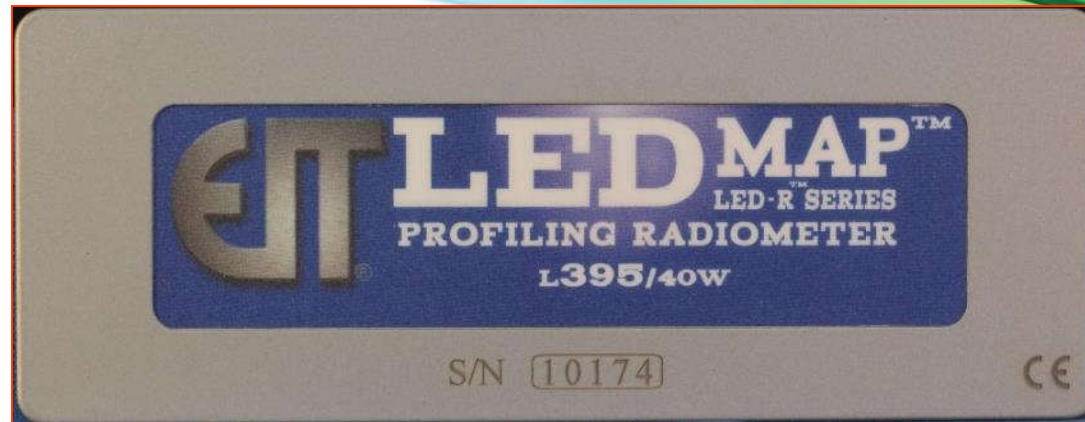
Digital Printers



Examples of instrument sample rate not matched to the UV source and collection speed

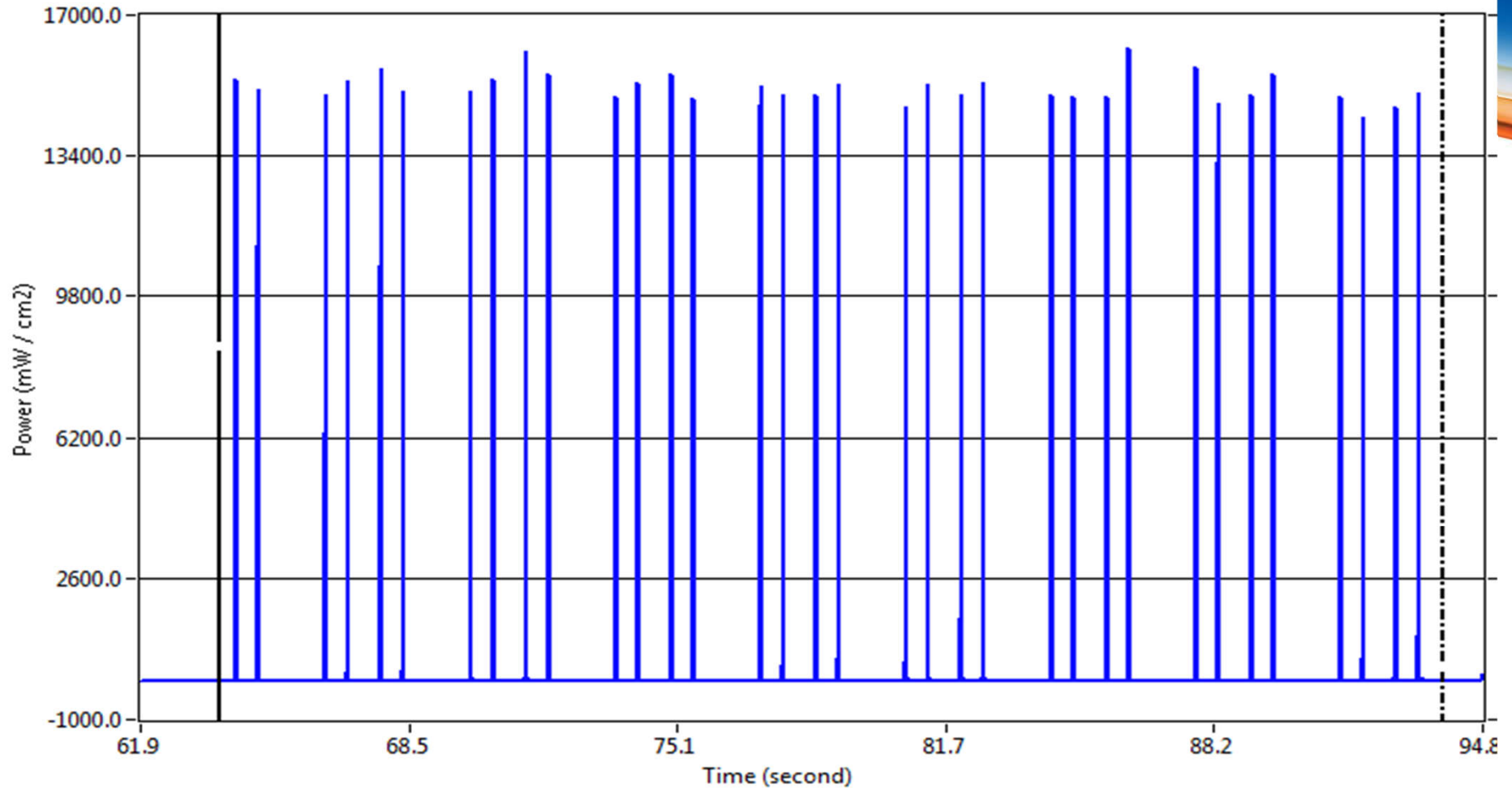
Individual data points shown in red

Digital Printers



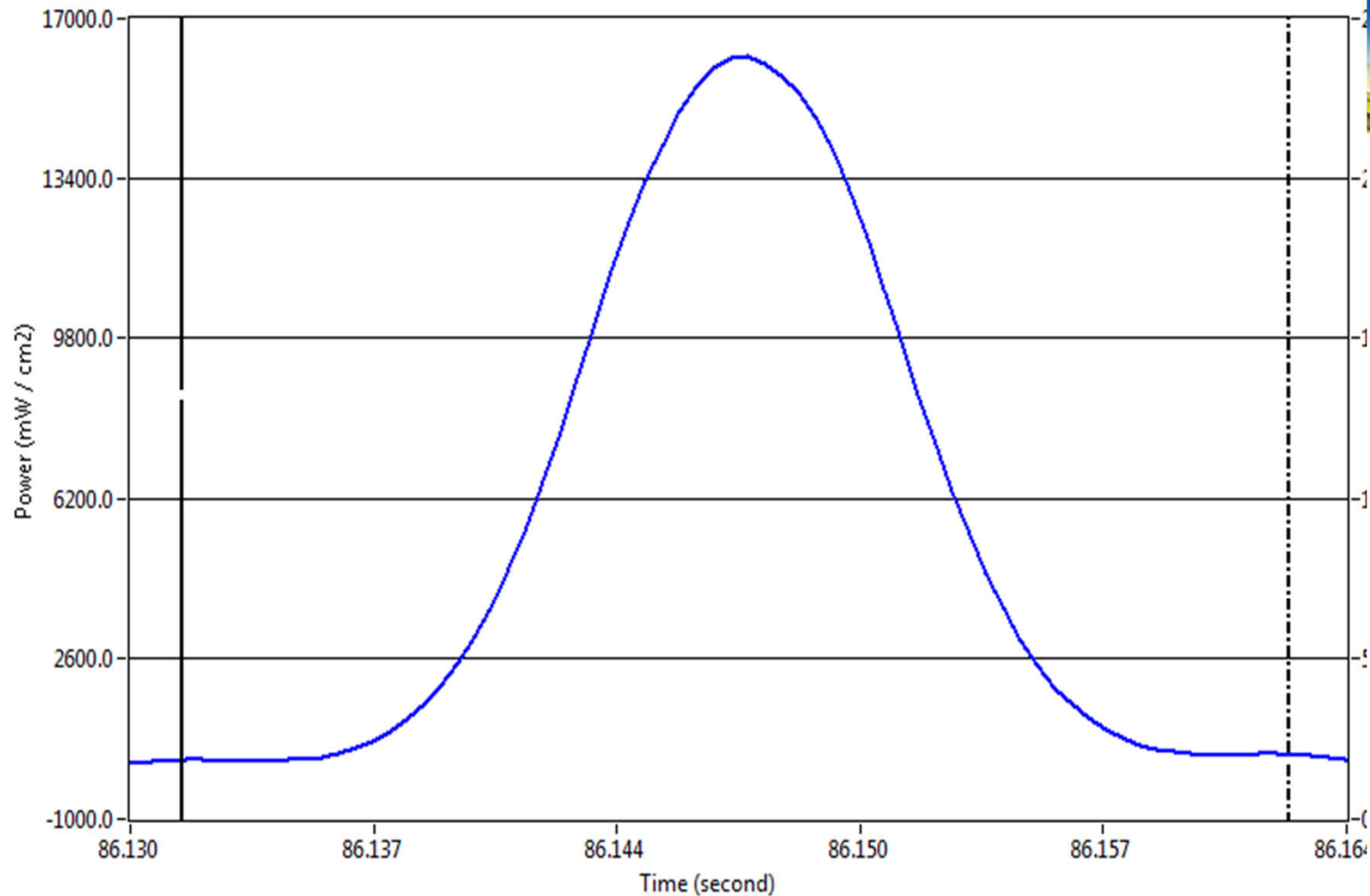
- LED radiometer built on the PowerMAP® II platform
- Released as L-395 single band
- L-Band Plus Temperature Profiling Radiometer
- User adjustable sample rate (128-2048 Hz) allows for accurate LED measurement in fast LED applications such as digital printers

Digital Printers



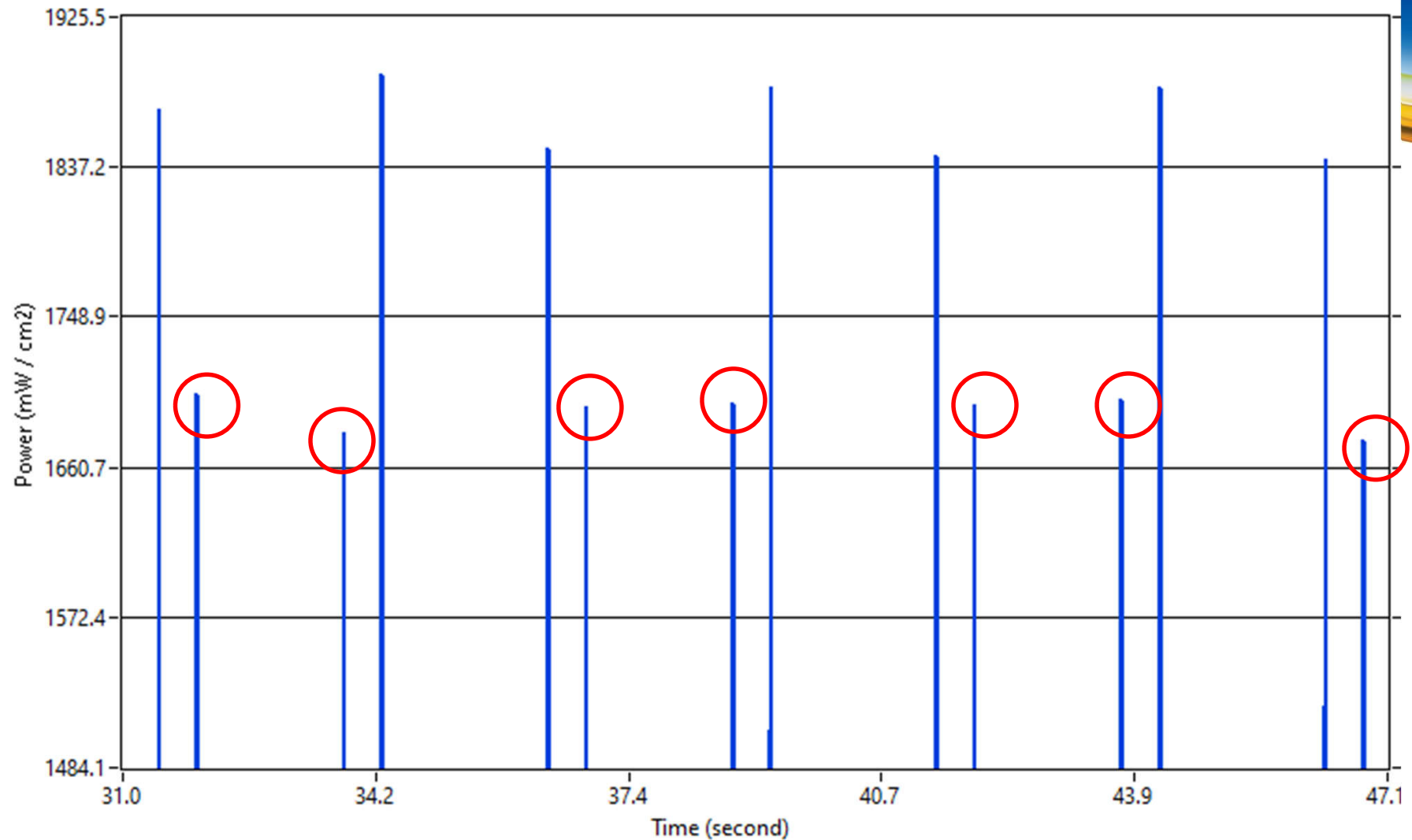
Digital printer: 34 individual LED peaks collected over 30 second interval at a speed of 400 fpm. The sample rate was 2130.5 Hz.

Digital Printers



Single pass from digital printer with LEDs. The time between the cursors is 0.03 seconds. At a sample rate of 2130.5 Hz, this equates to 64 individual sample points on the irradiance profile


Digital Printers



Comparison of Left and Right UV sources with a significant difference between the two sources



Summary

- Effective (equivalent) sample rate found in many of today's high-quality production radiometers allows better resolution
 - Understand your radiometer and its limits for data collection.
 - Wide variations in irradiance values from one run to another may indicate an insufficient sampling rate.
 - Select a sample rate that is appropriate for the application and collection speed.
 - Remember to collect data in a manner that does not damage the process equipment, instrument, or injure the person trying to 'catch' the instrument.
 - Follow speed limits and avoid going to UV traffic court
 - Tests are on going on fast digital printers
- 



Thank you



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