Great UV Measurement Expectations

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EIT Instrument Markets

When it comes to UV measurement, one could make the case that too often that the "Dickens Rule" applies. UV users hope, on the one hand, for Dickens' great expectations; and then reality sets in and at one time or another most users have screamed: "What the Dickens is going on with my UV System?"

In this article we will look at three areas of UV Measurement and how each impacts users' great expectations:

- Process & Communication Expectations
- Instrument Expectations
- Dealing with Readings Outside Expectations

Process & Communication Expectations

Make sure you know what you've got before it's gone

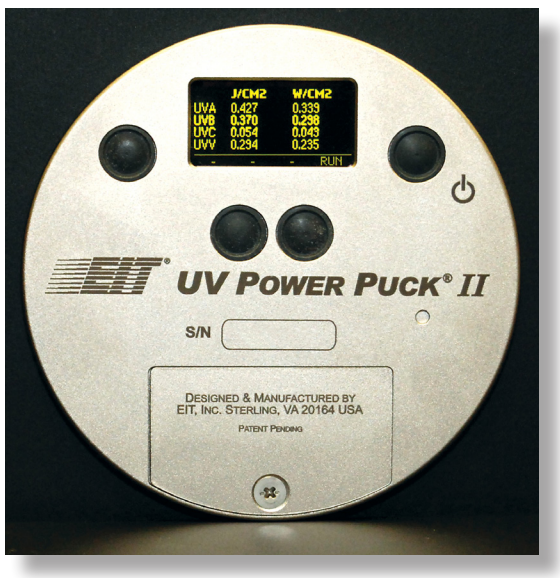
Producing quality products requires an understanding of both your equipment and the UV process. When your UV process is running smoothly, life is good. When your process is not curing, often it takes so long to get back to where you need to be because you failed to document, track, measure, monitor and maintain during your trials, not when you are in production. The trials are also a time to improve or establish a relationship with all suppliers which should include coatings, equipment, measurement and substrate suppliers.

When you fail to communicate

Communication and cooperation between all parties involved is preferred to finger pointing and shoulder shrugging. Instrument Bandwidths are defined by each manufacturer. Two instruments both labeled as "UVA", from two different manufacturers, can give different results because their spectral responses are different. These differences can go unreported and this failure to communicate can be costly and misleading.

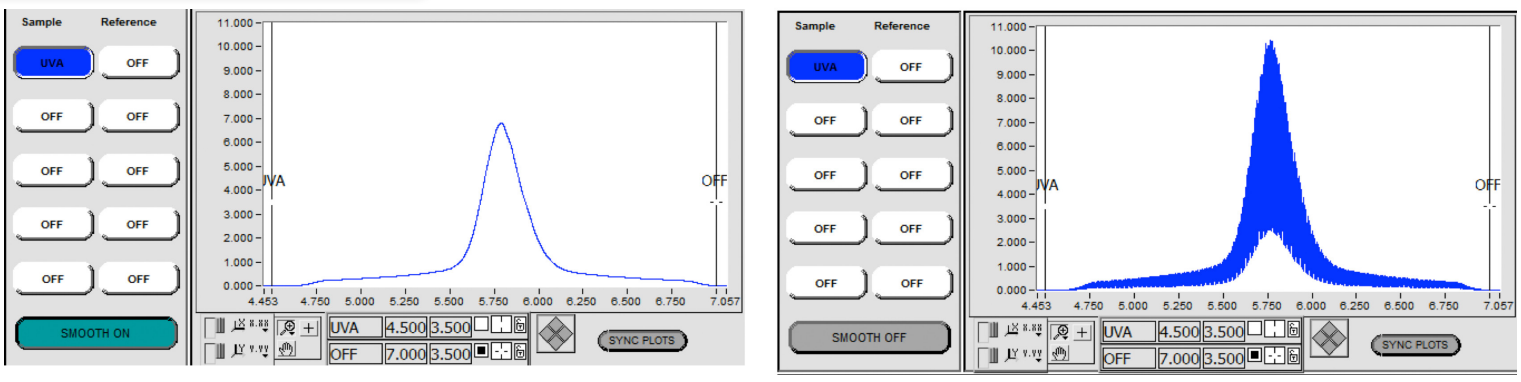
R.W. (Dick) Stowe of Fusion UV Systems has long advocated reporting values in a format that identifies the measurement value, bandwidth and instrument that measured the reading. An example of a complete 'joule' reading would be: 300 mJ/cm^2 UVA (EIT 320-390 nm). Reporting values in this format avoids confusion. He recommends showing the exact model of radiometer, at an absolute minimum.

Example of a radiometer



Today's radiometers have the ability to sample much faster than previous versions. Faster sample rates allow the instrument to 'catch' more accurately the peak UV irradiance value. If you see fluctuations in the irradiance values, try collecting your data at either a slower process speed or increase the sampling rate on the instrument if this is possible.

Radiometers when set to faster sample rates (1024 or 2048 Hz) are able to 'see' the UV fluctuate with the alternating current (AC) in the power supply. Fast sampling EIT radiometers have the ability to report the 'instantaneous' peak irradiance ('smooth off' value) and/or the 'average' (RMS) peak irradiance ('smooth on' value). Understand what your instrument options are, decide as a company what you will use and be sure to communicate this in irradiance values that you record and share. Example: 450 mW/cm2 UVA (EIT 320-390 nm, Smooth On). The energy density (J/cm^2) values measured in 'smooth off' or 'smooth on' mode are similar.



Profile of the same Fusion microwave system with an EIT PowerMAP. (PowerMAP is set to a sample rate of 2048 Hz, threshold at 5 mW. X-Axis is time, Y-Axis irradiance.)

The profile at the top left is a maximum 'smooth on' irradiance value of 6,795 mW/cm^2. The profile at the top right of the same lamp is a maximum 'smooth off' irradiance value of 10,459 mW/cm^2. In both profiles, the energy density was measured at 2,568 mJ/cm2,

This shows the importance of making sure that you communicate clearly when expressing radiometer values.

Instrument Expectations

Avoiding collection errors in your readings

Radiometers are often used in challenging, harsh, industrial environments in the presence of coatings. (See the separate box section below on cleaning the optics on your instrument.) Radiometers need to be handled as instruments, calibrated and serviced as required.

User expectations of UV measurement instruments often exceed their actual performance. EIT radiometers are sold as ±10% instruments and under controlled collection conditions, their performance can improve to much better than that. To get the most out of your radiometer, it is important to understand and use it properly and to also use collection techniques consistent with the instrument design. Work to avoid introducing collection errors to your readings.

Things to keep in mind include:

- Instrument Ranges: Make sure the dynamic range of your UV instrument matches the irradiance levels of your source. Measuring small amounts of UV with an instrument designed to measure high power sources may register a reading, but it may be out of the ideal instrument range. Measuring UV on a highly focused system may require a different dynamic range instrument if that same UV source is used in far field (dimensional) curing.

Feature	Standard Range 10W	Mid Range 1W	Low Power 100 mW
Suggested Operating Range UVA, UVB, UVV	100 mW/cm^2 to 10 W/cm^2	10 mW/cm^2 to 1 W/cm^2	1-100mW/cm^2
Start Threshold Serial vs. USB	Serial:10-40 mW/cm^2 USB: 4-12 mW/cm^2	Serial: 1-4 mW/cm^2 USB: 400-1200 µW/cm^2	Serial: 100-400 µW/cm^2 USB:40-120 µW/cm^2
Suggested Operating Range UVC	10 mW/cm^2-1W/cm^2	1 -100mW/cm^2	1 -100mW/cm^2
Start Threshold UVC	Serial: 1-4 mW/cm^2 USB: 400-1200 µW/cm^2	Serial: 100-400 µW/cm^2 USB: 40-120 µW/cm^2	Serial: 100-400 µW/cm^2 USB: 40-120 µW/cm^2

Dynamic Range Table for EIT Power Puck II/UviCure plus II Instruments showing 10W, 1W and 100 mW units, their suggested operating range as well as expected start thresholds for both serial and USB port instruments

- Temperature: Long, slow, repetitive measurements with an instrument, especially on high power UV sources can cause the instrument to overheat. If your radiometer beeps as it exits a UV source is not a good sign. At high internal temperatures, readings may vary slightly. My common sense rule: If the instrument is too hot to touch, it is probably too hot to take an accurate measurement. Let the instrument cool down before trying again.
- Calibration Sources: Calibrating an instrument to one type of spectral source (mercury) and then using it under a second source (mercury-additive bulb) can lead to small differences in the readings. If you will consistently use the radiometer under a specific lamp source, ask the manufacturer to calibrate the instrument under that type of UV source.
- Electronics: Differences in the electronics between instruments and product families can cause one instrument to reach threshold and start counting UV while another instrument needs a higher irradiance value to reach threshold and count UV. On long slow runs, this can cause variations in the energy (J/cm^2) measured.

Dealing With Readings Outside Your Expectations

Make sure you know what condition your condition is in

If someone were to ask for your UV conditions from yesterday, would you able to show them what condition your condition was in? Logs, which can be as simple as a clipboard, are used to track the operation and performance of UV systems and should be kept and referred to if things stop working. Track the items that are important for your process. The good news about getting radiometer readings outside of expected values is that it means that you have established targets. As a result, you can show more precisely what was occurring if things go wrong.

When you get readings outside of your targets or things stop curing, work through the steps below. The first reaction of most people is to call their suppliers and blame them: "The coatings were not right!" "The lamps fluctuate in power!" or "The substrate did not meet the specs." The steps below are generic and will need to be modified for your process.

Steps To Take When Readings Are Outside Your Target Values

1. Confirm key equipment and process settings, and measure the UV exposure.
2. If the readings are still outside your target values, perform basic UV system maintenance. This may include cleaning of reflectors, quartz plates and the bulb for each system. Check the cooling and air flow for your system type. A clean system (reflector, quartz plate, bulb) is able to deliver UV energy across the entire spectrum (UVA, UVB, UVC and UVV). A UV system that is not clean, delivers reduced amounts of UV, especially in short wave UV. A multi-channel radiometer allows you to compare the ratios of short and long wave measurements, and identify changes in the system and when maintenance is required.
3. Once maintenance has been completed, measure the UV again, looking for improvement and movement back towards the process window.
4. If needed, replace UV system components (bulbs, reflectors, quartz plates, system components) or adjust key equipment variables until the readings are back in your process window
5. Review your process log. Does your log include notes as to process changes or changes in suppliers? Will it help you look for clues on why the readings are outside of your process window? Was there a gradual change over time outside your process window or was it a sudden change?

Questions To Ask When Radiometer Readings are Outside Expectations

1. Do I have the right dynamic range instrument? Do I have too low of a UV range for my instrument? Am I exceeding the irradiance range of my instrument with too strong of a UV source?
2. Do the instrument features and response match the UV source? Examples of mismatches could occur for additive bulbs, LED sources and pulsed sources. How do my current readings compare with historical data?
3. Do the irradiance values (W/cm^2) follow the energy density values (J/cm^2)? What happens when I make changes to my process? Do the Joule values go down if I increase the line speed?
4. When was the last time my instrument was serviced? If I note a change in the readings after calibration, did I review the changes made to the instrument when it was serviced? Have I dropped the instrument or are the optics covered with coatings? On what source was the instrument calibrated and what source am I trying to measure?
5. How is my instrument set up? Is the sample rate adequate for my process speed? Are the irradiance values displayed as average (Smooth On) or instantaneous (Smooth Off)? Am I recording the values correctly on my log?
6. Is there a long run time in which the instrument could heat up?
7. Is there a long slow run of low intensity in which one instrument could turn on and one not turn on?

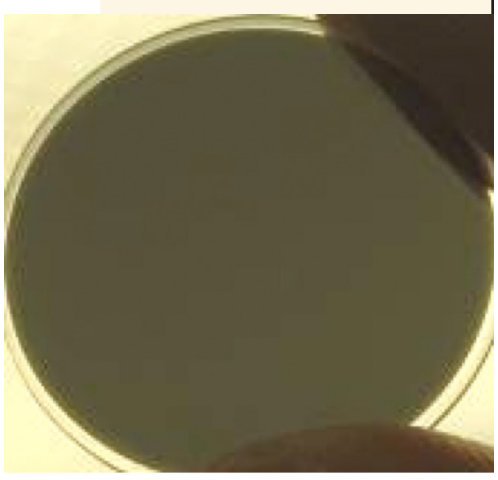
Summary

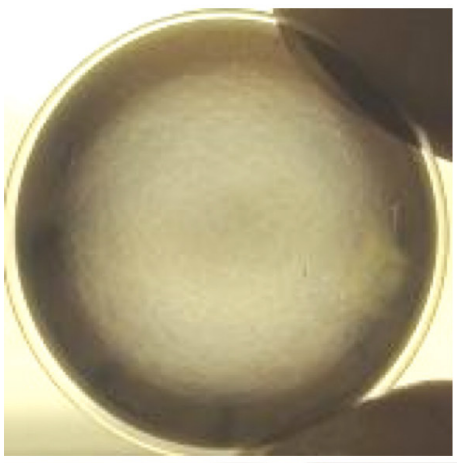
Hopefully this article has given you a better understanding of the process, communication, and instrument expectations as well as steps you can take when dealing with readings outside what is expected. Both the EIT and Fusion web sites have additional articles on UV measurement and process control.

This article was based on a presentation given in November 2010 at a Fusion UV Systems Seminar in Japan.

Cleaning EIT's Optics

1. LOOK: Closely examine the optical surface. If no contaminant is visible, it is best not to clean the instrument
2. BLOW: Dry nitrogen, Chemtronics® Duster, rubber air bulb, compressed oil-free 'instrument' air
3. FLOOD: Once with isopropyl alcohol (IPA), and if needed once again with acetone
4. WIPE: Use a lint-free wipe or a cotton swab, wipe the surface clean





Top: New EIT Optical Filter

Middle: EIT Optical Filter that has been damaged by repeated improper cleaning

Bottom: EIT Optical Filter that has been damaged by a scratch