Crystal IS
High Performance UVC LEDs

WHITEPAPER:

The Case for UVC LEDs in Spectroscopic Instrumentation:

UVC LEDs Pave the Way for the Development of More Cost Effective Instruments

Advantages of Developing Instruments with UVC LEDs

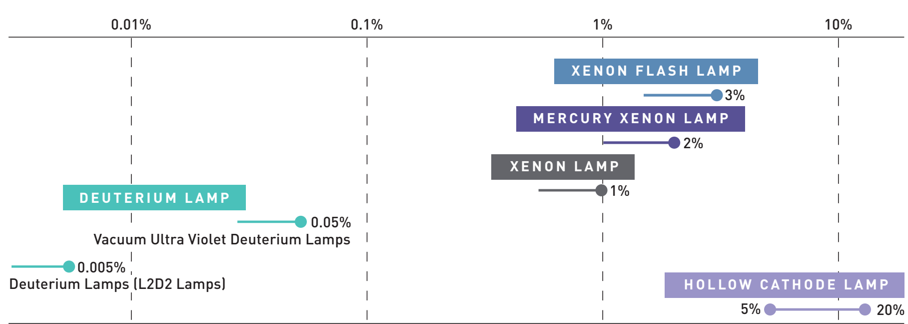
A key trend driving overall market growth and innovation in spectroscopic instrumentation is the need for cost-effective instruments. Wavelength-specific instruments that employ UVC LEDs instead of UV lamps offer affordable, compact instrument designs while consuming less power. UVC LED-based instruments allow manufacturers to address a wider range of market segments. The footprint, cost or complexity of operation is far less and UVC LED-based versions are much more accessible as compared to UV lamp solutions. Manufacturers developing less costly, “lite” versions of instruments are able to increase their product penetration at existing customers. They can offer lower cost instruments tailored for initial evaluation or for monitoring specific compounds or parameters.

UVC LEDs Supersede Deuterium Lamps in HPLC

HPLC is a separation technique in which a sample mixture is introduced into a column. The distinct compounds of the mixture pass through the column at varied rates due to differences in their partitioning behavior between the mobile phase and the stationary phase. Once detected, these components are analyzed using a UV spectrophotometer. HPLC is primarily used for protein purification, routine process monitoring in pharmaceutical and beverage manufacturing, process quality control and biotech research.

Current HPLC detectors typically use deuterium (D2) lamps as their primary light source because of their high stability of light output. The output stability of a light source is measured by fluctuations in light output over short periods of time, such as the duration of a measurement. High light output stability of a UV light source in HPLC ensures detection of lower concentrations of compounds. D2 lamps are more stable than many UV lamp alternatives (by almost two orders of magnitude over xenon flash lamps), as seen in Figure 1.

FIGURE 1



Stability of light output for various traditional UV light sources. Source: Adapted from Hamamatsu Light Source, http://www.hamamatsu.com/resources/pdf/etd/LIGHT_SOURCE_TLSZ0001E01.pdf, Apr. 2014.]

While the long life and relatively high light output of D2 UV wavelengths for HPLC applications is favored, D2 lamps require a very stable power supply in order to maintain their performance. They also require a warm up period of 30 minutes or more to allow the lamp to reach thermal equilibrium. For this reason, most lamps are left on while not in use so that the instrument is ready as needed—wasting much of the lamp's useful life.

High performance UVC LEDs can provide better light stability than high-end D2 lamps and offer more light output and useful life. UVC LEDs reach full stability instantaneously, unlike deuterium lamps. This allows end users to take complete advantage of the LED's lifetime—typically 3000 – 8000 hours depending on application conditions. In addition, UVC LEDs emit negligible front-side heat, which makes them ideal for heat sensitive samples.

IN LIFE SCIENCE LABORATORY ENVIRONMENTS, "LITE" INSTRUMENTS CAN BE STATIONED AT BENCHES THROUGHOUT THE ORGANIZATION TO INCREASE PRODUCTIVITY AND REDUCE LAB BOTTLENECKS. END USERS USE THE RESULTS OF INITIAL EVALUATION TO DETERMINE WHETHER FURTHER ANALYSIS IS NECESSARY BY TRADITIONAL FULL- SPECTRUM INSTRUMENTS.

With UVC LEDs, manufacturers can offer smaller, more cost effective instruments to end users that require one or more fixed wavelengths. This evolution of low cost, fixed wavelength HPLC detectors will enable adoption in new applications such as caffeine detection in beverages and increase penetration in applications such as preparation HPLC.

COST ANALYSIS OF A TYPICAL FIXED WAVELENGTH HPLC INSTRUMENT

The table below provides typical component and operating costs for a fixed wavelength HPLC detector using D2 lamps versus UVC LEDs. This illustrative example assumes detection for two fixed wavelengths, and thus requires two UVC LEDs. Operating costs are estimated based on a typical laboratory operation where a D2 lamp would be on 12 hours a day, 52 weeks a year and assumes four hours of sample measurement per day. For this analysis, the instrument using the LED is turned on only when needed.

	High End Deuterium Lamp	UVC LEDs
Instrument Cost		
Lamp	$400	$600
Socket	$100	n/a
Monochromator	$950	n/a
Power Supply	$1,450	$50
Beam Splitter	$200	$200
Detector	$5	$5
Heat Enclosure	$900	n/a
Total	$4,005	$855
Operating and Maintenance Over 5 Years		
Power Consumption*	$6	$2
Replacement Lamps	$1,600**	n/a
Total	$1,606	$2

Notes:

** Energy cost of $0.12/kWhr*
*** Four annual replacements for the deuterium lamp at $400 each.*

UVC LEDS ARE MORE COMPACT AND ALLOW FOR REMOTE OR HANDHELD DEVICES THAT CAN BE BATTERY OR SOLAR POWERED. THIS CAN LEAD TO INSTRUMENTS UP TO 60% SMALLER COMPARED TO MERCURY LAMP-BASED VERSIONS.

Business Case:

In HPLC, detection of different compounds is primarily analyzed by absorption spectroscopy with UV detectors that typically use D2 lamps as their primary light source. Optan, a long lifetime UVC LED from Crystal IS, has enabled manufacturers to replace D2 lamps with UVC LEDs for fixed wavelength applications. Optan is fabricated on lattice matched aluminum nitride substrates, which leads to ten thousand fold fewer defects and much longer lifetimes compared to LEDs fabricated on sapphire substrates. In addition, UVC LEDs not only match or exceed the lifetime of D2 lamps; they also have more useful life. D2 lamps require long warm up times which wastes the functional life of the lamp. LEDs require almost no warm up time and can be turned on only when a measurement is required, eliminating waste and reducing the frequency of part replacement.

UVC LEDs Improve Measurement Performance for Ozone Monitoring

Commonly found air pollutants or "criteria pollutants" include particulate matter, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides and lead. Exposure to ozone, at even relatively low levels, is harmful to health and can result in reduced lung function and aggravation of pre-existing respiratory conditions. Considering that ozone is also used in industrial applications in processes as varied as semiconductor cleaning to water purification, monitoring of ozone levels is critical. Countries in Europe and Asia have even taken measures to limit auto traffic in cities or to shutdown factories in order to curb emissions in densely populated areas.

The current EPA ozone standard is set at a level of 75 parts-per-billion (ppb)—this quantification of ozone in air is measured using UV absorption spectroscopy. Ozone monitors traditionally use mercury lamps as the light source for their measurement, as ozone has a strong absorbance at approximately 254 nm—the emission line of a low-pressure mercury lamp. Generally, ozone concentration is determined with sequential measurements of the sample gas and zero gas being fed alternatively through a chamber. This makes it important for the intensity of the light source to be stable between the two measurements. Mercury lamps that have been used have higher power consumption and lower stability of light output than other UV light sources (as seen in Figure 1).

UVC LEDs provide high power output and stability of light required for trace detection of pollutants at the ppb level to comply with government regulations. This allows end users to achieve more accurate measurements and benefit from the instant on/off nature of LEDs.

Other inherent benefits of LEDs make them attractive light sources for these instruments. UVC LEDs employ DC power, operating from 6-10 volts depending on drive current, which allows remote or handheld instruments to be battery or solar operated. This, coupled with the compact size of the LED, can lead to instruments that are up to 60% smaller than those using mercury lamps. UVC LEDs are a non-toxic source of ultraviolet radiation—unlike mercury, which contains hazardous waste. In addition, manufacturers are looking for

IN WATER AND WASTEWATER MONITORING, UVC LEDS ENABLE THE DEVELOPMENT OF SENSORS FOR REMOTE MONITORING OF WATER QUALITY.

alternatives to mercury lamps, to address international agreements and regulations such as the Minamata Convention that are aimed at reducing mercury pollution. By migrating from mercury lamps to UVC LEDs, engineers can reduce the footprint, power consumption and environmental impact of their instrument without sacrificing measurement accuracy.

COST ANALYSIS OF A TYPICAL OZONE MONITOR

The table below provides typical component and operating costs for an ozone monitor for fixed wavelength detection at 255 nm using mercury lamps versus UVC LEDs. The operating costs are estimated based on a typical real-time monitoring application where the mercury lamp would be on 24 hours a day, 52 weeks a year and the LED is operated continuously at a 10% duty cycle. Note that the mercury lamp is kept on continuously due to its slow warm up time and to avoid lifetime degradation with on/off cycles.

	11W Mercury Lamp	UVC LEDs
Instrument Cost		
Lamp	$25	$300
Filter	$350	n/a
Power Supply	$50	$50
Detector	$5	$5
Heat Enclosure	$150	n/a
Total	$580	$355
Operating and Maintenance Over 5 Years		
Power Consumption*	$58	$1
Replacement Lamps	$100**	n/a
Lamp Disposal	$25	n/a
Total	$183	$1

Notes:

** Energy cost of $0.12/kWhr*
***Four annual replacements for the mercury lamp at $25 each.*

Business Case:

Since ozone measurement is a sequential comparison between sample gas and zero gas, the stability of the light source can affect the lower limits of detection. Crystal IS UVC LEDs have higher stability of light output than mercury lamps, which reduces system noise and enables measurement of lower levels of ozone. Public health authorities issue a range of cautionary warnings and alerts based on the ozone concentration; thus good linearity of measurement across a wide range of concentrations is essential. The spectral quality of Optan provides a better linearity of measurement across a range of concentrations in absorption spectroscopic measurements. The smaller footprint and lower power consumption of LEDs also enables deployment of a network of portable sensors to help meet new EPA standards.

UVC LEDs Enhance Water Quality Tracking

Water purity is a major consideration for developed and developing nations alike, with fracking and climate changes highlighting water quality concerns. The impact of natural events, such as rainfall and accompanying runoffs, and industrial water treatment are increasingly felt in water distribution networks across the world. Rapid detection of changes in water quality is critical to ensure consumer health and environmental preservation. Wastewater treatment plants and industrial facilities monitor influent and effluent water quality for productivity, effectiveness, and compliance with regulatory requirements. The collection of ongoing, real-time data on contaminant levels can decrease the response time to potential quality issues from days to hours. This depends on the use of autonomous water monitors—ones that need to be compact and cost effective—that continuously monitor water quality at multiple locations along the network.

Typical causes of changes in water quality include natural events, such as flooding, accidental discharge or spills, or other sources of contamination. UV photometry provides quantitative analysis of the organic content in water. By using continuous spectroscopic measurements instead of intermittent chemical testing with grab samples, end users gather process information, detect issues in water quality and make the necessary process changes in real time.

Traditionally, these water quality measurements have used xenon flash lamps as the light source for spectroscopy. Xenon flash lamps provide a broad spectrum of wavelengths and often require an expensive photodiode array for detection. These lamps also require an expensive power supply to maintain lamp performance. Although these high quality instruments offer precise, accurate measurements of multiple parameters of water quality, they are often more than what a water facility requires. The associated costs are also restrictive to small water utilities, and unreasonable for developing regions.

Engineers can achieve the same benefits of xenon flash lamps for a subset of parameters by using UVC LEDs, a less costly detector, and power supply. High performance UVC LEDs offer linearity of measurement that matches the performance of expensive xenon flash lamps. Linearity refers to the correlation between an optical method of water quality measurement with a reference method (e.g., a chemical measurement in the lab). A more compact, less costly instrument can thus become accessible to a wider cross section of the market. Additionally, the reduced size and low power consumption of these instruments open possibilities for remote monitoring.

COST ANALYSIS OF A TYPICAL WATER QUALITY MONITOR

The table below provides figures for the typical cost of a broad spectrum xenon flash lamp-based monitor versus a dual wavelength specific LED version. The UVC LED instrument assumes fixed wavelength detection at two wavelengths, 255 nm for the standard UV254 measurement and a second UV wavelength depending on the water quality parameter of interest. Operating costs are estimated based on a typical water quality measurement where the light source would be used for continuous measurement at a duty cycle of 1% (1 msec on, 100 msec off).

	35W Xenon Flash Lamp	UVC LEDs
Instrument Cost		
Lamp	$447	$600
Socket	$100	n/a
Power Supply	$750	$50
Beam Splitter	$200	$200
Detector	$2,000	$5
Total	$3,497	$855
Operating and Maintenance Over 5 Years		
Power Consumption*	$31	$2
Replacement Lamps	$447**	n/a
Total	$478	$2

Notes:

** Energy cost of $0.12/kWhr*
***One replacement of the xenon flash lamp at $447 after typical life to 1E9 flashes.*

BY TRANSITIONING TO UVC LEDS INSTRUMENT MANUFACTURERS CAN REDUCE INSTRUMENT COSTS BY 40-80%.

Business Case:

Water treatment facilities are increasing their use of UV light for drinking water disinfection. Optimizing the dose for disinfection requires real-time monitoring of water quality. UVT is a measure of water quality and indicates the percentage of the incident light that is able to pass through water. Brighter, long lifetime UVC LEDs from Crystal IS have created new opportunities for the use of LEDs for UVT. The LED enables a smaller footprint for UVT-LED and makes it easy to use across multiple water treatment environments: directly in a pipe, in an open channel, or used offline as a battery-operated, handheld instrument. Additionally, the long lifetime and low power consumption of Crystal IS deep UV LEDs allows for extremely stable readings in all conditions over an extended lifetime.

Cost Effective, Compact Instruments for the Future

For years, the selection of UV lamps in instrumentation focused on the benefits of the lamp while making concessions in instrument design due to limitations of the light source. High-performance UVC LEDs enable design engineers to address market pressure for lower cost products with instruments tailored for specific applications in life sciences and environmental monitoring. By transitioning to UVC LEDs instrument manufacturers can reduce instrument costs by 40-80%. These cost savings continue at the customer site by drastically reducing operating and lamp replacement costs over a five-year period. In addition, these "lite" instrument versions can capitalize on the instant on/off, low power consumption and high sensitivity features of UVC LEDs for competitive differentiation.

THE UVC LED ADVANTAGE

Long Lifetime—Lower maintenance costs

The long lifetime of UVC LEDs means less frequent replacement compared to traditional UV lamps. This leads to lower maintenance costs over the lifetime of the instrument.

Stable Light Output—Improved measurements

Stability of light output is critical to ensuring low noise levels. Our UVC LEDs enable lower limits of detection in applications such as HPLC and ozone monitoring.

Excellent Spectral Quality—Increased accuracy

The full width half max (FWHM) of the Crystal IS LED spectrum is sufficiently small, allowing for all of the diode's intensity to be focused into a very narrow wavelength, reducing stray light and increasing linearity of measurement over a range of concentrations.

High Light Output—Stronger signal

The high light output leads to stronger signals in fluorescence spectroscopy. Crystal IS LEDs enable detection of smaller concentrations of fluorescent compounds such as oil and bacteria in water.

We invite you to learn more about our UVC LEDs.

Crystal IS™
High Performance UVC LEDs

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