Crystal IS™
High Performance UVC LEDs

WHITEPAPER:

Addressing Regulatory Trends with UVC LED-based Sensors

Global environmental concerns over water and air pollution are leading to new regulations that require real-time monitoring. Existing regulations are being tightened to monitor lower concentrations of compounds and more compounds are being brought under regulatory control. As a result, companies and utilities will need to develop a network of cost-effective sensors for monitoring and response in real-time. The use of optical spectroscopy with lattice matched UVC LEDs can address these requirements.

Monitoring water quality in India

In 2015, the Central Pollution Control Board (CPCB) in India mandated 24/7 monitoring of effluent for 17 highly polluting industries. This is believed to be the first mandatory large scale online monitoring of its kind in the world. Periodic inspections have not been effective since the polluting factories would "clean up and behave well" for inspections. Consequently, nearly 40% of treated (and discharged) water in India is not in regulatory compliance. In response, the Government has instituted 24/7 monitoring to keep polluters in check and improve transparency. In addition, online monitoring of effluent discharge is required for industries discharging into the 2500 km Ganges River. As a result, the Indian water and wastewater equipment market is expected to double in size over the next five years.

The installed systems will perform 24/7 monitoring of effluent discharge. Four different parameters of water quality (BOD-Biological Oxygen Demand, COD-Chemical Oxygen Demand, pH and TSS-Total Suspended Solids) must be monitored and reported back to the CPCB every 15 minutes. BOD and COD can be measured using chemical methods or by UV spectroscopy at UVC wavelengths of 280 nm and 255 nm, respectively. Optical monitoring using UVC LEDs is expected to become the predominant method of choice due to lower cost of ownership—which includes system cost and operation and maintenance expenses.

THE UVC LED ADVANTAGE

Lower cost of ownership—Monitor more locations

LED-based optical measurement sensors have a lower system cost than chemical methods of measurement. In addition, the maintenance costs are lower because LEDs have long lifetime with less upkeep unlike frequent replenishment of consumables in chemical-based sensors.

Small footprint—Maximize space while increasing instrumentation flexibility

Optical sensors are much smaller than chemical sensors. In addition, the miniature nature of LEDs offers significant footprint advantages over traditional UV lamps which are bulky and fragile.

Instant on-off cycles—Conserve power and preserve lifetime

UVC LEDs enable instantaneous output modulation, meaning that they are only turned on when measurements are taken. Alternative UV light sources, like UV lamps, require a warm up time to reach stability so they are often left on while not in use.

Reducing emissions from ships

To reduce sulfur dioxide (SOx) emissions from ships, the International Maritime Organization's (IMO) regulations on sulfur content in marine fuel will continue to tighten until 2020. In 2015, the limit for sulfur content dropped from 1% to 0.1% in Emission Control Areas (ECA), which includes North America and northwestern Europe. When the global limit drops to 0.5% in 2020, the shipping industry will face a difficult decision—switch to expensive low sulfur fuel (with an economic impact estimated at tens of billions of dollars annually) or implement relatively cheaper exhaust cleaning systems.

Exhaust cleaning systems use gas scrubbers to reduce emissions. In addition to SOx, emissions from marine diesel engines contain particulate matter and PAHs or polycyclic aromatic hydrocarbons. Wet scrubbers clean a wide range of pollutants out of exhaust gas, including SOx and PAH. One of the principal challenges associated with wet scrubbing is handling the wash water discharge since PAHs are harmful to both people and the environment. Therefore, after scrubbing, the wash water is treated and monitored for PAHs prior to being discharged into the sea. This reduces the possibility of pollution shift from air to water, which would negate the environmental benefits of exhaust gas cleaning.

PAHs can be measured using fluorescence spectroscopy at 255 nm, which can detect very small concentrations. In fluorescence spectroscopy, the emission intensity (signal) is directly proportional to the concentration of the fluorescent compound over a very broad range of concentrations. The emission intensity is also directly dependent on the intensity of excitation. Compared to a xenon flash lamp, a traditional light source for instruments measuring PAH, lattice matched UVC LEDs offer higher intensity at 255 nm and therefore better sensitivity at lower concentrations that meet IMO limits.

Lattice matched UVC LEDs

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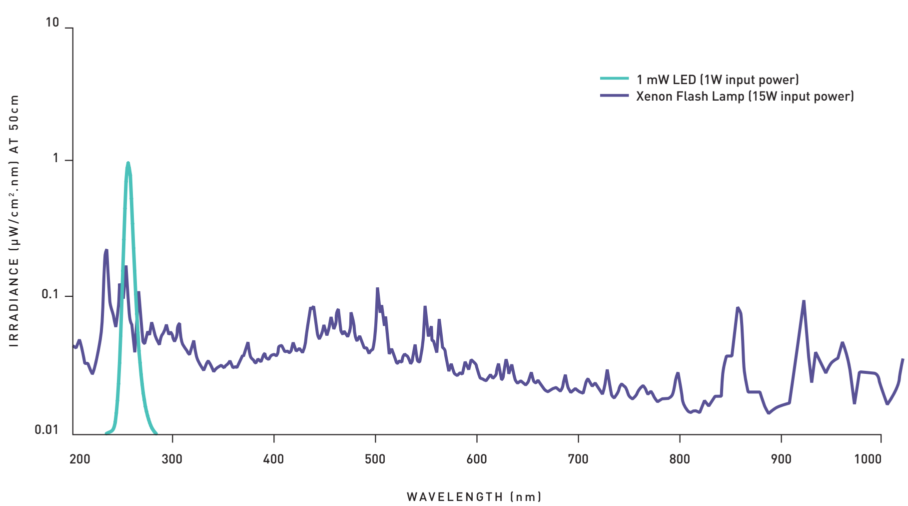
FIGURE 1



Irradiance comparison of UVC LED and Xenon Flash Lamp at 255 nm.

Fluorescence Spectroscopy

FLUORESCENCE SPECTROSCOPY MEASURES THE ABSORPTION OF LIGHT ENERGY AT ONE WAVELENGTH AND RE-EMISSION AT ANOTHER, USUALLY LONGER, WAVELENGTH. THE EMISSION INTENSITY (SIGNAL) IS DIRECTLY PROPORTIONAL TO THE CONCENTRATION OF THE FLUORESCENT COMPOUND OVER A VERY BROAD RANGE OF CONCENTRATIONS. THE EMISSION INTENSITY IS ALSO DIRECTLY DEPENDENT ON THE INTENSITY OF EXCITATION.

THE UVC LED ADVANTAGE

Light output — Greater irradiance increases sensitivity

UVC LEDs have a higher intensity than xenon flash lamps, which leads to better sensitivity and measurement of lower concentrations.

Spectral quality — Superior accuracy

High spectral quality of Optan UVC LEDs means less stray light reaches the detector so the sensor response is linear over a wider concentration range.

Simpler optical design and electronics — Lower system costs

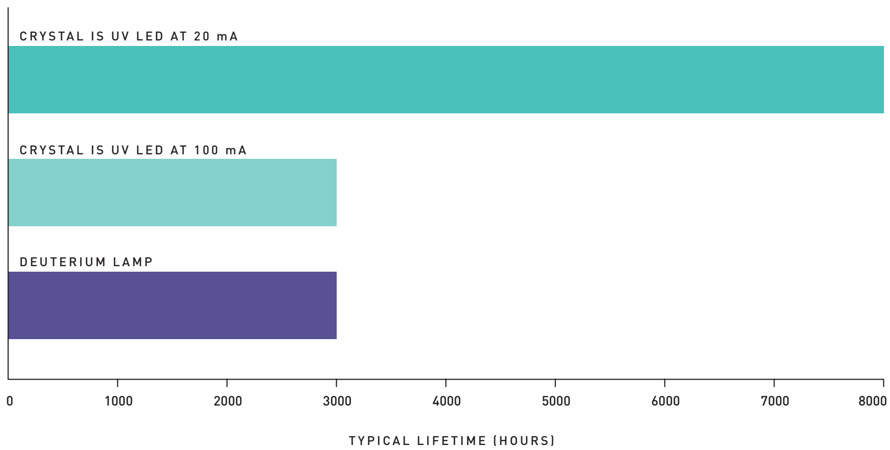
Monochromaticity of UVC LEDs enables a simpler optical train and a relatively inexpensive photodiode for detection. Coupled with simple power supply requirements of LEDs, this equates to instrument cost savings from 40-80%.

Protecting communities around refineries

The EPA has recently tightened emission control requirements for storage tanks, flares and coking units at petroleum refineries. These standards are intended to control toxic air emissions from petroleum refineries and provide important information about refinery emissions to the public and neighboring communities. These new rules are the first time that refineries are required to monitor emissions at key sources within the facility and around fence lines.

The regulations require the deployment of benzene detectors that will monitor real-time concentrations and alert plant operations when levels exceed the EPA standards. Most of these emissions occur during startup and shutdown or during equipment malfunctions or "upsets." The current methods of monitoring benzene emissions at these plants require weeks of collection and analysis. However, the new regulation necessitates monitoring equipment that offers sensitivity and real-time data. Optical monitoring can provide continuous data as opposed to the periodic results of grab sampling. UV monitoring provides 20 times the sensitivity compared to other optical methods, like infrared detection. Traditional UV monitors for benzene employ deuterium lamps due to their relatively high light output in the UV, albeit over a broad wavelength range. Lattice matched UVC LEDs provide much higher levels of light output in a narrow wavelength range. In addition, because deuterium lamps require a warm-up period they are left on all the time, which increases frequency of lamp replacement.

FIGURE 2



Comparison of the typical lifetime of Crystal IS UVC LEDs and deuterium lamps

THE UVC LED ADVANTAGE

LEDs with distinct peak wavelengths in the UV—Better selectivity

UVC LEDs offer distinct peak wavelengths that match the absorption spectrum of the BTEX compounds (benzene, toluene, ethyl benzene and xylene) that are included in refinery emissions. The monochromaticity of UVC LEDs allows for better selectivity and sensitivity for measuring the required compounds.

Instant on-off cycles—Conserve power and preserve lifetime

UVC LEDs enable instantaneous output modulation, meaning that they are only turned on when measurements are taken, equating to replacement cycles on the order of years.

The complexity of ozone regulations

The EPA's ozone regulation has been a hot topic of public discourse in 2015. In October, the ground-level ozone standard was lowered from 75 parts-per-billion (ppb) to 70 ppb. The emissions that create ozone come from a variety of sources—cars and trucks, refineries, power plants, factories, oil and gas wells. The new regulations will lead to many changes in how this pollutant is measured and monitored with significant economic impacts.

Improving ozone data with lightweight instruments

THE COMPACT, LIGHTWEIGHT NATURE OF UVC LEDs MAKES THEM IDEAL FOR NEW MONITORING EQUIPMENT TO IMPROVE OZONE MEASUREMENTS. INSTRUMENTS USING UV SPECTROSCOPY WITH UVC LEDs CAN MEASURE STRATOSPHERIC OZONE LEVELS TO DETERMINE THE DIFFERENCE IN OZONE CONCENTRATIONS CONTRIBUTED BY THE ATMOSPHERE VERSUS MANUFACTURED OZONE POLLUTANTS. ALSO, THESE LIGHTWEIGHT MONITORS CAN BE USED TO VALIDATE THE EPA'S AIR POLLUTION EXPOSURE MODEL (APEX). APEX SIMULATES TYPICAL ACTIVITIES AND BREATHING RATES OF INDIVIDUALS AND PREDICTS THE IMPACT OF OZONE EXPOSURE ON THEIR HEALTH. PERSONAL OZONE MONITORING INSTRUMENTS CAN VALIDATE THE MODEL AND INFLUENCE FUTURE STANDARDS WITH A MORE ACCURATE VIEW ON THE IMPACT OF POLLUTANTS.

In addition to emissions from tailpipes and smokestacks, the total ground level ozone concentration is also impacted by background or stratospheric ozone. Background ozone refers to pollution that drifts from other parts of the world, and "exceptional events" like wildfires, methane leaks or lightening storms. In the US, the higher elevations in the West lead to higher background ozone concentrations. As the EPA lowers the threshold for ground level ozone, the impact of background ozone increases and must be accurately quantified. This enables local communities to determine the allowable emissions from industrial plants and cars in their jurisdiction while staying inside the total ozone limit.

The quantification of ozone levels in air is done using UV absorption spectroscopy. This involves sequential measurements of the sample gas and a zero gas, or a gas with no ozone, which are fed alternatively through a chamber. It is therefore important that the intensity of the light source be stable between the two measurements to ensure a high accuracy response. Lattice matched UVC LEDs have superior stability compared to other UV light sources making them well suited for these instruments.

THE UVC LED ADVANTAGE

Safer and sustainable method of measurement—Low voltage, low power consumption, no mercury

Compared to mercury lamps, UVC LEDs are a low voltage light source, which consume less power. Additionally, they are an environmentally-friendly solid-state light source for measurement.

Stability of light—Accuracy of measurement over time

The better light stability of UVC LEDs over mercury lamps allows for better accuracy across sequential measurements, and equates to detection of lower concentrations.

Preventing biofouling with UVC LEDs

Biofouling is the accumulation of microorganisms, plants, algae, or other organisms on wetted surfaces. It affects a range of systems and components across many industries, especially those deployed in the coastal and marine environments. Sensors and cameras used for underwater imaging, along with lenses used for optical communication, can be adversely affected within a week of deployment. Overall, the cost to industry due to biofilms is estimated to be at least $200 billion annually in the United States alone.

Anti-fouling paints such as tributyltin (TBT) were previously used to prevent biofouling. However, these biocides do not discriminate and persist in the water to harm sea life, the environment, and enter the food chain. Consequently, the use of TBT was completely banned in 2008 by the International Maritime Organization. Given the great economic impact of biofouling, industries have been seeking a suitable, environmentally friendly method for biofouling control.

The mechanism of fouling involves the initial bacterial absorption and formation of a biofilm on the surface, followed by the attachment of larger marine organisms. Light in the UVC wavelengths of 250 nm -280 nm deactivates bacteria, viruses, and other microbes by destroying the genetic information encoded in the DNA. By deactivating the microorganism, it prevents the formation of a biofilm, thereby preventing the later phases of biofouling that render the instrument inoperable (or ineffectual). Although the potential of UV radiation for biofouling control has been known for some time, traditional UV lamps containing mercury are not a feasible option due to their bulk, fragility, high power consumption, and toxicity. These lamps are also difficult to start in cold environments, making them unsuitable for many marine deployments. UVC LEDs offer a better solution that overcomes the limitations of mercury lamps.

THE UVC LED ADVANTAGE

No toxic materials—Environmentally friendly option

UVC LEDs are a solid-state light source with no toxic materials, unlike mercury lamps or TBT.

Compact footprint—Flexible protection

UVC LEDs are compact, making the solution customizable to the size and shape of the instrument and area to be protected.

Regulatory trends across environmental sensing markets continue to increase as does the availability and performance of UVC LEDs. Lattice matched UVC LEDs offer manufacturers design flexibility, high light output and stability, lifetime advantages and environmental-friendliness. By developing sensors with UVC LEDs over UV lamps or other traditional methods, manufacturers can reduce costs by 40 – 80% while meeting regulatory challenges.

We invite you to learn more about our UVC LEDs.

Crystal IS™
High Performance UVC LEDs

70 Cohoes Avenue
Green Island, NY 12183
U.S.A.

www.cisuvc.com
518.271.7375
sales@cisuvc.com

 1050-1511