

## IIoT Enabled Smart UV Systems

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### Abstract:

Microwave UV Systems have been playing a key role in many industrial manufacturing applications and markets. Most of the high-power Microwave UV Systems contain two major modules, an Irradiator (lamp head) and a Power Supply with controls. Up until now, due to the harsh environment inside the Irradiator (high temperatures, large RF fields, large amounts of scattered UV photons), very limited sensors could be incorporated for monitoring the operation of these systems. With advancements in sensor technologies and digital control circuits, we are now able to develop and integrate several sensors to measure UV intensity, bulb temperature, air pressure, air temperature, humidity, etc. within the Irradiator while in operation. Real-time system performance as measured by such sensors is continuously extracted and reported by an intelligent power supply connected to an “Advanced Intelligent Monitoring System” (AIMS). Thus, expanding upon operational intelligence. Such data can be continuously monitored and analyzed for improved process control and equipment maintenance, predictive diagnostics, as well as to provide valuable system performance to minimize unscheduled equipment shut down and reduce overall cost of ownership. Ultimately the data provided by the Smart UV System can be transferred to a Cloud-based environment to support Industry 4.0 architectures.

Keywords: [Intelligent, Irradiator, Microwave, Photon, Smart, Industry 4.0]

Most high-power UV systems contain two major parts, an Irradiator (lamp head) and a Power Supply with controls. We introduced “The Intelligent Power Supply” in 2014, enabling the capability of the “Advanced Intelligent Monitoring System” (AIMS) that provides real-time data monitoring of many electrical parameters measured from the Power Supply for the end user. Due to the harsh environment inside the Irradiator (high temperatures, large RF fields, large amounts of scattered UV light, high flows of particulates), very limited sensors are incorporated for monitoring the operation of the system. The Irradiator, which is the core of the system, remained a “risk”.

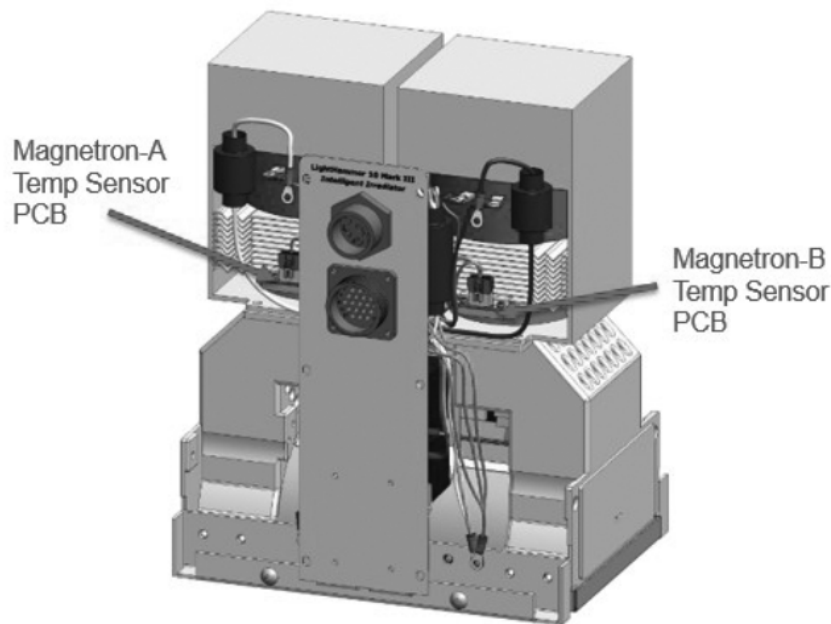
Due to advancements in sensor technologies and digital control circuits, we strategically selected, developed and integrated the following sensors into the Irradiator, creating the “Intelligent Irradiator”:

- 1) **UV sensor** to measure the UV intensity and to better enable large system integration into a sensitive process control for the end user.
- 2) **Analog pressure sensor** to precisely measure the forced air cooling within the Irradiator. This allows the integral control system to detect under/over cooling conditions and operate

the UV system at optimum efficiency. Also enables variable cooling function required for varying power supply power levels ensuring optimal and efficient bulb and UV performance.

- 3) **Orientation sensor** to detect and optimize performance in vertical vs horizontal installations. This sensor is critical to reduce ‘color separation’ or material segregation in certain UV bulb chemistries.<sup>1</sup>
- 4) **Inlet air temperature and humidity sensor** to detect possible installation errors or system changes when heated exhaust air is circulated back into the system. In addition, humidity data can be utilized in process control.
- 5) **Contactless bulb temperature sensor** (up to 1200°C) to detect abnormal operation and provide feedback for predictive maintenance.
- 6) **RF Magnetron temperature sensor** to allow detection of abnormal operation (i.e. insufficient cooling or component malfunction) and provide feedback for predictive maintenance.

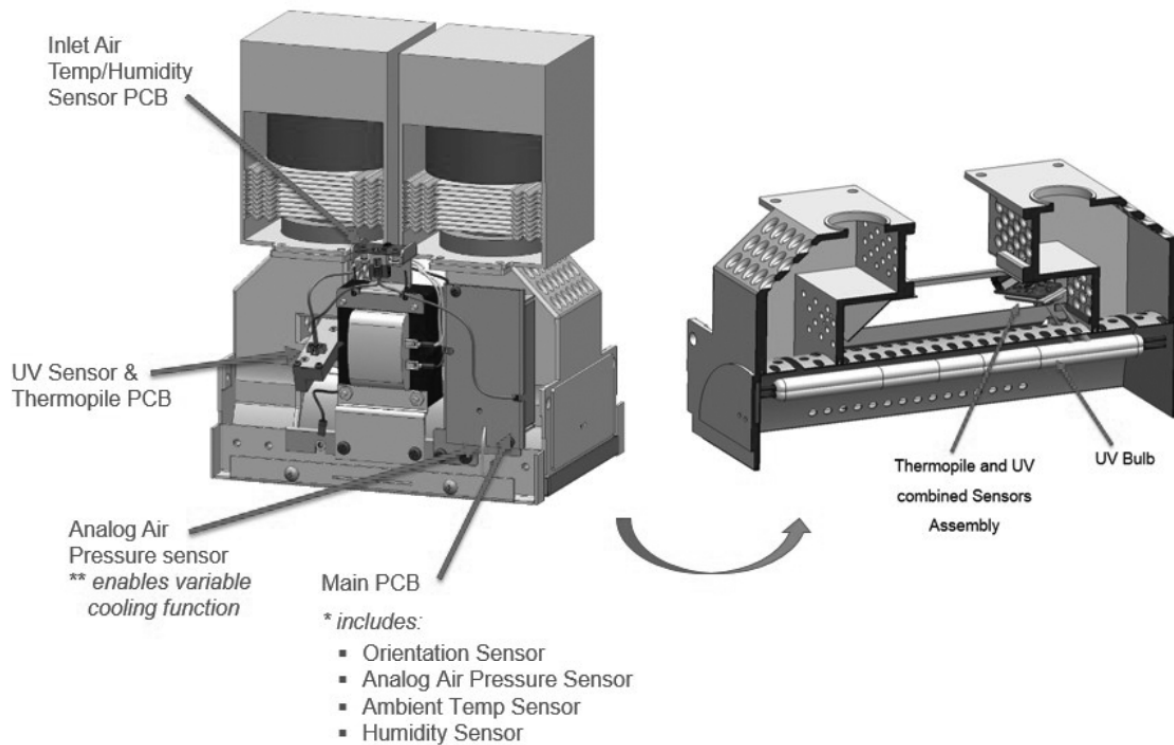
Figures 1 and 2 show the integration of these critical sensors inside an Intelligent Irradiator.



**Figure 1, Inside Intelligent Irradiator (Front View)**

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<sup>1</sup> D. Leonhardt, B.K. Skinner, M. Gharagozloo, C.H. Wood, P.K. Swain, “A Method for Driving Microwave-Driven Additive Lamps for Improved Performance,” at RadTech NA, Chicago, IL (9 May 2018).

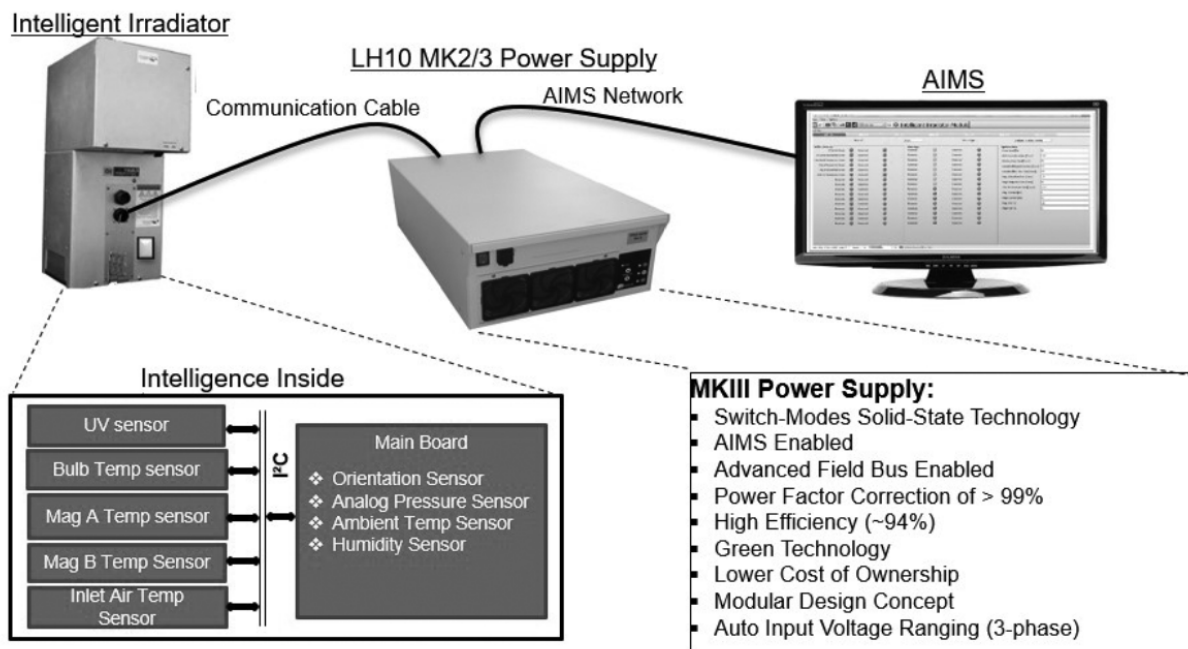


**Figure 2, Inside Intelligent Irradiator (Back View)**

The aforementioned sensors in combination with the electrical parameters measured from the Intelligent Power Supply enable extensive predictive maintenance capabilities to the user. This improves process up-time and reduces unscheduled shut-downs, which are extremely expensive in most applications. The IIoT Enabled Smart UV System, or more simply **Intelligent UV System** provides a comprehensive set of operational and diagnostic insights to monitor and evaluate the entire UV equipment and system performance, identify equipment at risk of failure, and to avoid costly and unscheduled downtime.

The Intelligent UV System provides far more process control data than any UV system on the market. This unprecedented capability to look in to the irradiator operation can help the customers with sensitive processes to monitor many process-related parameters. The new “Intelligent Irradiator” is backward compatible with any LH Mark II power supplies via software update through the power supply. The new Intelligent Irradiator design utilizes a proprietary communication protocol to communicate the sensors’ data back to the power supply (CPU board), and then transferred to AIMS network or can be accessed directly through industry standard protocols (DeviceNet, EtherNet/IP, ProfiBus, Profinet, etc...) for system monitoring, diagnostic and preventive maintenance.

Figures 3 and 4 show the complete Intelligent UV System:



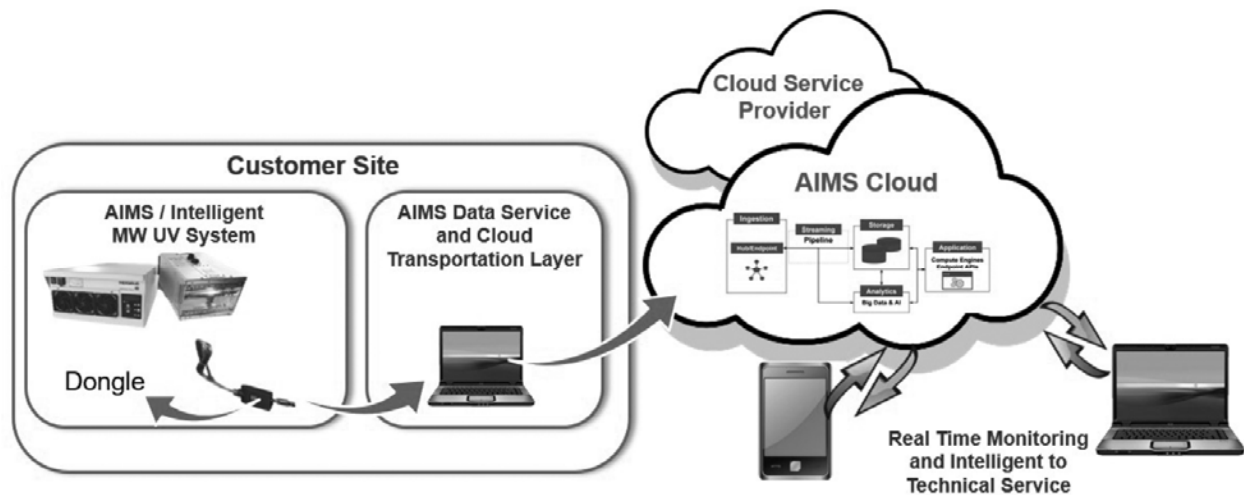
**Figure 3, Complete Intelligent UV system, showing Intelligent Irradiator, Intelligent Power Supply, and AIMS software GUI**



**Figure 4, Advanced Intelligent Monitoring System (AIMS) Displays**

Ultimately the data gathered by AIMS can be transferred to a Cloud-based environment to support Industry 4.0 architectures. To further build upon this tool and to become part of the age of digitization/Industry 4.0/“smart factory,” AIMS can be used as the stepping stone into even greater digitalization capabilities. Using predictive algorithms/analytics, AIMS can provide Predictive & Actionable Intelligence directly to the user. This enables the possibilities to access data globally while harmonizing processes and operational efficiencies.

Finally, in Figure 5 an example of “Industry 4.0” and a “smart factory” using Intelligent UV System and AIMS.



**Figure 5,** Advanced Intelligent Monitoring System (AIMS) Displays

In conclusion, we have shown an Intelligent UV System with many sensors strategically selected and integrated to provide real time system performance data to the user. This system provides far more process control data than any UV system on the market. This unprecedented capability to provide continuous critical data of UV system performance can help the user to proactively monitor many process-related parameters. Also, such data can continuously be analyzed for predictive diagnostics and provide valuable system performance to identify equipment at risk and minimize costly unscheduled factory shut down.