UV Measurement in the Disinfection Range 220-310nm

Presentation – NIST Workshop on Ultraviolet Disinfection Technologies and Healthcare Associated Infections: Defining Standards and Metrology Needs

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January 14-15, 2020

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For purposes of this discussion, the Ultraviolet (UV) range extends from about 220nm to 400nm, and the UVC range from about 220-310 nm. Figure 1A shows the spectra from a medium pressure mercury lamp (Hg) and Figure 1B is the output spectra from an UV LED with a central (Cp) wavelength of about 270 nm.

Note that the Hg spectrum has multiple lines while the LED has only one.

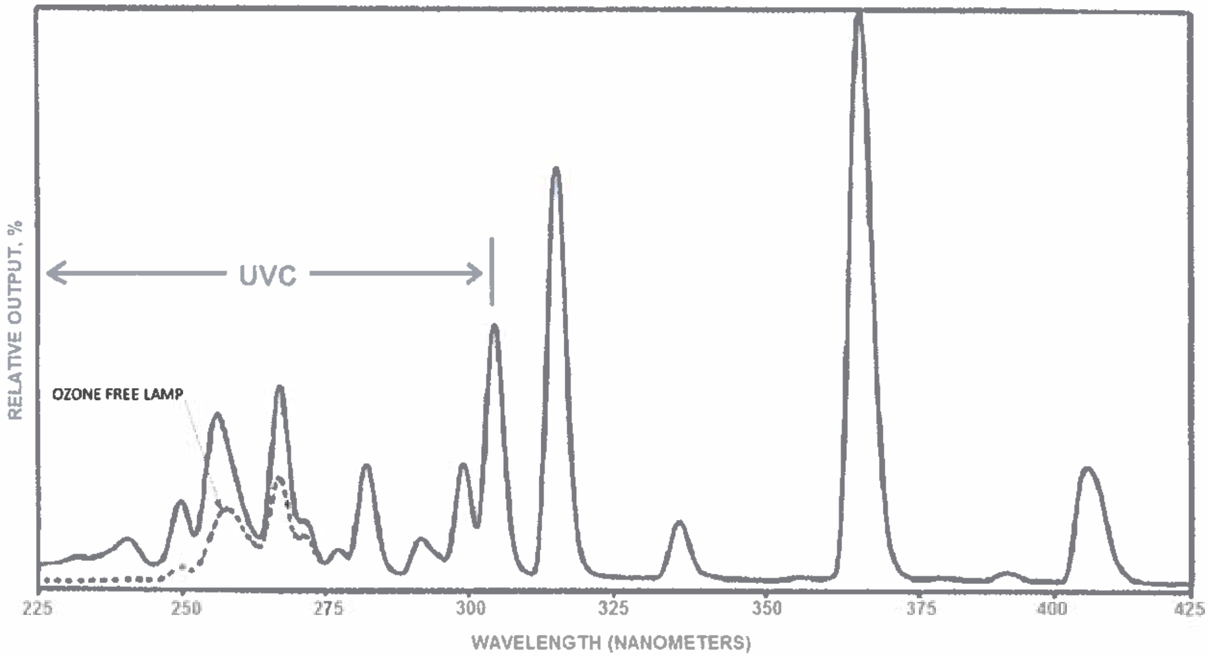

Figure 1A – Output Spectra, Medium Pressure Hg Lamp

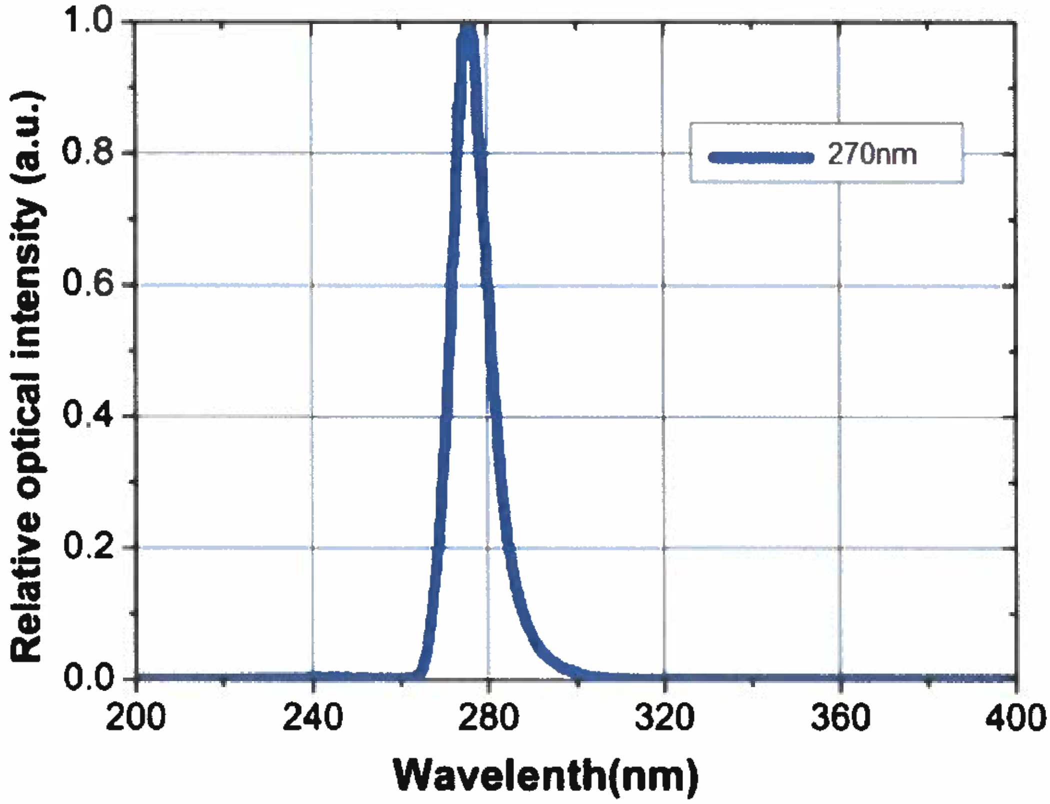

Figure 1B – Output Spectra 270nm UV LED

While there are several technologies available for measuring UV in general, and UVC in particular, this discussion will address the method that utilizes a photodiode to convert UV energy to a current which is proportional to the UVC energy impinged on it.

Figure 2 shows a typical optical stack used in a UV radiometer. UV light enters the protective quartz window and passes through a diffuser which produces uniformly distributed energy while providing an approximate cosine response. An optical aperture reduces the effective energy level by several orders of magnitude and provides optical characteristics which dramatically improve the performance of the bandpass filter which follows it. The function of the bandpass filter is to pass only the wavelengths of interest while rejecting all others.

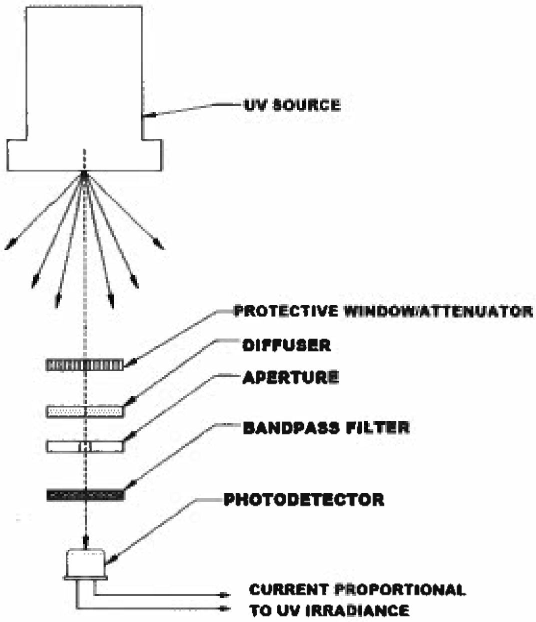

Figure 2 – Typical UV Radiometer Optical Stack

A bandpass filter may be either cut glass or color interference. However, to make absolute energy measurements, as opposed to relative measurements, a color interference filter with a passband over the range of interest (e.g. 260-290 nm) is required. Figure 3 is a stylized response curve for a UVC bandpass filter.

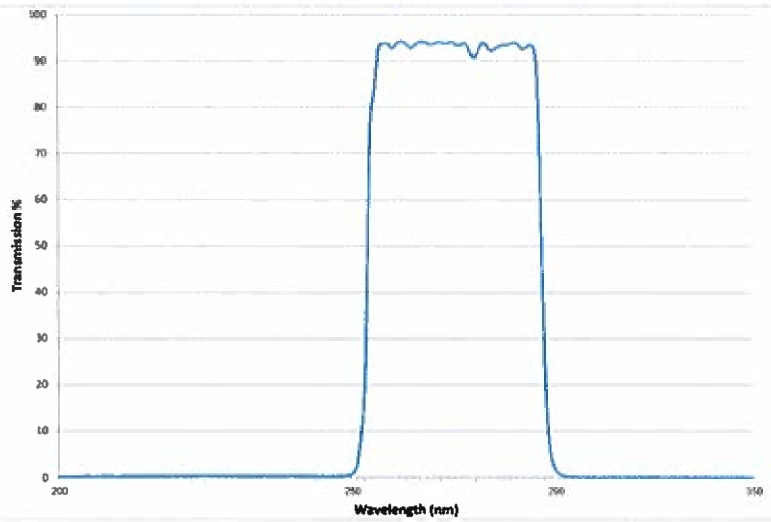

Figure 3 – Transmission Curve for UVC Color Interference Filter (Courtsey EIT, LLC)

Finally, a solid-state photodiode converts the UV energy to a current which is proportional to the absolute energy in the UVC band of interest. The response curve of a typical photodiode is shown in Figure 4.

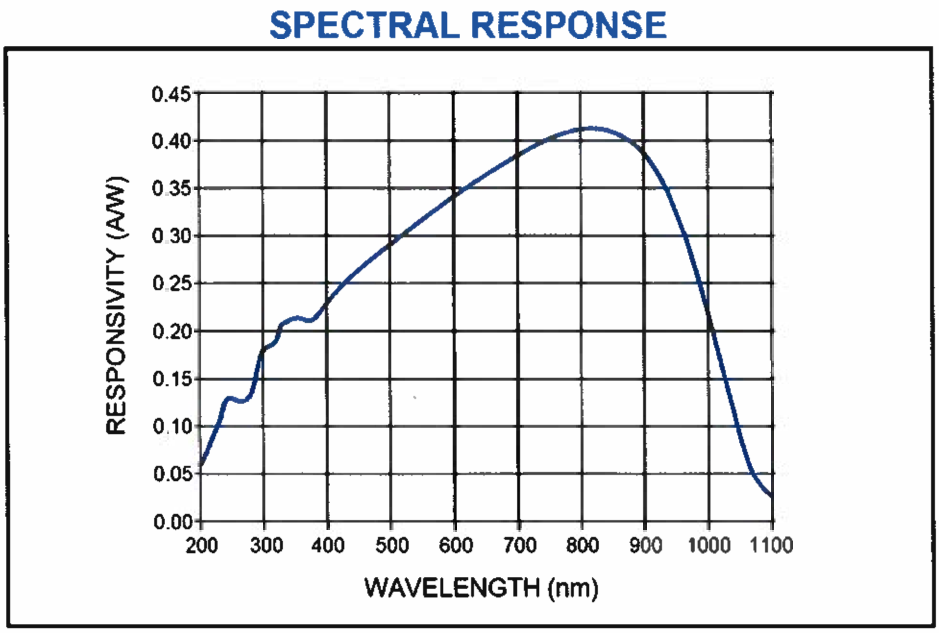

Figure 4- Typical Photodiode Spectral Response

<u>Design Challenges</u>

Making UVA and UVB (340nm to 420nm) measurements, both relative and absolute, is relatively straightforward using existing technology. However, UVC measurements are much more difficult and the technology not so mature. The following section discusses some of the difficulties in making UVC measurements.

1. Solarization

   UVC photons, since they possess higher energy levels than UVA or visible light, are more likely to produce solarization effects on the optical components in the UV sensor. Based on some work of about 15 years ago, EIT has developed an optical stack which has been operated in excess of

6,000 hours in a UV environment with < 2% solarization effect.[1, 2]
Longevity of the optical stack is very important in obtaining good long-term measurements.

Key considerations here are using ultra-low solarization materials in the high energy areas and attenuating the high energy levels to very low energy levels early in the optical stack. Since the likelihood of solarization is a function of the number of high energy photons striking to the surface, less is better. However, the numbers of photons arriving at the detector must be large enough to operate the detector in its linear range.

2. Optical Response

Each of the elements in the optical path has its own spectral response and they generally vary with wavelength. This is particularly so for the bandpass filter and the photodiode detector. Some typical responses are shown in Figures 3 and 4.

All of this attention is paid to the optical responses because each of the individual responses are convoluted with each other and often produce an overall optical response which is very asymmetrical. And the consequence of the asymmetry is a relative reading which can only be used to compare readings made with the same instrument on the same source. Absolute measurements can be compared unit to unit, location to location and between each other.[3]

[11] Unpublished Paper: Long Term Stability and Reliability of Permanently Installed On-Line UV Sensors; Kyle Bostian, EIT, Sterling VA, April 2006
[2] UV Sensor, US Patent 6278120, J MAY, EIT, Sterling VA 2001
[3] A much more comprehensive analysis can be seen at: Introduction of New UV LED Radiometers, J. May, M. Lawrence, EIT, LLC, March 2016

Present State of Measurements

At present, relative and absolute UV LED energy measurements can be made reliably over the Cp range of 365nm to 405nm (Figure 4). Long-term stable relative measurements are being made at various points along the UVC spectrum, particularly 254nm.

However, it would be quite desirable to make absolute measurements for LEDS with Cps near or at 230nm, 250nm, 270nm and 290nm. Further, if efficacy curves can be generated for these Cps, EIT believes these curves could be designed into measurement responses to obtain optimum sterilization performance. [See stylized efficacy curve, Figure 5]. Based on current literature we've reviewed it might require individual responses for each pathogen. While this is not a huge task, it would require substantial development work.

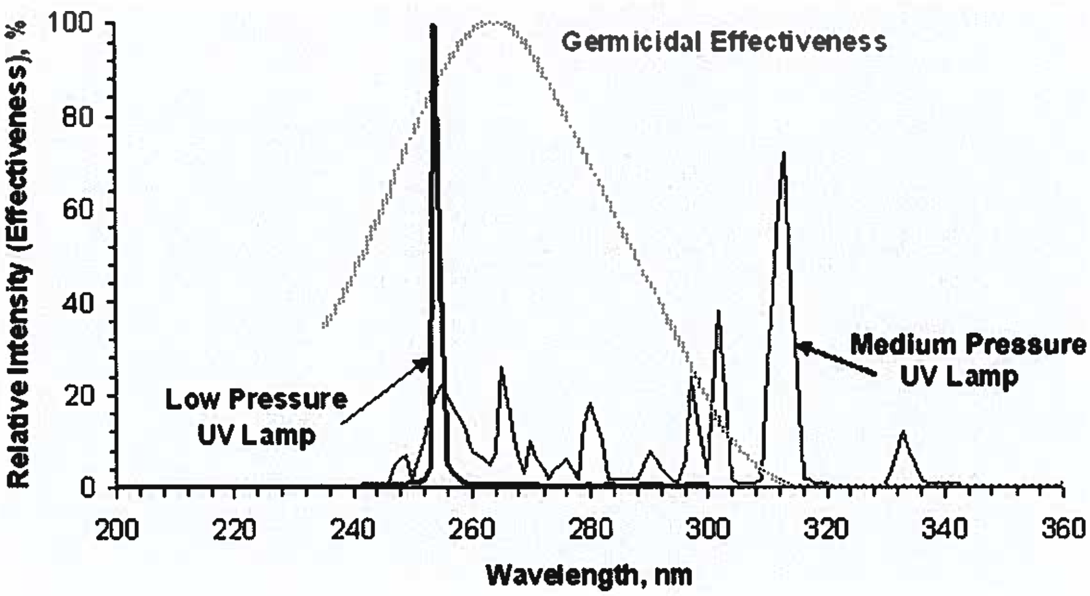

Figure 5 – Stylized Germicidal Efficacy Curve

Conclusions

Useful UV irradiance and energy measurements can already be made or are technically possible. However, there is room for improvement particularly in the area of measuring pulsed sources[4] and incorporating Efficacy Curve responses in the measurement path.

[4] Method and Apparatus for Pulsed UV Measurements; US Patent 7,601,964; EIT, Sterling VA; J. May, MMconnell, S. Snyder, October 2009