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Selecting Suitable Source to Calibrate Ultraviolet Radiometer

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Abstract: Broadband Ultraviolet UV radiometers are widely used in a variety of applications including industrial process monitoring (e.g. UV curing, photolithography), medical testing, health and environmental testing, solar UV radiation measurement and other applications. Calibration of these instruments is necessary for accurate service. Calibration laboratories establish their own setup for calibration, which depends on the source of ultraviolet radiation. In this research three ultraviolet sources; (Deuterium lamp, Mercury arc lamp, Quartz Halogen Tungsten QTH lamp), are examined to find the most suitable one for the calibration system. The investigation of these sources based on measuring their spectral power distributions, uniformity and stability. It found that the QTH lamp has uniform distribution about 90.5% and high stability than deuterium and mercury arc lamps. In spectral range from 200 nm to 800 nm, Deuterium lamp emits 70% from its total radiation in the UV range, which is twice and half than that radiation emitted from mercury arc lamp. However, this work shows that the mercury arc lamp is the most suitable source for the calibration system of UVA radiometer.

***Keywords*: Radiometers; Ultraviolet radiation; Irradiance measurements; Uniformity; Spectral power distribution; Stability,**

I. INTRODUCTION

Ultraviolet sources are natural radiation sources such as sunlight or artificial sources. The ultraviolet radiation sources that come from sunlight are not normally used with laboratory optical instrument. UV radiation is produced either by heating a body to high temperature, as in the case of solar UV, or by passing an electric current through a gas, usually vaporized mercury[1], [2].Artificial sources of UV radiation emit a spectrum of wavelengths that differ from one source to another. These light sources can exist in many forms, architectural light sources, broad continuum high-pressure arc lamps, low-pressure discharge lamps, etc.[3]. Recently LEDs used as UV sources in very narrow fields. Their radiance of UV sources is measure by using special radiometers. Optical sensors should be calibrated using sources that are physically large enough to fill the sensor's field-of-view. However, the calibration standards often only calibrated over a limited range of physical parameters [4]. The National Metrology Institutes (NMIs) are responsible for calibrating these instruments. UV Radiometers calibrated in NIS using the comparison method for effective irradiance responsively. The NIS laboratory sources Deuterium lamp, Hg Arc lamp and Quartz Tungsten Halogen QTH lamp characterized to choose the most suitable one for calibration. It is necessary to determine the spectral power distribution, uniformity and stability of the source for accurate selection.

II. MATERIAL AND METHODS

Three different ultraviolet sources from Newport studied in this research. 30W deuterium lamp model 63165with its house model 7342, The lamp current was stabilized by high stable power supply Model 68942 that keep light ripple from 0.2% to 0.5% peak to peak maximum.Also 1000W QTH lamp with its house model 66885 the lamp current was stabilized by power supply Model 69935 with a specified accuracy of <0.05% and 500W Mercury arc lamp with its house Model 66905, supplied by stabilized current power supply Model 69910 with a specified accuracy of < 0.05%. Fig. 1 shows the Schematic Diagram of the systems used in this study.

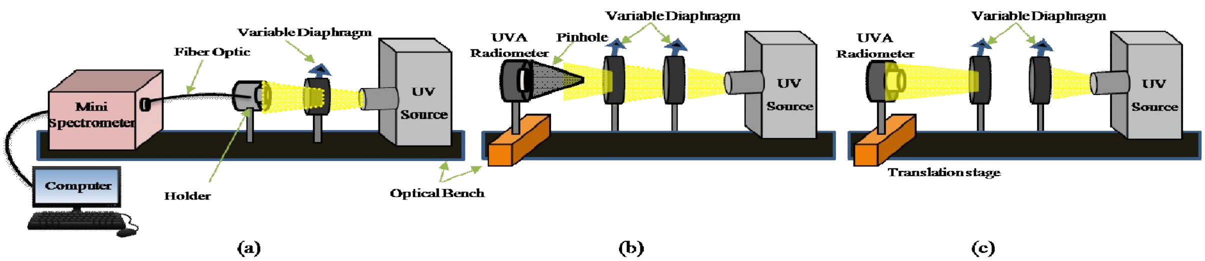


Fig. 1Schematic Diagram of measurement setup (a) spectral power distribution, (b)Uniformity and (c) Stability.

The spectral power distribution measurements performed with CCD Spectrometer model C10082CAH from Hamamatsu Fig.1a. The sources given enough time (about 30 min.) to warm up and its radiation directed to the entrance of the spectrometer through a fibre optic cable. The spectral power distribution is directly display on the computer as a function of wavelength versus count that represents the power. There are two techniques used to evaluate the uniformity of the system: One of them is the spatial uniformity of the UV beam spot; it is measured using a UV detector with 2mm pinhole. Scanning is taken along the UV spot area of 8× 8cm^2 at a step of 5mm for Hg Arc lamp and QTH lamp, while the scan is performed across the UV spot area of 5 × 5 cm^2 at a step of 5mm for Deuterium lamp due toits small beam spot area. The measurements carried out under the dark environmental conditions Fig. 1b.Uniformity is calculated statistically using equation 1[5].

$$\mathbf{Uniformity}\,\% = \left(1 - \frac{SD}{\bar{X}}\right) \times 100 \qquad (1)$$

Where SD is the standard deviation and$\bar{X}$ is the mean irradiance record.

The other technique is the non-uniformity of the measured system, the irradiance uniformity of the active area of the input optics and the response uniformity of UVA detector, has measured by using a setup in Fig. 2. The active area of UVA detector scanned using a micro positioning stage, which permits displacements along two perpendicular axes in a plane perpendicular to the optical axis. Horizontal and vertical scans made along the active area with 3 mm steps. The correction factor for the non-uniformities, *fUnif(λ)*, caused by the response of UVA detector $S(x,y,\lambda)$, the response of reference detector $S_R(x,y,\lambda)$ and the real irradiation field $E_{real}(x,y,\lambda)$, is calculated according to the following formula[6], [7]:

$$f_{Unif}(\lambda) = \frac{\int_A S(x,y,\lambda)dA}{\int_A S(x,y,\lambda)E_{real}(x,y,\lambda)dA} \cdot \frac{\int_A S_R(x,y,\lambda)E_{real}(x,y,\lambda)dA}{\int_A S_R(x,y,\lambda)dA} \qquad (2)$$

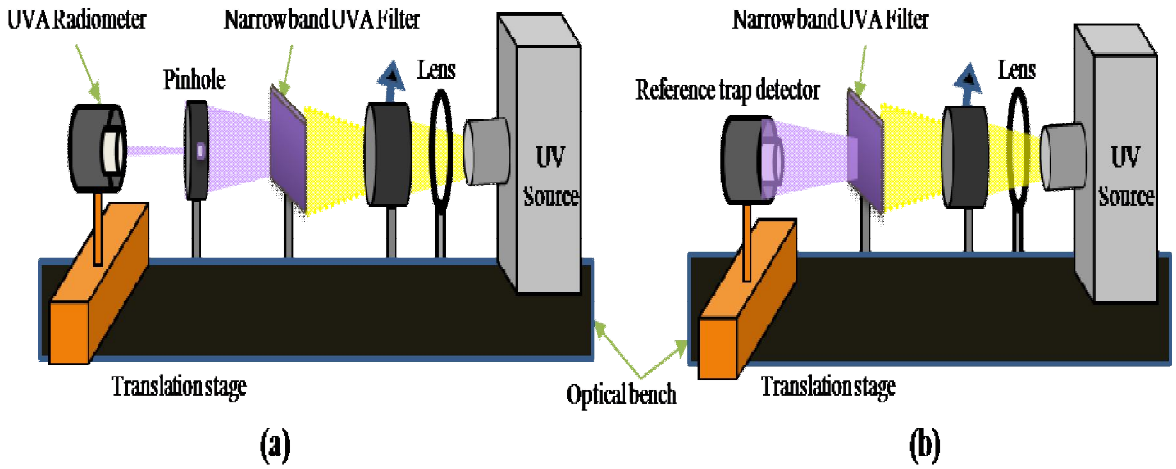


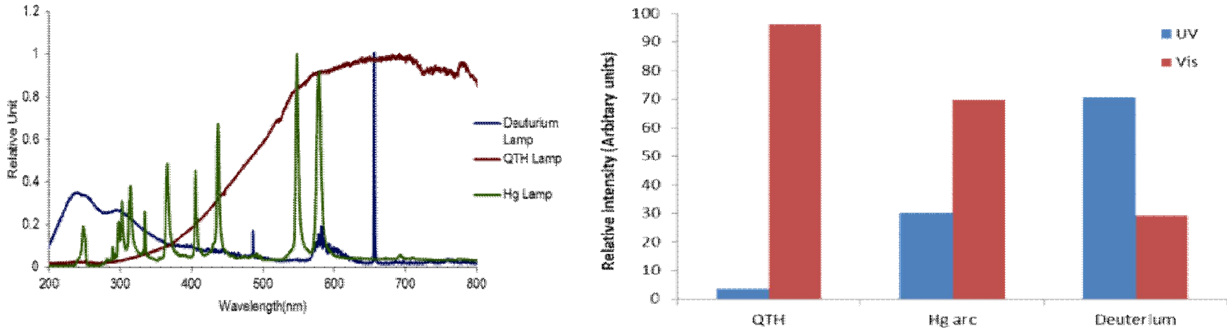
Fig. 2 Setup used for non-uniformity caused by (a) Response of the active area of the detector and (b) irradiation field.

The stability of UV sources tested in a period of 60 minutes after warming up for one hour. The experimental time for stability measurements considered according to the duration of the actual time of calibration. The UV output was measured by a UV meter at a time interval of one minute. Fig. 1c shows the system used for stability measurement.

III. RESULTS AND DISCUSSION

A. Spectral Power Distribution

Fig.3a shows the spectral power distribution of UV radiation emitted from the three lamps. The data of the power distribution evaluate by normalizing it for each lamp to its maximum and calculating the areas under curves. It is observed from Fig. 3bthat Deuterium lamp emit about 70.7% UV radiation and 29.3% visible light, while the QTH lamp emit about 3.8% UV radiation and 96.2% visible light. It is also observed that the mercury arc lamp emit about 30.1% UV radiation and 69.9% visible light. The intensity of the UV radiation, particularly of wavelengths shorter than 300nm,emitted by deuterium lamp while Hg Arc lamp emits higher intensity of the UV radiation than that emitted by QTH lamp. The spectrum of QTH lamp and Deuterium lamp is a continuous spectrum, but the spectrum of Hg Arc lamp consists of intense emission lines at 254nm, 313nm and 365nm.

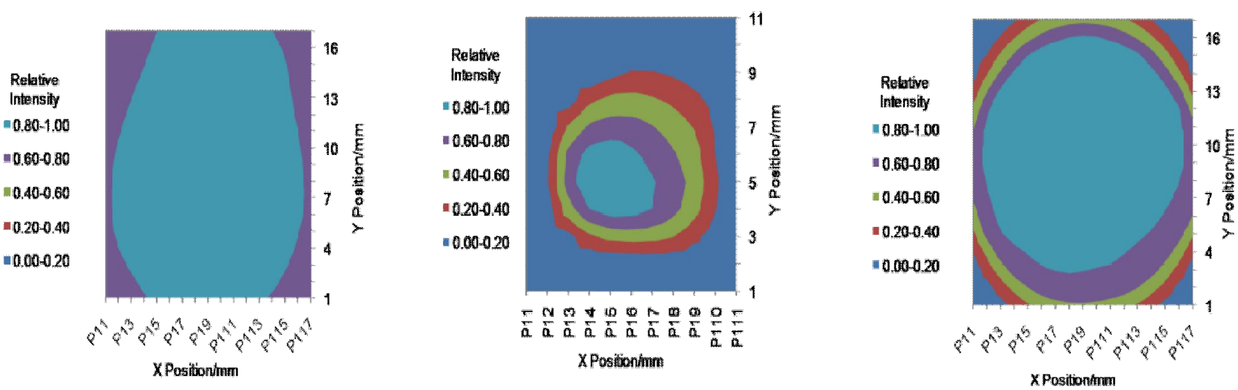


(a) (b)

Fig. 3 (a) Spectral distribution of three common sources used in calibration of UV radiometers and (b) Relative UV and Visible intensity for the three lamps.

B. Uniformity

Uniformity is the most effective factor in irradiance measurements that measurements require beam uniformity to be meaningful. There are two factors in uniformity measurement, one of them is the response uniformity of the detector and the other is spatial uniformity of beam spot. The spatial uniformity of beam spot at measurement plane of each UV source was investigated in the measurement system. The result of the measurements is shown in Fig.4.The spatial uniformity of the sources are not the same, it differs from one source to another depending on many factors especially the alignment and the position of the source in the system. According to equation one results, show that the QTH lamp is the most uniform source used in this work 91%. On the other hand, the uniformity for Hg Arc lamp is 60% but the Deuterium lamp gives bad uniformity about 34%. Measure uniformity by this method caused large standard uncertainty (0.5%, 2.4% and 12.2% respectively at K=2).To perform high accuracy measurement and get better uncertainty the uniformity of the system is measured. A setup in Fig. 2 used to evaluate the response uniformity of detector and irradiance uniformity. Results show that the uniformity of the irradiation field coming from QTH, Hg arc and deuterium lamps are 86%, 94% and 96% respectively. Whereas the response uniformity of the UV detector gives bad uniformity in all cases (≅ 33%). The correction factors due to the response and irradiance uniformity, *fUnif(λ)*, are 0.92 , 0.96 and 0.98 with a relative standard uncertainty of 1.45%, 0.98% and 0.55% respectively at K=2. In spite of this bad response uniformity from the UV detector, the correction factor is nearly unity as we have a high uniform irradiation field. The QTH alone produce high uniformity of beam spot and bad uniformity in the system due to its low emission power in the UV range and the effect of the system optics. While the deuterium lamp has behaves an opposite to QTH lamp due to its richness by UV radiation, which improved by the system optics.



(a) (b) (c)

Fig. 4 spatial uniformity of (a) QTH lamp, (b) Deuterium lamp and (c) Hg Arc lamp.

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C. Stability

Stability of lamps not only depends on the type of lamp but also varies from one lamp to other lamps of the same type. The difference in stability of the three lamps during 60 minute is illustrated inFig.5. The standard deviation of the mean of readings for QTH, Deuterium and Hg Arc lamps was about 0.014%, 0.014% and 0.10% respectively. These results indicate that the QTH lamp and Deuterium lamp are superior in ageing stability to the Hg Arc lamp.

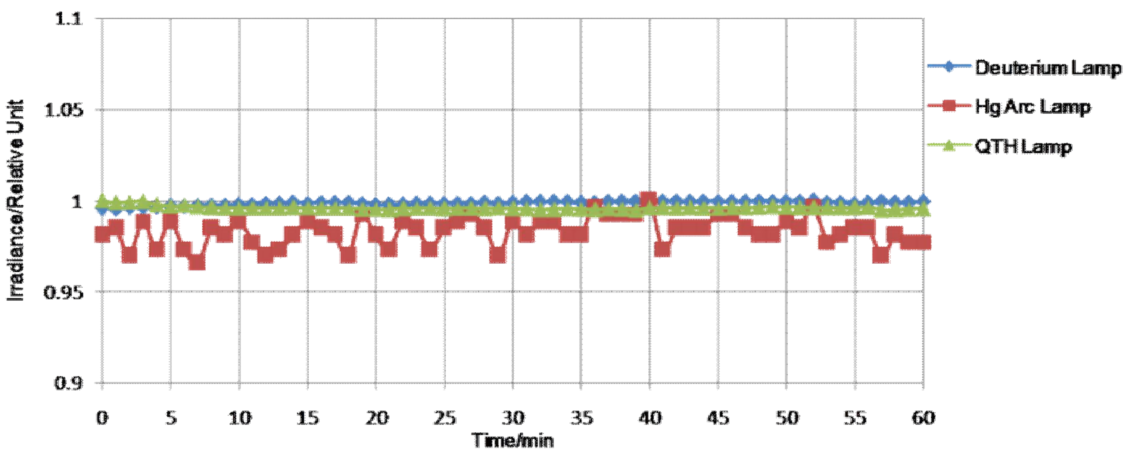

Fig. 5 Comparison between the stability of QTH, Deuterium and Mercury Arc lamps.

IV. CONCLUSION

The three different ultraviolet sources emit three different spectra, QTH have spectral properties that vary smoothly with wave length and very poor power in the UV range. Otherwise deuterium is very rich and continues in the UV range and Mercury is very intense and non-continues spectrum. Uniformity is a critical and effective parameter in calibration system. All the three lamps have a different uniform spatial distribution over the field of exposing.QTH lamp is spatially uniform and has the best spatial uniformity distributional one without any optics but in the system of calibration considered the worse one, due to its filament nature and its weakness of power in that range. While the beam spot of deuterium lamp has the lowest spatial uniformity distribution. It has a high uniform irradiation field in the system. In addition, the Hg Arc lamp has moderate uniformity and high irradiation field in calibration system. Therefore, the optics has significantly effect in uniformity measurements. The stability of the lamps is variable and can be arranging from the better as QTH, Deuterium and Mercury arc. The stability of lamps usually improved during the operation time. Finally, it found that Deuterium source is suitable for calibration and characterization systems of UV radiometers in spectral measurements. While Mercury arc source found more applicable as a radiometric source for the calibration system of UVA radiometer especially when used in selectable ranges at the peaks of the Mercury spectrum. QTH is not appropriate in the Ultraviolet range.

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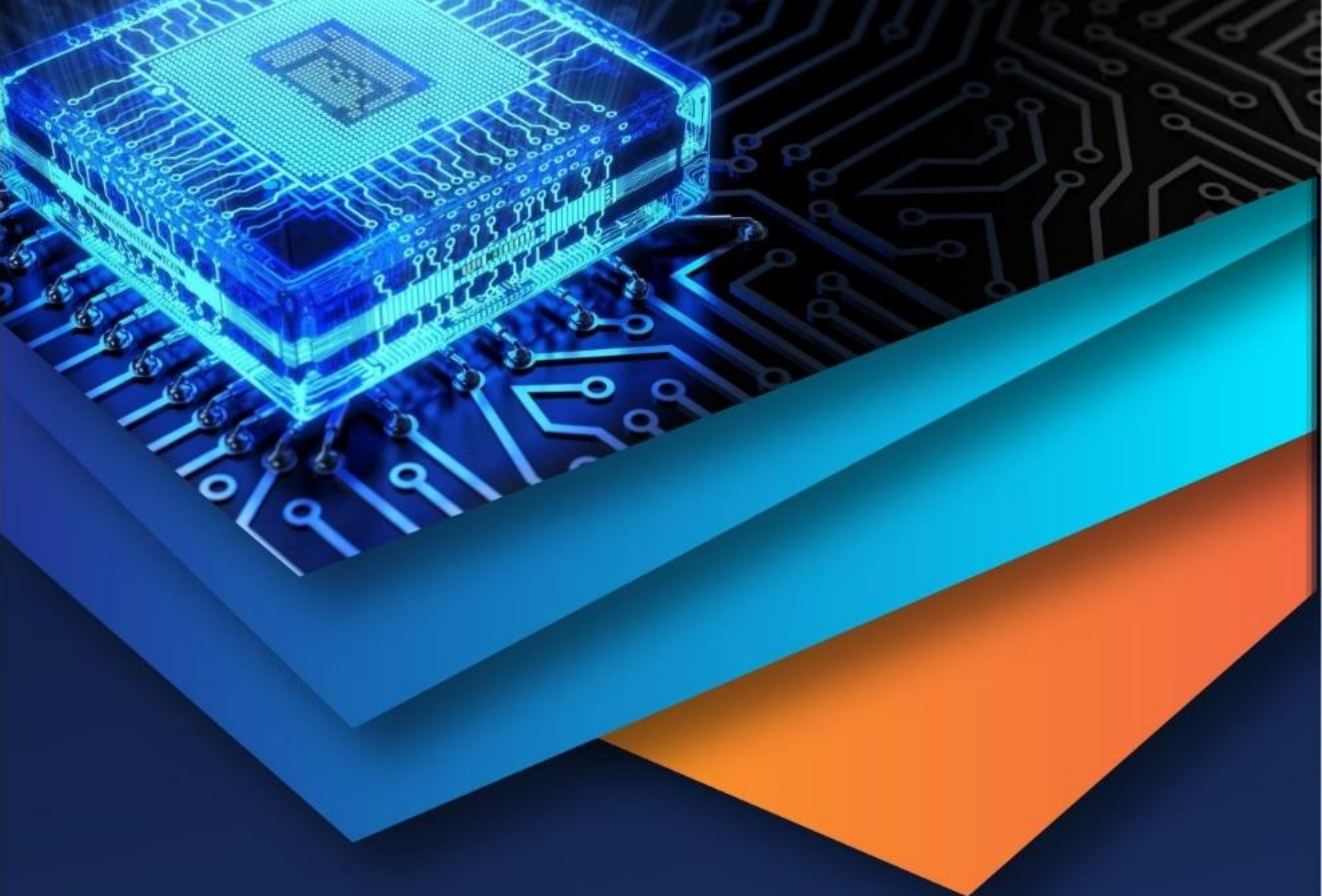

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