Calibration of UVA Radiometers

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Abstract: A general methodology of the calibration of broad band ultraviolet (UVA) radiometers is considered and categorized in this paper, based on the concepts of comparison method of effective irradiance responsivity. Also an example of calibration set-up and uncertainty budget presented.

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Key words: Radiometry, Radiometer calibration, UVA radiometer.

1. Introduction:

Naturally the irradiance level of UVA changes due to region and time where it is measured. Also lamp aging affects the level of irradiance from artificial source at the same measuring condition.

Low cost and ease of use, ultraviolet (UVA) radiometers (some times called UVA meters) are widely used for measuring UVA radiation in various industrial, medical, environmental, health and other applications.

UVA radiometers usually comprise of a detector head, a signal converter and a display unit. The detector head consists of a photo-detector, a spectral filter, a beam-limiting aperture and a diffuser .The spectral filter is used to shape the spectral response of the detector head to match a spectrum of the application. For example, to study the effect of solar radiation on human skin, the spectral response of the UV meter should match the action spectrum of the erythemal function. For UVA measurement, the required spectral response is a square function from 315nm to 400nm. Therefore, a UV meter is usually designed to measure the effective irradiance generated by a source defined as the irradiance spectrally weighted by the action spectrum of the phenomenon of concern.

Previous work provide the theoretical basis for the calibration of broadband UV meters

$$E_c = \int_0^\infty E_{\lambda,c} s(\lambda)_{act} \, d\lambda \qquad (1)$$

Where, $E_{\lambda,c}$ is the spectral irradiance produced by a source *c* at the position of measurement.
And $s(\lambda)_{act}$ is the action spectrum with peak value of unity.

The calibration of a UV irradiance meter is the ratio of its output and the actual value of the effective irradiance produced by the calibration source at the meter head:

$$R_c = \frac{i}{E_c} = \frac{i}{\int_0^\infty E_{\lambda,c} s(\lambda)_{act} \, d\lambda} \qquad (2)$$

Or

$$R_c = \frac{i}{E_c} = \frac{A s_0 \int_0^\infty S_{\lambda,c} s(\lambda)_{rel} \, d\lambda}{\int_0^\infty S_{\lambda,c} s(\lambda)_{act} \, d\lambda} \qquad (3)$$

Where *i*, A are the output and receiving area of the meter head,

$s(\lambda)_{rel}$ is the relative spectral responsivity, normalized to its peak value s_0.

and, $S_{\lambda,c}$ is the spectral radiant power of the source received by the detector. The detector head should be overfilled by the radiation flux. [1,2].

2. Terminology

- A radiometer is a device for measuring the power of electromagnetic radiation.
- Ultraviolet (UV) light is electromagnetic radiation with a wavelength shorter than that of visible light, but longer than x-rays, in the range 10 nm to 400 nm, and energies from 3eV to 124 eV.
- UVA sub-range of ultraviolet range defined by ISO 21348 as the longer ultraviolet range of $(315 \le \lambda < 400)$ nm.[3]
- UVB sub-range of ultraviolet range defined by ISO 21348 as the medium ultraviolet range of $(280 \le \lambda < 315)$ nm. [3].
- UVC sub-range of ultraviolet range defined by ISO 21348 as the short wave, or

germicidal ultraviolet range of (100 ≤ λ < 280) nm. [3].

- UVA Radiometer is a device for measuring the irradiance of electromagnetic radiation in the range 315nm-400nm., in (W/m^2) and its multiplications.

3. Scope

This method is carried out for calibration of UVA radiometrs with spectral responsivity range 315- 400 nm peaked at 365nm.

4. Description of the type of item to be tested or calibrated

The procedure directed to calibrate the radiometers that measure the UVA irradiation in Watt/meter^2 and its multiplications. These devices mainly are consider as one unit (sensor and read out unit). Also these devices can be with digital or analog outputs.

5. Parameters or quantities and ranges to be determined

This method of measurements use multiplications of the irradiance unit μW/cm^2 at the range 200 μW/cm^2 - 6000 μW/cm^2 .

6. Apparatus and equipment, including technical performance requirements

The set up of this calibration include the following apparatus:

1- UV light source.
2- Reference Radiometer, calibrated at the range of UVA radiation.
3- UVA filter.
4- Variable diaphragm.
5- Computerized linear translation stage if available, can be substitute by linear manual stage.
6- Alignment laser.
7- Light enclosure.
8- Optical bench if available can be substituted by flat rugged table.
9- Optical accessories (bases, holders,.atc).

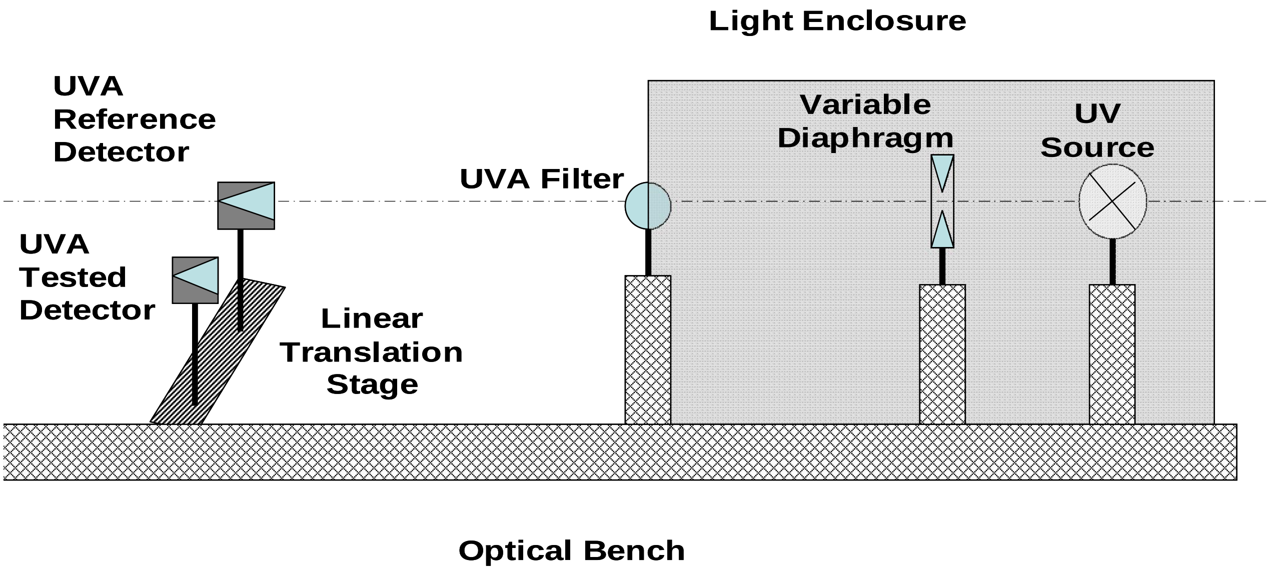

Fig. 1: Sketch of the used experimental apparatus.

7. Reference standards and reference materials required

Calibration methods of these kinds of instruments are detector or source method. In this procedure calibration of UVA meters carried on using substitution method following the requirements of ISO 17025. This rise the importance of using calibrated radiometer at range of interest. Also the filter spectral transmission range is very important to be known. In this method the radiometer to be calibrated is compared with the standard radiometers when both are exposed to the same irradiance from a given source.

8. Environmental conditions required and any stabilization period needed:

Stabilization of environmental condition is a common in calibration procedures. In this procedure the environmental condition is not critical but the calibration temperature at which the reference radiometer was calibrated should be followed other wise temperature correction must be applied.

9. Description of the procedure:

9.1- The test radiometer should be checked for battery level, irradiance range, and dark current.

9.2- Use the alignment laser to alingen radiometers head so that the irradiance is normal to its geometrical center. Attention should be taken on the alginment of the tested radiometer and its plane position must be the same as the standard radiometer.

9.3- Method of recording:

9.3.1-The UV lamp should be turned on for 30 minutes until it became stable.

9.3.2-Chick the enviromental condition to be mached with that obtained on the standard radiometer was calibrated, otherwise temperature correction applied.

9.3.3-Adjust each radiometer before calibration testing to indicate zero with no irradiance on its head.

9.3.4-Record the irradiance value given by the standard meter. Replace the standard radiometer head with the head of the tested radiometer and record its reading. Then use the standard radiometer head again to perform the original reading.

9.3.5-Reading of both radiometres at different irradiance levels which cover the range of the tested radiometre can be tabulated by a way that clearly show readings of standard radiometer, reading of testeed radiometer, and the repetation of measurements at each irradiance level.

9.3.6-Cover the radiometer head between each recorded measurements, at each successive point of calibration expose the heads to the source for sufficient time for the reading to settle before recording the reading.

Notes:

1- Special precautions should be taken to prevent stray irradiance, i.e. irradiance which does not come directly from the source but is scattered off the walls, floor and ceiling, from reaching the radiometer head.

2- Safety precautions of UV exposure should by taken.

10. Sources of Uncertainty:

1- Calibration uncertainty of the reference detector.

2- UV source stability.

3- Stray radiation.

4- Uncertainty of meter alignment and positioning.

5- Calibration uncertainty of photocurrent amplifier if there.

6- Mismatch of the measured radiometer with respect to the standard one.

7- Resolution of the measured radiometer.

8- Repeatability of photocurrent reading

Conclusion:

UVA radiometers mentioned in this paper are basically instruments with law- accuracy due to its diminution of spectral resolution. Two basic procedures can be used to calibrate it. Here the procedure of calibration use the detector based method so; it is completely independent on the source of UV, but highly depending on the calibrated UV radiometer. It is clear that for calibration of UV radiometers using detector method may follow steps discussed before to achieve applicable procedure with high accuracy of measurement and acceptable uncertainty level.

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