New CIE TC on Broadband UV LED Radiometric Measurements, 320 nm to 420 nm

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Outline

- Problems using the “old” CIE TC2-47 TR
- Solution of problems: New TC 2-87 to
  - develop LED source standards (satisfy ASTM-E1417)
  - develop a standard UV broadband measurement procedure
  - develop reference UV-meters that satisfy the procedure
    - Filtered Si
    - Low-NEP pyroelectric
  - Comparison of integrated irradiance of 365 LEDs using spectral method and new broadband procedure
  - Integrated irradiance of deep-blue LEDs (2nd example)
- Conclusions

Problems using the “old” CIE TC2-47 TR

- The “old” TC2-47 TR characterizes and calibrates UV radiometers that are matched to various action spectra and the CIE rectangular shape functions are accepted for standardization. Since the spectral matches to these functions are poor in the realizations, the measured signal strongly depends on the spectral shape of the test-source. The TC2-47 suggested method requires spectral mismatch corrections and it is accurate only for equal types of devices.
- Standardization of the spectral response function of LED measuring radiometers cannot solve the problem.

Solution of Problems: New TC2-87

Terms of Reference:

Standard LED sources with different peak wavelengths (colors) and a standard broadband LED measurement procedure will be worked out to perform uniform, fast, and low-uncertainty radiometric LED measurements.

In contrast to existing detector-responsivity based standards, **the procedure is based on uniform signal measurements where the signal is the spectral product of the test-LED distribution and the spectral responsivity of the measuring reference radiometer**.

If the response of the reference meter is constant for the emitted radiation of the measured LED, standard LED source is not needed.

This one-step LED measurement can be applied for all kinds of LEDs and/or groups of different LEDs.

• Example to use the new procedure

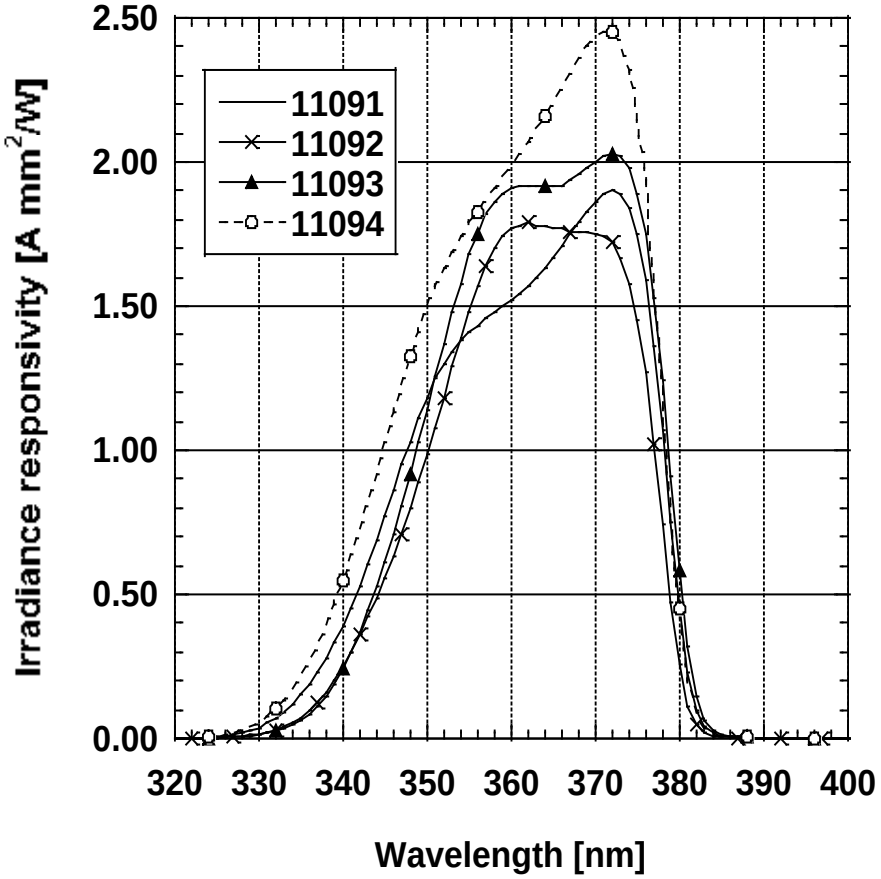
for broadband measurement of LED-365 sources
in nondestructive fluorescent crack-recognition using liquid penetrant

UV SOURCE STANDARD: Satisfies the requirements for source-distribution: Use LEDs with 365 nm +/- 4 nm peaks and a maximum spectrum-half-width (FWHM) of less than 15 nm. **Source standard is needed if the UV meter does not have spectrally "flat" response!**

BROADBAND UV MEASUREMENT PROCEDURE: The spectral response of the UV meters is matched to the 365-nm source-distribution-function such that the spectral product of the source-distribution and meter-responsivity will produce signals with differences (errors) less than the required measurement-uncertainty when different UV meters (models) and/or different 365-nm sources are used.

Development of filtered-Si UV meters for LED-365 sources

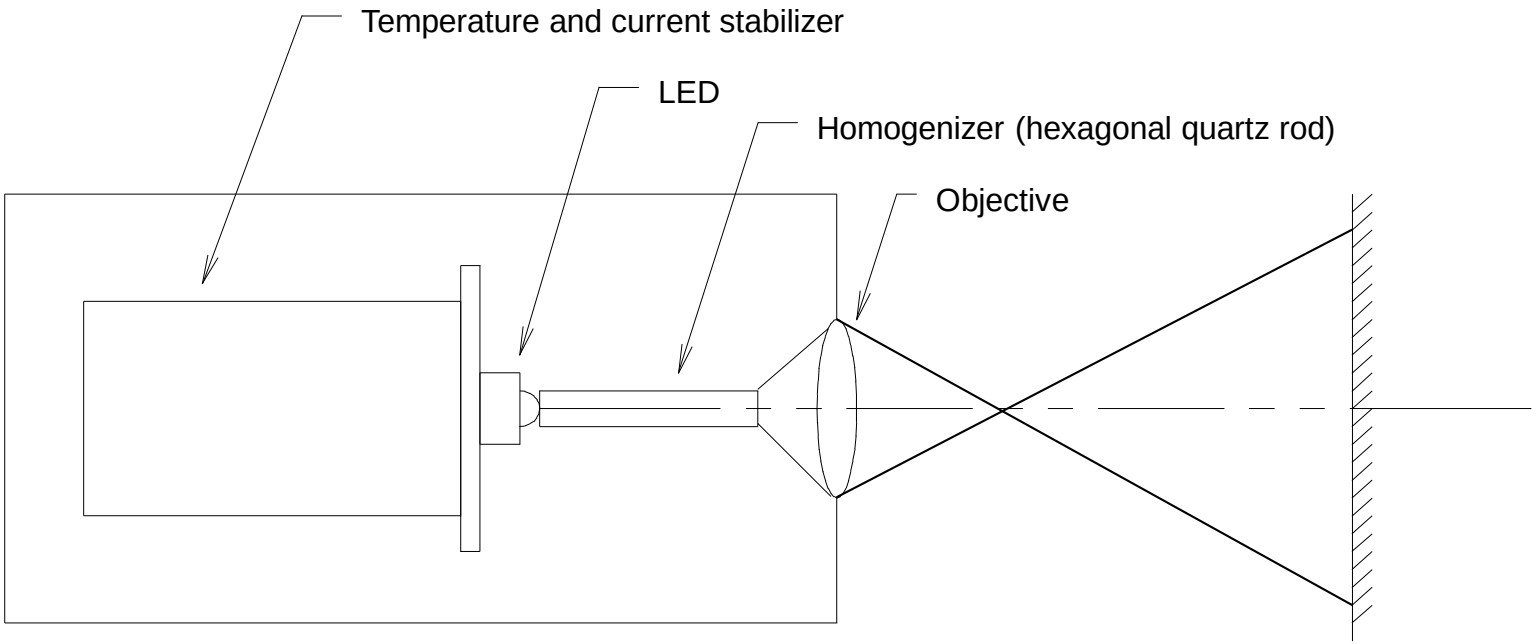
that satisfy the new broadband UV measurement procedure



NIST developed Si UV meters:
In the meters multilayer thin-film and glass filters are used . They are stable but their shapes are different which is acceptable for the new standard procedure.

Development of LED-365 reference irradiance sources

that satisfy the new broadband UV measurement procedure



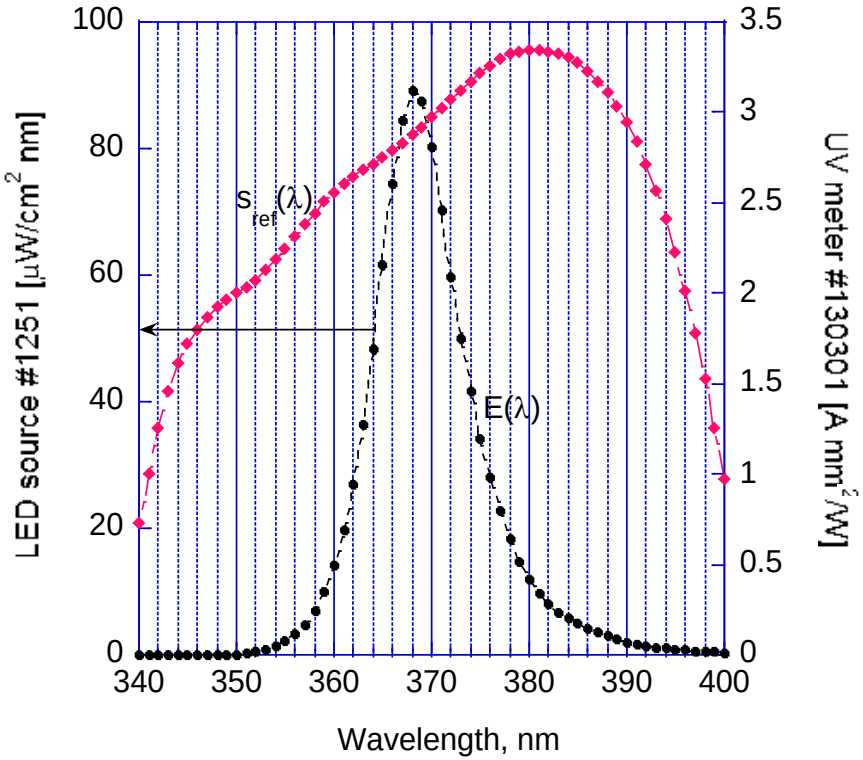
Integrated irradiance, $\overline{E}$

needs to be measured for test UV (LED) sources

1. Non-flat response method that needs an LED-365 source standard

a) Calibration of LED-365 source standard against an FEL standard lamp at NIST

b) Calibration of spectral irradiance responsivity of reference UV irradiance meter at NIST



Measurement equation:

$$i_{ref} = \int_{\lambda} E(\lambda) s_{ref}(\lambda) \mathrm{d}\lambda$$

$$\overline{E} = \frac{i_{ref}}{\overline{s}_{ref}} \qquad \overline{s}_{ref} = \frac{i_{ref}}{\int E(\lambda)\mathrm{d}\lambda}$$

c) Calibrate test-meter for integrated irradiance responsivity against reference irradiance meter

d) Measure the field UV source with the calibrated test-meter at a distance of 40 cm

The ASTM required integrated irradiance must be at least 1 mW/cm^2!

Integrated irradiance, $\overline{E}$ (cont.)

without using a UV (LED) standard source

2. Flat-response standard-meter is used made with either

- filtered quantum detectors (like silicon detectors and glass input-filters) or
- low-NEP pyroelectric detectors.

$s_{\mathrm{ref}}(\lambda) = s$ = constant,

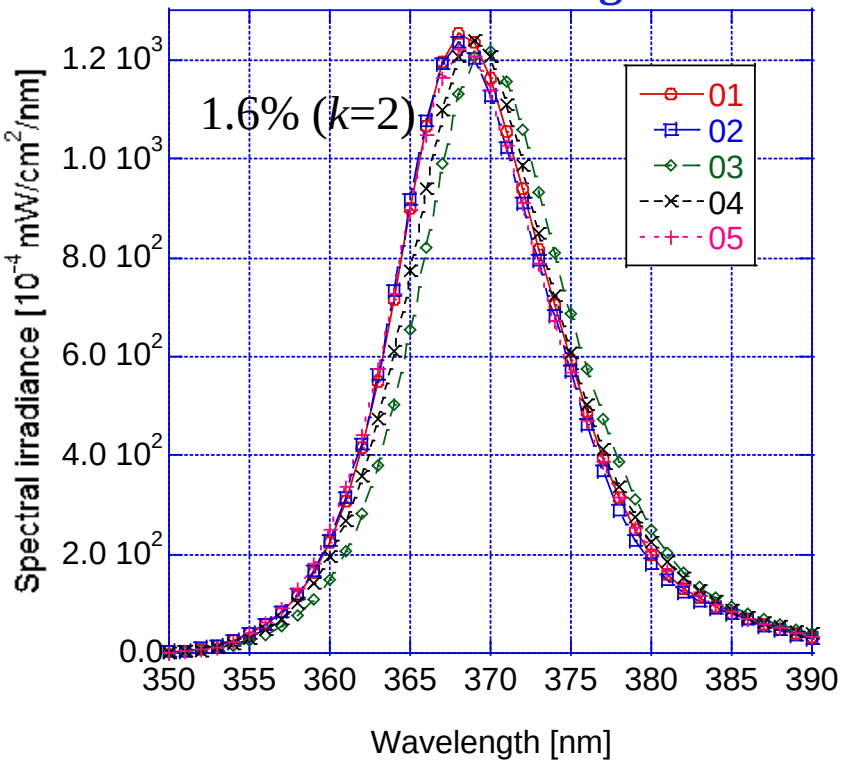
$$i_{ref} = i = s\int_{\lambda} E(\lambda)d\lambda$$

$$\overline{E} = \frac{i}{s}$$

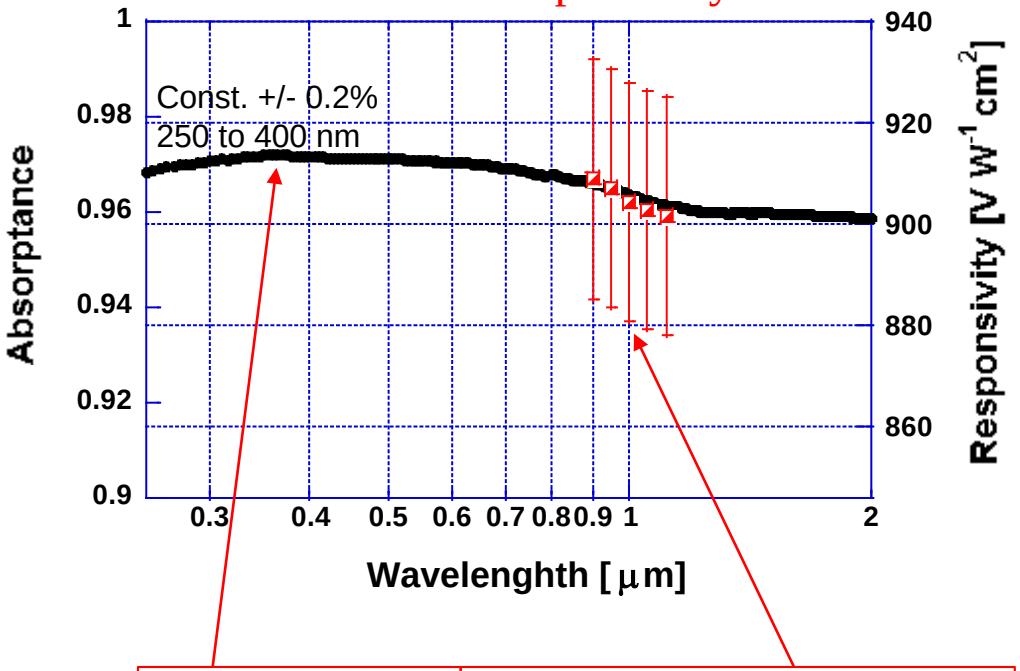
where the unit of i is A, the unit of s is A cm^2/W, and the obtained unit for $\overline{E}$ is W/cm^2.

Reference integrated irradiance calibrations

UV365 standard sources **against FEL**



against flat response of pyroelectr. standard:
new UV irradiance responsivity scale



From spectral reflectance

Irradiance responsivity tie points against a sphere-input extended-InGaAs radiometer

LED#	FEL S193 based mW/cm²	Pyro-based mW/cm²	FEL/Pyro
161001	1.6236	1.59	1.021
161002	1.596	1.58	1.010
161003	1.5689	1.56	1.005
161004	1.5913	1.57	1.013
161005	1.6113	1.59	1.013
		Average	1.012

Integrated irradiance ratios of five LED-365 sources from spectral and broadband calibrations.

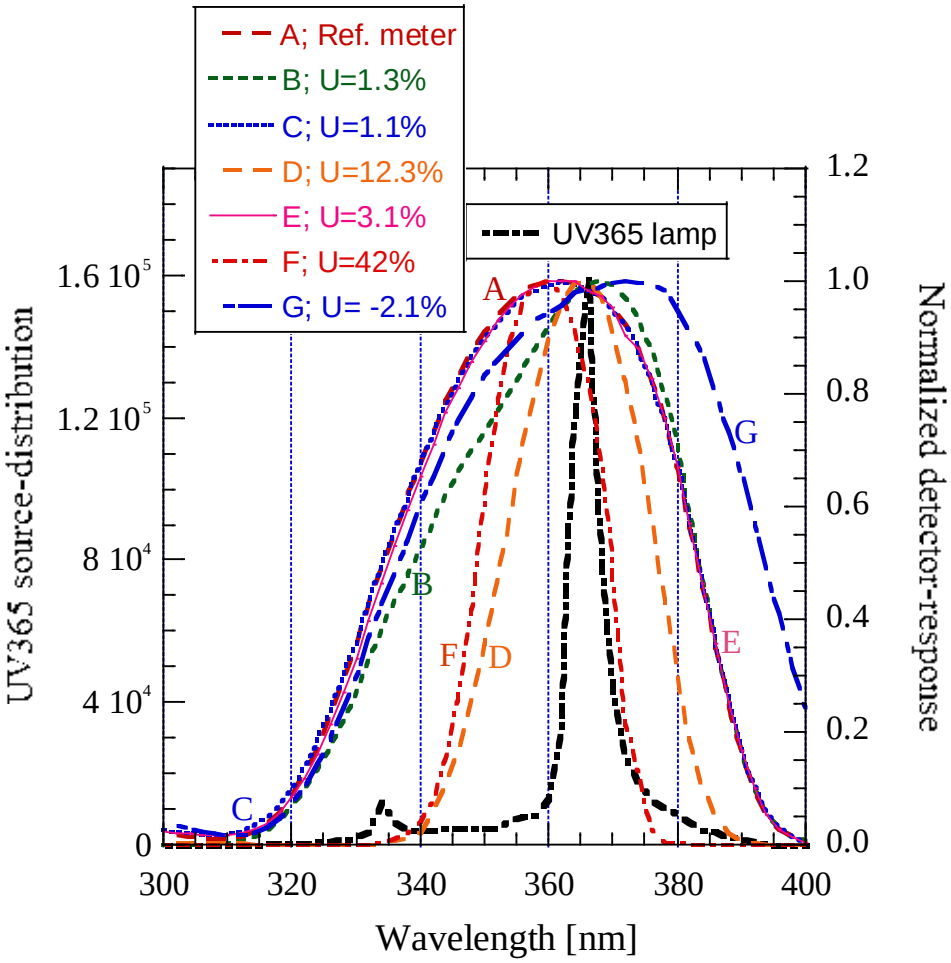
Integrated irradiance measurements with test UV meters

- Test UV irradiance meters, with close to constant spectral response for the measured radiation, are to be selected.

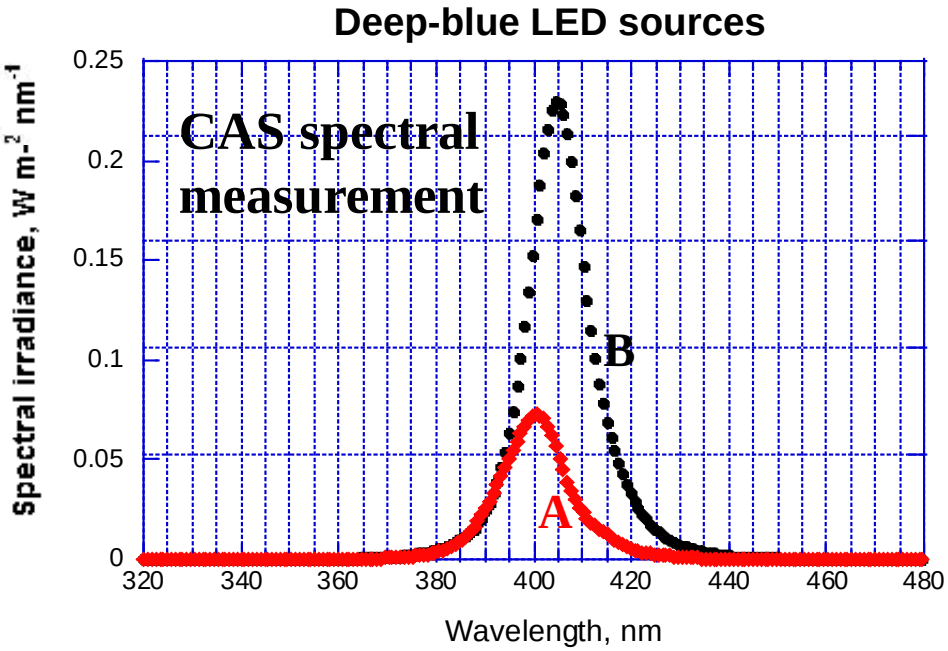
- The meter response curves and the source distribution function should be matched such that the response curve is spectrally wider than the source distribution function.

- Following the source and meter selections (matching the spectral functions), the test-meter can be substituted for the reference pyroelectric meter (of known constant irradiance responsivity) and the signal ratio, when they are measuring the same source, can be used to determine the “flat” irradiance responsivity of the test-meter.

- The integrated irradiance from the source(s) will be equal to the ratio of the test-meter’s output signal divided by its “flat” irradiance responsivity.



Integrated irradiance of deep-blue LEDs measured with the flat pyroelectric meter



E_A(integrated) = 0.14 mW/cm^2

E_B(integrated) = 0.42 mW/cm^2

Estimated low-end limit for pyroe. meter is 2 μW/cm^2 at a S/N of 100

Conclusions

- LED-365 irradiance-source standards have been developed
- A broadband UV measurement procedure has been developed to calibrate UV-to-blue LED sources for integrated irradiance
- Reference UV irradiance meters have been developed
  - Filtered Si
  - Spectrally flat pyroelectric
- A spectrally constant +/- 0.2 % UV absorptance function has been realized from 250 nm to 400 nm
- The future plan is to obtain the uncertainty of the "flat" UV power- and irradiance-responsivity scales to ~0.25 % (k=2) using Si-trap reference detector