

Broadband UV LED measurements at NIST

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Outline

- **Problem:** There is **no standard** for broadband UV measurements. Results are **large errors**
- **Solution** of problem:
 - Use **broadband (standardized) measurement procedure**
 - To simplify procedure: Use irradiance **meters of constant (flat) spectral responsivity:**
 - Filtered Si
 - Low-NEP pyroelectric
 - **Measure integrated irradiance** from LED sources

Broadband measurement procedure

A broadband UV measurement **procedure**, earlier developed at NIST, is used where the source distribution and meter response functions are designed (or selected) such that output signal is not affected by the changes of these functions.

The NIST suggested standard broadband measurement procedure is:

The spectral response of the UV meters is chosen 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 UV sources are used.

Integrated irradiance \bar{E} measurement

Measurement equation:

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

where $E(\lambda)$ is the spectral irradiance of the source, $s_{ref}(\lambda)$ is the spectral responsivity of the reference UV-meter, and λ is the wavelength.

When a reference UV-meter with flat-response is used:

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

$$i_{ref} = i = s \int_{\lambda} E(\lambda) d\lambda \quad \text{is measured by the reference UV-meter}$$

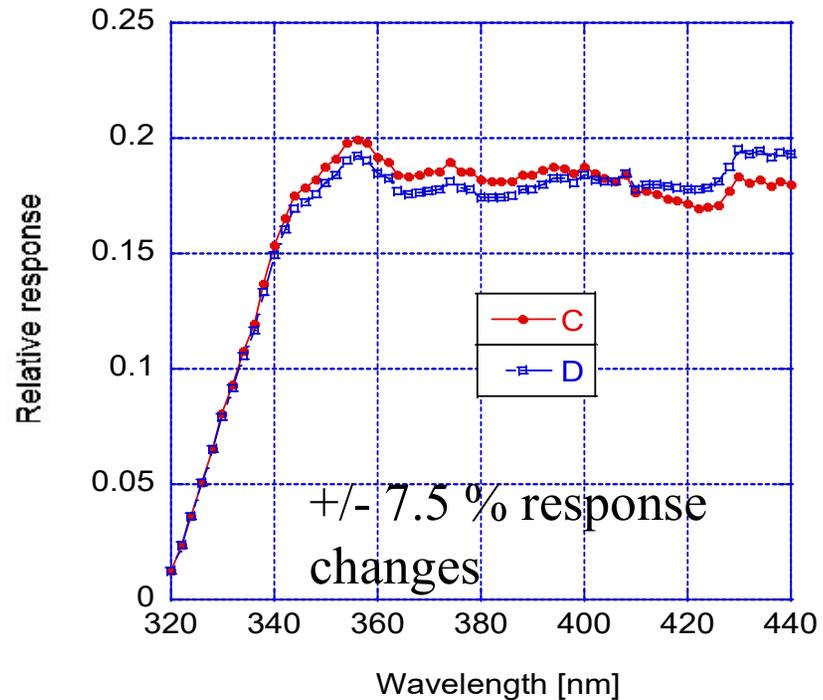
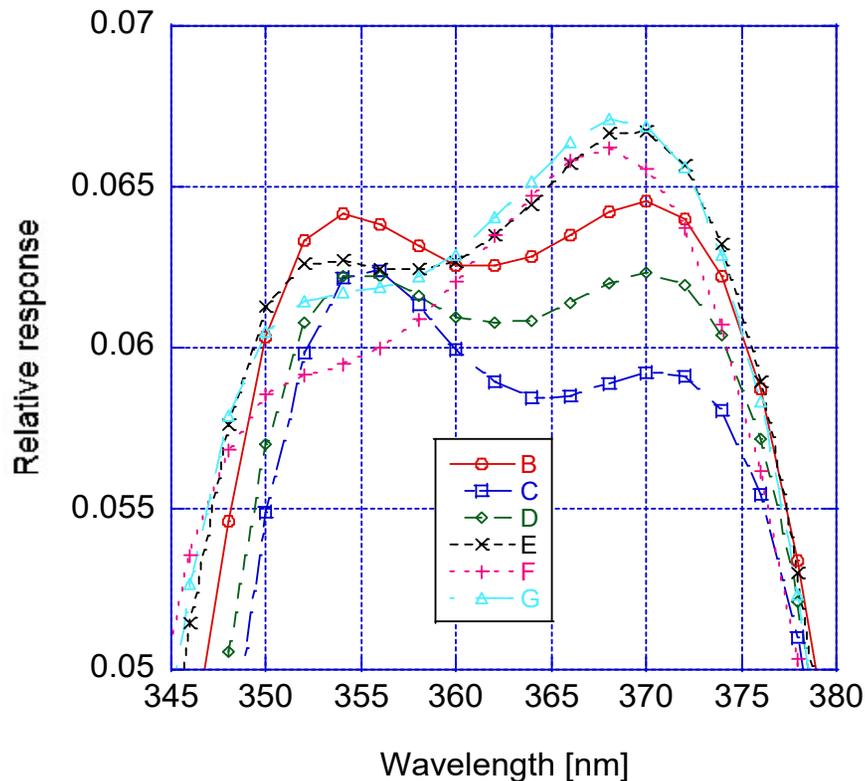
Standard source is not needed!

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

where the unit of i is A, the unit of s is A cm²/W, and the obtained unit for \bar{E} is W/cm².

Development of reference irradiance meters

1) Filtered-Si UV meters for LED-365 sources and the 345-440 nm range



In the UV-365 meters multilayer thin-film and glass filters are used. They are stable but their shapes are different. The response changes are close to 10 % ! They will be used as field-level reference meters.



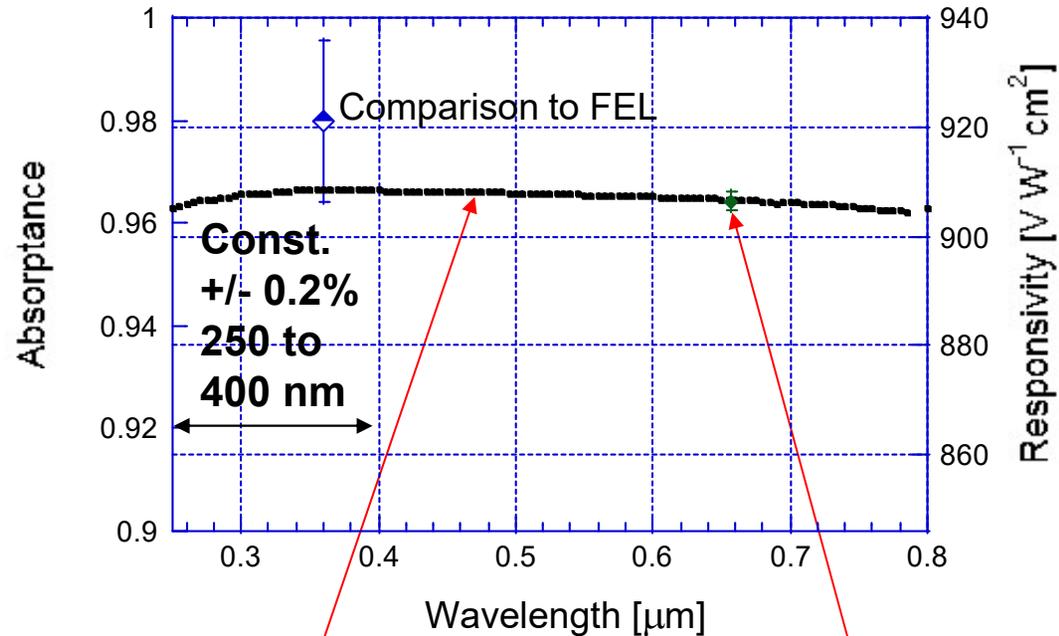
2) Flat-responsivity pyroelectric detector of low-NEP for high-level (reference) standard



The absorptance of the black detector-coating, which is proportional to the response of the detector, is equal to $1 - \text{reflectance (measured)}$ if the transmittance of the coating is negligibly small. Irradiance responsivity tie point(s) can convert the flat relative response curve into absolute spectral irradiance responsivity.

Flat spectral irradiance responsivity of the reference pyroelectric detector

Realization of a new UV-VIS irradiance responsivity scale



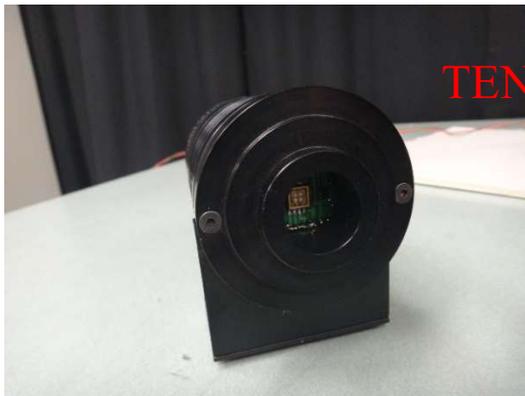
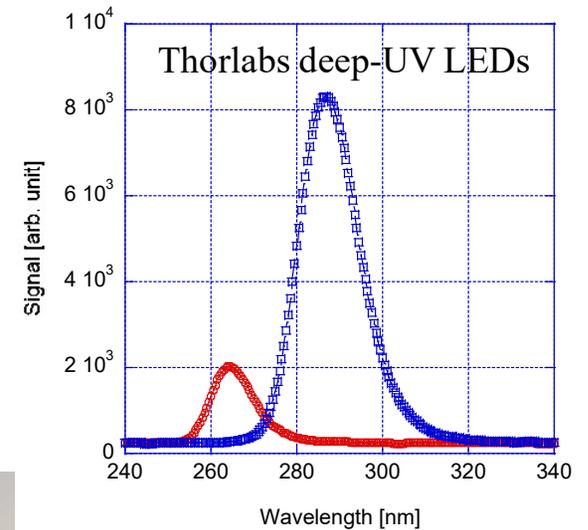
Relative spectral response from spectral reflectance measurement

Irradiance responsivity tie point using 660 nm LED against Si-trap detector. Spectral irradiance responsivity uncertainty is 0.25 % ($k=1$).

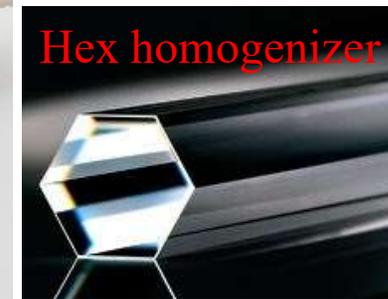
UV LED broadband measurements using the constant-response pyroelectric detector

Integrated irradiance, E , at 40 cm; Uncert. <1% ($k=2$):

ILT E275P (1 mW flux)	$E = 0.71 \mu\text{W}/\text{cm}^2$ at 19.8 mA
Thorlabs M265L3 (10 mW)	$E = 80 \mu\text{W}/\text{cm}^2$ at 300 mA
Thorlabs M285L4 (45 mW)	$E = 0.44 \text{ mW}/\text{cm}^2$ at 325 mA
Tenzi 365	$E = 2.20 \text{ mW}/\text{cm}^2$ at 400 mA
LED Engin LZ1 365 (1 W)	$E = 48.6 \text{ mW}/\text{cm}^2$ at 1.0 A
Old blue LED 400 nm	$E = 0.14 \text{ mW}/\text{cm}^2$ at 400 mA



TENZI 365



Hex homogenizer



Thorlabs mounted deep-UV LEDs



$f/1$ UV-lens added for collimation

**Variable output (0.5 - 7 mW/cm²) LED-365 irradiance source
for Army non-destructive crack-inspection at 40 cm distance**

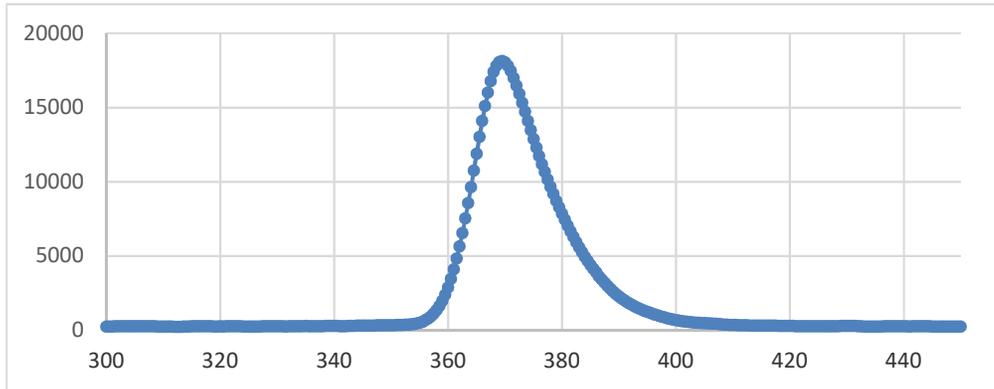


LED temperature (to 25.0 °C)
and feed-current are stabilized



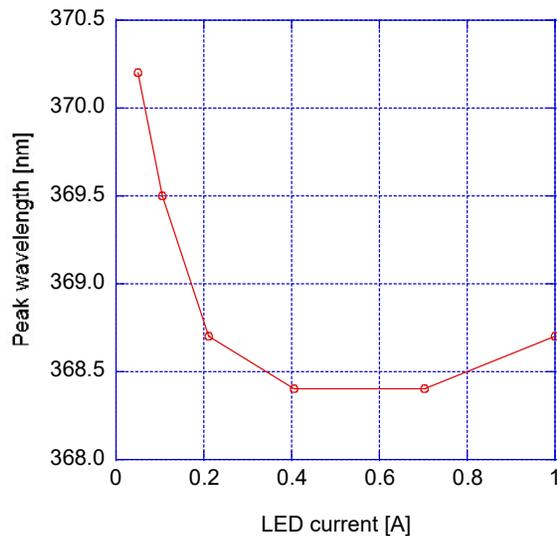
LED ENGIN, Model LZ1-10UV00-0000, LED cluster
with integrated glass lens, 1 W output-flux at 1A.

Variable output (0.5 - 7 mW/cm²) LED-365 irradiance source characteristics

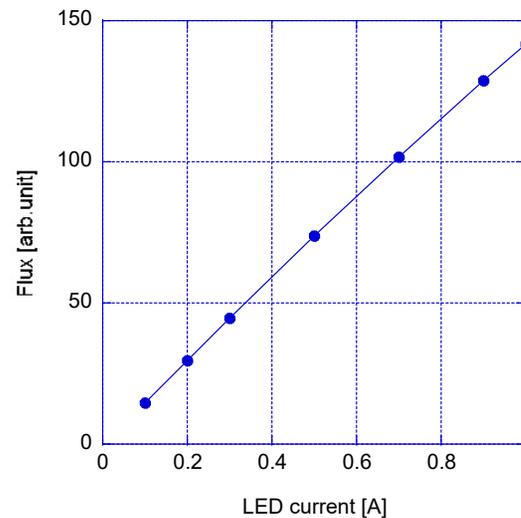


Spectrometer measured spectral power distribution at 0.1 A LED feeding current.

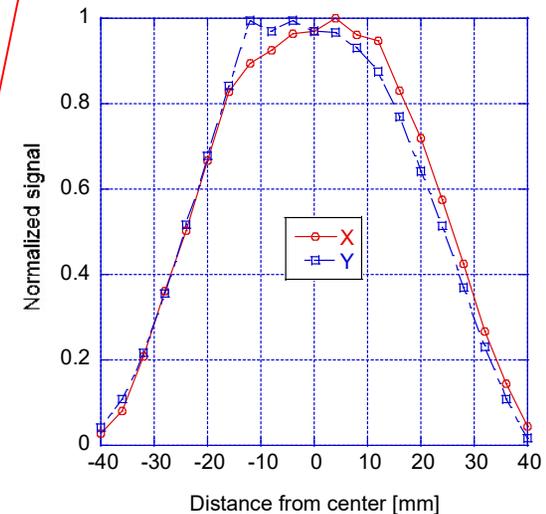
Integrated irradiance can be used for UV hazard evaluations as well !



For current change from 50 mA to 1 A peak changes 1.5 nm



Integrated irradiance: 48.6 mW/cm² at 1.0 A LED feeding current and source - detector distance of 40 cm



Spatial nonuniformity of target spot of -12 mm to +12 mm (for both X and Y) at 40 cm: +/- 5 %; for -5 to +5 mm spot: +/- 0.4 %

Conclusions

- The NIST developed **broadband UV measurement procedure** has been simplified to measure integrated-irradiance from UV LEDs simply with low uncertainty
- **A broadband UV-LED measurement capability** has been developed at NIST including development of **flat-response UV irradiance meters**:
 - Filtered Si (for field applications in UV-A)
 - Low-NEP pyroelectric (**standard detector** for 250 nm to 750 nm)
- The pyroelectric standard (**without a source standard**) can be used to
 - calibrate UV-A meters and to
 - measure UV-VIS LEDs for **integrated (broadband) irradiance**