Development of monitoring sources based on UV light-emitting diodes

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The development of compact, stable, portable, and robust monitoring sources based on state-of-the-art, commercially available UV light-emitting diodes (LEDs) is one of the tasks within the European Metrology Research Programme (EMRP) Project "Traceability for surface spectral solar ultraviolet radiation". It is aimed towards shortening the traceability chain and reducing the uncertainties of spectral solar UV radiation measurements in the wavelength range 280 nm to 400 nm. These monitoring sources will be used to maintain the spectral calibration of spectroradiometers while deployed at solar UV measurement sites.

As a first step, commercially available LEDs with flat emission windows in TO-18 housing have been selected in such a way that the wavelength range from 280 nm to about 450 nm is covered. The peak wavelengths of the investigated LEDs (three per wavelength) have been determined to be 285 nm, 299 nm, 310 nm, 323 nm, 333 nm, 342 nm, 352 nm, 369 nm, 401 nm, and 437 nm, see Figure 1.

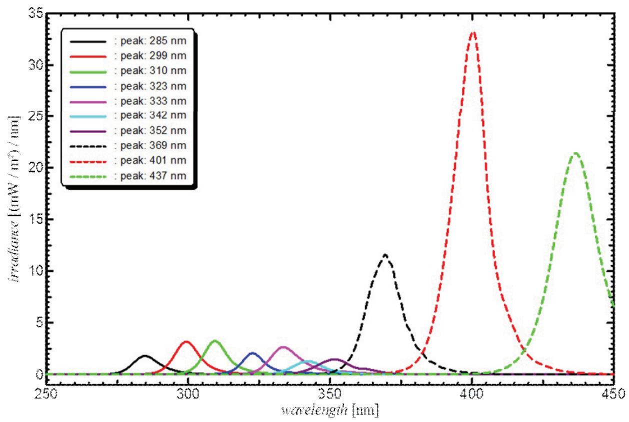

Figure 1. Estimated spectral irradiance of ten different LEDs after aging. Distance of LEDs to entrance optics of a spectroradiometer approximately 5 cm.

In order to study the aging behavior, the irradiance of each LED was monitored in a fully automated measurement setup with a Si photodiode and a calibrated UV array-spectroradiometer. The LEDs were driven in constant current mode. All LEDs were mounted in separate holders, each equipped with a thermostat. The aging of the LEDs has been performed until the drift in irradiance was less than 0.05% per hour (as required for the project goals) or no further change could be expected in reasonable time. Consequently, the operating times ranged between about 100 to over 600 hours. Please see Table 1 for details.

Table 1. Drift in irradiance after operating the LEDs in constant current mode.

peak wavelength	operating time	operating temperature	drift in irradiance
285 nm	565 h	25°C	-0.08% / h
299 nm	402 h	25°C	-0.05% / h
310 nm	476 h	25°C	-0.05% / h
323 nm	120 h	25°C	-0.01% / h
333 nm	101 h	25°C	-0.03% / h
342 nm	134 h	35°C	-0.04% / h
352 nm	120 h	25°C	-0.02% / h
369 nm	134 h	35°C	-0.01% / h
401 nm	120 h	25°C	< -0.01% / h
437 nm	120 h	25°C	0.02% / h

While aging the devices, the spectral irradiance has been monitored and a change in the centroid wavelength towards longer wavelengths has been observed, however, this shift has been calculated to be well below 10-3 nm per hour (Table 2). Also, the full width half maximum (FWHM) value of the emission peak is slightly increasing over time.

Table 2. Shift in centroid wavelength and FWHM for selected UV-LEDs.

peak wavelength	operating temperature	shift in centroid wavelength	shift in FWHM
285 nm	25°C	$1.7 \cdot 10^{-4}$ nm / h	$0.9 \cdot 10^{-4}$ nm / h
299 nm	25°C	$0.8 \cdot 10^{-4}$ nm / h	$0.3 \cdot 10^{-4}$ nm / h
310 nm	25°C	$0.4 \cdot 10^{-4}$ nm / h	$<0.1 \cdot 10^{-4}$ nm / h
333 nm	25°C	$5.1 \cdot 10^{-4}$ nm / h	$6.1 \cdot 10^{-4}$ nm / h
342 nm	35°C	$5.4 \cdot 10^{-4}$ nm / h	$3.5 \cdot 10^{-4}$ nm / h
369 nm	35°C	$1.3 \cdot 10^{-4}$ nm / h	$7.8 \cdot 10^{-4}$ nm / h

Another requirement for the monitoring sources are irradiance levels of at least 1 mW m^{-2} nm^{-1} for wavelengths between 280 nm and 330 nm, and 5 mW m^{-2} nm^{-1} for longer wavelengths. A prototype monitoring source has been designed to hold 10 LEDs, which were selected after analyzing their aging behavior. Unfortunately, the irradiance levels of the available LEDs around 340 nm have proved to be not very high (see Figure 1); to compensate, two LEDs emitting at peak wavelengths of 352 nm have been selected instead of a LED with the peak emission at 342 nm, as this has a more favourable effect for the expected total irradiance of the monitoring source. The total spectral irradiance expected from the 10 selected LEDs in a distance of 5 cm to the entrance optics of a spectroradiometer is shown in figure 2, along with the required irradiance levels, and the irradiance of a tungsten lamp (FEL, distance 50 cm). The irradiance levels probably will not meet the requirements over the whole spectral range; however, the

LEDs will offer higher levels than the FEL in the low wavelength range.

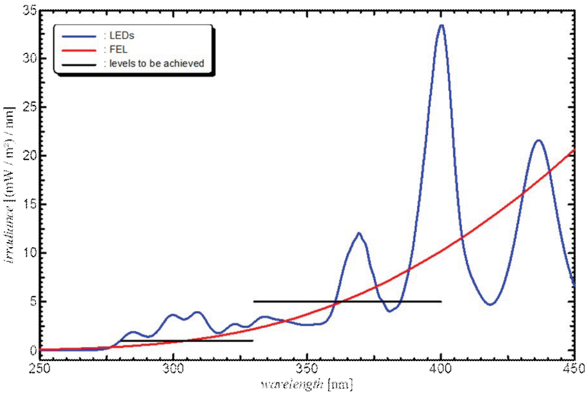

Figure 2. Blue curve: expected spectral irradiance from the ten selected LEDs. Red curve: spectral irradiance from a tungsten lamp (FEL, distance 50 cm). Black lines: desired irradiance levels.

A prototype of a monitoring source has already been constructed. The ten selected LEDs are mounted into an aluminum block, along with a SiC monitoring photodiode. A Peltier element is used for temperature controlling. A spacer - a cylinder of stainless steel - is mounted between the aluminum/LED block and interchangeable flanges. These flanges are used as mechanical interface to different types of entrance optics of spectroradiometers, ensuring a reproducible geometry between the LEDs and the diffuser heads. The cylinder is, however, thermally isolated from the aluminum block by a Teflon spacer. See figure 3 for a picture of the prototype. At the moment, this prototype is being tested for temperature stability. Further investigations will provide the level and stability of irradiance, its reproducibility and the time needed to reach steady state conditions after switching on the LEDs. If these tests are successful, field measurements with this prototype will be undertaken in the near future.

Figure 3. Assembled prototype of the monitoring source based on UV-LEDs.

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