New spectral irradiance traceability scale at LNE-CNAM

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The LNE-CNAM developed a new spectral irradiance measurement facility covering the spectral range from 250 nm to 2500 nm. This bench allows calibration of irradiance spectral density of a source using a high temperature black body (HTBB) and a filter radiometer. The filter radiometer used is traceable to the cryogenic radiometer which is our radiometric reference. It extends our measurement capacity up to 250 nm and reduces by at least a factor two our measurement uncertainties over the entire range.

This paper shows our new traceability scheme for spectral irradiance, the method used, and its validation.

NEW TRACEABILITY SCHEME

Up to now, the irradiance spectral density measurement is based on the thermodynamic temperature reference at LNE-CNAM [1] and our Calibration and Measurement Capabilities (CMC) is between 300 nm and 2500 nm.

We have recently simplified our traceability scheme in order to reduce our measurement uncertainties and to extend our measurement capacity up to 250 nm. For this, we have set up a new measurement facility. It allows calibration of absolute spectral irradiance of a lamp based on the comparison with a black body (HTBB) whose temperature is assessed by measuring the irradiance with a calibrated filter radiometer and calculating the spectral radiance at one wavelength. The calibration method is similar to those previously developed in other National Measurement Institutes [2]. The HTBB temperature measurement follows the method detailed in [6].

Spectral responsivity of the radiometer is obtained in three steps: the calibration of spectral responsivity of the Silicon trap detector with our cryogenic radiometer [3], the calibration of the spectral regular transmittance of its bandpass filter with our primary spectrophotometer [4] and the calibration of its aperture with our devoted setup [5].

The traceability of spectral irradiance with national realisation of watt and meter is shown on Figure 1.

To minimize uncertainties, corrections on temperature homogeneity and emissivity of HTBB are applied [6].

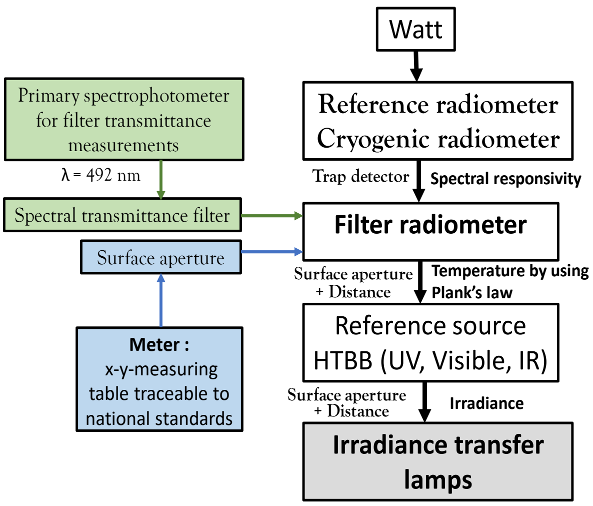

Figure 1. Traceability chain for the spectral irradiance calibration at LNE-CNAM.

DESCRIPTION OF THE BENCH

The spectroradiometer of the LNE-CNAM is described in Figure 2.

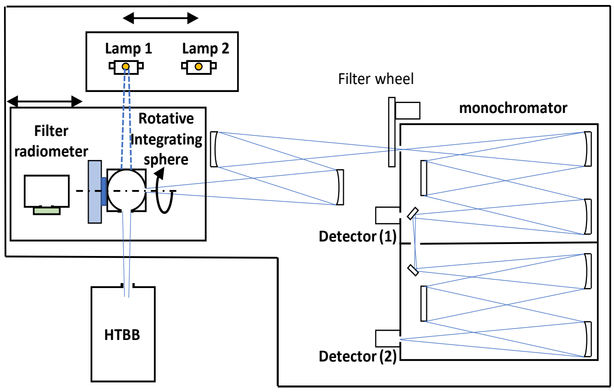

Figure 2. Diagram of LNE-CNAM calibration facility.

The HTBB is used as an irradiance reference for the calibration of transfer sources. A cavity heated up to 3100 K provides radiation which can be used in the 250 nm to 2500 nm range. A spectroradiometric system compares the spectral irradiance of HTBB and transfer lamps (Lamp1 and Lamp2). It is composed of:

- an integrating sphere that receives the flux from the sources with an entrance port equipped with a circular diaphragm. The sphere has an output port located at 90° with a rectangular slit shape of 2 mm x 15 mm.
- two Ø 150 mm spherical mirrors that focus the image of the sphere exit slit on to the entrance slit of a dual monochromator.
- a filter radiometer with a transmittance centred on 492 nm.
- a Jobin Yvon HRD640 double monochromator on which the manual wavelength selection mechanism has been replaced by a high precision motorized translation stage and equipped with three pairs of gratings to cover the wavelength range.

The filter radiometer and the integrating sphere are placed on the same translation stage. That allows to perform in one cycle the blackbody temperature measurement with the calibrated filter radiometer and the irradiance spectral comparison of the HTBB and the lamps. The integrating sphere is rotated by 180° around the axis centred on the exit slit. This allows to collect either the HTBB or the transfer lamps flux.

The entire facility is placed in a box with two compartments, one for the source part and one for the monochromator, in order to avoid stray light.

The bench is fully automated and controlled by a custom LabVIEW software.

VALIDATION

For the validation of this new measurement setup, our set of four reference transfer lamps have been measured and compared with their historical values on the range 300 nm to 2500 nm. The historical and new measurement uncertainties (k=2) of a lamp are showed in the Table 1.

Table 1. Historical and new measurement uncertainties of a lamp.

Wavelength (nm)	Relative expanded uncertainty (k = 2) / (%)	
	2016	**2019**
250		7.2
260 - 290		3.0 - 1.4
300 - 310	3.9	1.2
320 - 390	2.6	< 1.2
400 - 1400	2.2	0.5 - 1.6
1500 - 2300	2.6	0.4 - 1.2
2400 - 2500	5.0	2.3 - 7.6

At the spectrum extremities at 250 nm and 2500 nm, the large uncertainties are due to the lack of flux.

The comparison results are showed in Table 2.

Table 2. Results of our lamps with the new bench.

Wavelength (nm)	Mean deviation 2019/2016 (%)	Comparison uncertainties 2019/2016 (k=2) / (%)
300	4.5	4.1
320-380	< 1.3	2.8
400-1050	< 0.6	2.3 - 2.6
1100 - 2200	0.1 - 2.6	2.3 - 2.8
2300 -2500	4.6 - 8.5	3.0 - 9.0

Most of the mean deviations 2019/2016 observed are smaller than the expanded uncertainty of the comparison. At 300 nm, the significant deviation observed seems to correct the deviation that we had during the last CCPR K1-a in 2005. It could be explained by lack of flux and the stray light of former simple monochromator.

CONCLUSION

From now on, LNE-CNAM spectral irradiance reference is based on the radiometric reference.

Thanks to the new setup, it is possible to measure the absolute irradiance of transfer lamps with a direct traceability to our cryogenic radiometer. This bench extends our measurement capacity up to 250 nm and reduces at least by a factor two our measurement uncertainties (excepted at 2500 nm).

In the future, optimisation of measurement facility will allow:

- a further reduction of uncertainties between 2400 nm and 2500 nm.
- an extension of our measurements up to 200 nm.
- an extension of our measurements up to 3000 nm.
- a radiance calibration in this spectral range.

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