Calibration of the Spectral Radiance of a Low Current Carbon Arc between 185 nm and 340 nm

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The spectral radiance L_λ of a low current carbon arc (current 7.3 amps, voltage 65 V) has been calibrated in the spectral range from the air cut-off ($\lambda \approx 185$ nm) to 340 nm with an uncertainty of $\pm 3\%$ utilizing the electron synchrotron radiation of DESY, Hamburg. In the wavelength range above 260 nm these values differ by less than $\pm 6\%$ from the measurements of Magdeburg and Schurer.

Introduction and Method

In the last decades, the spectral radiance of different types of the carbon arc has been determined in a number of experiments with different methods [1–10].

The spectral radiance of the carbon arc mainly utilized in the USA (current: ≈ 12 amps) was investigated in the uv spectral region down to the air cut-off [4, 7, 10] ($\lambda \approx 185$ nm), but the spectral radiance of the low current carbon arc used here (current: $i = 7.3$ amps) is only known in the spectral region above 260 nm [5, 8], with a relative uncertainty of $\pm 5\%$ at $\lambda = 260$ nm and $\pm 3\%$ above $\lambda = 300$ nm. Differences of the spectral radiance values above 260 nm between both types of differently driven carbon arcs are only in the order of 3%, too, and will not be discussed in this paper. The measurements reported here were undertaken in order to extend the spectral radiance calibration of this type of carbon arc down to the air cut-off and to improve the accuracy with respect to the results of Magdeburg [5] and Schurer [8] between 260 nm and 340 nm.

The measurements were carried out by means of a radiometric device that is being in service at DESY (Deutsches Elektronensynchrotron, Hamburg), using the electron synchrotron radiation of DESY. Arragement and procedure are described in detail elsewhere [11]. As described in [11], the low current carbon arc to be calibrated is located outside the vacuum tank and is operated under atmospheric pressure without any direct contact to the vacuum system. Therefore, a fused silica window is posed in the optical path which is serving as a vacuum sealing. A direct spectral radiance calibration of the low current carbon arc in the uv utilizing the synchrotron radiation without an auxiliary source would require an accurate determination of the transmission factor of this window and of the optical path-length between the window and the anode. Users of the spectral radiance values of the low current carbon arc then would be forced to arrange their optical devices either with identical path-lengths or to take into account different path-lengths in the evaluation of their results. In order to overcome this difficulty, in a first step a deuterium lamp was calibrated with respect to the spectral radiance by means of the electron synchrotron radiation without a window under vacuum conditions. Subsequently the radiometric device was vented to atmospheric pressure, and in a second step the spectral radiance of the low current carbon arc was calibrated (in air) by a radiometric comparison with the radiation of the deuterium lamp, continuously operated in the meantime, using only the uv-monochromator of the arrangement described in [11].

Results and Error Discussion

The operating parameters of the carbon arc have been identical to those used by Magdeburg [5] and Schurer [8] (anode: RW II+, 6.3 mm ∅, cathode: Noris D*, 7 mm ∅; current 7.3 amps, geometrical arrangement of electrodes: 90 degrees). During operation of the low current carbon arc, the electrode spacing was automatically adjusted by means of a motordriven mechanism for both electrodes to maintain the anode face in the plane normal to the anode axis by keeping the voltage between the electrodes at a value of (65.0 ± 0.5) V.

The spectral radiance values of the low current carbon arc calibrated indirectly by means of the synchrotron radiation in the spectral range between 185 nm and 280 nm are presented in Fig. 1, as well

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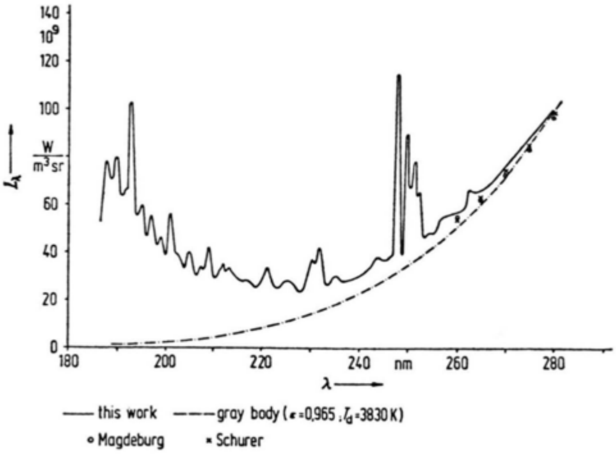

Fig. 1. Spectral radiance of the low current carbon arc between 185 nm and 280 nm in comparison to the results of previous investigations. The spectral radiance values for the gray-body were computed for $\varepsilon = 0.965$, $T_d = 3830$ K. Spectral resolution in this work: $\Delta\lambda \leqq 0.6$ nm.

λ[nm]	$L_\lambda [\mathrm{W \cdot m^{-3} \cdot sr^{-1}}]$
260	$56 \cdot 10^9$
265	66
270	76
275	89
280	102
285	115
290	130
295	149
300	169
305	189
310	213
315	238
320	265
325	294
330	326
335	358
340	392

Table 1. Spectral radiance L_λ of the low current carbon arc. (current: 7.3 amps, voltage 65 V, anode material: RW II, 6.3 mm in diameter, cathode material: Noris D, 7 mm in diameter, geometrical arrangement of the electrodes: 90 degrees).

as the spectral radiance values of Magdeburg [5] and Schurer [8].

In the spectral range above 270 nm the spectral radiance of the carbon arc is approximated by that one of a gray-body radiator [6] (distribution temperature $T_d = 3830$ K, emissivity $\varepsilon = 0.965$) represented in Fig. 1 as a dotted line. Below 270 nm the spectral radiance L_λ of the low current carbon arc is summed up from the radiation of the incandescant anode and that of the arc stream in front of the anode. With decreasing wavelength, the portion of the radiation emitted from the incandescant anode to the total emitted spectral radiance L_λ decreases considerably and therefore the low current carbon arc is a convenient uv-transfer standard only down to 270 nm, with restrictions down to 235 nm. Below 235 nm the emitted spectrum is distorted by a number of emission lines.

Because of the predominant quality of the arc stream radiation its sensibility to alterations of the arc current and the geometric operating parameters seems to be considerably enhanced, and that results in a loss of stability and reproducibility.

In the spectral range from 260 nm to 340 nm the spectral radiance L_λ of the low current carbon arc has been determined at equidistant wavelengths by steps of 5 nm. The best fitting of these values is presented in Table 1. The relative uncertainty of the spectral radiance of the low current carbon arc amounts to $\pm 3\%$, summed up from the uncertainty in the spectral radiance calibration [11] of the deuterium lamp ($\pm 2\%$) and the comparison between the deuterium lamp and the low current carbon arc ($\pm 1\%$). The results based on reference blackbodies as performed by Magdeburg [5] and Schurer [8] differ by less than 6% from the values reported here. This is within the combined estimated uncertainty range of both calibration procedures.

For wavelengths smaller than 280 nm the deviations are probably caused by the growing relative uncertainty due to the decreasing signal to noise ratio of the blackbody measurements as well as to the very high ratio of the fluxes to be compared. The deviations for wavelengths $\lambda > 330$ nm could possibly be caused by inherent systematic errors of the optical device for spectral radiance calibrations by means of electron synchrotron radiation [11]. To check this possible error source, the spectral radiance of the low current carbon arc has been calibrated additionally with a tungsten strip lamp (see Sect. 5.5 in [11]) first with the uv-monochromator at DESY and second with an optical device being in service at the PTB in Berlin, that is mainly used for other radiometric measurements [14]. The deviation of the spectral radiance values of the latter measurements in comparison to the synchrotron based values is always smaller than 3%. This result was also confirmed by two earlier experiments [12, 13].

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