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# Certificate of Calibration

0478

## FEL LAMP F-1380
## ABSOLUTE SPECTRAL IRRADIANCE



FOR: NERC Field Spectroscopy Facility
University of Edinburgh
Grant Institute
James Hutton Road
Edinburgh
EH9 3FE

DESCRIPTION: The lamp was a Gooch & Housego FEL tungsten halogen filament lamp, type OL FEL-U, of nominal power 1 kW.

IDENTIFICATION: The number F-1380 was marked on the front of the lamp base.

DATES OF CALIBRATION: 5 July 2016 to 13 July 2016

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k = 2$, providing a coverage probability of approximately 95 %. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

**Reference: 2016020157/IB2-16** **Page 1 of 7**

**Date of issue: 18 July 2016** **Signed:** **(Authorised Signatory)**

**Checked by:** **Name: B Duncan** **on behalf of NPLML**

MEASUREMENTS

The removable alignment jig was placed vertically in the lamp mount, using a spirit level balanced on the top of the alignment jig to set the vertical alignment. The lamp mount was then adjusted so that the measurement axis, defined as the axis passing through and perpendicular to the centre of the measurement aperture, passed through the centre of the alignment crosshairs marked on the jig and was perpendicular to the jig. The jig was then carefully removed from the mount and the lamp inserted in its place with the lamp number facing the measurement instrument. The calibration refers to the absolute spectral irradiance at a distance of 0.500 m, measured from the front face of the alignment jig.

The lamp was operated from an actively stabilised dc power supply at 8.000 A. The polarity of the electrical current was as marked on the lamp, it was not changed. The lamp was ramped up and run for 30 minutes before measurements commenced. The voltage was monitored during measurement and is given for checking purposes only.

Spectral irradiance measurements were made over the range 250 nm to 1000 nm with an instrument bandwidth of approximately 7 nm (FWHM) and from 1000 nm to 2500 nm with an instrument bandwidth of approximately 14 nm (FWHM). Measurements were made against a series of NPL standard lamps calibrated against the $NPL_{2010}$ spectral irradiance scale.

Ambient temperature during measurement was in the range 21° C ± 2° C.

RESULTS

The table on pages 4 to 7 gives values for the spectral irradiance in mW $m^{-2}$ $nm^{-1}$ at 10 nm intervals over the wavelength range 250 nm to 2500 nm.

Values for the chromaticity coordinates and correlated colour temperature, calculated from the unrounded spectral data, appear in the table below, together with the measured lamp voltage.

| **Parameter** | **Value** | **Uncertainty** |
|---|---|---|
| x | 0.4325 | ± 0.0011 |
| y | 0.4028 | ± 0.0003 |
| u | 0.2482 | ± 0.0006 |
| v | 0.3468 | ± 0.0002 |
| Correlated colour temperature | 3066 K | ± 18 K |
| Voltage | 110.8 V | |



**Checked by:** LJ SSH

UNCERTAINTIES

The total expanded uncertainty of the absolute spectral irradiance calibration was estimated not to exceed the value given in the table on pages 4 - 7 for each individual point.

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k = 2$, providing a coverage probability of approximately 95 %.

The results and uncertainties quoted refer to on-the-day values, and no allowance has been made for subsequent drift.



**Checked by:** LJ SSH

**FEL Lamp F-1380**

| Wave-length | Absolute Spectral Irradiance | Uncertainty | Wave-length | Absolute Spectral Irradiance | Uncertainty |
|---|---|---|---|---|---|
| nm | mW $m^{-2}$ $nm^{-1}$ | % | nm | mW $m^{-2}$ $nm^{-1}$ | % |
| 250 | 0.1427 | 2.5 | 580 | 111.4 | 1.1 |
| 260 | 0.2495 | 2.4 | 590 | 117.3 | 1.1 |
| 270 | 0.412 | 2.4 | 600 | 123.1 | 1.1 |
| 280 | 0.652 | 2.4 | 610 | 128.9 | 1.1 |
| 290 | 0.994 | 2.4 | 620 | 134.4 | 1.1 |
| 300 | 1.459 | 2.2 | 630 | 139.8 | 1.1 |
| 310 | 2.071 | 2.2 | 640 | 145.2 | 1.1 |
| 320 | 2.853 | 2.2 | 650 | 150.3 | 1.1 |
| 330 | 3.84 | 2.2 | 660 | 155.2 | 1.1 |
| 340 | 5.07 | 2.2 | 670 | 160.1 | 1.1 |
| 350 | 6.56 | 2.1 | 680 | 164.6 | 1.1 |
| 360 | 8.30 | 2.2 | 690 | 170.3 | 2.0 |
| 370 | 10.33 | 2.1 | 700 | 173.5 | 1.1 |
| 380 | 12.69 | 2.0 | 710 | 177.0 | 1.1 |
| 390 | 15.35 | 2.0 | 720 | 181.0 | 1.1 |
| 400 | 18.31 | 1.8 | 730 | 184.4 | 1.1 |
| 410 | 21.77 | 2.2 | 740 | 188.0 | 1.1 |
| 420 | 25.43 | 1.4 | 750 | 191.0 | 1.1 |
| 430 | 29.32 | 1.7 | 760 | 194.1 | 1.1 |
| 440 | 33.5 | 1.3 | 770 | 196.7 | 1.1 |
| 450 | 38.0 | 1.3 | 780 | 199.3 | 1.1 |
| 460 | 42.8 | 1.3 | 790 | 201.3 | 1.5 |
| 470 | 47.8 | 1.2 | 800 | 203.7 | 1.2 |
| 480 | 53.0 | 1.2 | 810 | 205.6 | 1.3 |
| 490 | 58.4 | 1.2 | 820 | 207.4 | 1.2 |
| 500 | 64.0 | 1.2 | 830 | 208.9 | 1.2 |
| 510 | 69.8 | 1.2 | 840 | 210.2 | 1.1 |
| 520 | 75.5 | 1.1 | 850 | 211.2 | 1.0 |
| 530 | 81.5 | 1.1 | 860 | 212.2 | 1.0 |
| 540 | 87.4 | 1.1 | 870 | 213.0 | 1.0 |
| 550 | 93.5 | 1.1 | 880 | 213.5 | 1.0 |
| 560 | 99.5 | 1.1 | 890 | 214.2 | 1.0 |
| 570 | 105.4 | 1.1 | 900 | 214.2 | 1.0 |



**Checked by:** LJ SSH

**FEL Lamp F-1380**

| Wave-length | Absolute Spectral Irradiance | Uncertainty | Wave-length | Absolute Spectral Irradiance | Uncertainty |
|---|---|---|---|---|---|
| nm | mW $m^{-2}$ $nm^{-1}$ | % | nm | mW $m^{-2}$ $nm^{-1}$ | % |
| 910 | 214.7 | 1.0 | 1240 | 174.0 | 1.1 |
| 920 | 214.7 | 1.0 | 1250 | 172.1 | 1.1 |
| 930 | 214.5 | 1.0 | 1260 | 170.2 | 1.1 |
| 940 | 214.5 | 1.0 | 1270 | 168.4 | 1.1 |
| 950 | 213.9 | 1.0 | 1280 | 166.5 | 1.1 |
| 960 | 213.5 | 1.0 | 1290 | 164.7 | 1.1 |
| 970 | 213.0 | 1.0 | 1300 | 162.8 | 1.0 |
| 980 | 212.3 | 1.0 | 1310 | 161.0 | 1.2 |
| 990 | 211.3 | 1.0 | 1320 | 159.2 | 1.2 |
| 1000 | 210.5 | 1.0 | 1330 | 157.4 | 1.2 |
| 1010 | 209.6 | 1.1 | 1340 | 155.6 | 1.2 |
| 1020 | 208.6 | 1.1 | 1350 | 153.8 | 1.2 |
| 1030 | 207.6 | 1.1 | 1360 | 152.0 | 1.4 |
| 1040 | 206.4 | 1.1 | 1370 | 150.2 | 1.4 |
| 1050 | 205.3 | 1.1 | 1380 | 148.4 | 1.4 |
| 1060 | 204.0 | 1.1 | 1390 | 146.6 | 1.4 |
| 1070 | 202.6 | 1.1 | 1400 | 144.9 | 1.4 |
| 1080 | 201.2 | 1.1 | 1410 | 143.0 | 1.4 |
| 1090 | 199.7 | 1.1 | 1420 | 141.2 | 1.4 |
| 1100 | 198.2 | 1.0 | 1430 | 139.4 | 1.4 |
| 1110 | 196.7 | 1.0 | 1440 | 137.6 | 1.4 |
| 1120 | 195.1 | 1.1 | 1450 | 135.8 | 1.1 |
| 1130 | 193.4 | 1.1 | 1460 | 134.0 | 1.1 |
| 1140 | 191.8 | 1.0 | 1470 | 132.3 | 1.1 |
| 1150 | 190.1 | 1.0 | 1480 | 130.6 | 1.1 |
| 1160 | 188.4 | 1.0 | 1490 | 128.9 | 1.1 |
| 1170 | 186.7 | 1.1 | 1500 | 127.3 | 1.0 |
| 1180 | 184.9 | 1.1 | 1510 | 125.6 | 1.0 |
| 1190 | 183.2 | 1.0 | 1520 | 124.0 | 1.0 |
| 1200 | 181.4 | 1.0 | 1530 | 122.4 | 1.0 |
| 1210 | 179.6 | 1.1 | 1540 | 120.8 | 1.0 |
| 1220 | 177.7 | 1.1 | 1550 | 119.2 | 1.0 |
| 1230 | 175.8 | 1.1 | 1560 | 117.7 | 1.0 |



**Checked by:** LM SSH

**FEL Lamp F-1380**

| Wave-length | Absolute Spectral Irradiance | Uncertainty | Wave-length | Absolute Spectral Irradiance | Uncertainty |
|---|---|---|---|---|---|
| nm | mW $m^{-2}$ $nm^{-1}$ | % | nm | mW $m^{-2}$ $nm^{-1}$ | % |
| 1570 | 116.1 | 1.0 | 1900 | 75.1 | 1.3 |
| 1580 | 114.6 | 1.0 | 1910 | 74.0 | 1.3 |
| 1590 | 113.1 | 1.0 | 1920 | 73.0 | 1.3 |
| 1600 | 111.6 | 1.0 | 1930 | 72.0 | 1.3 |
| 1610 | 110.1 | 1.3 | 1940 | 71.0 | 1.3 |
| 1620 | 108.7 | 1.3 | 1950 | 70.0 | 1.3 |
| 1630 | 107.3 | 1.3 | 1960 | 69.1 | 1.3 |
| 1640 | 105.9 | 1.3 | 1970 | 68.2 | 1.3 |
| 1650 | 104.6 | 1.3 | 1980 | 67.3 | 1.3 |
| 1660 | 103.2 | 1.3 | 1990 | 66.4 | 1.3 |
| 1670 | 101.8 | 1.3 | 2000 | 65.5 | 1.3 |
| 1680 | 100.5 | 1.3 | 2010 | 64.5 | 1.3 |
| 1690 | 99.2 | 1.3 | 2020 | 63.6 | 1.3 |
| 1700 | 97.9 | 1.3 | 2030 | 62.7 | 1.3 |
| 1710 | 96.6 | 1.3 | 2040 | 61.8 | 1.3 |
| 1720 | 95.3 | 1.3 | 2050 | 60.9 | 1.3 |
| 1730 | 94.0 | 1.3 | 2060 | 60.2 | 1.3 |
| 1740 | 92.8 | 1.3 | 2070 | 59.5 | 1.3 |
| 1750 | 91.5 | 1.3 | 2080 | 58.9 | 1.3 |
| 1760 | 90.3 | 1.3 | 2090 | 58.2 | 1.3 |
| 1770 | 89.0 | 1.3 | 2100 | 57.5 | 1.3 |
| 1780 | 87.8 | 1.3 | 2110 | 56.7 | 1.3 |
| 1790 | 86.6 | 1.3 | 2120 | 55.9 | 1.3 |
| 1800 | 85.4 | 1.3 | 2130 | 55.1 | 1.3 |
| 1810 | 84.4 | 1.4 | 2140 | 54.4 | 1.3 |
| 1820 | 83.4 | 1.4 | 2150 | 53.6 | 1.3 |
| 1830 | 82.3 | 1.4 | 2160 | 53.0 | 1.3 |
| 1840 | 81.3 | 1.4 | 2170 | 52.3 | 1.3 |
| 1850 | 80.3 | 1.4 | 2180 | 51.6 | 1.3 |
| 1860 | 79.3 | 1.4 | 2190 | 51.0 | 1.3 |
| 1870 | 78.2 | 1.4 | 2200 | 50.3 | 1.3 |
| 1880 | 77.1 | 1.4 | 2210 | 49.6 | 1.7 |
| 1890 | 76.1 | 1.4 | 2220 | 49.0 | 1.8 |



**Checked by:** LJ SSH

**FEL Lamp F-1380**

| Wave-length | Absolute Spectral Irradiance | Uncertainty |
|---|---|---|
| nm | mW $m^{-2}$ $nm^{-1}$ | % |
| 2230 | 48.3 | 1.8 |
| 2240 | 47.6 | 1.7 |
| 2250 | 47.0 | 1.6 |
| 2260 | 46.4 | 1.7 |
| 2270 | 45.9 | 1.7 |
| 2280 | 45.3 | 1.7 |
| 2290 | 44.8 | 1.7 |
| 2300 | 44.3 | 1.3 |
| 2310 | 43.7 | 1.5 |
| 2320 | 43.0 | 1.6 |
| 2330 | 42.5 | 1.6 |
| 2340 | 41.9 | 1.5 |
| 2350 | 41.3 | 1.5 |
| 2360 | 40.8 | 1.5 |
| 2370 | 40.3 | 1.5 |
| 2380 | 39.9 | 1.5 |
| 2390 | 39.4 | 1.5 |
| 2400 | 39.0 | 1.3 |
| 2410 | 38.5 | 2.0 |
| 2420 | 38.0 | 2.0 |
| 2430 | 37.6 | 2.0 |
| 2440 | 37.1 | 2.0 |
| 2450 | 36.7 | 2.0 |
| 2460 | 36.2 | 2.0 |
| 2470 | 35.7 | 2.0 |
| 2480 | 35.3 | 2.0 |
| 2490 | 34.9 | 2.0 |
| 2500 | 34.4 | 2.0 |



**Checked by:** LJ SGH