REVISED REPORT OF CALIBRATION *

for

One Standard of Spectral Irradiance

OL FEL-M, S/N: F-1711

Calibration Date: December 16, 2021
Certification Date: December 17, 2021
Revised Report Date: May 26, 2022
Report No: 11537A_2

* This report was revised on May 26, 2022 to correct the relative expanded uncertainty previously provided on Table 2. Appendix B provides a side-by-side comparison of the previous reported uncertainties and the corrected values.

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4632 36th Street, Orlando, Florida 32811 USA
T +1 407 422 3171 W optroniclabs.com

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for

One Standard of Spectral Irradiance

Customer: Wet Labs
Philomath, OR 97370
Contact Information: Klytle@seabird.com
Purchase Order No: 29749
Sales Order No: 11537

1. Material.

One new 1000-watt (FEL) quartz-halogen tungsten coiled-coil filament lamp Standard of Spectral Irradiance (OL FEL-M) was supplied by Optronic Laboratories and bears the designation F-1711 .

2. Method of Calibration and Standards.

For information regarding the mounting, orientation, and alignment processes performed during the calibration, refer to Appendix A.

The calibration of Standard F-1711 was performed by direct comparison to an Optronic Laboratories FEL 1000-watt lamp Standard of Spectral Irradiance, S/N: F-1670. The calibration of Standard F-1670 was performed by direct comparison to a NIST supplied FEL 1000-watt Standard of Spectral Irradiance, S/N: F-714, at a range of 250 nm to 1100 nm and is traceable to SI units through NIST. The calibration was performed using procedure(s) LAMPP02.

The measurement procedure employs the highly accurate wavelength-by-wavelength method of comparison. The spectral irradiance of both lamps is measured at a set wavelength by translating the double monochromator along the optical bench to view each source. Three detectors are used at the exit port of the double monochromator to cover the range of 250 nm to 1100 nm.

The ambient temperature was 23 °C ± 2 °C; and the relative humidity was < 60 %.

3. Results.[1/]

The spectral irradiance values from 250 nm to 1100 nm provided in Table 1 are covered by the ISO/IEC 17025:2017 accreditation of Optronic Laboratories. Refer to A2LA Certificate Number 6064.01.[2/] Table 2 provides the relative expanded uncertainty (k=2) for an OL FEL-M lamp Standard of Spectral Irradiance provided by Optronic Laboratories for the wavelength range of 250 nm to 1100 nm.

1/ Note: FEL lamps can exhibit narrow band emission lines at 257 nm, 266 nm, 309 nm and 395 nm. The intensities of these lines are generally less than 15% of the adjacent continuum as measured with the spectroradiometer adjusted for a 0.05 nm bandwidth. In addition, a decrease in the output due to absorption by the lamp itself is seen at 279 nm. Historically, this absorption has been known to change with burning time. While 280 nm data is reported, care should be taken when measurements are made near 279 nm. If the instrument to be calibrated has a narrow bandpass, checks should also be made in the areas of the emission lines. (This information was obtained from NIST TEST No.: 844/250074-92).

2/ This certificate shall not be used to claim product certification, approval, or endorsement by A2LA, NIST, or any agency of the U.S. Government.

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4. General Information

These lamps operate at very high temperatures such that the quartz envelope is above the flammable point of organic materials. They may thus cause fires, plus the burning of lint, dust, etc. on the envelope may result in optical damage to its surface. It should be emphasized that these lamp standards should be handled with the care normally given to delicate optical components. Installation and use of the OL FEL Irradiance Standard should be done by qualified personnel only.

For highest accuracy, allow the OL FEL-M lamp to warm up for 10 minutes.

Previous tests on similar lamps indicate that the average long term photometric stability is specified at ≤ 0.06 % per hour of operation.[3/]

Optronic Laboratories will provide the calibration data files by email.

The results of this calibration apply only to the lamp referenced in this report. This report of calibration shall not be reproduced, except in full, without written approval of Optronic Laboratories, Orlando, Florida.

Calibration Performed by:

Bart Lovell – Senior Optical Technician

Calibration Certified by:
OPTRONIC LABORATORIES

Deborah Griffith
Calibration Laboratory Manager

Reviewed by:

Bart Lovell
Senior Optical Technician

[3/] The lamp is under warranty for a period of 50 hours of use or one year, whichever occurs first.

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TABLE 1

Spectral Irradiance of Standard F-1711 at a Distance of 50 cm
when Operated at 8.200 Amperes DC

Wavelength [nm]	Spectral Irradiance [W/(cm² nm)]
250	1.653E-08
260	2.955E-08
270	4.934E-08
280	7.817E-08
290	1.184E-07
300	1.727E-07
310	2.435E-07
320	3.354E-07
330	4.467E-07
340	5.895E-07
350	7.589E-07
360	9.567E-07
370	1.189E-06
380	1.453E-06
390	1.753E-06
400	2.087E-06
450	4.260E-06
500	7.113E-06
555	1.062E-05
600	1.347E-05
654.6	1.660E-05
700	1.874E-05
800	2.181E-05
900	2.285E-05
1050	2.171E-05
1100	2.092E-05

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TABLE 2 [4/]

Relative Expanded Uncertainty (k=2) for the
OL FEL-M Spectral Irradiance Values [W/(cm^2 nm)] Provided by Optronic Laboratories

Wavelength [nm]	Relative Expanded Uncertainty (k=2) (%)
250	6.5
260	5.6
270	4.8
280	4.8*
290	4.1
300	4.1*
310	3.4
320	3.4*
330	2.9
340	2.9*
350	2.9*
360	2.5
370	2.5
380	2.4*
390	2.4
400	2.4*
450	2.4*
500	1.7
555	1.7*
600	1.7*
654.6	1.3
700	1.3
800	1.3
900	1.3
1050	1.3
1100	1.3

[4/] Please refer to Appendix B for the previously reported uncertainties and the revised relative expanded uncertainty values.

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APPENDIX A

LAMP POSITIONING AND ORIENTATION

The following provides information on the mounting, orientation and alignment of the OL FEL Irradiance Standard for calibration purposes. Optronic Laboratories utilizes several accessories to minimize errors due to alignment and orientation. The OL 61 FEL Lamp Holder, OL 62 FEL Alignment Jig, and OL 63 Adjustable Lamp Holder Mount are designed to allow the user to control the physical orientation of the lamp including the horizontal positioning, vertical height, pitch (tilt), yaw (rotation) and roll. These instructions are based on using these accessories to properly align the lamp standard to the measurement device or instrument's optical axis.

The OL 61 FEL Lamp Holder provides for precise kinematic mounting of the lamp standard on the correct optical axis. It also provides the electrical contacts for operating the FEL lamp.

The OL 62 FEL Alignment Jig is used to define the centerline axis of the lamp filament for ease of alignment. It is used to establish the calibration distance from the lamp to the limiting aperture of the measurement instrument. The required calibration distance is 50 cm from the front face of the OL 62 FEL Alignment Jig to the instrument's limiting optical input aperture.

The OL 63 Adjustable Lamp Holder Mount allows for adjustment of the alignment jig for horizontal (left-right) positioning, vertical height, and lamp attitude (pitch, yaw and roll).

Alignment Tolerances

There are six dimensional variables involved in the alignment of the lamp standard relative to the measurement instrument:

1. Distance from the lamp (alignment jig) to the limiting aperture of the measuring instrument.
2. Horizontal distance (lateral left-right position) off the optical axis.
3. Vertical height to the optical axis.
4. Pitch (tilt)
5. Yaw (rotation) } Lamp Attitude
6. Roll

Instruments will vary in their sensitivity to lamp misalignment. Variation in the instrument's responses is due to the interaction of a lamp's non-uniform irradiance field with an instrument's geometrical detection sensitivity, along with a small component due to error in the lamp to instrument distance. The alignment tolerances required by each instrument must be determined by the user. However, from the present examination of lamp non-uniformity, it is clear that good results will require very tight control of lamp attitude and lamp to instrument distance. Angular positioning of the lamp relative to the instrument's optical axis will need to be within tenths of a degree, and lamp to instrument and optical axis distances must be made to within 0.25 mm to 0.5 mm if the systematic errors due to physical positioning of the lamp are to be kept down in the tenths of a percent range.

Lamp Installation and Alignment

A. Figure 1

1. The first step in the alignment process is to determine the optical axis height of the measurement instrument. If this height is not known, measure the height from the table top to the center of the limiting aperture of the instrument.
2. Loosen the stand locking clamp and install the OL 63 onto an appropriate support stand post. Tighten the locking clamp to secure in place.
3. Loosen the lamp holder locking clamp on the OL 63 and install the post of the OL 61 into the V-groove portion on the OL 63 at the desired height. To secure in place, tighten the lamp holder locking clamp (do not over tighten).
4. With the power supply turned OFF, attach the positive and negative power supply cables to the electrical connector screws on the positive and negative bi-post locator bars. Tighten the cables securely (refer to Figure 2).
5. Loosen the two clamping screws on the bi-post locator bars on the OL 61 (do not remove the screws).
6. Carefully install the two bottom pins on the OL 62 into the bi-post locator bars on the OL 61 until completely seated with the Model No. ID label on the OL 62 facing away from the limiting aperture of the measuring instrument.
7. Secure the OL 62 into place by gently tightening the two clamping screws on the bi-post locator bars on the OL 61 making sure to tighten the NEGATIVE bar's screw first and the POSITIVE bar's screw second (do NOT over tighten).
8. Using a small level or alignment square, adjust the pitch and roll knobs on the OL 63 so that the front face and side of the OL 62 are perpendicular to the table top (optical axis).
9. Loosen the lamp holder locking clamp and adjust the height of the horizontal line of the alignment crosshair until the reticle is at the same height as the measurement instrument's limiting aperture centerline (optical axis). To secure in place, tighten the lamp holder locking clamp (do not over tighten).
10. Position the assembly with the front face of the OL 62 at 50 cm from the limiting aperture of the measuring instrument and secure the assembly in place.
11. After alignment is complete, remove the OL 62 by loosening the two clamping screws on the OL 61 (do not remove the screws).

B. Figure 2

1. Carefully install the medium bi-post pins on the OL FEL Irradiance Standard into the bi-post locator bars on the OL 61 until completely seated with the label on the OL FEL facing away from the limiting aperture of the measuring instrument.
2. Secure the OL FEL into place by gently tightening the two clamping screws on the bi-post locator bars on the OL 61 making sure to tighten the NEGATIVE lead screw first and the POSITIVE lead screw second (do NOT over tighten).

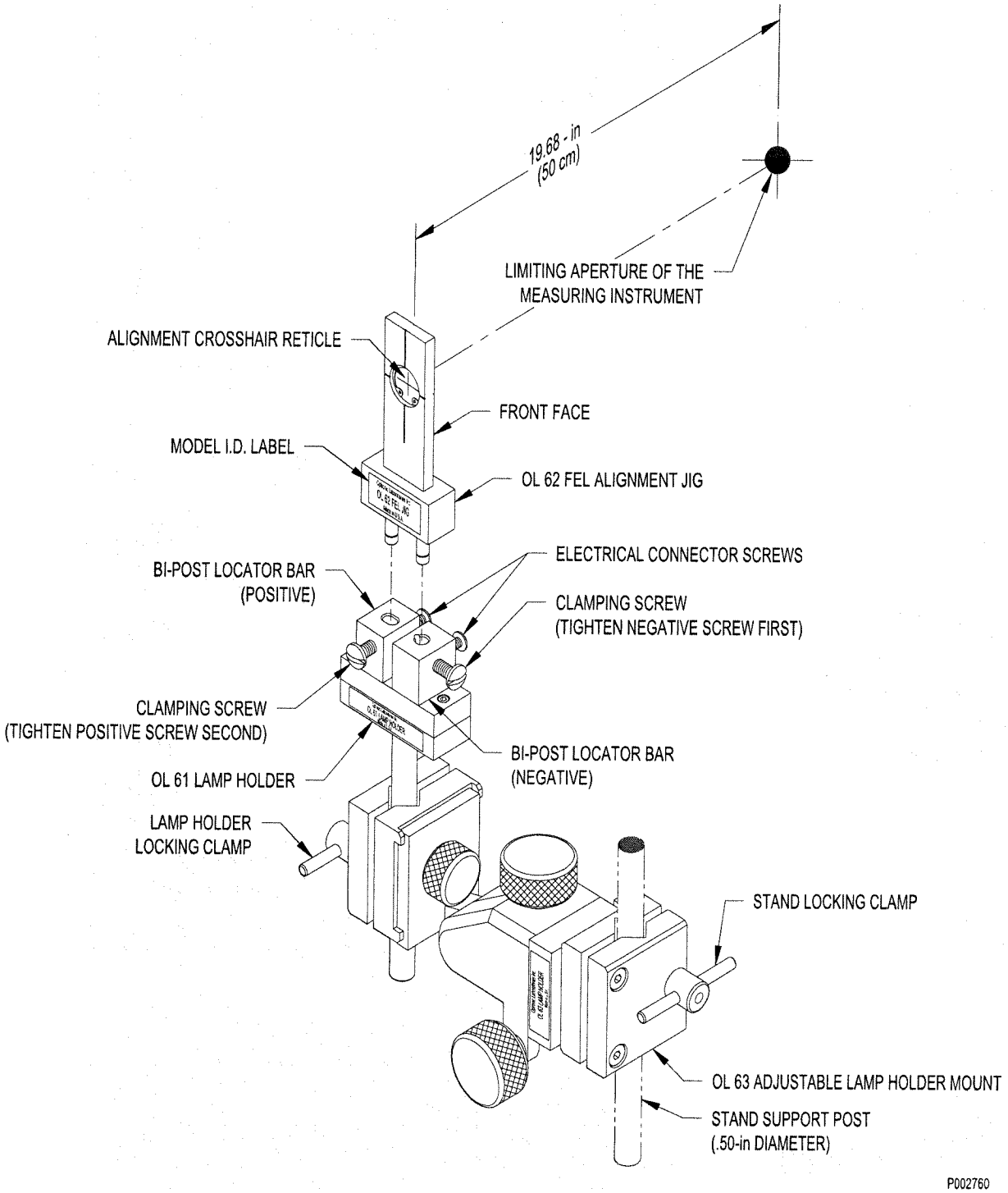

Figure 1

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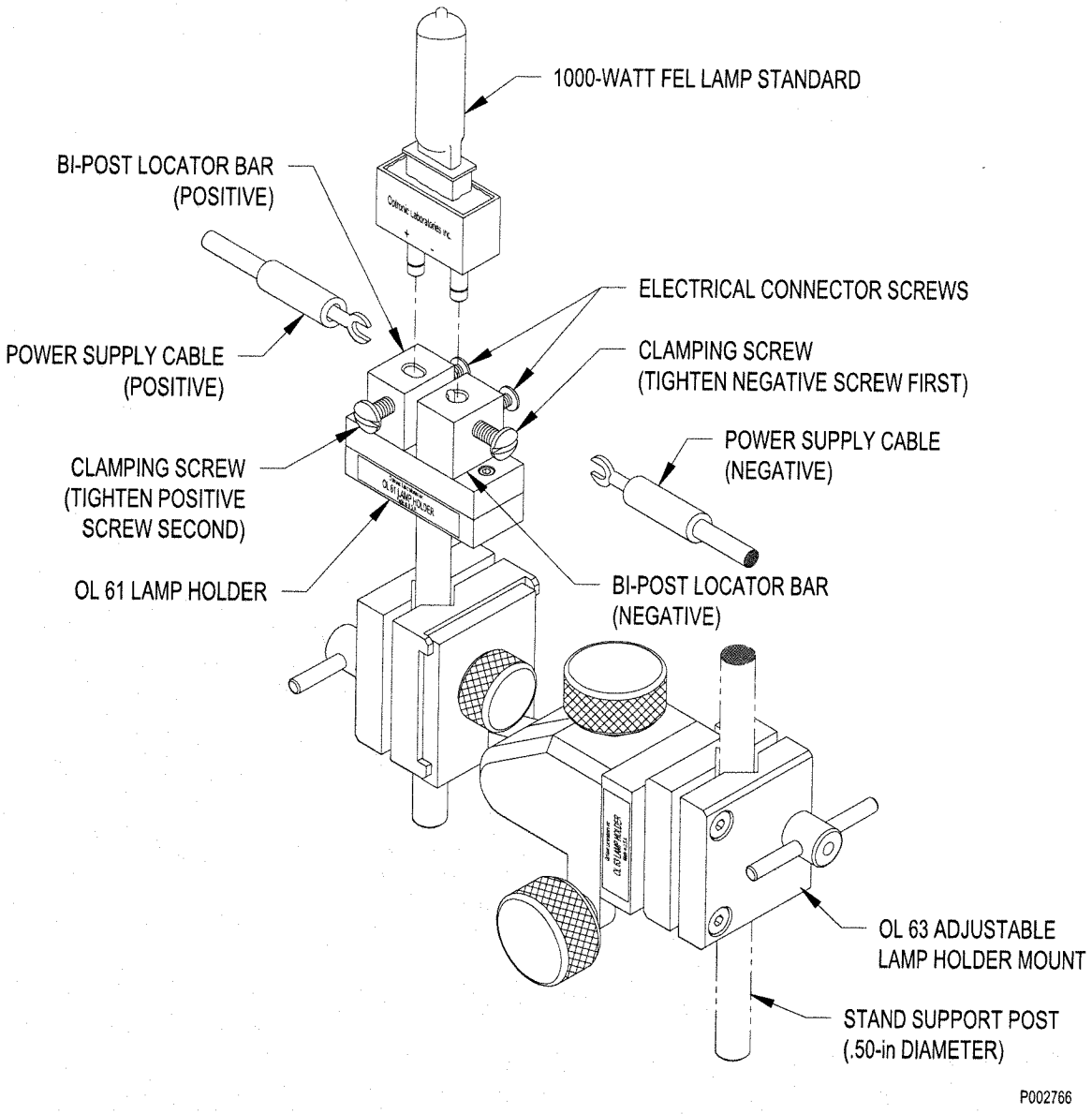

Figure 2

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APPENDIX B

The table below provides the original reported uncertainties along with corrected uncertainties. Values that have changed are notated with an asterisk.

Wavelength [nm]	Previously Reported Relative Expanded Uncertainty (k=2) (%)	Corrected Relative Expanded Uncertainty (k=2) (%)
250	6.5	6.5
260	5.6	5.6
270	4.8	4.8
280	4.3	4.8*
290	4.1	4.1
300	4.0	4.1*
310	3.4	3.4
320	3.2	3.4*
330	2.9	2.9
340	2.7	2.9*
350	2.7	2.9*
360	2.5	2.5
370	2.5	2.5
380	2.1	2.4*
390	2.4	2.4
400	2.3	2.4*
450	2.0	2.4*
500	1.7	1.7
555	1.5	1.7*
600	1.5	1.7*
654.6	1.3	1.3
700	1.3	1.3
800	1.3	1.3
900	1.3	1.3
1050	1.3	1.3
1100	1.3	1.3

* Indicates a correction was made to the uncertainty value.