New Facility for Deuterium Lamp Calibrations at SURF III

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A new facility for the irradiance calibration of deuterium lamps has been constructed and commissioned at the Synchrotron Ultraviolet Radiation Facility (SURF III) at NIST's Gaithersburg, MD campus. This facility enables the calibration of the irradiance from a lamp under test against the primary standard of irradiance from the NIST synchrotron in the spectral range from 200 nm to 400 nm and longer wavelengths. The uncertainty achieved is on the order of 1% throughout this spectral range.

CALIBRATION FACILITY

The primary standard of irradiance is the synchrotron radiation from the SURF III electron storage ring. The irradiance as a function of wavelength is calculated from a few accelerator parameters: the magnetic field strength, the bending radius of the electron orbit, and the stored electron beam current. BL–2 has been rebuilt with improved baffling and stray light control for the new calibration facility.

The beamline is fitted with two fused silica windows that transmit the synchrotron radiation while maintaining the vacuum integrity of the storage ring and beamline. The transmission of these windows is measured and accounted for as part of the calibration process.

The spectrally resolving detector system is a diffuser, monochromator, photodiode, and amplifier system. The diffuser is a fused silica optical flat that incorporates a high density of scattering centers. The transmitted light is well diffused and is completely unpolarized, even for the linearly polarized incident radiation from the synchrotron. The monochromator is a commercial Czerny-Turner monochromator which has been modified by removing internal heat sources and mounting on a thermally conducting base plate. These modifications significantly improved the thermal stability of the system. The detector is a commercial Si photodiode, and the photocurrent is converted to voltage by a specially constructed low-noise transimpedance amplifier in the same housing as the photodiode. The amplifier has a fixed gain of $3x10^{10}$ V / A. The output is measured by a digital voltmeter.

The detector system is mounted on a yaw rotation stage. After measurement of the synchrotron radiation, the stage is rotated so the irradiance from the deuterium lamp is incident on the diffuser at the entrance aperture.

The irradiance from the lamp is determined by comparison of the detector signal when looking at the lamp under test to that when looking at the known SURF irradiance. An overview of the system is shown in Fig. 1 and a detail of the detector system in Fig. 2.

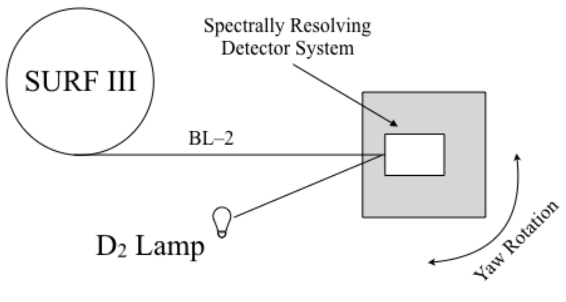

Figure 1. Overview of the calibration system for comparing the irradiance from a deuterium lamp to

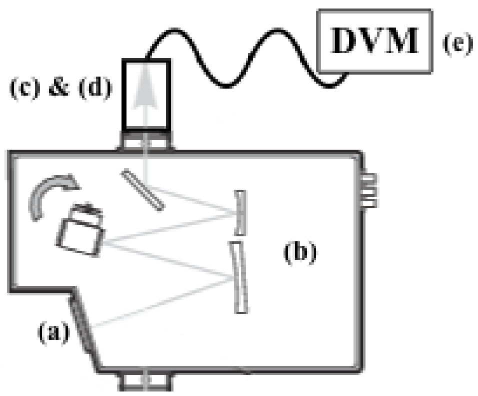

Figure 2. Layout of the spectrally resolving detector system showing the (a) diffuser, (b) monochromator, (c) detector, (d) amplifier, and (e) digital voltmeter.

CALIBRATION PROCEDURE

The calibration procedure begins with a determination of the detector system's responsivity by measuring the voltage signal produced by the known incident irradiance from the synchrotron. In the absence of the intervening fused silica windows, this would be a simple measurement. However, this determination must be made from a set of three measurements to properly account for the window transmission. The first window is mounted in the gate of a high-vacuum gate valve and is inserted by closing the valve. The second window is mounted on a vacuum-seal flange at the end of the beamline and is inserted by installing the flange. Removal of the second window vents the beamline from the end up to the first window.

The responsivity η_0 of the monochromator is given by:

$$\eta_0 = \frac{\eta_1 \eta_2}{\eta_{1,2}^{air}}, \tag{1}$$

where η_1 is the responsivity measured with only the first window inserted in the beam, η_2 is the responsivity measured with only the second window inserted in the beam, and $\eta_{1,2}^{air}$ is the responsivity measured with both windows inserted in the beam. The beamline section between the windows is vented for the measurement with both windows.

In practice, a fourth measurement is made of $\eta_{1,2}^{vac}$ with both windows inserted but the intervening section under vacuum. This allows a determination of the transmission of the first window T_1 without any effect from air absorption at short wavelengths.

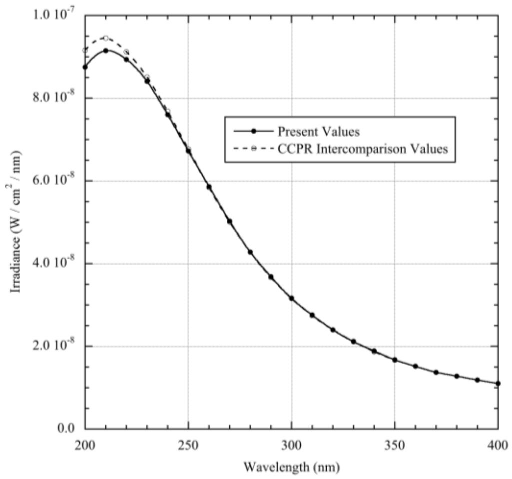

Figure 3. The calibrated irradiance from a deuterium lamp measured on the new facility (solid circles) and prior values from a CCPR intercomparison (open circles).

Once the detector system's responsivity η_0 is known, the irradiance from the lamp E_{lamp} is determined from η_0 and the lamp signal V_{lamp}:

$$E_{lamp} = \frac{V_{lamp}}{\eta_0}. \tag{2}$$

Figure 3 shows the results of the calibration of a deuterium lamp and historic data from a prior CCPR intercomparison.

UNCERTAINTY BUDGET

The full assessment of the uncertainty in the final lamp irradiance calibration is ongoing. Table 1 shows the preliminary uncertainty budget.

The uncertainty is dominated by the statistical (Type A) uncertainty in the repeatability of the detector system calibration. The total uncertainty (k = 1) in the irradiance from the deuterium lamp is about 0.7%.

Table 1. Preliminary uncertainty u_c in the irradiance calibration of a deuterium lamp.

Uncertainty Component	**u_c in Irradiance**
Detector System Calibration	
Statistics	0.60%
Electron energy	0.10%
Electron current	0.20%
Distance to tangent point	0.01%
Uncertainty in Detector	*0.64%*
Lamp Calibration	
Statistics	0.10%
Distance to lamp	0.01%
Monochromator stability	0.20%
Uncertainty in Lamp	*0.22%*
Comparison (common mode)	
Scattered light	0.20%
Entrance aperture area	0.01%
Uncertainty in Comparison	*0.20%*
Total Uncertainty	**0.71%**