From X-rays to T-rays: Synchrotron Source-based Calibrations at SURF III

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The calculability of synchrotron radiation (SR) makes electron storage rings wonderful light sources for radiometry. The broadband nature of SR allows coverage of the whole spectral region from the x-ray to the far-infrared. Compact low-energy storage rings like the Synchrotron Ultraviolet Radiation Facility SURF III are perfect sources for radiometric applications, because the output spectrum can be custom-tailored to the user's needs: Low current operations can help simulate the solar spectrum, changes to the electron energy can help to deal with higher-order contributions of spectrometers and monochromators, and manipulation of the source size can increase the lifetime or change the radiation density, if necessary. At large scale multi-user facilities these special operational conditions are generally not possible, since many users have to be satisfied simultaneously. Compact storage rings for radiometric applications are so advantageous that the Physikalische-Technische Bundesanstalt (PTB) in Berlin, Germany, decided to build one to improve its radiometry capabilities.

At SURF currently two beamlines make use its well-established calculability. Beamline 2 (BL-2), the spectrometer calibration beamline, provides absolute irradiance calibrations of spectrometers and other radiometric instrumentation. This beamline is partly funded by the National Aeronautics and Space Administration (NASA), because most of its customers work within NASA-funded programs, like, *e.g.*, the "Living with a Star" or "Sun Earth Connection" programs. Beamline 3 (BL-3), the ultraviolet source-calibration beamline, became recently the U.S. primary standard for deuterium lamp irradiance calibrations. Its usefulness was first proven during the Consultative Committee for Photometry and Radiometry (CCPR) key comparison CCPR-K1.b "Spectral irradiance" in the wavelengths range from 200 nm to 350 nm with deuterium lamps.

Recently the University of Alaska Fairbanks performed a calibration using BL-2 at a wavelength of 0.2 nm (roughly 6200 eV photon energy). This calibration was only possible by increasing the energy of the electrons stored to the absolute maximum the magnet allows. The increase from the standard operating energy of 380 MeV to this maximum energy of 408 MeV pushed down the critical wavelength λ_c, which is a measure of the short wavelength cut-off of the emitted synchrotron radiation, from 8.5 nm to 6.9 nm.

During the key CCPR-K1.b comparison "Spectral irradiance", NIST was the only laboratory to use synchrotron radiation in the calibrations process, leading to the smallest uncertainties among the participating laboratories. The uncertainty achieved at SURF was 0.5 % (coverage factor $k = 1$) for the entire spectral range. Since then this new calibration capability has been used extensively and several deuterium lamps have been calibrated directly against SURF.

SURF maintains one of the best synchrotron radiation based calibrations programs in the world, which has now proven to reach into the soft x-ray range. Standard lamp calibrations, detector calibrations, and measurements of optical properties are routinely performed at SURF with great reliability and accuracy.