The metrology line on the SOLEIL synchrotron facility

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Abstract. In the new SOLEIL synchrotron facility one line will be devoted to metrology, providing 3 branches for hard-X, X-UV and UV-VUV radiation applications. So metrology between about 5 eV to 14 keV (250 nm down to 0.09 nm) will benefit from this calculable radiation source. The UV-VUV branch is expected towards the end of 2006.

Introducing SOLEIL

SOLEIL (Source Optimisée de Lumière d'Energie Intermédiaire du LURE = Optimized source of mid-level energy light in LURE) is a 3rd generation 2.75 GeV synchrotron. Building began in 2000, and the first lines are to open end of 2006, followed by 14 others between 2006 and 2010 - potentially 40. It is designed and managed from the beginning to host international teams.

This synchrotron facility built in the Optics Valley addresses new or increasing needs in X to UV applications such as X lasers or deep UV lithography. It will inherit and amplify the high level-activity of the former LURE synchrotron.

The metrology line partners

There will be 3 main users of this metrology line: SOLEIL itself for its own instruments testing, the French Agency for Nuclear Energy (CEA) and the National Test and Measurement Laboratory (LNE). LNE has taken over the former BNM since beginning of 2005, including now the BNM previous members. The 3 LNE laboratories involved in the metrology line are the LNE-LNHB, the LNE-INM and the former LNE.

Radiation metrology benefits from the synchrotron radiation (SR) characteristics

Situation in France

Up to now, different laboratories (now members of LNE) have performed a metrological activity with SR. INM carried on its first SR applications in 1974, establishing an electric arc as a secondary standard by comparing both radiations. LNHB characterized and calibrated X detectors. And outside metrological laboratories, SR enabled several metrological achievements such as optical components and detectors qualification for hot plasma X diagnosis.

Situation in other countries

In Germany, PTB runs a well-known and important facility at BESSY II, providing monochromatic radiation between 3 eV and 15 keV. Due to the increasing demand for SR access, the MLS (Metrology Light Source) new facility is expected to complete BESSY II in 2008, with a spectrum ranging from infrared to deep UV.

In the US, NIST uses the SURF III facility in Gaithersburg as a calculable source in the 50 to 260 nm range, and as a UV source calibration to a cryogenic radiometer in the 125 to 320 nm range.

In Russia, the VEPP facility in Novosibirsk provides radiation between 120 and 400 nm for calibration of lamps and detectors.

Other facilities are used for radiometry in **China** and **Japan**.

One of the main issues for radiometry with SR is access to the beam: not enough available time or too scattered. And it is worse with operating requirements often incompatible with other more widespread SR applications.

Characteristics of the SOLEIL SR

The synchrotron radiation shows a broad continuous spectrum, and its characteristics (irradiance, polarization, coherence, beam profile and pulse shape) are calculable with the Schwinger theory, with an accuracy only limited by the determination accuracy of the influence parameters, which can be very good. The output power can be adjusted on a 12 orders of magnitude scale.

The SR emits pulses with a 50 ps width every 140 ns typically. Polarization can be adjusted from linear to circular.

Metrology line characteristics

SOLEIL committed the "Optics" special team to initiate and assist the users in designing the metrology line. The general requirements are a well-collimated beam, a high spectral purity (almost no harmonics), very low scattering, and a large spectral range, especially for absolute calibration of detectors, relying on the possibility to calculate the exact incident power.

The "Sources and Accelerators" special team will provide measurements and develop methods to perfectly control the key machine parameters, in agreement with the metrology users requirements.

The 8-mrad beam available at the end of the magnet will be spatially split into 3 branches, each of them devoted to a specific energy (spectral) range.

We will focus now on the VUV branch, and mention only for completeness sake the hard and soft X-ray lines.

UV-VUV branch

The design is not yet definitive. This branch is now optimized for the 7 to 70 eV (18 to 180 nm) range. The beam will pass through a monochromator yielding a simulated photon flux above $1.5.10^8$ photons/s, with a peak of 10^{11} photons/s at 50 nm, respectively above 1 nW and 300 nW. At the output focus, the beam has a rectangular shape of 45 x 600 µm. The spectral width varies between 20 and 120 pm.

X-UV branch

This branch will be operated between 30 eV and 2 keV, with a focused or collimated output beam, and a harmonic rejection rate of 0.1 %.

Hard-X branch

This branch will be operated between 0.5 and 12 keV, with a focused or collimated output beam.

Uncertainties

The main interest of SR in radiometry is the possibility to calculate the incident flux from the measurement of independent operating parameters. At BESSY, the combined uncertainty has been assessed to 0.2% at 1 eV and 0.35% at 5 keV. The dominant term belongs to the geometrical factors in the optical range, and to the electrical ring parameters in the X range.

Of course there are other contributions to the final uncertainty in a complete calibration process. In the case of the already running synchrotron calibration facilities, the final uncertainty amounts generally to a few percent. It has not yet been assessed at SOLEIL.

Expectation in UV Metrology

The SOLEIL metrology line is expected to bring a breakthrough in UV calibrations through the realization of standard references for detector sensitivity and energetic source properties (radiance, irradiance, radiant intensity). It will of course enhance comparison possibilities with other international realizations of the same quantities, and the transfer to end-users. It is true that the main demand on UV radiometric calibration is still in the less energetic range (above 200 nm), where applications such as therapy or diagnostic will bring more stringent demand on accuracy. However the emerging applications in biology, industry or scientific research (astronomy, plasma, fluorescence) and above all in photolithography are driving calibration needs toward the VUV (vacuum ultraviolet) range. In this range only will the SR prove more efficient than laser or high temperature blackbody sources.

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