Procedures of absolute calibration for the Space Solar Patrol instrumentation at the Synchrotron radiation source

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Abstract. The paper describes basic and additional calibration procedures for absolute measurements of an optical-electronic instrumentation at a synchrotron radiation (SR) sources in the spectral range from 0.25 up to 122 nm (5000 - 10 eV). The procedures have been proposed to realize the absolute calibration of the Space Solar Patrol (SSP) instrumentation, which has been created to monitor the ionizing radiation from the Sun in the spectral range 0.14 – 198 nm. For this goal, the metrological stations at the SR sources of the storage rings VEPP-3 and VEPP-4 (at the Budker Institute of Nuclear Physics (INP), Novosibirsk, Russia) has been developing. The basic requirements for the absolute spectral measurements are also considered.

Introduction

The SSP instrumentation consists of a Radiometer with 20 filters and two grating spectrometers (an extreme ultraviolet (EUV) Spectrometer of normal incidence and a X-ray/EUV Spectrometer of grazing incidence) [Avakyan et al., 1998; Afanas'ev et al., 2005]. All measuring channels of the SSP have the "solar-blind" detectors – open secondary-electron multipliers (SEM), which are "blind" to near UV and visible radiation of the Sun [Avakyan et al., 1998].

The main task to perform the metrological calibration of the SSP apparatus in the wide spectral range 0.25-122 nm (5000 - 10 eV) is creation of specialized SR beamlines and experimental stations at the electron-positron storage rings VEPP-4 and VEPP-3. Calibration of the large dimension apparatus of the SSP (the radiometer and the spectrometers) is intended to execute at the SR experimental station of the VEPP-4 storage ring. But, the auxiliary measurements for small dimension devices and components of the SSP (SEMs, filters), as well as testing the reference detectors is envisaged to carry out at the VEPP-3 storage ring. Such specialized SR beamlines and experimental stations for calibration of the space-destined apparatus is creating for the first time in native practice that originates the experimental basis for further development of these works in Russia.

The calibration ranges for the SSP instrumentation:
- Radiometer with filters – from 0.25 to 122 nm;
- EUV-Spectrometer – from 56 to 122 nm;
- X-ray/EUV Spectrometer – from 1.8 to 122 nm.

Requirements to the calibration

For successful realization of the absolute spectroradiometric calibration of all SSP apparatus at a SR beam it is necessary to execute:
1) Providing the SR beam being stable in space and in time with monitoring of its intensity, lateral dimensions and position at the entrance of calibration chamber for the SSP;
2) Maintenance of the vacuum degree in an experimental calibration volume is not worse than 5×10^{-6} mm Hg;
3) Providing antijamming operation of electronics of photoreceiving tracts of the SSP apparatus in real conditions of the complex of storage rings VEPP-3 and VEPP-4;
4) Obtaining monochromatic radiation from a "white" SR beam with the help of monochromators: in range from 0.25 up to 122 nm, having not less than 60 spectral points;
5) Providing radiation intensity at the entrance of the apparatus that must not be less than the intensity of an average solar flux. Besides, the intensity of the SR beam at all wavelengths must correspond to the region of the measured counting rate from 10^3 up to 10^4 pulses/sec in the SSP channels, i.e. the middle of registering region of the SSP photoreceiving tract, that is about six orders (from 4 to 3×10^6 pulses/sec [Avakyan et al., 2001]). So, using the counting rate in this region as an index of true "one--electron" mode of input signal registration, it is possible to achieve a high accuracy calibration [Afanas'ev et al., 2004].
6) Determination of absolute SR fluxes at the entrance of calibration chamber of the SSP apparatus with the use of absolutely calibrated detectors and with the help of well-calculable "white" SR beam.
7) The required accuracy of absolute calibration of all complex of instrumentation - is not worse than 10%, thus calibration of separate devices (Radiometer, EUV-Spectrometer and X/EUV-Spectrometer) it is not worse 7%.
8) Decreasing of the high energetic particle flux (with energies more than 5 keV) in SR beams up to the reasonable level (for a given accuracy of calibration) at the entrance of the calibration chamber and providing the effective suppression of photon fluxes with energy, which is multiple of calibration energy.

The basic calibration procedure at the SR beam

In a basis of calibration of the SSP instrumentation lays the method of a reference detector according to which a radiant power of a monochromated SR beam, incoming in the SSP spectrometer or radiometer, is measured by the reference detector with known spectral sensitivity. The important element of such calibration method is the choice and verification of the reference detector. In our case, it is offered to use the silicon photodiodes AXUV-100 produced by the IRD Incorporation (USA). The spectral properties of the detector are defined by its coating (the thin metal film evaporated on the surface of the detector) and can be changed by a controllable way. This opportunity will be used for an estimation of power of parasitic background component, past through monochromator, and its contribution to the output signal of the detector. The information, given by the IRD Inc., enables to calculate spectral prop-

erties of detectors (with different coatings) with sufficient accuracy to realize the calibration. Besides, it is offered the additional calibration of the reference detectors by the method of selective absorbing filters, which has been developed and successfully applied by authors from the INP at the performance of the International Science and Technology Center (ISTC) project # 438 [Pindyurin et al., 2000].

Features of calibration of the SSP instrumentation with the method of the reference detector at the SR beam:

- Time modulation of the SR beam:

The SR beam from the storage ring VEPP-4 is the short and periodically repeated flashes (with duration less than 1 nsec and the frequency about 1 MHz). As the photodetectors of the SSP instrumentation work in an pulse registering mode [Avakyan et al., 2001], that the part of multi-electron events (i.e. more than 1 photoelectron emission from a photocathode of the detector) in the output signal grows when the loading of the detector is increased. To minimize the systematic error, which connected to this phenomenon, the loading of detectors is necessary to limit up to 10^5 pulses/sec, by decrease of intensity of the SR beam. Calculations show, that in this case the part of multi-electron events will not exceed 5.5 %. Thus maintenance of loading of the detector in a range $10^3 – 10^4$ pulses/sec gives the best accuracy of calibration measurements [Afanas'ev et al., 2004].

- Polarization of the SR beam:

In contrast to the non-polarized solar radiation, the SR beam in the median plane of the orbit is linearly polarized. To consider the possible systematic error connected to it, measurements with the spectrometers in different positions relatively to the plane of polarization are provided.

- Phase volume of a radiation source:

From the point of view of the optical circuits of the SSP spectrometers [Avakyan et al., 1998, 2002], the Sun is the removed source with the limited angular size, whereas the SR source is almost indefinitely removed point source. As the focusing optical circuits of the SSP spectrometers have been developed to register the solar radiation, then for the account of the given geometrical factor on results of calibration, it is offered to carry out additional experiments.

The additional calibration procedures

The method of the absolute calibration of SEMs, filters, gratings, as well as the apparatus as a whole, consists in a determination of a radiant power of a SR beam for a given wavelength that comes through an entrance of the element under calibration. The SR flux can be calculated theoretically or measured experimentally with calibrated detectors. The radiation of the necessary wavelength is extracted either by spectrometers or diffraction gratings, or multilayer mirrors and filters. The earliest variant of the absolute calibration method was described in Ref. [Afanas'ev et al., 2005]. Now together with the basic procedures, it is offered to apply two identical spectrometers of the SSP, located consistently [Avakyan, 2005], for the calibration goal.

The procedure consists in a performance of two stages:

1. The spectrometer #1 (we suppose to use the X-ray/EUV spectrometers) without the SEM detectors is set at a SR beam, while the completely equipped spectrometer #2 with its input slit is alternately integrated to an output slit of each channels of the spectrometer #1. After execution of measurements of a counting rate with the SEM with scanning of all ranges of the spectrum of the spectrometer #2 [Avakyan et al., 2002], the spectrometer #2 is removed, and its SEMs are replaced in corresponding channels of the spectrometer #1. Then the measurements of counting rate with scanning of all ranges of the spectrum are carried out again. The difference in results of measurements with the SEM at the spectrometers is the spectral efficiency of diffraction grating of the spectrometer #2. After that the grating from the spectrometer #2 is replaced in the spectrometer #1, and the control measurements, including measurements of absolute spectral efficiency of the SEM, and finally, a spectral throughput of the SSP spectrometer #1, are carried out. For this goal, at a final stage of theoretical and/or experimental works (with use of absolute detectors) are executed by definition of the spectral intensity of the entrance SR beam.

2. For absolute spectral calibration of the SSP radiometers (with filters) there will be used the spectrometer #1 plus a radiometer. But at the first stage the single SEM will be graduated at all four channels of this spectrometer. Then a radiation transmission of the set of filters in a disk of radiometer [Avakyan et al., 1998] in the given structure of placing of two devices is measured with the calibrated SEM. Advantage of the offered way of absolute calibration with use of the pair of the SSP devices (one of which is the spectrometer) is an opportunity of the simplified consideration of geometry of the absolute measurement experiment and, as a result, increase of accuracy of the calibration.

Conclusion

It is offered the absolute calibration procedures at the synchrotron radiation sources in the spectral range from 0.25 up to 122 nm (5000 - 10 eV) for the Space Solar Patrol (SSP) instrumentation. Thus, methods of reference detectors and selective absorbing filters are accepted as a basis. The unique methods based on use of the SSP spectrometers and radiometers are also offered as additional calibration procedures. Moreover, requirements to the metrological stations organized for the calibration have been considered.

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