Radiation Protection Issues at SOLARIS - Safety Assumptions and Project Status.

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Abstract

SOLARIS, the first synchrotron radiation source in Poland managed by the Jagiellonian University, is a replica of the 1.5 GeV MAX IV storage ring. The machine, consisting of a 550 MeV linear accelerator and the 1.5 GeV storage ring, will be operated in ramping and decay modes. The SOLARIS team cooperates with synchrotron facilities all over the word, in particular with the MAX IV Laboratory and with Elettra Sincrotrone Trieste. Now the project is approaching the final stage of development, the machine is installed and preliminarily commissioned. The next step is to perform final commissioning of the whole machine and then to start up the first two beamlines.

In the planning of the operation of SOLARIS it was essential to make proper radiation protection assumptions, to design sufficient shielding walls and to have a correctly configured and tested Personal Safety System. These aspects will be presented together with the formal Polish radiation protection requirements, commissioning results and synchrotron parameters, shielding considerations, the Personal Safety System elements of the machine and of the beamlines, the Radiation Monitoring System and the purchased measurement equipment.

1. Synchrotron SOLARIS – general description

1.1. Project

After over a dozen years of discussions about building the first synchrotron in Poland, the construction of the SOLARIS facility started in January 2012. It took more than 2 years to finish the building, but finally in May 2014 the facility was taken over and the installation of the machine began. The SOLARIS is managed by the Jagiellonian University and it is constructed within a project financed from European Union Structural Funds, which will finish at the end of 2015.

Signing the special agreement between the Jagiellonian University and the MAX IV Laboratory enabled to construct the SOLARIS storage ring as a copy of the 1.5 GeV MAX IV storage ring [1]. During the machine designing and installation, the SOLARIS team has strongly cooperated with a few synchrotron facilities all over the word, in particular with the MAX IV Laboratory (e.g. machine design, control system) and with Elettra Sincrotrone Trieste (e.g. Personal Safety System, beamlines and control system).

Presently the synchrotron is preliminary commissioned with first beam accumulations in the storage ring and two beamlines are almost installed. The ongoing aims are the final commissioning of the machine and then the start-up of the beamlines.

1.2. Machine

The first part of the machine, the linear accelerator (7.7 m below the ground), contains the RF thermionic gun with a BaO cathode supplied by an RF unit (ScandiNova modulator powering a Thales klystron) and 6 S-band (2998.5 MHz) acceleration sections supplied by 3 RF power units (ScandiNova modulators powering Toshiba klystrons). The linac is about 40 m long and accelerates electrons to the energy about 550 MeV. It is designed to work with electron bunch frequency up to 100 Hz. At the end of the linac there is a transfer line, transporting electrons into the storage ring one floor above [2].

The 1.5 GeV storage ring is a 3rd generation light source with the 96 m circumference, placed on the level of 3.2 m below the surface. It consists of 12 identical Double-Bend Achromat cells, representing new technology of magnets integration in one solid iron block (bending magnets and correctors), 12 straight sections, each 3.5 m long, and 2 main cavities (100 MHz). This light source has been designed to operate with 500 mA stored current and to have an emittance of 6 nmrad [3,4].

The machine scheme is presented in the Fig.1.

Fig.1 – The layout of the SOLARIS machine.

1.3. Beamlines

SOLARIS is designed to have at least over a dozen of beamlines, but as a part of the project two of them are financed.
The first beamline PEEM/XAS uses a bending magnet as a source and works at the energy range 200 - 2000 eV. It has 2 end stations: PEEM/LEEM (Photoemission Electron Microscope/Low-energy electron microscope) and XAS (X-ray Absorption Spectroscopy). The second beamline UARPES (Ultra Angle Resolved Photoemission Spectroscopy) bases on quasi-periodic undulator and uses the energy range 8 - 100 eV.

2. Shielding elements

Shielding walls (Fig.2) of the accelerator tunnels where calculated basing on the MAX IV shielding report [5] and they are made of ordinary concrete (~2.3 g/cm3) and of heavy concrete (~3.2 g/cm3). The roof of the ring tunnel is removable, made of concrete slabs, to enable inserting machine's components into it.

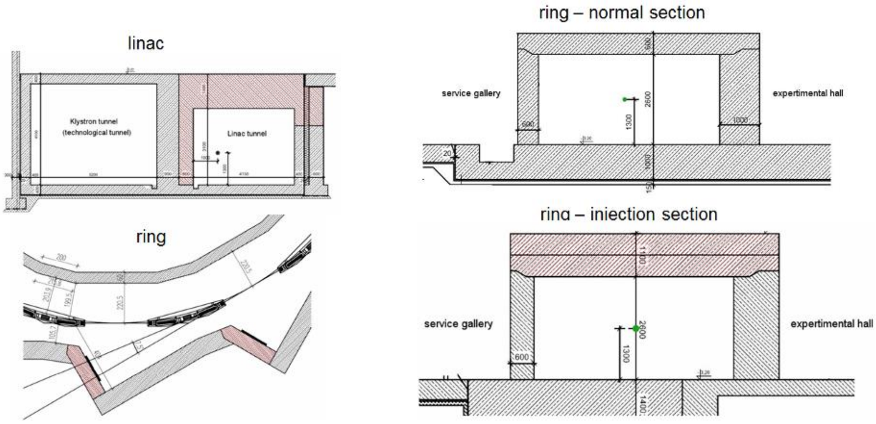

Fig.2 – SOLARIS shielding walls. Red colour indicates heavy concrete.

Inside the ring tunnel on every front-end wall an additional steel block is mounted, and also in the sections of existing beamlines there are walls made of lead bricks. All the unused or empty holes, cables and pipes trenches are filled with bags containing concrete powder or with concrete bricks. The holes for future beamlines are already drilled and temporarily closed with concrete plugs (Fig.3). These solutions guarantee limiting radiation levels outside the accelerator tunnels.

Fig.3 – Shielding solutions at SOLARIS.

Present beamlines' designs require constructing only optical hutches (Fig.4), placed next to the ring front-end walls in the experimental hall. The thickness of lead of the PEEM/XAS hutch is 2 mm and the hutch has a removable roof. In case of the UARPES beamline, the lead thickness is 5 mm, the hutch has a fixed roof and a doubled door.

Fig.4 – The optical hutches at SOLARIS.

3. Formal radiation protection requirements

In Poland all the radiation protection aspects are regulated by the main act – Atomic Law - and a few government regulations basing on European rules. The National Atomic Energy Agency is the institution, which gives the permissions for all nonmedical activities connected with ionizing radiation, and it also performs periodical controls in such facilities.
The legislation imposes preparing and implementing the Quality Management Programme (which derives from Quality Management System) in the range of radiation protection, defines the facility director as a person responsible for proper radiation protection and determines that the radiation protection officer (with national authorization) performs supervision on radiation safety in the facility. Among others, it also regulates the dose limits, doses controls and surveys, the A and B categories of workers and their medical examinations.

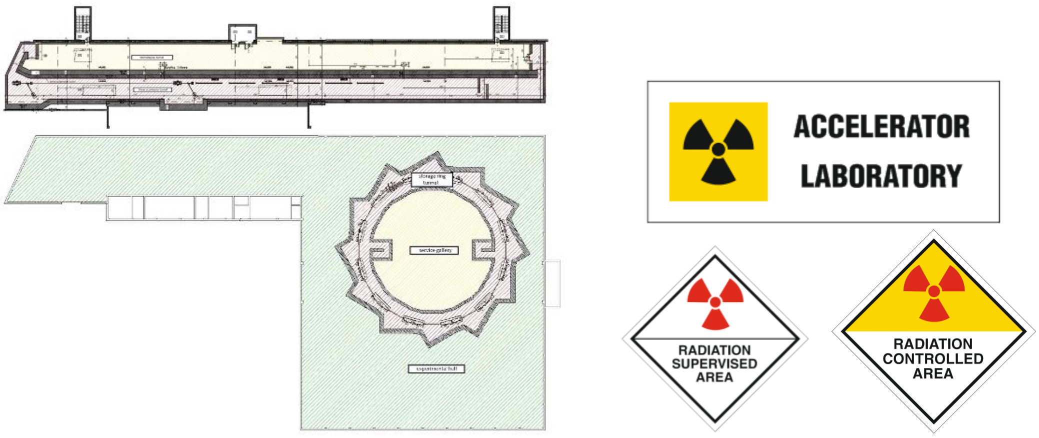

Fig.5 – The SOLARIS zones: controlled (red), supervised (yellow) and unclassified areas (green). The area signs.

Following the formal requirements, the SOLARIS zone is the accelerator laboratory and it is divided into controlled areas (linac tunnel, ring tunnel), supervised areas (klystron tunnel, service gallery) and unclassified areas (experimental hall, laboratories, control room) as it is presented in the Fig.5. The areas are signed according to polish law.

4. Radiation measurement equipment

The SOLARIS facility is equipped with a radiation monitoring system. It is provided by Thermo Scientific and it presently contains 7 stations on trolleys with local displays and alarming modules (Fig.6): 5 gamma stations and 2 gamma-neutron stations. The gamma detector is the ionization chamber FHT 192 and the neutron detector is BF_3 Thremo FHT 752. The system has dedicated software available in the control room, presenting measurements results and a history of doses and alarms.
The environmental dosimetry is also realized with thermoluminescence dosimeters (TLDs). They are deployed in various places in the facility and accumulated doses are read out once per month.

Periodical radiation measurements are performed with portable radiometers, such as the Thermo FH 40 G-L10 proportional counter, Fluke ASM 990S with the 489-35 Geiger–Müller counter and the Rotem RAM ION ionization chamber. The measurements involve verification of efficiency of the synchrotron shielding walls and looking for activated components in the machine, which are especially important during the first phase of the machine operation - commissioning.

Fig.6 – A radiation monitoring station and the dedicated software at SOLARIS.

During work at SOLARIS all the technical employees are obliged to wear personal TLD dosimeters, which enable to estimate received annual doses. Read-outs of the registered doses take place once per month and they are performed by an external accredited company.
People can also use electronic personal dosimeters (Thermo EDP-G) to receive the current read-out of received dose. Everybody, who wants to enter potentially dangerous places, is obliged to take the dosimeter and this condition is particularly important in case of external workers, apprentices, guests ect. The electronic dosimeters alarm when set radiation levels are exceeded.

5. Personal Safety System

The Personal Safety System (PSS) was designed and delivered by Elettra Sincrotrone Trieste according to Solaris requirements [6]. Its role is to protect people against ionizing radiation at SOLARIS.
The synchrotron's PSS applies to the accelerator’s tunnels, which are divided into 3 zones – Zone1 and Zone2 in the linac tunnel and Zone3 in the ring tunnel. Every zone has its own search procedure, which is necessary to guarantee no presence of people inside the tunnels during operation of the machine.
Each door of the tunnels is equipped with an electromagnetic lock, a mechanical micro-switch and a magnetic micro-switch. Next to the main doors of the tunnels on the external and internal sides, the PSS panels are placed. They are used during the controlled access and the search procedures, and they also show the present state of access (free, controlled or interdicted).

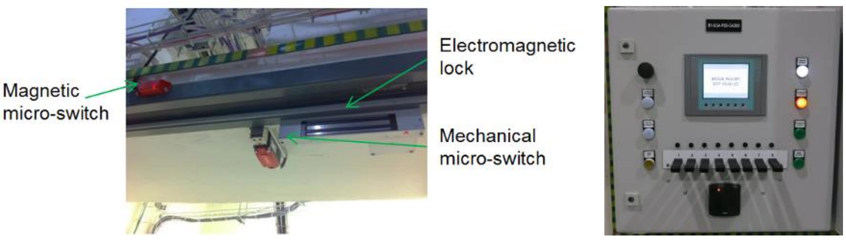

Fig.7 – Equipment of the tunnel door and the external PSS panel.

The beamlines’ PSS concerns optical hutches and safety shutters in the front-end parts inside the ring tunnel. Every beamline has 2 safety shutters (Fig.8), which has to be opened to start an experiment. Opening them requires a number of conditions fulfilled, among others rotating a special key to proper position by an authorized person, interlocking the hutch and no electron injection into the storage ring.
The door of the hutch is equipped like the tunnel’s door: with electromagnetic locks and 2 redundant micro-switches. Outside of the hutch door there is a PSS panel, presenting the state of the hutch and enabling performing the search of the hutch.

Fig.8 – PEEM/XAS safety shutters and the beamline's PSS panel.

The PSS has dedicated software available in the control room (Fig.9).
Presently 4 radiation monitoring stations are connected to the Personal Safety System, so they stop the machine operation in case of high radiation levels. Two of them are placed in the injection region and two belong to the beamlines.

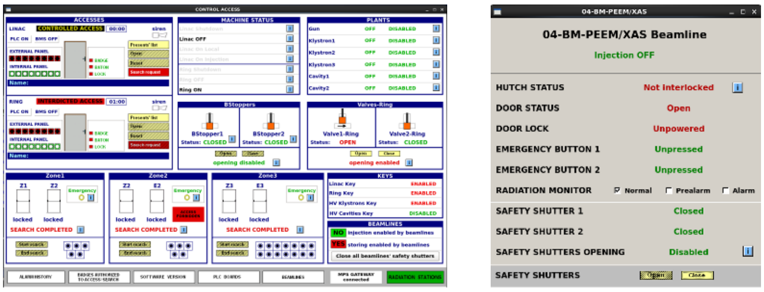

Fig.9 – The PSS software.

6. Machine commissioning

The first phase of the synchrotron commissioning started in December 2014 and finished in February 2015. It was the conditioning and the preliminary commissioning of the linac. Because the installation of the storage ring was not finished, it was necessary to bypass the ring's Personal Safety Sysyem and to separate the ring tunnel from the linac tunnel. To do this, the transfer line holes were closed with heavy concrete slabs, lead bricks and bags with concrete powder, and 2 radiation monitoring stations (connected to the PSS) were placed close to this shielding. These solutions allowed to work inside the ring tunnel and to perform commissioning at the same time.
On 23th February 2015 the 300 MeV electron beam reached the beam dump at the end of the linac. It was possible to observe it on the YAG screen before the beam dump, what is presented in the Fig.10.
There were no increased levels of radiation in the experimental hall but in the service gallery close to the cable trenches in the injection area dose rate amounted up to 4 μSv/h.

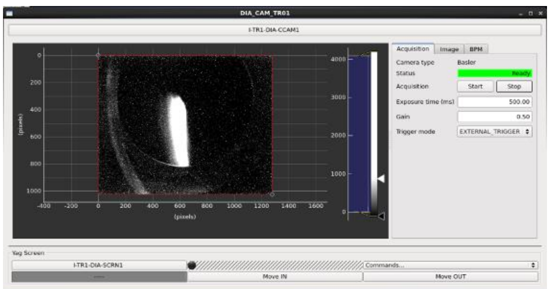

Fig.10 – The electron beam at the end of the linac tunnel on 23th February 2015.

The second phase of commissioning began in May 2015. It consisted of 2 weeks of the machine conditioning and then operation with the electron beam. The previous temporary solutions were removed and the PSS had been finally tested. To guarantee safety of all the people, it was forbidden to enter the service gallery and the experimental hall during the electron injection into the storage ring.

On 27th May 2015 the first beam was registered in the storage ring. Beam parameters were 320 MeV, 1.5 nC/bunch and 180ns long bunch train.
During this phase of the commissioning higher radiation levels were found (fig.11). It means that special attention need to be paid to this problem and some additional shielding is required. Especially, radiation levels in the experimental hall have to be reduced.

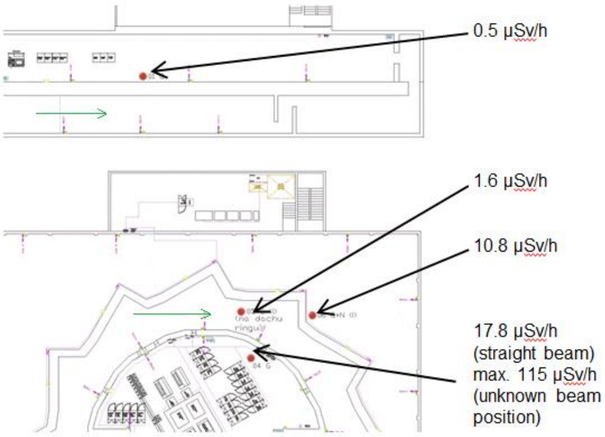

Fig.11 – Radiation levels during electron injection into the storage ring on 27th Mary 2015.
The direction of the beam is marked with the green arrows.

Currently the commissioning of the machine is running. The operators work on receiving satisfying electron beam in the linac and in the storage ring, on setting all the machine parameters and on accumulating the beam in the storage ring.
All the time radiation measurements are preformed and some areas with high radiation levels are excluded from access. The radiation safety rules are reviewed continuously and modified if needed. Also, the work on designing some additional shielding is ongoing.

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