Update of the commissioning of the SOLARIS 1.5 GeV storage ring

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Abstract

SOLARIS is the first synchrotron in Poland, made up of a 550 MeV linear accelerator and the 1.5 GeV storage ring [1]. The commissioning of the ring has started in May 2015 and now it has entered the advanced stage - in the near future it is expected to achieve well optimized, useful electron beam. Moreover, the commissioning of the UARPES beamline has begun and first tests with a photon beam on the PEEM/XAS beamline has already started, but the most important commissioning work on the beamlines will be carried out in the next few months. It is planned to provide the beamlines to users in 2018.

During the machine commissioning, radiation measurements have been continuously preformed to verify shielding effectiveness of the ring walls and additional shields. Also the beamline radiation protection solutions has been tentatively checked but they require further verification during the beamline commissioning.

Results of radiation measurements together with operation conditions are presented.

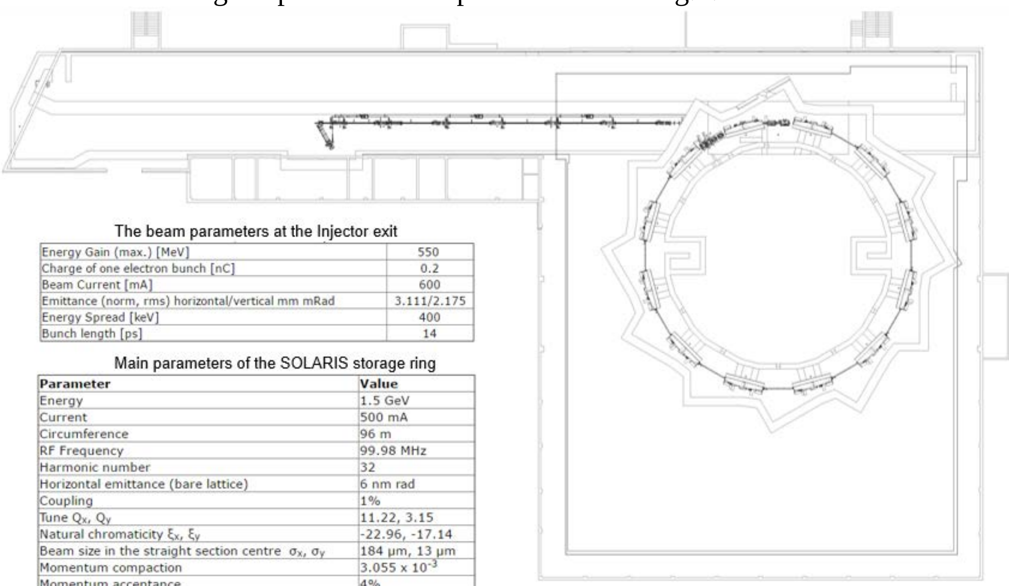
1. Synchrotron SOLARIS – general description

1.1. Machine and beamlines

The SOLARIS machine includes three parts: a linear accelerator, a transfer line and a storage ring.

The linear accelerator is made up of a thermionic gun supplied by an RF unit and 6 acceleration sections supplied by 3 RF power units. This 40m-long accelerator provides the ring with about 550 MeV electrons through a transfer line. The 1.5 GeV storage ring consists of 12 Double-Bend Achromat cells, 12 straight sections, 2 main cavities and 2 Landau cavities. This 3rd generation light source is designed to operate with 500 mA stored current [2].

The machine scheme and designed parameters are presented in the Fig.1.



The beam parameters at the Injector exit

Energy Gain (max.) [MeV]	550
Charge of one electron bunch [nC]	0.2
Beam Current [mA]	600
Emittance (norm, rms) horizontal/vertical mm mRad	3.111/2.175
Energy Spread [keV]	400
Bunch length [ps]	14

Main parameters of the SOLARIS storage ring

Parameter	Value
Energy	1.5 GeV
Current	500 mA
Circumference	96 m
RF Frequency	99.98 MHz
Harmonic number	32
Horizontal emittance (bare lattice)	6 nm rad
Coupling	1%
Tune Q_x, Q_y	11.22, 3.15
Natural chromaticity ξ_x, ξ_y	-22.96, -17.14
Beam size in the straight section centre σ_x, σ_y	184 μm, 13 μm
Momentum compaction	3.055×10^{-3}
Momentum acceptance	4%
Total lifetime	13 h

Fig.1 – The scheme and designed parameters of the SOLARIS machine.

It is foreseen to build a dozen or so beamlines at the SOLARIS facility but now two of them are already installed and during the commissioning. The PEEM/XAS beamline has a bending magnet as a source, works at the energy range from 200 eV to 2000 eV and includes two different end stations [3]. The UARPES beamline uses a quasi-periodic undulator and the photon energy range from 8 eV to 100 eV [4]. The next one, PHELIX, is under construction and a few more beamlines are planned to build in following years.

1.2. Shielding elements

Shielding walls of the accelerator tunnels at SOLARIS are made of combination of ordinary concrete (density ~2.3 g/cm3) and heavy concrete (density ~3.2 g/cm3). Walls thickness and materials arrangement are presented in Fig.2.

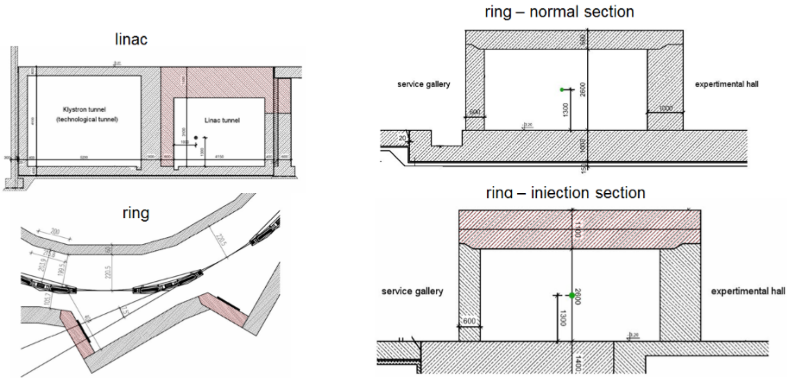


Fig.2 – SOLARIS shielding walls. Red colour indicates heavy concrete, grey – ordinary concrete.

Unused holes, cables and pipes trenches are closed with bags containing heavy concrete powder and with ordinary concrete blocks. On every front-end wall inside the ring there is an additional steel block mounted and in the sections with installed beamlines there are additional lead walls. Also, next to the kicker and the septum magnets lead walls are installed to reduce radiation levels outside the ring walls.

1.3. Operation status

The commissioning of the machine has begun in December 2014 with the operation of a linac and then in May 2015 the ring has been started. Now the commissioning of the machine is still in progress - the injection and the electron orbit optimization has been carried on, beam measurements have been performed, RF units parameters have been improved and the electron current with good beam lifetime still has increased. Till now 400 mA of maximum beam current has been reached.
Also the beamlines commissioning is in progress – starting from April 2016 in case of the UARPES beamline and from April 2017 in case of the PEEM/XAS. One more beamline – PHELIX – is under design will be installed soon.

2. Assumptions during the commissioning and radiation measurement equipment

Polish regulations define areas classification limits as: for unclassified areas – up to 1 mSv per year, for supervised areas – up to 6 mSv per year and for controlled areas – more than 6 mSv per year. Having it in mind, during the commissioning some area classification is followed, as it is presented in the Fig. 3. This is a conservative assumption and it guarantees safety of all the people at SOLARIS.

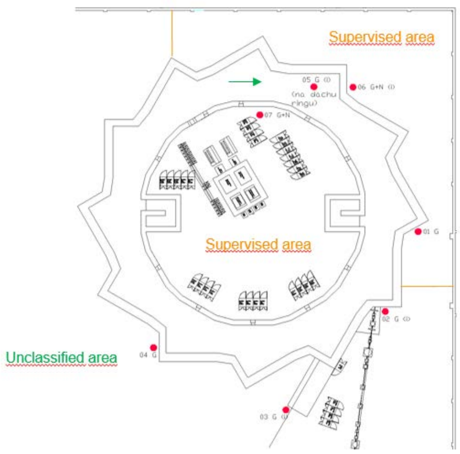


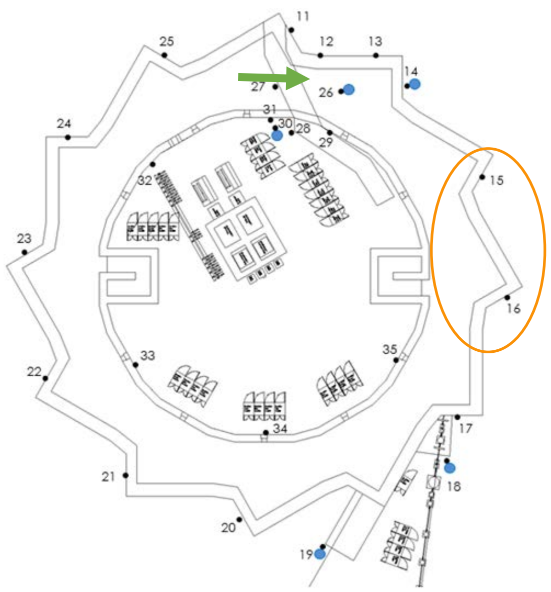
Fig.3 – Area classification during the commissioning at SOLARIS.

The SOLARIS facility uses the Thermo Scientific radiation monitoring system to continuously measure and to present radiation levels around the machine walls and near the beamlines. Now seven stations on trolleys with local displays and alarming modules are working, including totally seven FHT 192 gamma ionization chambers and two FHT 752 neutron detector. Four of the stations are connected to the Personal Safety System and influence on the machine operation in case of exceeding radiation limits or failures.
Additionally, thermoluminescence dosimeters (TLDs) are used to estimate gamma environmental doses. They are read out every three months by an external accredited company and the results are analysed to determine radiation supervised and controlled areas.
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, are used to perform periodical radiation surveys and all necessary measurement next to the machine walls and around beamlines.

3. Machine commissioning

3.1. Doses in 2015 and 2016

During all the machine commissioning doses measurements were performed using thermoluminescence dosimeters (TLDs). Generally registered doses depend on machine operation modes, total duration of operation and beam currents, what is expressed as so-called integrated current in Ah. The measurements are useful to evaluate radiation shielding effectiveness but they also help operators to find beam missteering points.
In 2015 the integrated current was only 10.4 Ah and doses results indicated that all the places next to the machine tunnel walls were unclassified areas.
Last year (2016) the commissioning speeded up and 197.66 Ah integrated current was reached. In two places, signed in Fig. 4 as 15 and 16, doses achieved radiation supervised area levels (from 1.788 to 6.788 mSv with the background radiation), 3.069 mSv and 3.906 mSv respectively. Doses at all the other places around the machine tunnel wall were on the level of the unclassified area.



No.	Accumulated dose [µSv] in a time period in 2016				Total accumulated dose [µSv]	Notes
	1	2	3	4		
11	92	218	179	183	672	
12	203	323	277	233	1036	
13	148	275	254	230	907	
14	475	310	287	268	1340	
15	1138	940	524	467	3069	Supervised area
16	457	1199	1175	1075	3906	Supervised area
17	90	214	319	176	799	
18	76	199	170	154	599	
19	107	211	167	169	654	
20	115	373	282	252	1022	
21	123	238	255	216	832	
22	74	247	183	204	708	
23	94	219	193	202	708	
24	71	214	183	185	653	
25	84	260	200	197	741	
26	168	284	209	195	856	On the ring roof
27	84	196	149	149	578	On the ring roof. guard rail
28	141	198	165	175	679	On the ring roof. stairs platform
29	319	369	233	230	1151	
30	168	227	184	169	748	
31	235	267	230	200	932	
32	162	230	213	200	805	
33	129	259	211	197	796	
34	129	240	226	207	802	
35	131	250	227	194	802	

Fig.4 – TLDs doses in 2016. Electrons injection into the ring is marked with the green arrow. Two points marked with the orange ellipse refer to supervised area.

Doses measurements with TLDs will be continued within next years of operation with paying special attention to the injection region and following sectors, where it is expected to find supervised and controlled areas.

3.2. Measurements during injection and accumulation with different current values

Parallelly to the doses measurements using TLDS, continuous measurements with Radiation Monitoring System (RMS) and periodical surveys with portable meters are performed. Especially, measurements with defined injected and ramped beam currents (250 and 350 mA) are repeated once a while to analyze the commissioning progress and beam optimization.
Last measurements performed using RMS during injecting and ramping of 350 mA of current confirmed that in the injection region temporary radiation levels exceed the unclassified area limit. Dose rates in the points 14, 26 and 30 marked in the Fig. 4 are presented in the Fig. 5. It is important that in the service gallery (point 30) the neutron dose rate has higher contribution in the total dose rate than in the other places because of relatively lower thickness of the tunnel wall.

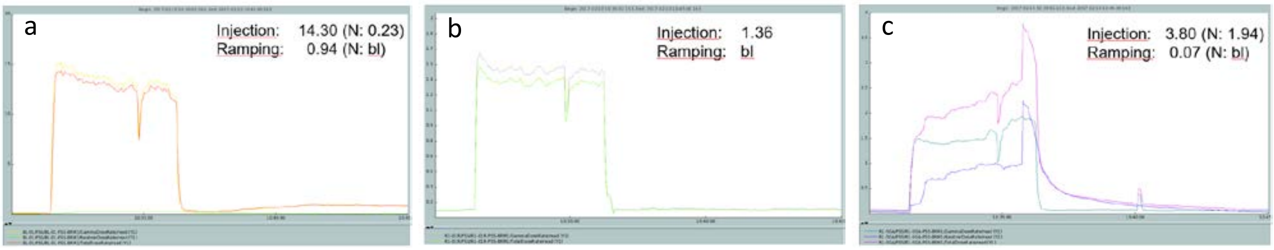


Fig.5 – Dose rates during injection and ramping of 350 mA of current measured on 10.02.2017.
a – point 14, b – point 26, c – point 30 marked in Fig. 3. Results in µSv/h.

In March 2017 precise measurements in every ring section were done using RMS stations while 250 mA of the beam current was injected and ramped. The measurement results are presented in the Fig. 6. They show that in a few places radiation levels are still higher than desirable during normal operation.

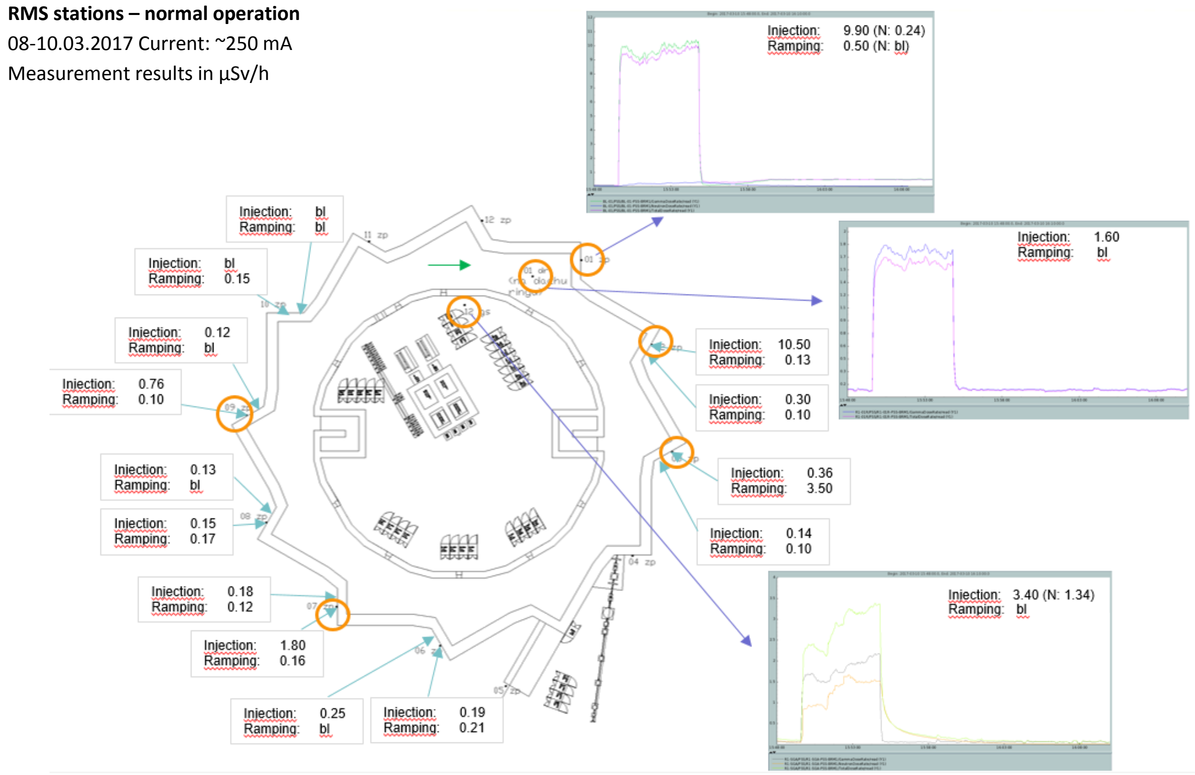


Fig.6 – RMS measurements: dose rates during normal operation on 08-10.03.2017; beam current ~250 mA. Electrons injection into the ring is marked with the green arrow. Orange points refer to supervised area.

During the commissioning operators perform some experiments and beam optimization, for example they make scrapers movement to check the minimum chamber aperture and to measure beam lifetime. In such situations we can observe radiation peaks even on the level of a few mSv/h. This kind of experiments are done very carefully, all dangerous places are fenced and signed and all the workers are informed about the experiments.

4. Beamline commissioning

In April 2016 the commissioning of UARPES beamline started with the low beam current in the storage ring. The current has been gradually increased in the course of time and it was possible to perform radiation measurement along the beamline components during beamline operation.
In the Fig. 7 dose rates values and the point of measurements (next to the beamline pipe leaving the optical hutch), performed in October 2016 with a RMS station, are presented. The radiation level of 0.64 µSv/h was reached with 210 mA of current. Around the hutch and along the beamline dose rates were below the unclassified area limit. The measurements have to be repeated as soon as possible and special attention has to be paid during operation with the beam current higher than 200 mA.

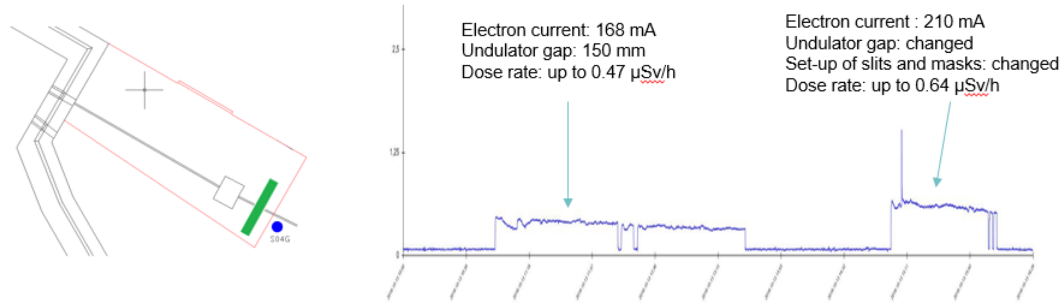


Fig.7 – Radiation measurements in the point of beamline pipe leaving the optical hutch (blue point on the left) - dose rates with different beam current in the ring (the plot on the right).

Beamline commissioning of the PEEM/XAS has just started with low beam currents in the ring and the radiation measurements will be done when it is possible and needed.

5. Summary – plans for the nearest future

At SOLARIS facility the commissioning of the machine and the beamlines will be continued in the next few months. All the time continuous radiation measurements and needed periodical surveys will be performed to monitor and to modify the supervised and the controlled areas. Gradual decreasing of radiation levels around the ring tunnel walls is expected due to vacuum conditioning and optimization of the electron beam. Additionally, radiation safety improvement in the injection region is foreseen after installation of the linac chopper.
The main aims for the next months are to receive a stable electron beam in the ring with the maximum current, to start and to open two beamlines to users in 2018 and to build a new beamline.
Regarding radiation protection, installation of additional shielding in the most problematic sections of the ring in the experimental hall and around beamline components may be needed to have all the exeprimentall hall as the unclassified area. It will depend on radiation measurements and final decisions will be made in a more advanced stage of the commissioning. Finally, additional RMS stations are already order and it is expected to receive them the end of the year 2017.

References

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