ISBN: 978-3-95450-240-0 ISSN: 2673-5539 doi:10.18429/JACoW-RuPAC2021-WEPSC08

VACUUM CONDITION SIMULATIONS FOR VACUUM CHAMBERS OF SYNCHROTRON RADIATION SOURCE

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Abstract

Analysis of gas loads for the vacuum system chambers of the 6GeV synchrotron radiation (SR) source are carried out. The main source of gas loads is the photostimulated desorption induced by SR. The influence of storage ring lattice, geometric dimensions and beam parameters on the vacuum conditions in SR-source prototype chambers is studied. The geometric model of the storage ring chamber designed for simulation is considered. The simulation of the radiation flux parameters generated by the charged particles passing through the section of the vacuum chamber has been performed. The technique of calculating the parameters of SR and photostimulated desorption by means of Synrad+ and Molflow+ codes is applied.

MODELING METHODS

During the operation of the SR-source, an intense flux of photon radiation is generated inside the storage ring. Most of this radiation will fall on the inner surface of the vacuum chambers, which leads both to an increase in thermal loads and to the appearance of synchrotron-stimulated desorption. In order to reduce the negative effects of incident radiation, special absorbers are installed in places with a high radiation load. The main part of the heat load is removed with their aid. They are made from a copper alloy (for example CuCrZr) and water cooling is provided in their design. With the change in the parameters and the storage ring geometry, the characteristics of the radiation flux density distribution in separate sections of the vacuum chambers will also change. The parameters of the vacuum system and absorbers must be calculated for these changes.

It is necessary to determine the relationship of changes in SR parameters with new requirements for radiation absorbers. Approaches to determining the characteristics of the radiation flux in the storage ring of the SR-source are considered. For this aim the capabilities of the SynRad + software module and its joint use with the Molflow + package for numerical simulation of accelerator complexes vacuum systems were studied [1].

Synrad+ [2] is a program for determining the parameters of the SR incident on the chambers walls (radiation flux, power, spectrum) by the Monte Carlo method. It calculates the power distribution of the synchrotron radiation incident on the surface. The use of this program in one package with Molflow+ makes it possible to calculate the desorption gas flow from the inner surface of the chambers by SR distribution. Thus, it is possible to determine the effect of changes in the storage ring geometry and optical system parameters on the vacuum level.

VACUUM SYSTEM

ESRF-EBS research accelerator complex, 4th generation synchrotron radiation source was taken as a prototype of the designed SR-source - Ultimate Source for Synchrotron Radiation (USSR, formerly known as "SSRS-4").

Improvement of the developed SR source parameters, such as high spatial coherence and brightness, required changes in the magnetic system of the facility. This, in turn, led to a change in the lengths of individual sections of the storage ring and vacuum chambers. The structure of the projected SR-source vacuum system was designed. The storage ring perimeter includes identical standard cell sections with identical vacuum chambers (see Fig. 1).

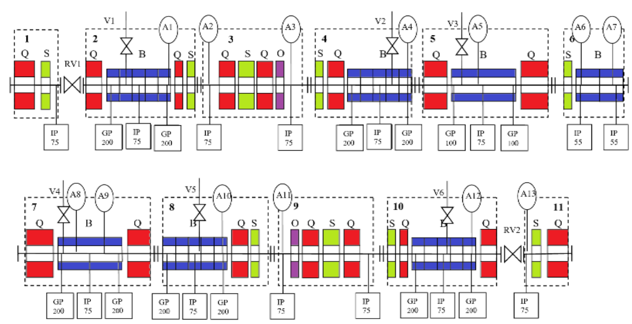

Figure 1: Standard cell: vacuum chambers 1-11, vacuum pumps IP and GP, absorbers A1-13.

Taking into account the change in the geometric parameters of the storage ring, the pressure profiles on the beam axis were modelled (see Fig. 2). There is an insignificant increase in pressure in the region of the chambers length increasing. This is due to an increase in the chambers walls surface area and a slight increase in the total thermal outgassing.

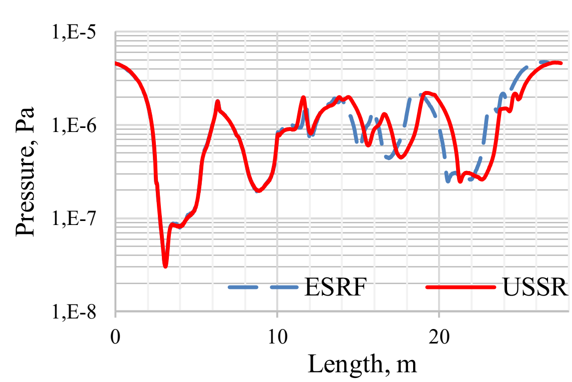

Figure 2: Influence of geometry changes.

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Additionally, the stability of the SR-source vacuum system to the dynamic growth of the gas load from the absorbers surface was evaluated. Different levels of the absorbers gas desorption in the three central chambers of the section were simulated (the boundaries of the chambers in Figure 3 are marked with dashed lines). The results of a proportional increase in pressure in the selected areas are explained by the dominant role of stimulated desorption from the absorbers surfaces in comparison with the background gas load from the inner surfaces of vacuum chambers that are not exposed to radiation.

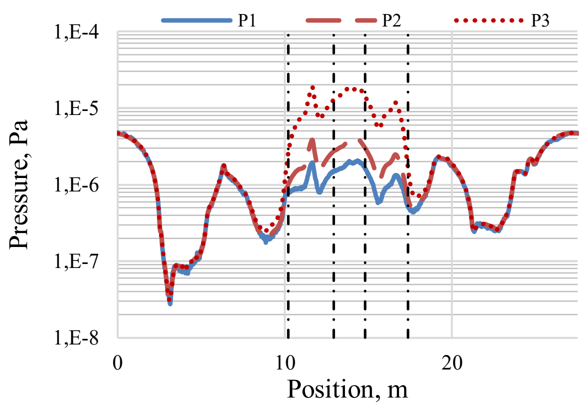

Figure 3: Pressure in the standard cell with different levels of absorbers outgassing; P1 – no changes, P2 – 2x gas desorption, P3 – 4x gas desorption.

SYNCHROTRON RADIATION

The method of modelling the characteristics of synchrotron radiation and photo-stimulated desorption was studied. For one cell of the prototype storage ring [3] simulation of the electron beam passage through the structure of the accelerator is performed. The influence of the SR flux power, generated by the bending magnet DL1, on the stimulated gas desorption of absorbers was investigated.

According to the technical description of the ESRF-EBS storage ring [3], the parameters of the electron beam (see Fig. 4) and the magnetic system (see Table 1) were determined.

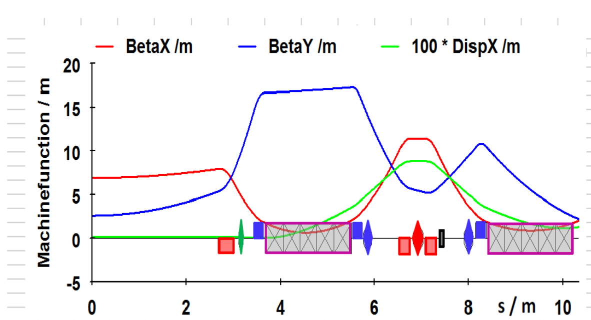

Figure 4: Beam property.

Table 1: Magnet System

Type	Symbol	Magnetic field, T	Length, м
drift			2,7
quadrupole	QF1	50,8	0,295
drift			1,02
quadrupole	QD1	-53,413	0,212
drift			0,37
dipole	DL1-1	0,62481	0,3804
dipole	DL1-2	0,4113	0,3504
dipole	DL1-3	0,30169	0,3573
dipole	DL1-4	0,22665	0,365
dipole	DL1-5	0,16731	0,3722
drift			0,37
quadrupole	QD3	-48,0415	0,162
drift			0,75
sextupole	SD1	-568,898	0,166

Applying Optics Builder [4] this data was added to the calculation model. The synchrotron radiation was generated by a 6 GeV electron beam with a current of 200 mA. The distribution of the absorbed SR flux is obtained for all radiation absorbers located in the selected area. The absorbed power density was on average up to 160 W/cm^2, and for some absorbers it was up to 278 W/cm^2.

The calculation results for the incident SR flux were exported from Synrad+ to Molflow+. Through the stimulated desorption coefficient, the SR power distribution was transformed into a stimulated desorption stream from the surface of the absorbers. For a radiation dose of 100 Ah, the level of gas desorption from these surfaces was $8\cdot10^{-8}$ - $6\cdot10^{-7}$ mbar·l/s·cm^2. The desorption value for other sections of the vacuum chambers was 10^{-11} mbar l/s cm^2. The obtained outgassing values were compared with the technical data of the prototype parameters [3] (see Table 2).

Table 2: Stimulated Desorption

Absorber	ESRF, mbar·l/s	model, mbar·l/s
ABS CH2-1-1	1.05e-07	8.2E-08
ABS CH3-1-1 Crotch	6.39e-07	9.9E-07
ABS CH4-1-1	3.94e-07	1.7E-07
ABS CH5-1-1	4.03e-07	6.2E-07
ABS5-1-1 H9	1.07e-08	1.3E-08
ABS5-1-1 H11	3.47e-08	9.6E-08

The considered modeling technique was also used in the further calculation of the designed SR source parameters.

The calculation of the generated radiation parameters for the bending magnet of the camera № 2 (DL1) has been carried out for the designed facility and for the prototype on the nominal operating parameters. Comparison of the results is necessary to assess the effect of changes in the characteristics of the magnet system.

27th Russ. Part. Accel. Conf. RuPAC2021, Alushta, Crimea JACoW Publishing
ISBN: 978-3-95450-240-0 ISSN: 2673-5539 doi:10.18429/JACoW-RuPAC2021-WEPSC08

For each option, a computational model was created and the total power and angular distribution of the radiation generated by the electron beam when passing through the magnet were calculated (see Fig. 5). The absorption of the generated SR radiation by a section of the vacuum surface - a rectangular face 80x25 mm in size, located 50 mm from the exit from the magnet was simulated.

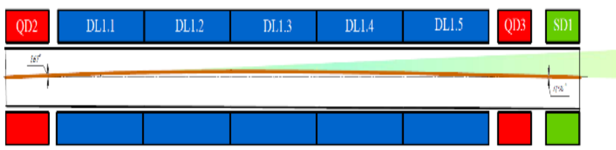

Figure 5: Synchrotron radiation of a bending magnet DL1.

Figures 6,7 and 8 show the results of the density and SR spectrum calculation for the prototype model and for the model of the constructing SR-source.

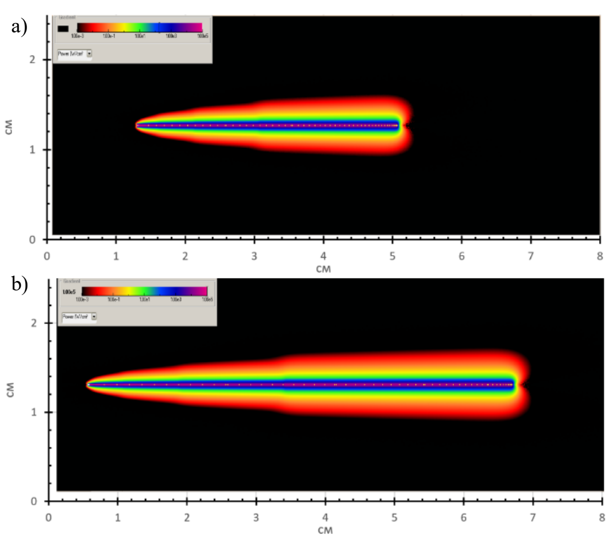

Figure 6: Synchrotron radiation of a DL1 dipole magnet, a) ESRF-EBS; b) USSR.

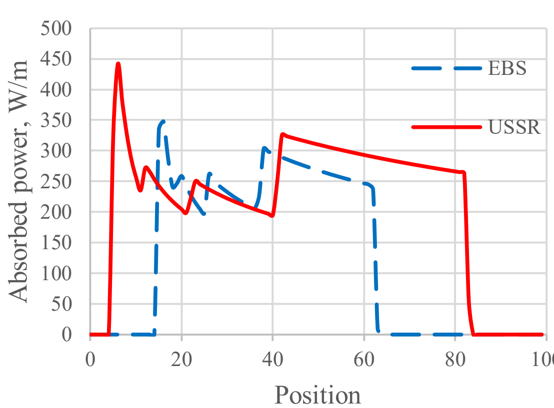

Figure 7: Linear distribution of absorbed power.

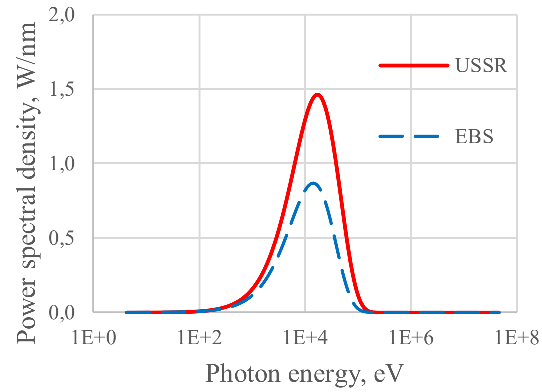

Figure 8: Spectrum of incident radiation.

The obtained results for the designed SR-source were compared with the calculation for the ESRF-EBS prototype. An increase in the length of the storage ring section and of the magnet field magnitude in the magnet sectors, together with a decrease in the beam emittance, led to an increase in the horizontal radiation angle and to an increase in SR power. Therefore, it will require clarification of the absorbers parameters and vacuum equipment.

CONCLUSION

The simulating model of the SR parameters and synchrotron-stimulated desorption based on the Monte Carlo method is considered. A modification of the magnet and vacuum systems elements dimensions and of the beam parameters will lead to different conditions for the radiation flux passage in the new geometry of the SR-source storage ring. Under these conditions, it will be necessary to design a new structure for the distribution of absorbers across the chambers, making changes to their design. It is also possible that the issues of correcting pumping systems will need to be considered.

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