PROJECT STATUS OF THE POLISH SYNCHROTRON RADIATION FACILITY SOLARIS [1)]

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Abstract The Polish synchrotron radiation facility Solaris is being built at the Jagiellonian University in Krakow. The project is based on an identical copy of the 1.5 GeV storage ring being concurrently built for the MAX IV project in Lund, Sweden. A general description of the facility is given together with a status of activities. Unique features associated with Solaris are outlined, such as infrastructure, the injector and operational characteristics.

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1. INTRODUCTION

The first ideas for a national synchrotron radiation facility in Poland were put forward in 1998 and several proposals made in subsequent years. In 2008 the government pledged funds of 143 MPLN with formal allocation after approval of a feasibility study from the Jagiellonian University for the construction of a light source with such a budget. In 2009 this study, based on the innovative ideas and technology of MAX-lab (ref. MAX III, [2]), was submitted and the National Synchrotron Radiation Centre Solaris was approved for construction in February 2010 using EU structural funds. The facility will be built on land allocated by the Jagiellonian university on the new campus in Krakow. In December 2010 an agreement was signed between the Jagiellonian University and Lund University Sweden, for the mutual cooperation and sharing of ideas and designs related to the construction of the two facilities. Solaris will be an identical copy of the 1.5 GeV ring of the MAX IV project and will use identical parts of the linac injector and transfer line [2, 3]. Major differences between the two machines are the infrastructures, the lower energy linac and the beamlines.

2. FACILITY

Building

The synchrotron radiation facility will be built at the campus III site of the Jagiellonian University in the city of Krakow. The land with an area of $\sim$ 22000 m^2 will site the machine, experimental hall, auxiliary service buildings, laboratories, offices and auditorium. The contract for the design and construction was awarded in the March 2011 to the consortium of companies: ALPINE Construction Polska Spółka z o.o. and Przedsiebiorstwo Budowlano-Produkcyjne ŁĘGPRZEM Spółka z o.o. The building permit was granted in December 2011 and the construction is in progress. The building is composed of a linac tunnel and an adjacent modulator and service gallery placed below the storage ring level. The length of the tunnel $\sim$ 100 m, within the constraints of land availability, foresees an upgrade to the linac to increase its energy for top-up injection. All services, power, HVAC and cooling will be built with this upgrade in mind. The experimental hall for beamlines houses the storage ring tunnel. The experimental hall has a surface area of 3000 m^2 and provision is made for its future extension on one side by 600 m^2. Access to the storage ring tunnel will be through chicanes on the inner side and the roof shielding will be removable for machine installation and maintenance. All equipment for the storage ring will be housed on the inner side of the ring tunnel. A crane, rated at 8 tonnes, spanning the experimental hall, will be used for machine and beamline installation and maintenance.

Injector

The linac injector for Solaris will initially be operated at 550 MeV with options for a full energy upgrade. The linac is composed of an RF gun and six normal conducting 3 GHz accelerating sections, of length 5.2 m, grouped into three units containing two accelerating sections [2]. Each unit will be powered through SLED cavities fed by a solid-state modulator driving a klystron. The linac sections are being manufactured by Research Instruments GmbH (D) and will have a guaranteed performance of 20 MV/m. The RF power from the SLED cavities feeding each unit will be split equally to the two linac sections. The first unit, however, will be configured to deliver RF power to the gun too.

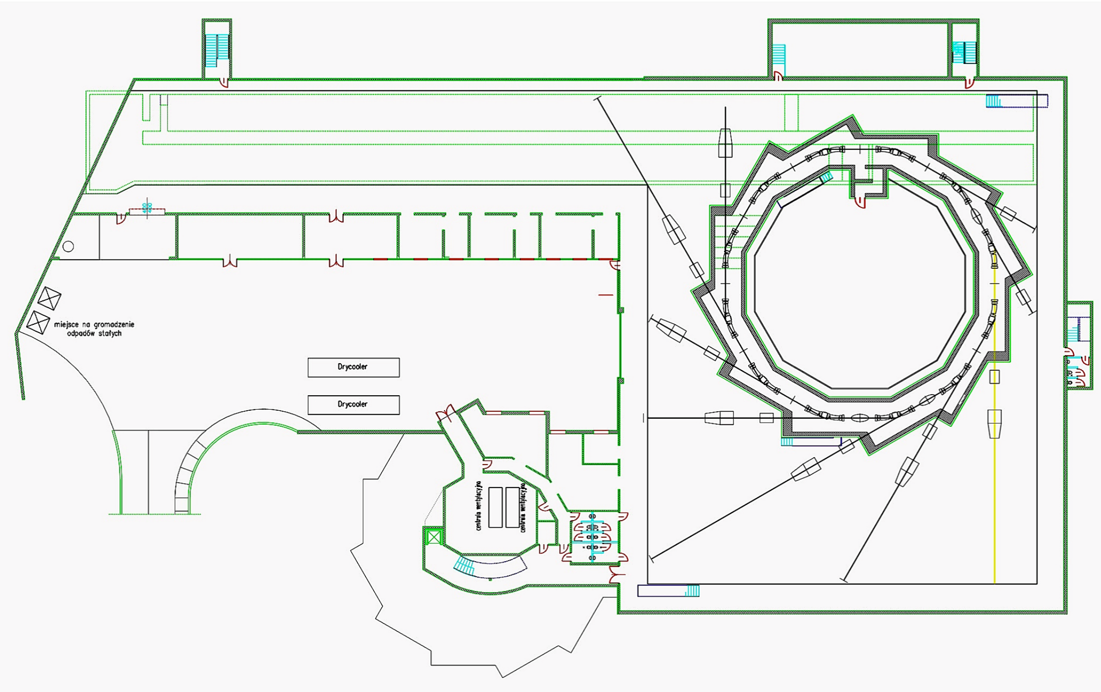

Figure 1: Concept layout of the facility. The experimental hall can be extended by 10 m on the right hand side at a later date. Above the linac tunnel ample covered space is available for pre-assembly and general laboratories.

In this case the first linac section will be given more RF power. The solid-state modulators, ordered and being manufactured by ScandiNova Systems AB (S), will power 35 MW klystrons at 10 Hz. The electron gun will be an upgraded version of that presently used at MAXlab. It will have a BaO cathode and a 180° bending magnet will be used for energy filtering.

Transfer line

The beam is transferred to the storage ring via a 27° vertical ramp. The linac will initially be placed close to the storage to reduce the length of transfer line and the gun relocated when the full energy upgrade will be performed. The vertical ramp is optically mirror symmetric and composed of two pulsed 10° magnets, two dipole magnets deflecting 17° and six quadrupoles. The pulsed dipole magnet in the linac tunnel in combination with a kicker magnet will in the future be used to share the linac beam between topping up and possible FEL experiments. The pulsed septum magnet at the end of the transfer line is a vertical Lamberston type, deflecting the beam into the horizontal plane. All magnets and power supplies are identical to MAX IV systems.

Injection process

Injection into the storage ring will be performed with a pulsed sextupole magnet [4, 5]. The scheme has many advantages over a conventional four-kicker injection bump especially for top-up operation. In the case of Solaris with straight section lengths of 3.5 m, a fourkicker scheme would require it to span two achromat sections that contain strong sextupoles and large dispersion that would affect the stored beam. Furthermore the conventional scheme would reduce the available space for insertion devices. The use of a pulsed sextupole magnet will simplify the scheme and circumvent the aforementioned disadvantages. The injection dynamics at a lower energy compared to the MAX IV case is considered in reference [4]. Care must be taken in the design of the pulsed sextupole magnet and associated power supply given the 320 ns revolution time of the storage ring, since a two turn injection scheme is less efficient compared to a single turn scheme. The possibility of using a single dipole kicker is also being evaluated to help facilitate the commissioning of the pulsed sextupole scheme [6]. Once accumulated the beam will be ramped to its final energy of 1.54 GeV. The behaviour and response of the magnets during ramping is expected to be similar to that of MAX III.

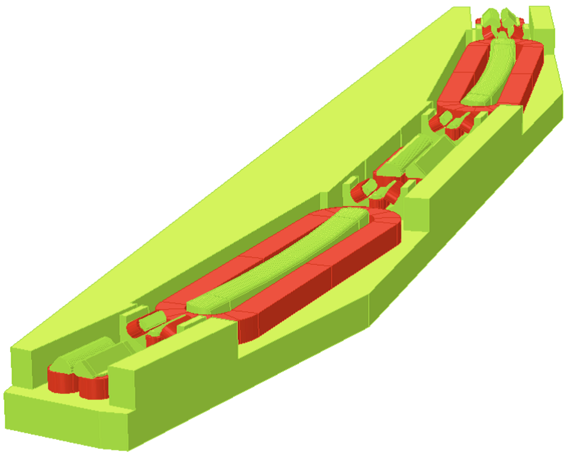

Figure 2: Magnet half block with coils in red [7].

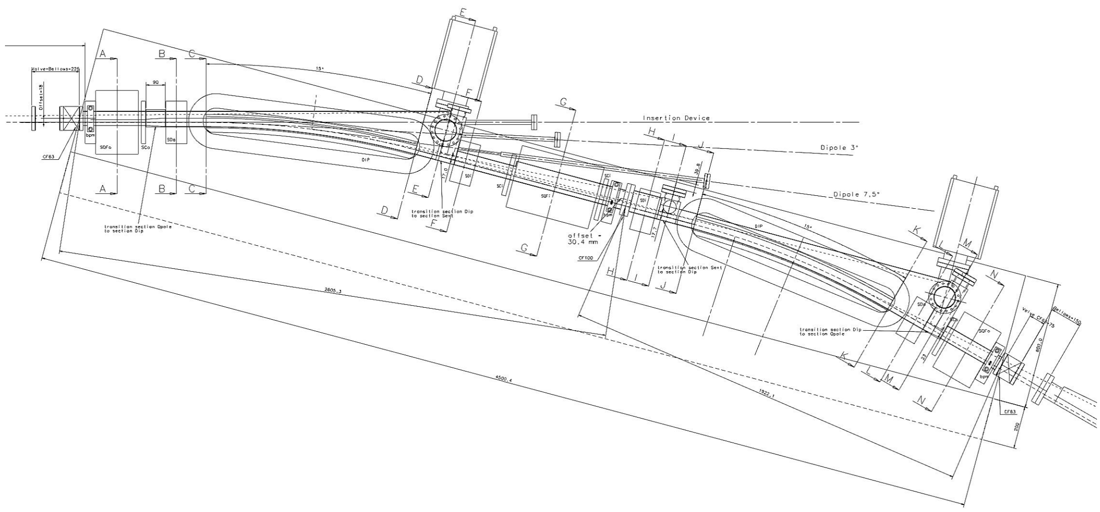

Figure 3: Preliminary vacuum chamber in stainless steel with antechambers [9].

Storage Ring Technology

The storage ring will be technologically identical to the MAX IV 1.5 GeV ring and is composed of 12 magnet blocks forming a 12 double bend achromatic structure. Bending magnet synchrotron radiation will be extracted for users from the first dipole in the achromat. The iron blocks machined to high precision will contain all magnetic elements allowing for a very compact design. The iron for the magnets has been purchased and is being thermally treated prior to machining. Magnet design [7] is in the final stages of completion and is being performed in parallel with the design activities of the vacuum chamber.

An evaluation has been performed of the technology to be used for the vacuum system. Both a wholly NEG coated chamber, similar to that adopted for the MAX IV 3.0 GeV ring [8], and a conventional system with antechamber and absorbers were examined. A conventional stainless-steel system was chosen on the basis of manufacturer availability, costs, technology requirements and project time-schedule. The vacuum system is being designed and the construction drawings prepared by the group from CELLS-ALBA Synchrotron in Cedanyola del Valles (E) in collaboration with MAXlab and Solaris. The system and magnet configuration foresees extraction of bending magnet radiation at either 3 or 7.5 degrees from the first bending magnet of the achromat.

The storage ring RF system is composed of two 100 MHz cavities similar to those used in MAX II and III. The cavities are normal conducting and of the capacity loaded type that have relatively high frequency higher order modes compared to pill-box type cavities. The cavities will be equipped with higher order mode coupling loops that will extract the residual high frequency modes. Cavities and couplers have been ordered and are being manufactured by Research Instruments GmbH. The ring also foresees operation with two passive Landau cavities at 300 MHz as designed by MAX-lab similar to the main cavities [10]. Either solid state or tetrode amplifiers will power the main cavities. Two such amplifiers will be combined to provide 60 kW of power per cavity via a circulator. The RF units will be controlled with a digital LLRF system.

Optics and Dynamics

The integrated magnets permit an ultra-compact double bend achromatic structure with low emittance and zero dispersion in the straight sections. The compact magnet design has three quadrupoles that focus in the horizontal plane while the vertical focusing is done by the gradient in the dipoles. Pole strips on the bending magnets will allow tuning of the vertical focusing. The focusing sextupoles have also been integrated into the focusing quadrupoles. Recently the lattice has been optimised for the ramped operation in Solaris where Touschek lifetime is important since the facility will not operate in top-up mode but in decay mode. The optimisation has focused on increasing the momentum acceptance by ensuring the lattice momentum acceptance match the RF acceptance of 4%. Together with the use of Landau cavities the Touschek lifetime at 500 mA is expected to reach 13 hours [6]. In each magnet block there will be three BPMs and three horizontal/vertical corrector coils mounted on the sextupole magnets. Two of the BPMs will be positioned at the ends of the achromatic block and one in the centre.

Table 1: 1.5 GeV Storage Ring Parameters

Current	500 mA
Circumference	96 m
Horizontal emittance	
(bare lattice)	6 nm rad
Coupling	1%
Tunes Q_x, Q_y	11.22, 3.14
Natural chromaticities ξ_x, ξ_y	-22.9, -17.1
Momentum compaction	3.04×10^{-3}
Momentum acceptance	4%

Beamlines

For the first phase of the project one beamline is planned to be financed from the project budget. The beamline will use bending magnet radiation and will have a X-PEEM/XAS/XMCD end-station. This activity is in cooperation with PSI. Funding proposals have been submitted for additional beamlines from undulators.

3. SCHEDULE AND MILESTONES

The project deadline for first light is the third quarter of 2014. The building construction has started and the beneficial occupancy of the building is programmed for the end of August 2013. Component schedules and purchasing milestones are linked to the MAX IV project schedule and are compatible with Solaris installation.

4. CONCLUSIONS

The Solaris project is a prime example of the benefits of sharing of state-of-the-art knowledge and resources for the rapid establishment of a national research infrastructure. Scientific collaboration is certainly not new in the field of accelerators but the direct utilisation of a design and its complete replication is unique. The collaboration maximises the utilisation of human and financial capital leading to more effective and efficient use of public funds. The collaboration permits quick training of new people with an initial focus on mobility and networking and an optimal use of mentorship and expert knowledge. Procurement efforts are rendered more effective by not duplicating tasks and allow industry to program its response to large-scale research infrastructure requirements. The advantages also extend to building design and construction since critical knowledge is shared. Furthermore there is benefit of the Solaris-MAX IV collaboration on other European laboratories from collaborations that are unique to either Solaris or MAX IV which extend the network and knowledge base.

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