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Wawrzyniak, Adriana; Bocchetta, Carlo; Leemann, Simon; Thorin, Sara

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Total number of authors:
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INJECTOR LAYOUT AND BEAM INJECTION INTO SOLARIS*

A. I. Wawrzyniak[#], C. J. Bocchetta, National Synchrotron Radiation Centre Solaris at the
Jagiellonian University, Krakow, Poland
S. C. Leemann, S. Thorin, MAX-lab, Lund, Sweden

Abstract

The Solaris synchrotron radiation storage ring to be built in Krakow, Poland is based on the MAX IV 1.5 GeV design. The injector will be a linear accelerator and its components identical to those for the MAX IV project, however, injection is not at full energy and the injector layout is different. The linac and transfer line layout, optics and injection scheme into the storage ring is presented and an analysis of accumulation before energy ramping is discussed.

INTRODUCTION

The Solaris, 3rd generation light source facility is being built in Krakow, Poland. The project is accomplished through very tight cooperation with the MAX IV project in Lund, Sweden. This is a unique collaboration and an important investment for Polish science. The facility will be built on terrain of the University's III Campus. More information about the project status can be found in [1].Solaris main components consist of a 0.55GeV electron injection linac with a thermionic RF gun, a vertical dog-leg beam transfer line (BTL) and a 1.5 GeV storage ring (SR) which is a copy of MAX IV 1.5 GeV storage ring. The Solaris injector, however, differs from that of MAX IV. Injection will take place at 550 MeV energy. After accumulation of electron beam, the energy will be ramped in the ring to 1.5 GeV.

INJECTOR LAYOUT

Pre-injector

As an electron source a thermionic RF gun with BaO cathode has been chosen due to simplicity of operation. This sort of gun is utilized at MAX-lab in their present injector [2,3] for the MAX rings.

The cathode diameter is 3 mm and is operated at a temperature of ~1000°C. Due to the issues of back bombardment the design with ½ + ½ + 1 cells was chosen with a field relation of 2.6 operating in $\pi/2$ mode [2]. The gun operates at 3 GHz frequency and has a normalised emittance of around 10 π mm mrad.

To focus and compress the bunch a solenoid and a 180° bending magnet will be placed after the gun [4]. The bending magnet will help to remove unwanted particles and minimise the energy spread.

Linac Sections

The Solaris main injector will be a linear accelerator consisting of six S-band travelling wave accelerating structures combined in three accelerating units. Each accelerating unit contains one SLED cavity, 3dB power divider and 2 linac structures. Each accelerating unit is powered by an RF amplifier. A total of three high power klystron-modulator systems (RF units) will be used to feed the linac structures and gun via a SLED cavity system. Each klystron output is compressed with a SLED and supplied to two five meter long accelerating structures except first RF unit which will supply also to the RF gun. The peak powers of the klystron and from the SLED cavity are 35MW and up to 200MW, respectively. The klystron output frequency is 2998.5MHz.

Between linac structures quadrupole magnets are placed to focus the beam. The last four quadrupoles are used as a matching cell to the transfer line. The optics were simulated with the code elegant [5]. The betatron functions along the injector and transfer line and the layout of the injector is illustrated in Figs. 1 and 2, respectively.

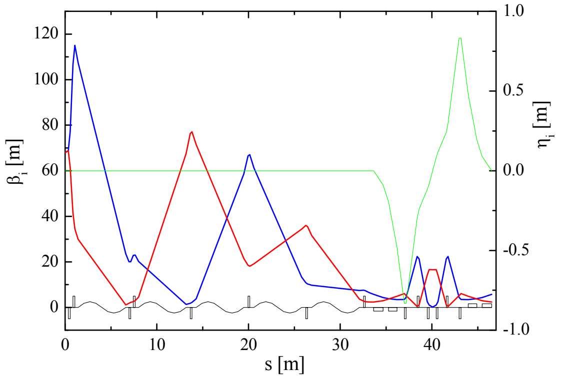

Figure 1: Horizontal (red) and vertical (blue) beta functions and vertical dispersion (green) along the linac and transfer line starting from 2nd accelerating structure.

Transfer Line

The beam from the linac is transferred to the ring by an achromatic bend in the vertical plane. There are two types of bending magnets, namely 10 degree Lambertson DC septa at the beginning and the end of transport system and two 17 degree vertical bends. These magnets will be connected in series. The total bend angle is 27 deg. The transfer line is designed to be symmetric and magnets are powered in series. There are three families of quadrupoles. The Twiss parameters at the beginning of transfer line are mirrored to the injection point (IP) in the storage ring. The matching to the IP is done by the matching section in the linac. The dispersion and betatron functions are given in the Fig.1.

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[#] adriana.wawrzyniak@uj.edu.pl

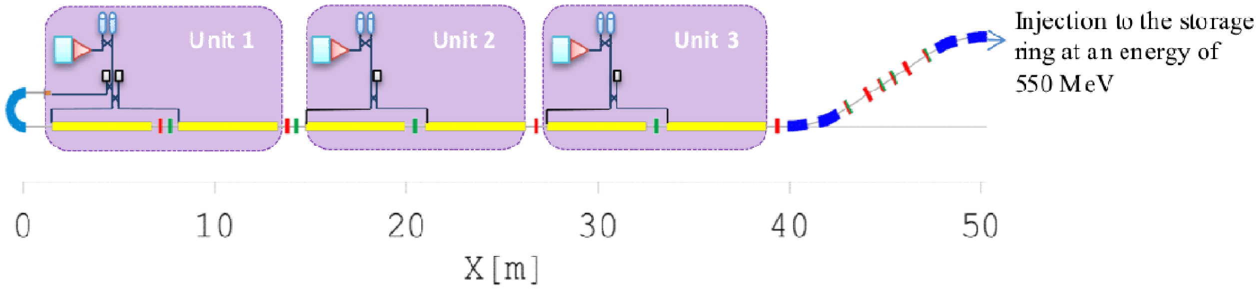

Figure 2: Layout of Solaris injector.

INJECTION

For the MAXIV/Solaris 1.5 GeV storage ring injection, a pulsed sextupole magnet (PSM) has been considered instead of using a conventional four kicker bump scheme. The pulsed multipole magnet injection relies on the fact that the stored beam passes through the center of the magnet without receiving a kick whereas the injected beam passes through the pulsed magnet off-center and is kicked by the pulsed magnet. To adjust kick strength and investigate the best placement of the PSM extensive studies have been done for the MAX IV 1.5 GeV storage ring [6,7]. The injection point is defined as the end of the septum magnet in the injection straight. This is located 1252 mm downstream of the center of the injection straight. The horizontal Twiss parameters at this location are β_{xinj} = 5.939 m and α_{xinj} = -0.2211. The septum blade occupies the space from -13.5 mm to -16 mm. The injected beam arrives at x_{inj}= - 17 mm and according to the formula

$$A_{inj}^2 = \gamma_{inj}x_{inj}^2 + 2\alpha_{inj}x_{inj}x'_{inj} + \beta_{inj}x'^2_{inj}$$

the injection invariant isA_{inj}^2= 51.037 mm mrad. The minimum reduced invariant A_{red}^2= 7.973 mm mrad can be achieved with a PSM strength $b_3l = 46.83\text{m}^{-2}$, kicking the injected bunch to x'=+0.25mrad after the PSM (Fig.3). It is also within the required dynamic storage ring acceptance of 17.7 mm mrad[8].

The injection and capture of the beam is presented in Figs. 4 and 5. As seen, the injected bunch receives a kick θ_{pm} at the PSM and is captured at a reduced invariant A_{red}^2= 7.973 mm mrad. The blue circles in the Fig.5 show the distorted beam motion resulting from nonlinearities of betatron motion at large amplitudes.

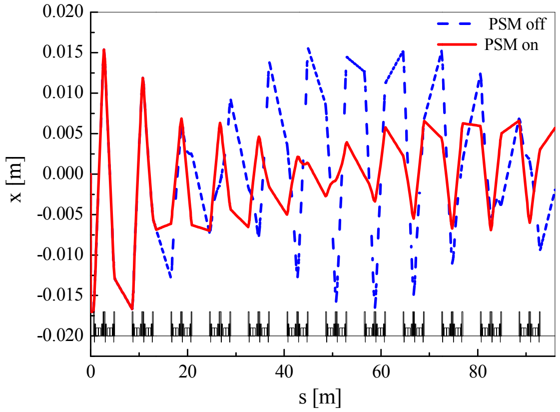

Figure 3: The orbit of the injected beam along a storage ring. The blue dashed line indicates beam oscillations after injection in the ring when the PSM is switched off, whereas the red line shows the orbit when the PSM is on.

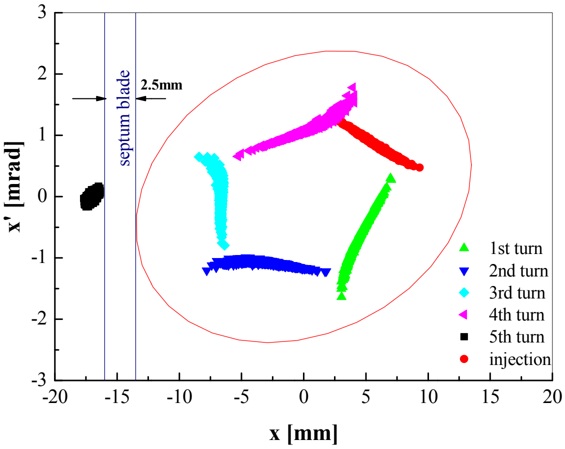

Figure 4: Injection to the storage ring. Tracking the injected beam at -17mm (black) during the first five turns.

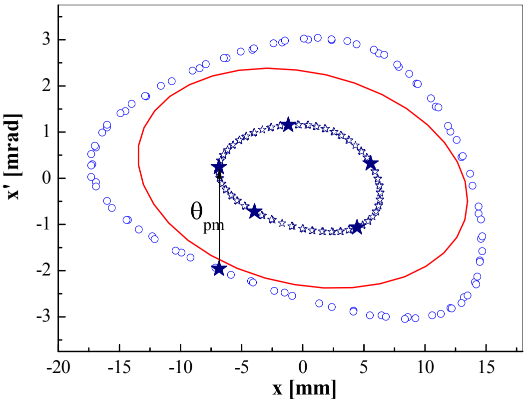

Figure 5: One turn injection. Capture at the PSM position and tracking for the first 100 turns (navy stars). Red line: ring acceptance, blue circles: the beam motion at PSM position when PSM is off.

Since the revolution time in the Solaris ring is 0.32μs, this puts a tight requirement for the pulse length of the kicker. However this can be relaxed by using two-turn injection. The half-sine pulse base for two-turn injection is 1.28μs and the injected beam receives two kicks, however the second kick ($(b_3 l)_2 = 33.11\ \mathrm{m}^{-2}$) is very weak since on the second turn the injected bunch has an amplitude x_{pm}=-1.198 mmat the entrance of PSM and the bunch receives the net kick of 47 μrad.Thus the new reduced invariant (A_{red}^2= 8.157 mm mrad) is not much different from this for one-turn injection scheme. The two-turn injection and capture of the beam is presented in Figures 6 and 7. Injection simulations have been done with the code elegant [5]. Tracking results were performed for 1000 particles with Gaussian distribution and cut off at 3σ. The normalised emittance of the injected beam was assumed to be 10 π mm mrad, with energy spread 0.1 %.

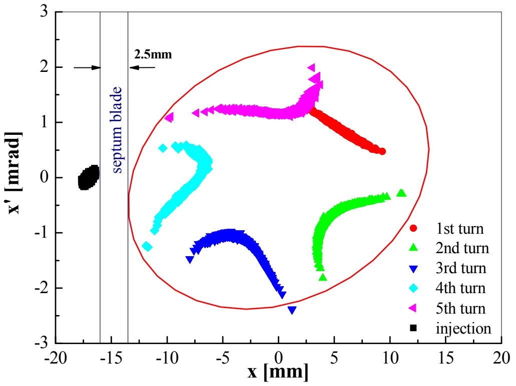

Figure 6: Two-turn injection into the storage ring. Tracking of the injected beam at -17mm (black) during the first five turns.

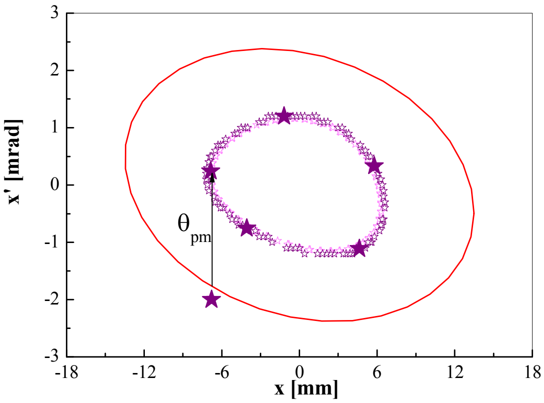

Figure 7: Two-turn injection. Capture at the PSM position and tracking for the first 100 turns (purple stars),pink stars correspond to reduced invariant after the first kick, red line: ring acceptance.

CONCLUSIONS

Solaris injector will consist of a RF thermionic gun, six S-band accelerating structures and a vertical dog-leg transfer line will allow beam acceleration up to 550 MeV and its transport to the ring injection point. Diagnostic, correctors and vacuum systems are still under design. For trajectory correction and beam measurements stripline beam position monitors and YAG screens will be used. Injection to the storage ring will be done by using a pulsed sextupole magnet. The novel injection scheme was studied at 1.5 GeV energy [6,7]. The preliminary studies done for Solaris shows that it is possible to use the PSM at a lower injection energy as well. Further studies will be done to investigate the dynamics of an injected beam with higher energy spread.

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