Injector System for the Polish Synchrotron Radiation Facility ‘SOLARIS’*

Piotr Tracz[1#], C.J.Bocchetta[1], P.Goryl[1], L.Walczak[1], A.Wawrzyniak[1], J.Wiechecki[1] M.Eriksson[2], D.Kumbaro[2], L.Malmgren[2], J.Modeer[2], S.Thorin[2]

[1]National Synchrotron Radiation Centre SOLARIS, Krakow, Poland
[2]MAX IV laboratory, Lund, Sweden

ABSTRACT

SOLARIS, the new synchrotron radiation (SR) facility is being built in Krakow, Poland. Solaris will be equipped with a linear injector and a storage ring operated at electron beam energy of 1.5GeV. The Solaris injector will be constructed in a modular way. It will be divided into three RF stations. Each station consists of an S-band klystron with a solid-state pulsed power modulator, followed by a SLED unit and a power divider. The modulator delivers RF power of 35 MW with a pulse length of 4.5 µs and will have a repetition rate that can be up to 100Hz. The three RF stations will feed six S-band linear accelerating structures each giving an energy gain of 100 MeV. The electron source will be a 3 GHz thermionic RF-gun and a magnetic energy filter will be used. The SOLARIS injector will initially be operated at the electron beam energy of 550 MeV with options for a full energy (1.5GeV) upgrade with supplementary RF stations and accelerating structures. The SOLARIS synchrotron radiation facility is based on a copy of the 1.5 GeV storage ring being concurrently built for the MAX-IV project in Lund, Sweden.

Index Terms — **injector, synchrotron, linac**

1 INTRODUCTION

The synchrotron radiation facility ‘SOLARIS’ is a 3th generation light source for science research applications presently under construction at the Jagiellonian University in Krakow, Poland. The accelerator complex includes a 1.5 GeV electron storage ring (SR) with 96 m circumference and a 550 MeV linear injector.

Approved in April 2011, the facility including the storage ring operating in ramping mode, one beamline and the linear injector (550MeV) is scheduled to start operation for users in October 2014. The Solaris injector will initially be operated at the electron beam energy of 550 MeV with the option for a full energy (1.5GeV) upgrade with supplementary RF stations and accelerating structures (see Ref. [1,2]).

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piotr.tracz@uj.edu.pl, www.synchrotron.pl

2 LINAC DESCRIPTION

The Solaris injector will have the six S-band linear travelling wave structures (linac sections) supplied by three RF power units (RFU). The first RF Unit (RFU 1) will feed the two linac sections, Linac 1a and Linac 1b and the RF thermionic gun. The second and third RF units, RFU 2 and RFU 3 will feed Linac 2a, Linac 2b and Linac 3a, Linac 3b (see Figure 1). The RF thermionic gun with a BaO cathode was chosen as an electron source. The choice of an RF gun simplifies the electron source and does not require a buncher cavity and a pre-accelerator linac and will simplify operations. To focus the beam a solenoid will be placed straight after the gun. The beam will be transported through a chopper section to fit a time structure of 100 MHz buckets in the storage ring. Using a thermionic cathode, however, requires consideration of back bombardment and the long energy tail. The gun as well as the accelerating structures will be supplied by the 3GHz klystron amplifiers. High pulsed power solid state modulators will be used as a source of high voltage for the klystrons feed. The available pulse length is 4.5µs (compressed in the SLED cavity to 0.75µs). The power is enough to extract more than 600mA from the gun (0.2nC per bunch). The normalized emittance is expected to be 10 π mm mrad. The RF gun with the thermionic cathode suffers from having a long low-energy tail, but allows the opportunity to shape the bunch length and an energy filter was therefore designed. The beam is bent by two 60° bending magnets to achieve a point with dispersion where a slit can filter out the low-energy electrons. To adjust the dispersion a focusing quadrupole is placed in the middle. The focusing is controlled by four additional quadrupoles.

In total the energy filter is a one DBA-cell. At the gun exit a solenoid magnet is placed to adjust for the changing divergence at different electron energies (due to changing geometry of the RF-fields at different excitations). The RF thermionic gun and the energy filter was designed and manufactured in MAX-lab. A detailed description can be found in [3, 4]. The six intersections between the linac sections have space for quadrupoles and diagnostics. The high pulsed RF power will be transported by a wave guide system from the klystron amplifiers to the SLED cavities then through power dividers (hybrid couplers) to the linac sections. Total length of the Solaris injector is 40.3 meters.

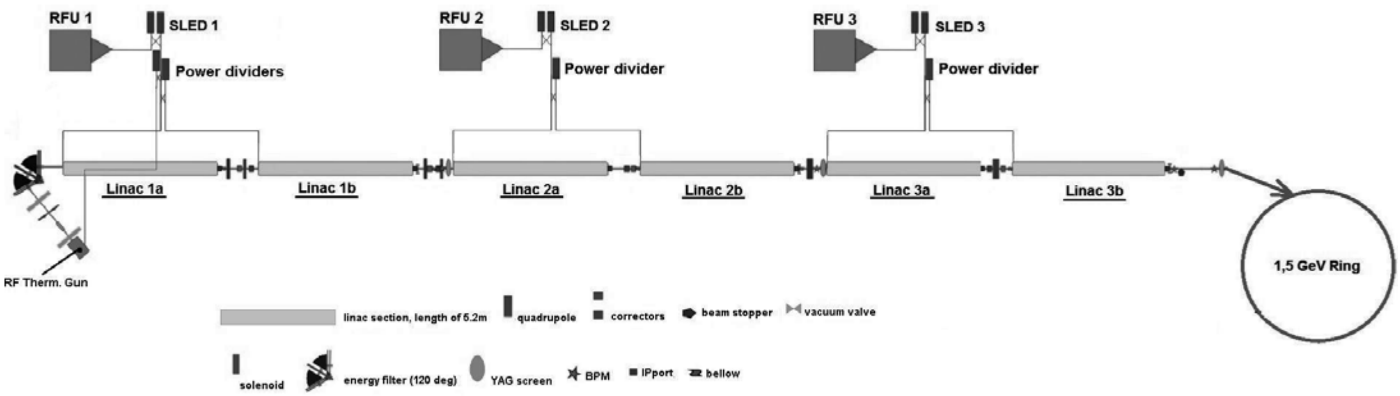

Figure 1. Layout of SOLARIS injector

3 RF SYSTEM

The Low Level RF (LLRF) system is an essential part of the RF system. The Solaris LLRF consists of a 3 GHz signal generator, 10W solid state amplifier, amplitude/phase control loops and RF interlocks. Three drive amplifiers are used for an appropriate input power level to the klystrons. 180° phase shifters are implemented for reversing the signal phase for the SLED cavities. For frequency control, another tuner controller module is used. The RF interlock signals come from excessive reflected RF power and arcs.

The main components of the High Level RF (HLRF) system are three RF stations which include 3 GHz (S-band) 37 MW klystrons fed by high pulsed power solid state modulators. Three RF stations supply the six S-band linear structures. The klystron amplifiers provide 4.5μs RF output pulses which travel through the waveguide system into the linacs. Overcoupled cavities (SLEDs) are used. The high power waveguide system has a 3dB hybrid coupler inserted after the klystron. The SLED cavities are assumed to be identical and turned to resonance. After the RF pulse is turned on, the fields in the cavities build up and a wave of increasing amplitude is radiated from the coupling apertures of each cavity. The two emitted waves combine so as add at the accelerator port of the 3 dB hybrid coupler, while they cancel at the klystron port. In addition to the wave emitted from the cavities, a wave travels directly from the klystron to the linacs. This direct wave, which is just the wave that would appear at the Linac if both cavities were detuned, is opposite in phase to the combined emitted waves. If the cavities are overcoupled, the emitted wave is larger than the direct wave. The net field at the input to the linacs, which is the sum of the direct and emitted waves, then goes through a phase reversal. One Linac filling time (0,7μs) before the end of the RF pulse, the 180° phase shifter reverses the phase of the output wave from the klystron. Immediately after this phase reversal, the emitted and direct waves add in phase at the accelerator, since the emitted wave (which is proportional to the stored fields in the cavities) cannot change instantaneously. Therefore, when the klystron phase is reversed, the field at the input to the accelerator increases (see Ref. [5]). The schematic layout of the accelerating unit is shown in Figure 2 and the diagram of the RF system for the Solaris injector in Figure 3.

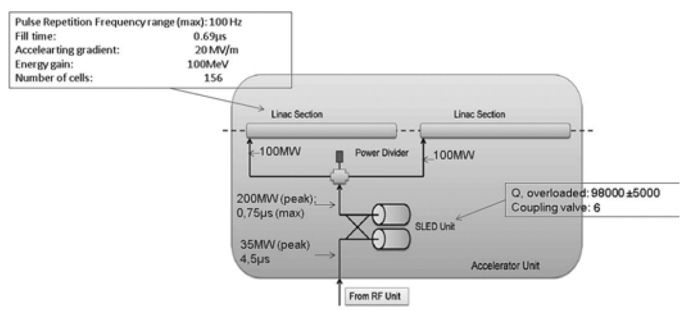

Figure 2. Schematic layout of accelerator unit

The first RF station (Klystron 1) supplies two linear structures (Linac 1a and Linac 1b) and the RF thermionic gun. A 3 GHz circulator, which can deliver 20MW pulsed RF power in the forward direction and permits 20MW reverse power at any phase will be used. A high power phase shifter will match the phase of the RF drive signal to bunch time structure. For monitoring the parameters of the RF signal (amplitude and phase), without interrupting the main power flow in system, directional couplers are used just after the klystrons, the SLED cavities and before the RF gun and linac sections. Three RF windows for a vacuum environment straight after the klystrons and two additional RF windows operating with SF6 separating the circulator from other components will be used.

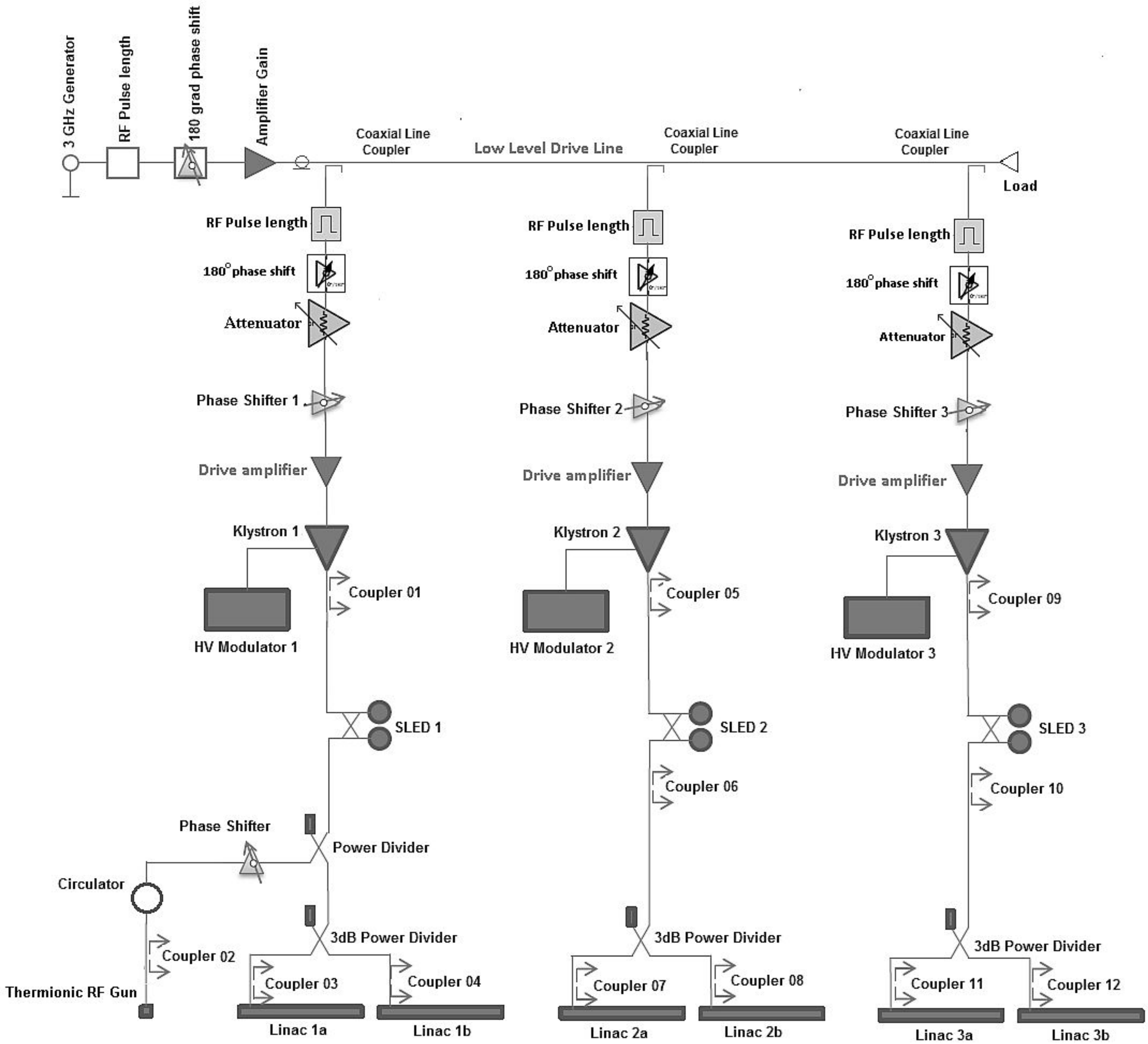

Figure 3. Diagram of the RF system for SOLARIS injector

4 WAVEGUIDE SYSTEM

The waveguide system will be divided into three Wave Guide Units (WGUs), which differ by different waveguide components. The waveguides WR284 will be used and most of them with LIL flanges. Because of usage of a ferrite circulator at the RF thermionic gun, some waveguide components including the circulator will have CPR284F flanges which are consistent with the circulator flanges. The straight sections as well as E-bends 90° of waveguide components will be used. The configuration of the first WGU, nominated as WGU-1 is shown in Figure 4. The first configuration of WGU is designed for transportation of pulsed RF power from RFU (S-band klystron amplifier) to two accelerating travelling wave structures (linacs) and to the RF thermionic gun. RF power is divided between RF gun and linacs in power divider and then in hybrid coupler between linacs. The coupling factor of power divider is not defined yet. WGU-1 will be under operation partly in vacuum and branch including the ferrite circulator will operate in SF_6 atmosphere. There is considered to use an extra pulsed power solid state klystron modulator which will supply the RF thermionic gun. That extra modulator will feed 3 GHz klystron with RF peak power at output up to 10 MW (300 W – average power). Then the RFU, like in the Figure 4, will supply only two linacs and not the RF gun. The RF gun will have separated supply and the power divider will not be needed then.

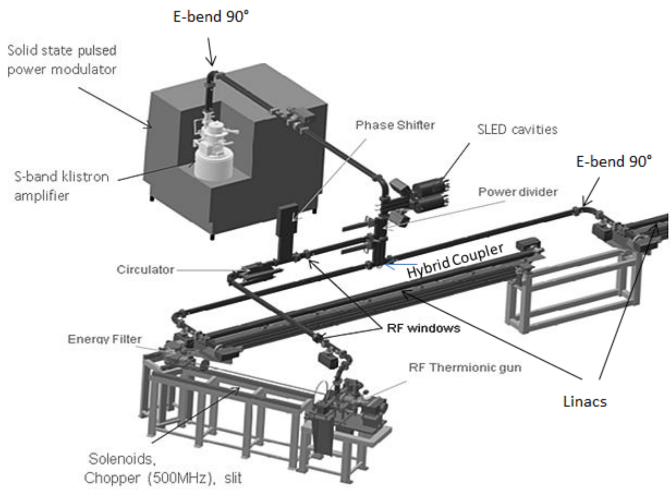

Figure 4. WGU-1 configuration

The WGU-2 and WGU-3 have the same configuration and are depicted in Figure 5. They will be operated under a vacuum environment. This WGUs differ from WGU-1 by different lengths of waveguide components. That results from different lengths of intersections (1.4m at WGU-1 and 1.1m at WGU-2 and WGU-3). RF components included in WGU-2 and WGU-3 remain the same excluding the branch designed for feed the RF gun (see WGU-1). Each WGUs include 9 ion pumps for keeping of high vacuum in wave guide system and linacs and WGU-1 has additional four ion pumps at the RF gun.

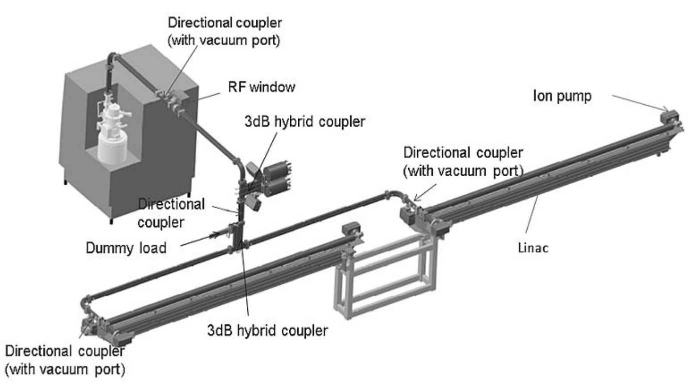

Figure 5. WGU-2, WGU-3 configuration

5 DIAGNOSTIC AND CORRECTOR SYSTEM

The diagnostics and corrector system has been designed. For beam position monitors stripline BPMs were chosen which are inserted in the intersections between Linacs 1b and 2a, Linacs 2b and 3a, and two BPMs between Linac 3b and the transfer line (see Figure 1). Three YAG screens as well as two current transformers (CT) will be used, too. A CT is located immediately after the gun and second one after the energy filter. There are also corrector magnets along the injector.

6 CONCLUSION

The Solaris injector includes the RF thermionic gun and the six S-band accelerating structures. This configuration will accelerate the beam to 550MeV with operational margin. The beam will be transported to the storage ring via a transfer line. The linac will be powered by the three solid state modulators feeding three SLED cavities. The design is based on MAX IV injector.

ACKNOWLEDGMENT

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