STATUS OF THE SWISS LIGHT SOURCE PROJECT SLS

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Abstract

The status of the SLS project is reviewed. This light source is based on a 270 m circumference electron storage ring with a reference energy of 2.1 GeV and a minimum emittance of 2.3 nm·rad. The lattice has been optimised introducing phase trombones to provide a large dynamic aperture with an energy acceptance of ±4% over a wide tuning range. Preliminary design of the quadrupole and sextupole magnets indicate that a maximum energy of 2.4 GeV is feasible. The full energy injector is based on a low emittance booster synchrotron in the storage ring tunnel. A test stand for the RF gun is in the comissioning stage.

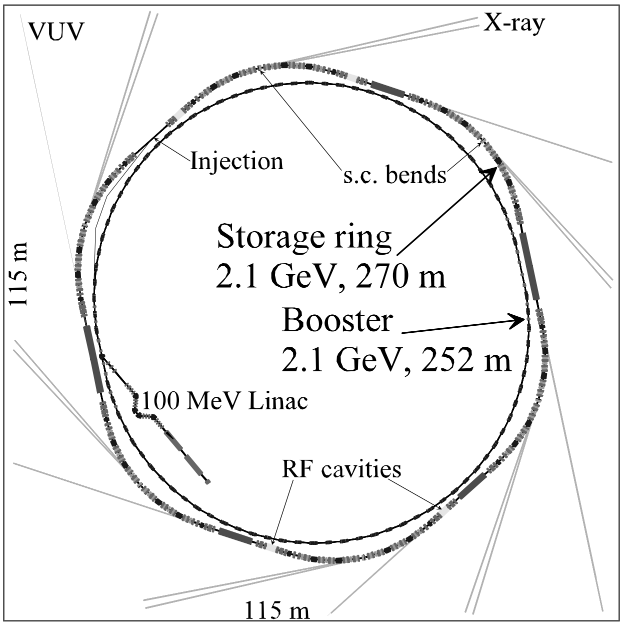

Figure 1: Layout of the SLS facility with linac, booster and storage ring. Shown are the possible photon beamlines from insertion devices and the possible twin beamlines from the six superconducting bending magnets.

1 STORAGE RING DESIGN

1.1 Layout.

The design as previously described [1] was further elaborated, increasing the flexibility and performance of the lattice. The layout of the storage ring (Fig.1) consists of six achromatic arcs, two very long (15.7 m) and four 8 m long straight sections, one of them reserved for injection. Each arc contains a superconducting bending magnet for hard X-ray production.

The circumference was increased from 252 m to 270 m introducing four phase trombones. They allow tuning of the lattice down to a minimum emittance of 2.3 nm·rad at the reference energy of 2.1 GeV with zero dispersion in all straight sections and ±4% energy acceptance. The straights sections may be tuned to meet individual user requirements.

However standard mode of operation is with the lattice tuned to an emittance of 3.6 nm·rad at 2.1 GeV, providing dynamic acceptances of approx. 40 µm·rad horizontally, 60 µm·rad vertically and ±5% longitudinally for the ideal lattice.

Table 1 displays the most important lattice parameters in the standard mode, and Figure 2 shows the optical functions of one quarter of the lattice.

Table 1: SLS storage ring main parameters

Maximum energy	GeV	2.4	
Circumference	m	270	
Harmonic number		450 = 15·30	
RF frequency	MHz	500	
Lattice parameters in standard mode:			
Tunes (*x*,*y*)		21.21	6.10
Chromaticities (*x*,*y*)		-52	-21
Momentum compaction factor		0.0006	
Equilibrium values at 2.1 GeV:			
Emittance	nm·rad	3.6	
Radiation loss	keV	480	
Energy spread r.m.s.		0.12 %	

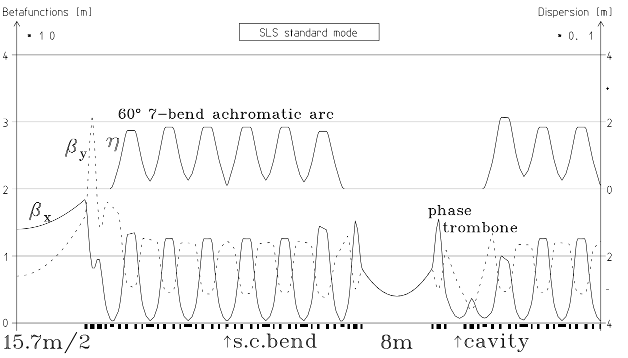

Figure 2: Beta functions and dispersion of one quarter of the SLS storage ring.

Four single 500 MHz RF cavitities with independent power sources are distributed around the ring for reliability, flexibility and in order to avoid coupled higher order modes. The cavities with their tapers will be accomodated in four dispersion free 2 m straight sections of the phase trombones.

1.2 Sextupole scheme

The nine terms of the map in first order of sextupole strength b_3, – four chromatic and five geometric modes, – are eliminated in one step. They are given by

$$h_{jklmp} \propto \sum_{n}^{N_{sext}} (b_3 l)_n \beta_{xn}^{\frac{j+k}{2}} \beta_{yn}^{\frac{l+m}{2}} \eta_n^p e^{i\{(j-k)\varphi_{xn}+(l-m)\varphi_{yn}\}}$$
$$\underbrace{-\sum_{n}^{N_{quad}} (b_2 l)_n \beta_{xn}^{\frac{j+k}{2}} \beta_{yn}^{\frac{l+m}{2}} e^{i\{(j-k)\varphi_{xn}+(l-m)\varphi_{yn}\}}}_{if \quad p \neq 0}$$

with $(b_2 l)$, $(b_3 l)$ the integrated quadrupole and sextupole strengthes, β, η, φ the betafunctions, dispersion and betatron phases.

h_{11001} and h_{00111} are the linear chromaticities. h_{20001} and h_{00201} create the momentum dependent beat of betafunctions and thus limit the longitudinal acceptance. h_{21000} and h_{10110} drive the integer, h_{30000} the third integer, and h_{10200} and h_{10020} the coupling resonances. Only for the chromatic modes ($p\neq0$) the quadrupole contribution has to be included.

With the N_{sext} sextupoles grouped into M_{sext} families, the nine equations form a $9\times M_{sext}$ linear system, since they are linear in sextupole strengths. This system is solved for the M_{sext} dimensional vector of sextupole strengths. Clearly, a solution requires rank 9 of the matrix. To fulfil this rank condition is difficult in a low emittance lattice with the phase advance per cell close to 180° (SLS: 144°...173°), since in this case the h_{20001} mode becomes directly proportional to the linear chromaticity (because $e^{i2\Delta\varphi} \approx 1$), and the rank drops to 8. This problem is solved by using the phase trombones between the arcs to introduce an additional betatron phase advance $\Delta\psi$ in such a way, that the real parts of the h_{20001} terms from the different arcs cancel:

$$\Re(h_{20001}[arc1]\cdot e^{i\Delta\psi}) + \Re(h_{20001}[\tfrac{1}{2}arc2]) = 0$$

The imaginary parts by definition cancel (at points of mirror symmetry) due to symmetry of the lattice.

Based on a sextupole configuration with all first order effects suppressed, careful numerical optimisation treats effects of second order in sextupole strength as amplitude dependant tune shifts, second order chromaticity and octupole like resonance driving terms. Using this procedure a longitudinal acceptance of at least ±4% and adequate transverse acceptances was achieved for all operation modes of SLS.

1.3 Orbit correction

As a low emittance light source SLS performance is limited by nonlinear effects, i.e. restrictions of dynamic acceptance and with it life time due to additional focusing from the sextupoles, seen by the closed orbit distortions due to magnet misalignments. Therefore beam position monitors are placed close to the sextupoles, since correction of the orbit will then restore the linear optics and hence the symmetry of the lattice. The orbit correctors are also located at the sextupoles, physically as additional coils.

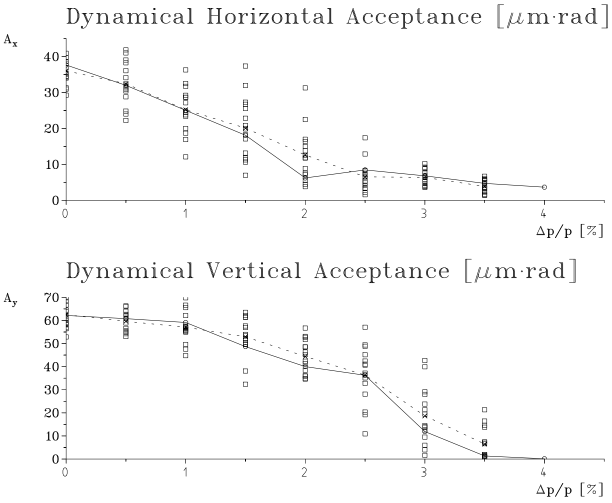

Figure 3: Horizontal and transverse dynamic acceptance area as a function of relative energy deviation:

–o—o– Error free lattice

··×·····×·· Average over 19 seeds (squares) for the error lattice with 200 μm r.m.s. (cut at 2σ) magnet misalignments.

Figure 3 shows the results for the transverse acceptances as a function of relative momentum deviation for the error free lattice and for a lattice with 200 μm r.m.s. magnets misalignment with following orbit correction, using 68 horizontal and vertical beam position monitors and correctors. Tracking included synchrotron oscillation (4 cavities, each 750 KV). The dip in horizontal acceptance at $\Delta p/p$ = 2% is produced by the $3\nu_x$ = 64 resonance, encountered due to as yet insufficient suppression of second order chromaticity.

2 BOOSTER DESIGN

The previous SLS complex layout contained a compact traditional booster. For the new layout we considered an economic solution with the booster in the same tunnel, escorting the main ring. Due to the large circumference it was possible to tailor the booster lattice for low emittance and low dispersion [2], allowing the use of a simple round pipe of 20 mm diameter for the vacuum chamber. The lattice is of FODO type with many small combined function magnets:

Name	**Number**	**Angle**	**Field**	**Gradient**
BD	44	7.0°	0.76 T	4.2 T/m
BF	42	1.3°	0.18 T	5.5 T/m

A cross section of one half of BF is shown in Figure 4:

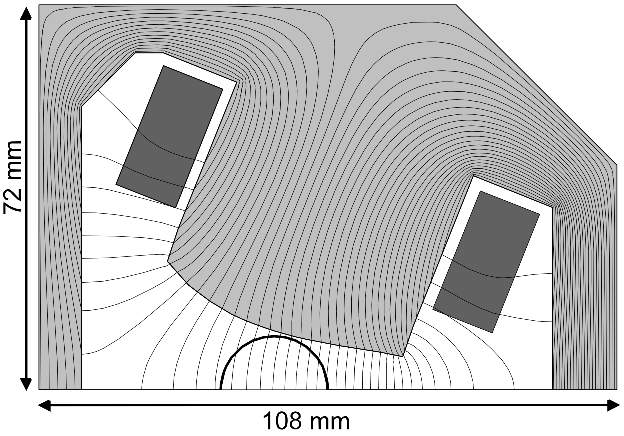

Figure 4: Horizontally focusing booster magnet BF (only upper half shown) with round beam pipe of 20 mm diameter.

Basically it is a half quadrupole with a mirror plate and an off-centered beam orbit. Note the small size of the magnet due to the low aperture requirements. Two straight sections were inserted into the booster lattice in order to follow most closely the ring. Booster parameters are given in Table 2 for comparison with the storage ring parameters. Clearly the low emittance will make injection very efficient.

Table 2: SLS Booster main parameters

Maximum Energy	GeV	2.4		
Circumference	m	252		
Harmonic number		420 = 14·30		
RF frequency	MHz	500		
Max. repetition rate	Hz	10		
Tunes (*x*,*y*)		13.74	12.64	
Chromaticities (*x*,*y*)		-21	-18	
Momentum compaction factor		0.0039		
Equilibrium values at 2.1 GeV:				
Emittance	nm·rad	4.9		
Radiation loss	keV	144		
Energy spread, r.m.s.		0.06%		
Damping times (*x*,*y*,*E*)	ms	16.6	24.5	16.1

3 PRESENT STATUS

The project is well on the way to the final approval by the Swiss Parliament. After the FIT Board (ETH Rat) has expressed its support for the project, the Swiss Federal Government, on March 18, 1996, decided to grant planning funds. The project will be submitted by the relevant minister to government approval in December 1996 and to Parliament approval in the first half of 1997.

An RF gun test stand, consisting of a 1½ cell RF thermionic gun and a 50 MeV linac section is nearing completion. A 35 MW RF source, built in collaboration with the CERN Collider Test Facility has passed acceptance tests and the RF gun is installed and is under vacuum. The first gun tests are awaiting a permit from the safety authorities.

REFERENCES

[1] W. Joho et al., „Design of a Swiss Light Source (SLS)“, in Proceedings of the EPAC94, London, June 1994, p.627

[2] G.Mülhaupt, „A few design considerations for injector synchrotrons for synchrotron light sources“, ESRF Report ESRF/MACH-INJ/94-3, March 1994