SOLEIL, a New Synchrotron Radiation Source for LURE[1]

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Abstract

LURE is designing a new storage ring of energy 2.15 GeV which will provide radiation in the intermediate energy range, 20 eV-1.5 keV, from undulators and 5 keV critical energy photons from dipole bends. On the basis of what was learned from Super-ACO experience, a number of criteria were retained for the new machine : large number of insertion sections (13), 3 and 5 m long, for a comparatively short circumference (216 m), moderate emittance (3.7 10^{-8} m.rad) to secure good Touschek lifetime for the operation with a few intense bunches and for a realistic energy acceptance. Particular attention is paid to all aspects leading to the stability of the photon beam. A decision is looked for 1993-94. The construction time should be 4 years.

I. INTRODUCTION

A new storage ring, named SOLEIL, is being designed at LURE with in mind to ultimately replace both DCI and Super-ACO, while retaining the potentialities of these two machines for the users.

The experience gained from Super-ACO in the last 5 years shows that an energy well above 1.5 GeV is necessary to reach a compromise between low emittance, good lifetime at high intensity, good lifetime with a small number of intense equidistant bunches, operation with a large variety of insertions. In consequence the choice was made to build a polyvalent radiation source with an energy of 2.15 GeV which will provide photons in the energy range 20 eV-1.5 keV from undulators, 5 keV critical energy photons from dipole bends and 10 to 30 keV X-rays from a wiggler magnet.

A number of specifications were defined by the users. These concern, for the multibunch operation, a beam current of 300 mA and a 15 hours lifetime and for the 6 bunch operation (temporal structure studies) a bunch current of 60 mA and a beam lifetime larger than 10 hours. These figures have to be reached as a compromise to low emittance. It ended up with the choice of an horizontal beam emittance of 35 10^{-9} m.rad.

From the past experience on Super-ACO, the following choices were made : implementation of insertions both in zero and non-zero dispersion straights and sextupolar coils inside the quadrupoles. Furthermore great emphasis was put by the users on the photon beam stability in all its aspects. This concerns positron filling to avoid ion and macroparticle trapping in all circumstances, transverse and longitudinal stability of the bunches and the overall stability of the photon beam with respect to experimental set-ups.

II. LATTICE PARAMETERS

For the required critical length 2.5 Å (ε_c = 5 keV) and for a 1.6 T magnetic field, the machine energy is 2.15 GeV. The structure is a Double Bend Achromat (modified Chasman-Green lattice) with parallel face magnets and zero field index. The doublet located in zero dispersion sections in Super-ACO has been replaced by a triplet. The chosen emittance leads to 8 periods.

The optical functions are presented on Figure 1. The main optical parameters are : ε_x = 37 nm.rad, Q_x = 9.70, Q_z = 8.70, α = 3.42 10^{-3} and σ_E/E = 8.53 10^{-4}.

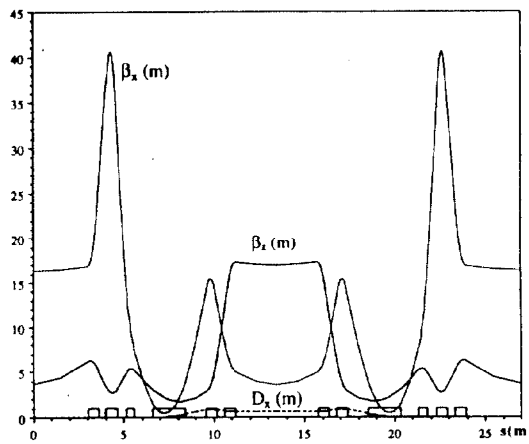

Figure 1.

The chromaticity correction is achieved using 2 sextupole families located in the non-zero dispersion sections and the dynamic aperture is optimized using 3 other families in the zero dispersion sections (Figure 2). A 25 T.m^{-2} sextupolar strength allows one to increase the chromaticity up to 3 units in order to combat the transverse mode coupling instability.

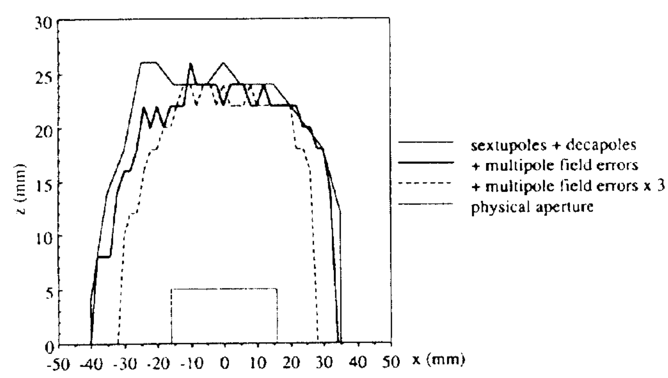

Figure 2.

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Figure 3 shows a schematic diagram of the location of beam position monitors (BPM) and correction dipoles in a typical cell of SOLEIL. There are per half cell, 3 BPM, 3 horizontal correctors and 3 vertical correctors. Both global and local correction will be provided. The global one, using all monitors and correctors, leads to zero on each BPM in both planes and a residual orbit distortion with a maximum value of 0.2 mm elsewhere. An adjustment in the straight sections can be made independently (angle and position) using photon BPM in beam line.

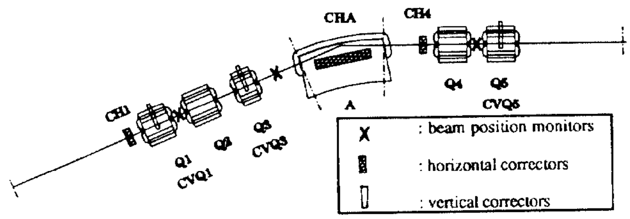


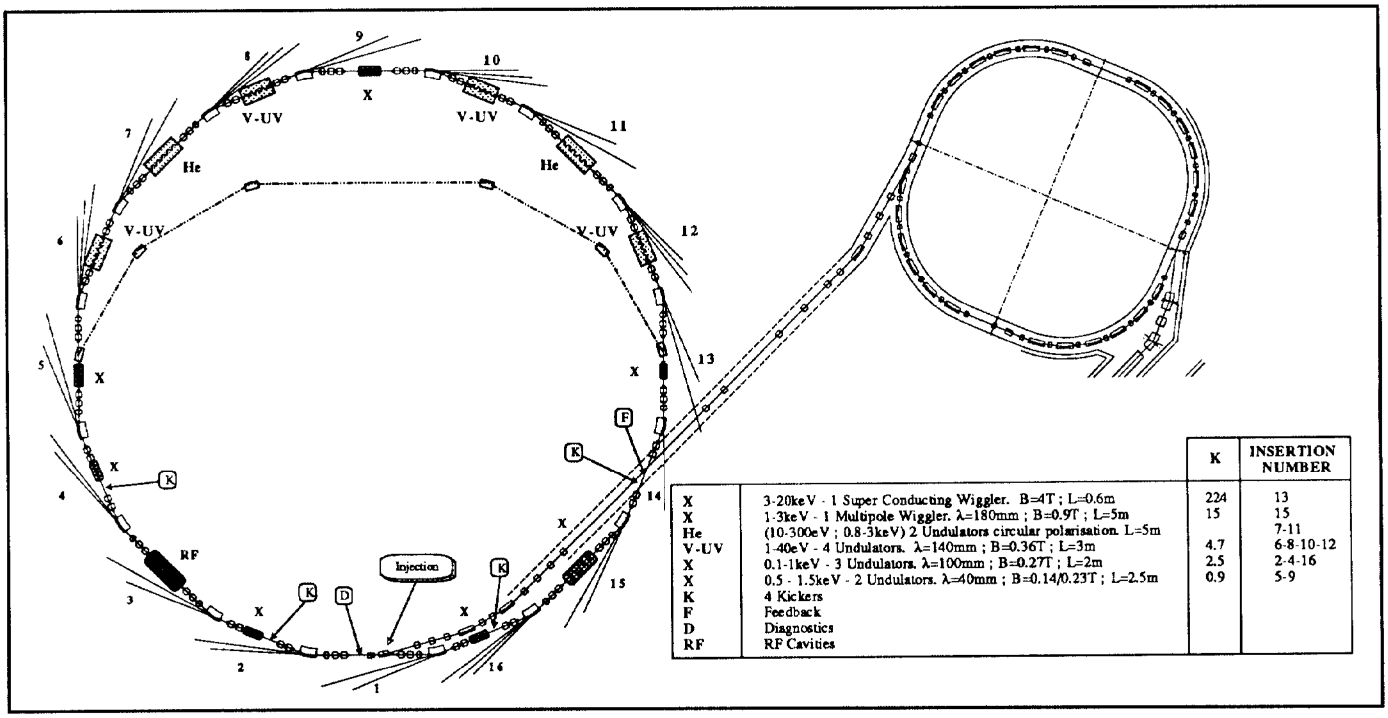
Figure 3.

III. PHOTON SOURCES

Figure 4 shows a general lay out of the storage ring together with the insertion and bending magnet beamlines.

The distribution of the beamlines and the transverse source sizes are :

- 24 bending magnet beamlines :
  - . 2 beamlines per odd numbered bending : $\sigma_x = 130\ \mu m$ $\sigma_z = 90\ \mu m$
  - . 1 beamline per even numbered bending : $\sigma_x = 260\ \mu m$ $\sigma_z = 80\ \mu m$
- 13 straight sections for insertion devices :
  - . odd straight $\sigma_x = 780\ \mu m$ $\sigma_z = 110\ \mu m$
  - . even straight $\sigma_x = 560\ \mu m$ $\sigma_z = 250\ \mu m$



		K	INSERTION NUMBER
X	3-20keV - 1 Super Conducting Wiggler. B=4T ; L=0.6m	224	13
X	1-3keV - 1 Multipole Wiggler. λ=180mm ; B=0.9T ; L=5m	15	15
He	(10-300eV ; 0.8-3keV) 2 Undulators circular polarisation. L=5m		7-11
V-UV	1-40eV - 4 Undulators. λ=140mm ; B=0.36T ; L=3m	4.7	6-8-10-12
X	0.1-1keV - 3 Undulators. λ=100mm ; B=0.27T ; L=2m	2.5	2-4-16
X	0.5 - 1.5keV - 2 Undulators. λ=40mm ; B=0.14/0.23T ; L=2.5m	0.9	5-9
K	4 Kickers		
F	Feedback		
D	Diagnostics		
RF	RF Cavities		

Figure 4.

The linear effects due to the insertions ($\Delta\nu_z$; $\Delta\beta z/\beta z$) are compensated by a local correction for the SC wiggler and the multipole wiggler, and a global correction for the undulators. The residual β-beat is less than 5 % everywhere except at the location of the SC wiggler where it reaches 20 %. The non linear effects (proportional to ($\beta_z^2\ B_0^2\ L / \lambda^2$)) act on the dynamic aperture which remains much larger than the physical aperture (Figure 5).

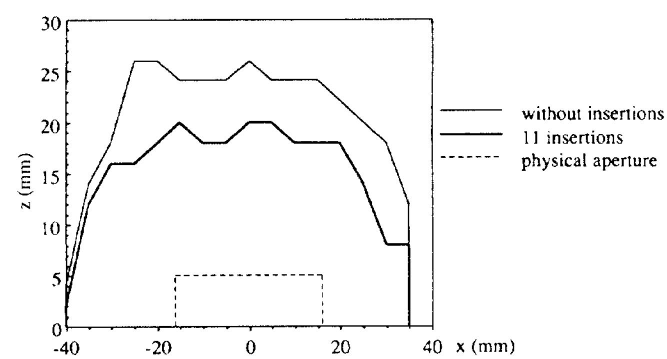


Figure 5.

IV. HIGH INTENSITY

A. Coherent instabilities

Monomode RF cavity is invaluable in order to ensure longitudinal and transverse stability for multibunch operation. It is especially important for SOLEIL since there will be insertions in non zero dispersion sections.

A 500 MHz superconducting cavity of the type which is being developed by CORNELL would suit the requirements. One aims at an accelerating voltage of 3 MV in order to reach an energy acceptance of 2.4 % and a beam power of 225 kW to cope for a maximum current of 0.5 A.

A five meter long straight section could house two cavities of this type.

B. Beam lifetime

Table 2 summarises the values of beam gas lifetime (τ_g) and Touschek lifetime (τ_T) for different situations, assuming 10 % coupling and a 10^{-9} Torr pressure nitrogene.

Table 2

I (mA)	300	6 x 10
τ_g (h)	24	82
$\varepsilon_E = \varepsilon_{RF}$ / V_{RF} (MV)	2.4 % / 3	
σ_ℓ (mm)	6.6	
τ_T (h)	405	33.7
τ_{total} (h)	23.5	24
ε_E / V_{RF} (MV)	1.8 % / 2	
σ_ℓ (mm)	7.2	
τ_T (h)	239	20
τ_{total} (h)	22	16

Remark : The computation of Touschek lifetime has been made with the nominal RF energy acceptance (2.4 %) and also in a most pessimistic case (1.8 %) taking into account the possible limitation due to the insertion non linearities.

Table 3 summarises the main machine parameters.

Table 3

Energy	E = 2.15 GeV
Maximum current	I_m = 300 mA
Maximum current per bunch	I_b = 10 mA
Emittancce	ε_x = 37 nm rad
Orbit length	L = 215.96 m
Revolution frequency	f_o = 1.388 MHz
Number of periods	8
Number of straight sections	8 x 6 m + 8 x 4.5 m
Magnets :	
Dipoles : number, length, gap, B_{max} :	16, 1.81 m, 0.06 m, 1.6 T
Quadrupoles : number, length :	80, 0.65/0.45 m
bore radius, G_{max} :	0.0575 m, 13 T.m^{-1}
Sextupolar coils : number, length :	80, 0.65/0.45 m
strength :	25 T.m^{-2}
RF system :	
Frequency	f_{RF} = 500 MHz
Harmonic number	h = f_{RF}/f_o = 360
Maximum voltage	V_{RF} = 3 MV
Energy acceptance	ε_{RF} = 2.4 %
Energy loss per turn (with insertions)	$\delta E \cong$ 450 keV

V. INJECTOR

A. Positron source

Depending on the filling mode of the machine, the gun will provide a 5 ns, 15 A pulse or alternatively 300 ns, 1.4 A pulse at a repetition rate of 10 Hz. A high current Linac with an energy of 200 MeV is followed by a quarter wave length converter and a 400 MeV positron Linac.

B. Booster

A Booster increases the beam energy to 2.15 GeV. It is a FODO structure with 4 periods and 108 m in circumference.

The main characteristics are shown in Table 4.

Table 4

Number of dipoles :	24
Number of quadrupoles :	32
Dipoles length :	$L = \rho \times \pi/12$ = 1.877 m
Quadrupoles length :	L = 0.4 m
Dipole maximum induction (E = 2.15 GeV) :	1 T
Quadrupole maximum gradient (E = 2.15 GeV) :	10 T/m
Tune ν_x, ν_z :	5.65, 2.65
β_{xmax}, β_{zmax} :	17 m, 17 m
Maximal dispersion, D_{max} :	$\approx$ 2 m
Emittance at 2.15 GeV :	ε_x/π = 3.84 10^{-7} mrad
Energy spread at 2.15 GeV :	6.8 10^{-4}

The Booster RF frequency is 100 MHz in order to match the 5 ns Linac pulse to the 500 MHz RF storage ring acceptance. Injection time is 5 mn for both operation modes.

VI. MISCELLANEOUS

A study of a By-pass option has been made aiming at a high gain Free Electron Laser tunable between 350 and 100 nm. It is schematically shown on Figure 4. It would allow a 12 m long straight section for the implementation of a set of optical klystrons.

The main characteristics are :

Energy	E = 1.5 GeV
Emittance	$\varepsilon_x \approx$ 20 nm rad
ℓ_{cavity}	25 m
Maximum current	40 mA in 4 bunches
Amplification	25 %
Beam lifetime	τ = 4 h

ACKNOWLEDGEMENTS

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