Positron Accumulation Ring for the SPring-8 Project

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Abstract

Design of a positron accumulation ring (PAR) for the SPring-8 project has been considered as an option to increase the injection rate into the storage ring via a synchrotron. The beam energy and the circumference of the PAR are 500 MeV and 28.294 m, respectively. The injection rate can be increased by about 10 times. Reduced bunch length in the PAR and RF synchronism between the PAR and the synchrotron are favorable to produce a pure single bunched beam in the storage ring.

I. INTRODUCTION

In the SPring-8 project, a 900 MeV positron beam is injected from a linac into a synchrotron, accelerated up to 8 GeV in the synchrotron, and stored in an 8 GeV storage ring with a repetition of 1 Hz. In this scheme, 8 pulses of positron beam with a beam current of 10 mA and a pulse length of 10 ns are accumulated in the synchrotron in the injection period. There is no synchronism of the RF frequensies between the linac and the synchrotron, but a synchronism between the synchrotron and the storage ring. Thus assuming an injection efficiency of 50 % and 100 % into the synchrotron and the storage ring, respectively, it is expected to take about 20 min to store a beam current of 100 mA in the storage ring. The assumption is rather simple, and the injection efficiency might be reduced much. Accordingly a positron accumulation ring (PAR) similar to those of DESY[1] and APS[2] has been considered as an option.

The PAR is to be placed between the linac and the synchrotron. Since the repetition of the linac is 60 Hz, about 55 pulses of the positron beam can be accumulated in the PAR during the ramping cycle (1 Hz) of the synchrotron, which increases the injection rate drastically. In addition, the reduction of emittance, energy spread and bunch length in the PAR and also RF synchronism between the PAR and the synchrotron are expected to increase the injection efficiency into the synchrotron, and especially favorable to produce a pure single bunched beam in the storage ring.

In this design, conversion of the components of a 300 MeV electron storage ring JSR, to be shut down soon, was taken into account.

II. LATTICE OF PAR

Fig.1 shows the structure of PAR placed between the linac and the synchrotron. The circumference of PAR is $2\pi R$=28.294 m, which is 1/14 of the circumference of the synchrotron. The revolution period is To=94 ns, long enough for the rize time of a kicker magnet in the PAR for beam extraction. The lattice is mainly composed of 8 bending magnets and 3 families of quadrupole magnets.

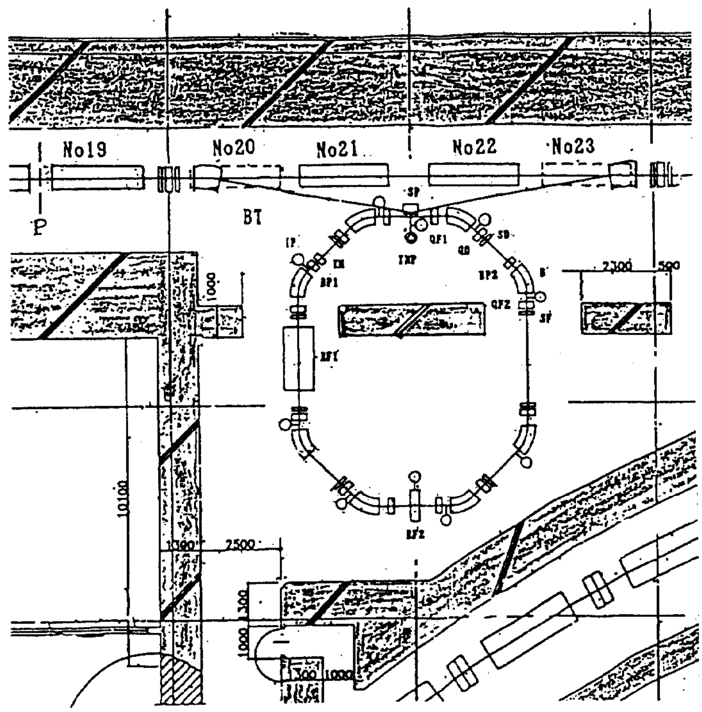

Figure 1. Structure of PAR placed between linac and synchrotron.

The radiation damping time in the PAR should be comparable with the repetition period 16.7 ms of the linac beam. Assuming to use the bending magnets of JSR with a length of 0.874 m, the orbit curvature was taken as ρ=1.113 m. For a small beta function and a stable operation and also for a smooth variation of beta function, a weak focusing of bending fields is quite favorable. In addition the radiation damping time can be reduced considerably by the use of the weak fucusing. The damping time is given by

$$\tau_x = 2ETo/JxUo = 2.5\times10^{-4} * 2\pi R/BE^2 \quad (Jx=1)$$

where E is the beam energy, Jx the horizontal partition number, Uo the radiation energy and B the bending field. The partition number is given by Jx=1-D with

$$D = \frac{1}{2\pi} \oint_B \eta(s) \frac{1-2n}{\rho^2} ds$$

where $\eta(s)$ is the dispersion function along the circumference, and n the n-value of the bending field. Thus an increase of n increases Jx, and consequently decreases the damping time. Fig.2 shows the relation of the damping time and the bending field with respect to the beam energy for Jx=1 or n=0.5. To avoid a strong field saturation, B=1.5 T and E=500 MeV are

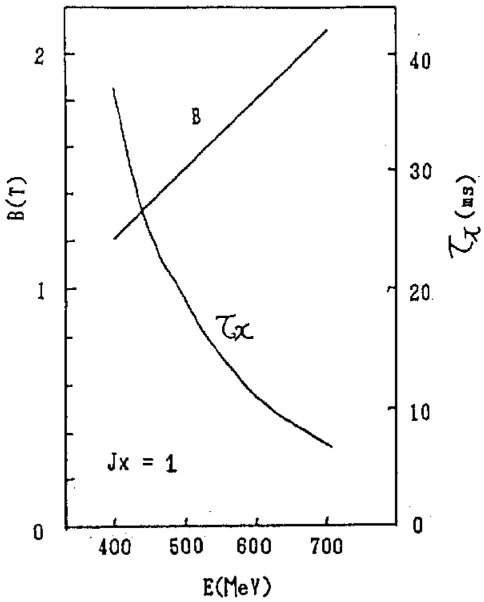

Figure 2 Relation of radiation damping time and the bending field with respect to the beam energy.

favorable, which gives τ_x=19 ms. Further increase of n reduces the damping time. The weak fucusing also reduces the emittance. Thus the pole pieces of the magnets of JSR are changed from a constant field type to a weak focusing type for the PAR with an n-value of 0.6, which gives a damping time of 15.5 ms.

Fig.3 shows the lattice functions of PAR. The dispersion is zero in the beam injection/extraction region, and becomes the maximum 3.2 m in the long straight section. The dispersion function is mainly determined by quadrupole magnets QF2, and the tune mainly by QF1 and QD. Sextupole magnets SF and SD are installed close to QF2 and QD to avoid the head-tail instability. The lattice parameters are shown in Table 1. The beam is injected and extracted through the same septum magnet at an angle of 9 degrees, and the beam passes QF1s between the poles and yoke. Two bump magnets and a kicker magnet are placed in short straight sections at a phase advance of $\pm\pi/2$ from the septum magnet. The horizontal excursion of the injected beam becomes the maximum of 50 mm at QF2.

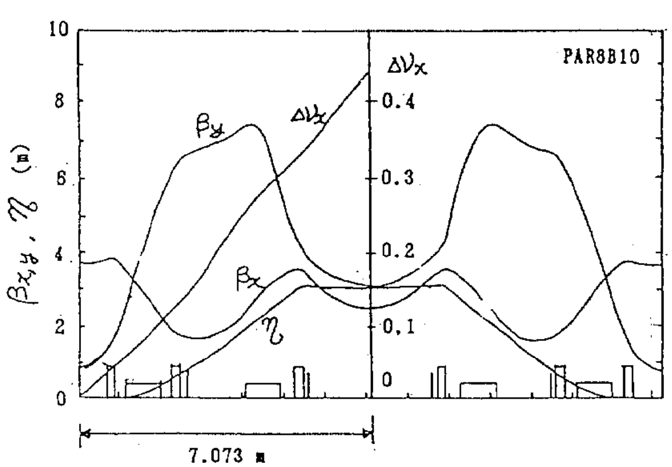

Figure 3. Lattice functions of PAR.

Table 1 Parameters of PAR.

Beam energy	E	500	MeV
Circumference	$2\pi R$	28.294	m
Revolution period	To	94.38	ns
Momentum compaction fac.	α	0.276	
Tune	ν_x/ν_y	1.76/1.38	
Chromaticity	ξ_x/ξ_y	-2.47/-0.004	
Partition number	$J_x/J_y/J_\varepsilon$	1.224/1.0/1.776	
Emittance	ε_x	0.44	mmmrad
Energy spread	σ_E/E	2.6×10^{-4}	
Radiation energy	U_0	4.97	keV/turn
Damping time	$\tau_x/\tau_y/\tau_\varepsilon$	15.5/19.0/10.7	ms
RF frequency	f1/f2	10.596/116.55	MHz
Harmonic number	h1/h2	1/11	
RF voltage	V1/V2	50/35	kV
RF bucket height	$\Delta E/E$	1.40/0.34	%
Bunch length	σ_τ	0.81/0.29	ns
Bending field	B	1.5	T
Curvature of bend	ρ	1.1128	m

III. RF SYSTEM

The RF system of PAR is composed of two cavities. One(RF1) is excited at the revolution frequency and a voltage of 50 kV, and the other(RF2) at the 11th harmonic or 116.55 MHz and 35 kV. For the latter the RF system of JSR can be converted. The 11th harmonic frequency can be generated by down counting and a phase lock loop as shown in Fig.4. RF1 is excited continuously, and RF2 just before beam extraction for 50 ms, so that about 55 macro-pulses of linac beam can be accumulated in one cycle of the synchrotron. During the accumulation, RF2 cavity is detuned by swithing to a matched load to avoid a beam bunching with an induced voltage.

Fig.5 shows the relation of RF bucket height and length compared with bunch length and energy spread. The damped bunch length in RF2 is $4\sigma_\tau$=1.2 ns, short enough for the beam injection into the RF bucket of

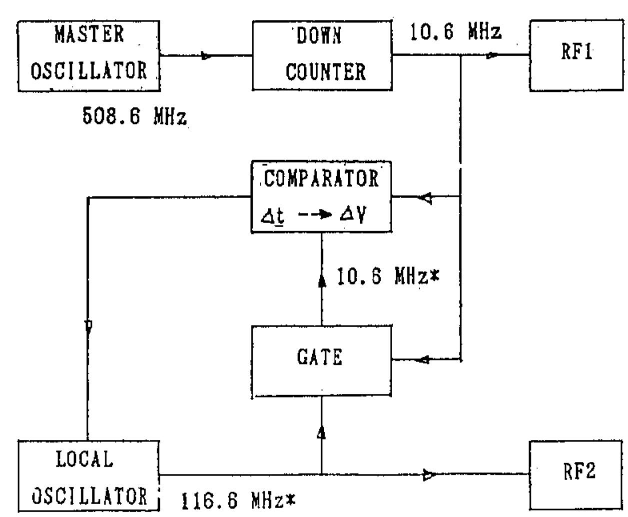

Figure 4. Generation of the 11th harmonic frequency with a phase lock loop.

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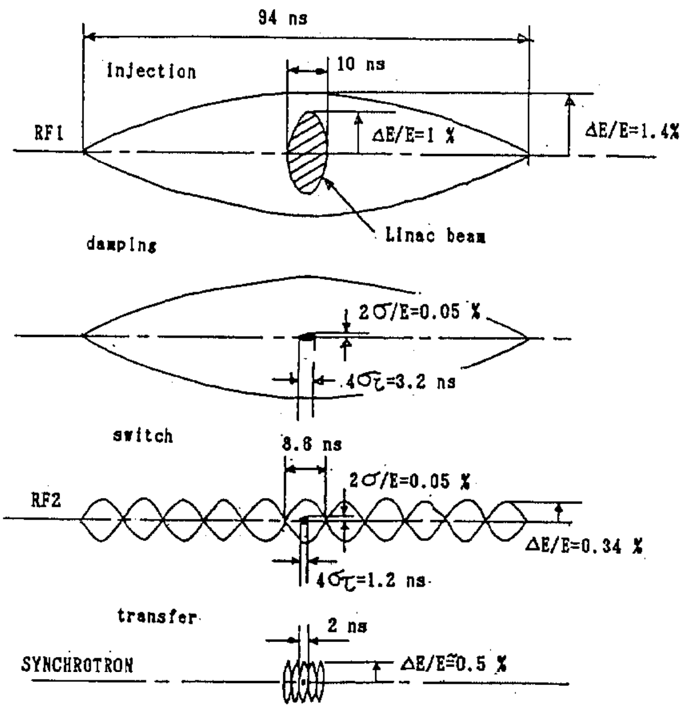

Figure 5. Relation of RF bucket height and length with respect to energy spread and bunch length in RF1, RF2 and synchrotron.

the synchrotron with a bucket length about 2 ns. Expected threshold current of the microwave instability is 13 A at peak for a longitudinal coupling impedance $Z_{\parallel}/n=10\Omega$, while the accumulated peak current is 7.5 A with an injection efficiency of 100 %, so that the bunch lengthening would not be induced.

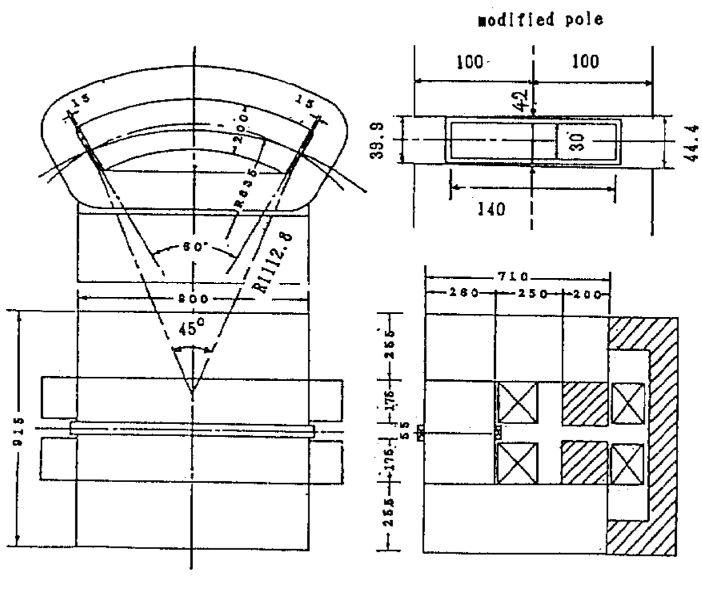

Figure 6. Bending magnet modified for PAR.

IV. MAGNETS

Bending magnets and the power supply of JSR can be converted to PAR with some modifications. The orbit curvature and the pole pieces are changed as shown in Fig.6. The pole gap is also reduced from 55 mm to 42 mm to produce an increased field of 1.5 T instead of 1.2 T of JSR with the same power supply. But we need two additional bending magnets and their power supply.

JSR has three families of Q magnets with 3, 6 and 6 each. The PAR needs three families with 4, 4 and 4 each, and the field strengths in the PAR is much weaker than those in JSR because of the use of weak focusing in bending magnets. Thus Q magnets and the power supplies of JSR can be converted to the PAR. The pole pieces of Q magnets should be changed to increase the good field region.

Sextupole magnets and the power supplies can be used, but the pulse magnets (septum, bumps and kicker) need to be newly constructed.

V. BEAM TRANSPORT

In the beam tranport line from the linac to the synchrotron via the PAR shown in Fig.1, 10 Q magnets are installed, and two acceleration sections of the linac are replaced with bending magnets, which deflect the beam by 9 degrees. Fig.7 shows the magnet arrangement and matched lattice functions of the beam transport line.

VI. REFERENCES

[1] A. Febel and C. Hemmie, IEEE Tr. NS-26, 3244 (1979).
[2] E. A. Crosbie, ANL Rept. Light Source Note, LS-109 (March, 1988).

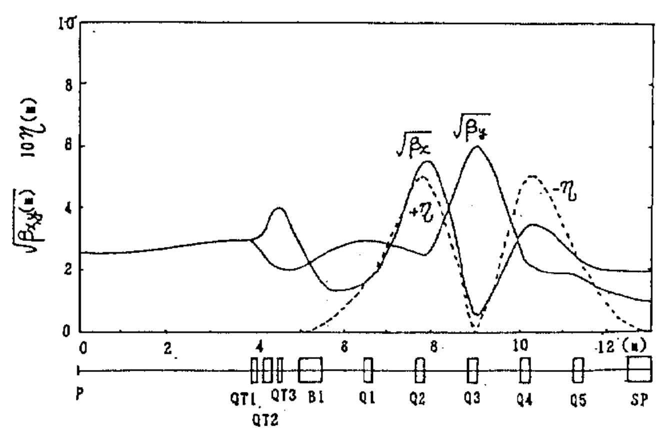

Figure 7. Matched lattice functions of beam transport line.