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THE POSITRON ACCUMULATOR RING FOR THE APS*

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Introduction

The Positron Accumulator Ring (PAR)[1] is designed to accumulate and damp positrons from the 450-MeV linac during the 0.5-s cycle time of the injector synchrotron for the APS 7-GeV storage ring. During 0.4 s of each synchrotron cycle, up to 24 linac pulses are injected into the horizontal phase space of the PAR at a 60-Hz rate. Each injected pulse occupies about 1/3 of the circumference of the accumulator ring. After 0.1 s for longitudinal damping, the single accumulated bunch is transferred to one of the 353-MHz buckets of the injector synchrotron RF system. The bunch is accelerated to 7 GeV and transferred to the storage ring, while the PAR accumulates the next bunch of positrons.

The design and operation of the PAR is very similar to that of the PIA ring in use at DESY.[2] Its position relative to the injector synchrotron is shown in Fig. 1.

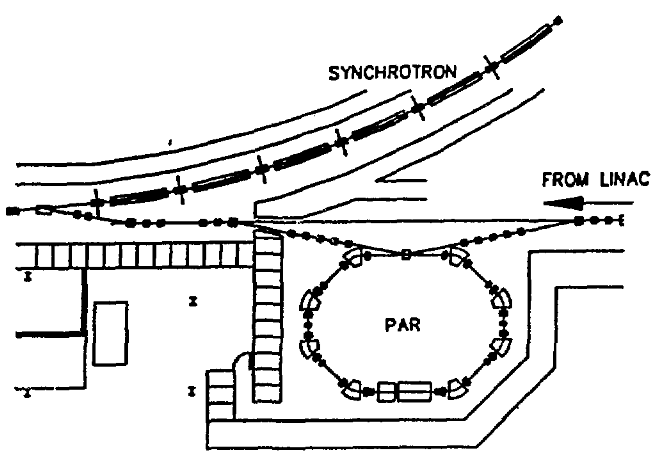

Fig. 1. Location of the Positron Accumulator Relative to the Injector Synchrotron.

Description of the Lattice

The rate at which positrons can be injected into the horizontal phase space of an accumulator ring is limited by the horizontal damping rate. Therefore, since the energy of the positrons is relatively small (450 MeV), the circumference of the ring and the radii of curvature of the bending magnets are as small as practical. The circumference of the PAR is 30.58 m, which is 1/12 that of the injector synchrotron. The total bend is supplied by four dipole magnets, each operating at 1.48 T. For additional reduction of the horizontal damping time constant, the magnets have a field index ($n = -\rho B'/B$) equal to 0.6. The horizontal and longitudinal partition numbers are 1.26 and 1.74, respectively. The horizontal and longitudinal damping time constants are, correspondingly, 20.5 ms and 14.8 ms.

The ring is divided into two cells, with each cell containing a 4.92-m dispersion-free straight section (Fig. 2). One of these straight sections contains a septum magnet, which is used for both injection and extraction. The other long straight section contains the two RF systems used to damp the bunch length.

Focusing for the lattice is provided by 16 quadrupoles. The lattice and dispersion functions for the conditions listed in Table I are shown in Fig. 3. The operating parameters are shown in Table II. Two families of sextupoles are used to adjust the chromaticity.

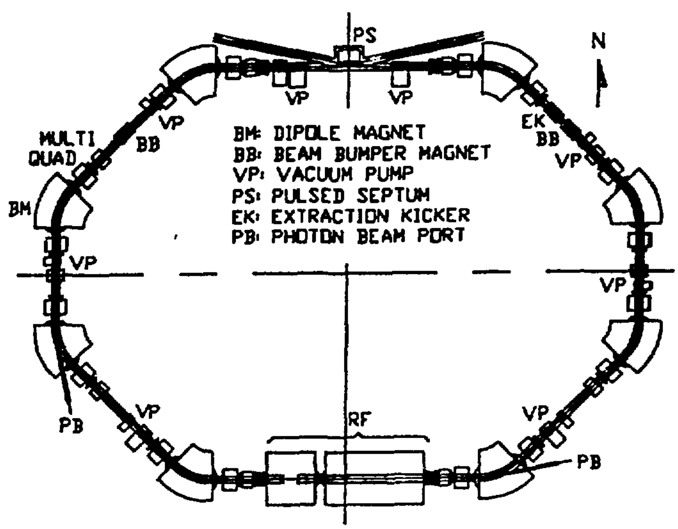

Fig. 2. Layout and Components of the Positron Accumulator Ring.

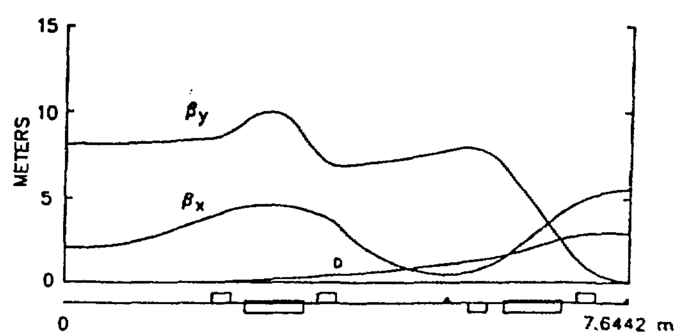

Fig. 3. Lattice and Dispersion Functions for the Positron Accumulator Ring.

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Table I

Positron Accumulator Ring Lattice Components

$B\rho$ = 1,5010 T.m (0.45 GeV)

Element		Length (m)	$B'/B\rho$ (m^{-2})
Drift L1	1.7092		
Multipole		0.20	
Drift	0.10		
Quadrupole	Q1	0.25	0.543
Drift	0.20		
Magnet*		0.80	1.4706
Drift	0.20		
Quadrupole	Q2	0.25	
Drift	1.39		
Multipole	S1	0.20	
Drift	0.20		
Quadrupole	Q3	0.25	-1.3607
Drift	0.20		
Magnet*	0.80		
Drift	0.20		
Quadrupole	Q4	0.25	1.3846
Drift	0.345		
1/2 Multipole	S2	0.10	
	Reflect		
TOTAL	7.6442		

*ρ = 1.0186, $\rho B'/B$ = -0.6.

Injection/Extraction

Positrons from the 450-MeV linac are injected into the horizontal phase space of the PAR at a 60-Hz rate. Each 30-ns linac pulse enters the injection system magnet at an angle of 11.5°, where it is bent parallel to the particle orbit at the center of the injection straight section. At the time of injection the circulating positrons are brought as close as possible to the septum of the injection, magnet by a system of two bumper magnets located 90° in phase upstream and downstream of the injection point. The injected positrons oscillate about the warped orbit. Immediately after injection the bumper magnets are turned off so that the injected particles clear the septum magnet during subsequent revolutions in the ring.

The septum of the injecton magnet is 3.0 cm from the central orbit. During injection the bumped orbit is at 1.8 cm. Including the 6.6 mrad-mm (95%) profile of the linac beam, the maximum oscillation displacement with respect to the orbit at the injection magnet is 2.2 cm. With a damping time constant of 20.5 ms, the oscillations are reduced by a factor of 0.44 in 1/60 s so that the bumper magnets can be turned on for injection of the next pulse.

A vacuum chamber width of 12 cm is required to adequately contain the injected beam in the region of maximum β_x and dispersion. The vertical gap is 3.6 cm.

Table II

Parameters for the Positron Accumulator Ring

Circumference (m)		30.5768
Revolution Time (ns)		101.994
Energy (MeV)		450
No. of Cells		2
No. of Dipoles		8
Dipole Field B (T)		1.476
Bend Radius ρ (m)		1.0186
Field Index ($-\rho B'/B$)		0.6
No. of Quadrupoles		16
Tunes ν_x/ν_y		2.19/1.27
Transition Gamma (γ_T)		1.93
Chromaticities (ξ_x/ξ_y)		-2.70/1.05
Partition Numbers $J_x/J_y/J_E$		1.257/1.000/1.743
Damping Time Constants $\tau_x/\tau_y/\tau_E$ (ms)		20.49/25.75/14.77
Energy Loss per Turn (keV)		3.56
Natural Emittance ε (mm mrad)		0.37
$\sigma E/E$ (damped)		0.41×10^{-3}
RF Systems		
System I		
f	(MHz)	9.8045
h		1
v	kV	40
f_s	(kHz)	19.1
σ_T (damped)	(ns)	0.92
System II		
f	MHz)	117.654
h		12
v	(kV)	30
f_s	(kHz)	60.5[a]
σ_T(damped)	(ns)	0.29[a]

[a]Systems I and II both on.

The circulating positrons are extracted in one turn using the upstream bumper magnet and a third identical magnet located just downstream of the bumper magnet. These two magnets cause the positrons to enter the septum magnet, where they are bent by 11.5° to follow the beam line to the injector synchrotron.

The injector synchrotron operates at 2 Hz. Since 0.1 s is required for compression of the bunch length in the PAR, it is possible to accumulate as many as 24 linac pulses for each injector synchrotron cycle. The number of positrons in each linac pulse is 1.5×10^9. Therefore, the maxiumum number of positrons in the PAR is 3.6×10^{10} (56.5 mA). If one assumes a pessimistic 50% efficiency, the time required to fill the storage ring to 2.2×10^{12} positrons is about 1 min.

RF Capture and Bunch Damping

Each macropulse from the 450-MeV linac is 30-ns long. The pulses are injected into a first-harmonic, 9.8-MHz, 40-kV RF bucket. Ninety-five percent of the beam is contained within an energy spread of ± 1%. The RF bucket height is ± 1.6%. Fifty milliseconds after injection of the last pulse, the first-harmonic system damps the bunch to $\sigma_E/E = 0.44 \times 10^{-3}$ and $\sigma_\tau = 0.99$ ns. At this time a second, twelfth-harmonic, 117.65-MHz, 30-kV RF system is turned on with phase of π at the bunch center. The combined RF system damps the bunch length to $\sigma_\tau = 0.3$ ns in an additional 50 ms. This length is adequate for transfer to the 353-MHz buckets of the injector synchroton.

References

1. E. A. Crosbie, "A Positron Accumulator Ring for APS," Argonne National Laboratory, Light Source Note, LS-109 (March 1988).

2. A. Trebel and G. Hemmie, "PIA, The Positron Intensity Accumulator for the PETRA Injection," IEEE Transactions on Nuclear Science, Vol. NS-26, No. 3 (June 1979).