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PIA, THE POSITRON INTENSITY ACCUMULATOR FOR THE PETRA INJECTION

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Abstract

The storage ring PETRA is designed to store $4 \cdot 10^{12}$ electrons and positrons in 2xfour 500 MHz rf buckets. Since the intensity of the positron linac is about $2 \cdot 10^{7}$ particles per 500 MHz bucket, $2 \cdot 10^{5}$ bunches are required for injection and accumulation in PETRA. In order to get reasonably short filling times the storage ring DORIS presently is acting as an intermediate bunch accumulation facility. This scheme has been successfully in operation since September 1978. Now the increased demand for elementary particle physics and for synchrotron radiation experiments at DORIS has motivated the construction of the small 450 MeV intermediate storage ring PIA, located between the positron linac and DESY. The circumference is 28,8 m. About $1 \cdot 10^{9}$ positrons will be injected at a rate of 50 Hz. A first harmonic cavity (10,4 MHz) accumulates positrons in a 0,8 m long bunch which is further compressed to 0,25 m length by a 12^{th} harmonic rf system (125 MHz) for injection into the DESY 500 MHz system. After acceleration to 6,5 GeV in DESY single positron bunches are injected into PETRA.

Introduction

The storage ring PETRA is designed to store up to $4 \cdot 10^{12}$ electrons and positrons. The particles of each kind are concentrated in four 500 MHz rf buckets equally spaced. Since the number of particles generated from the positron linac is only about $2 \cdot 10^{7}$ per 2 ns bucket length $2 \cdot 10^{5}$ injection pulses have to be accumulated in PETRA during the filling period. At 6,5 GeV transfer energy between the injector synchrotron DESY and PETRA the highest injection rate is 10 Hz. This would lead to an unacceptable filling time for positrons of nearly 6 hours. Therefore the storage ring DORIS is used for intermediate accumulation and storage[1]. In this scheme 30 linac bunches can be utilized every 20 ms leading to a 150 times shorter filling time. Fig. 1 shows the principle of operation. Since Sept. 78 it has become routine operation for the positron filling of PETRA.

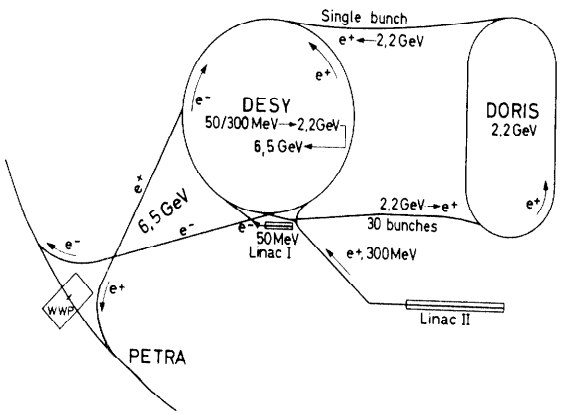

Fig. 1 PETRA INJECTION

In order to relieve DORIS from the PETRA injection task which absorbes a fair fraction of the total DORIS operation time, the small intermediate storage ring PIA (for Positron Intensity Accumulator) has been proposed[2] and constructed.

Deutsches Elektronen Synchrotron DESY
Notkestrasse 85, 2000 Hamburg 52, W.Germany

Some Principal Characteristics of PIA

PIA is located at the end of the Linac II building, where there is space enough for a ring of up to 40 m circumference. To make synchronization easier the orbit length is fixed to 28,8 m which corresponds to 1/11 of the DESY circumference and 1/80 of PETRA's.

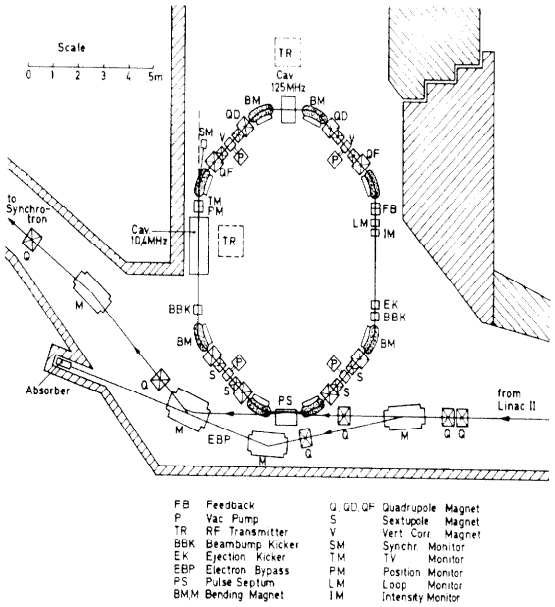

Fig. 2 PIA-POSITRON-INTENSITY-ACCUMULATOR

Injection and accumulation will be done in a single turn mode. The particle bunch length will be damped down and compressed longitudinally by use of two rf systems that act on the beam one after the other.
In order to simplify the ejection technique the stored particles will be gathered in only one bunch. Therefore the accumulation will be done by using a 10,4 MHz rf-cavity first (harmonic number h = 1). About 20 linac pulses will be injected and accumulated at 450 MeV. After a time interval of 60 ms for longitudinal damping a second rf cavity acting on the 12^{th} harmonic number (125 MHz) is powered additionally. The bunch which had already been damped down to 0,80 m length will be captured adiabatically within one of the twelve buckets and compressed to a final bunch length of about 0,25 m. This bunch will be ejected, transferred to and injected into DESY. There it will be captured in one of the 528 DESY 500 MHz rf buckets. After acceleration up to 6,5 GeV and transfer to PETRA the positron bunch finally will be accumulated in the predetermined PETRA bucket.

Filling Time Consideration

20 linac pulses, each of them containing 10^{9} positrons lead to a total number of 10^{10} particles stored in PIA if one assumes 50 % accumulation efficiency. This corresponds to 16 mA beam current in PIA.
It has already been experimentally verified that DESY can handle such high bunch intensities with the help of a feedback system to overcome head-tail instabilities.
At 450 MeV the damping rate of the horizontal betatron oscillation in PIA is 24 ms, thus allowing for 50 Hz accumulation frequency. Particle transfer to PETRA will be at 2 Hz, and the maximum filling time for $4 \cdot 10^{12}$ particles in PETRA will be 3,3 min.

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Parameter Discussion

The requirement to achieve short damping times leads to small bending radius in the dipole magnets. Since the separate function lattice leads to difficulties in getting small horizontal damping rates, a combined function bending magnet has been chosen. This allows equal damping partition numbers in horizontal and vertical phase planes, while the synchrotron damping partition becomes half the number of the transverse ones.

With 1,5 Tesla on the equilibrium orbit at 450 MeV we get the horizontal damping time constant τ_x = 24 ms. This is sufficiently small for 50 Hz injection sequence. Further optical conditions were: nearly dispersion free zone at the injection septum, large horizontal acceptance and about 180 degrees phase advance between the two injection beam bump kickers (Fig. 3). The sextupoles are designed to compensate horizontal and vertical chromaticity in order to avoid head tail instabilities.

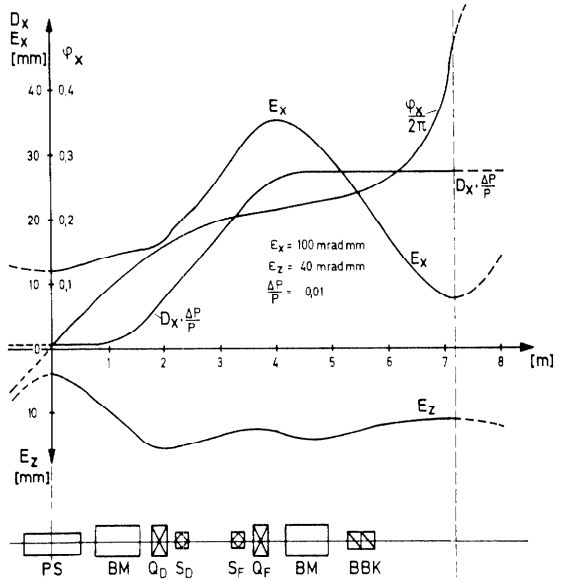

Fig. 3 PIA OPTICS (one quadrant)

During the accumulation period (about 400 ms) the shunt impedance R_s of the harmonic cavity (125 MHz) will be lowered by a pin diode switch. This reduces the induction of beam loading voltage to a sufficient small amount.

In order to achieve a single bunch of 0,25 m in PIA it is more economic to design two rf systems instead of only one.

Injection and Ejection

The positrons accelerated up to 450 MeV by the S-band Linac II will be steered and matched by the transport system to the horizontal acceptance of PIA which is shifted over the septum conductor by means of the two fast beam bump kickers (BBK, see Fig. 2). At the end of the accumulation and compression period the bunch will be deflected additionally by the ejection kicker (EK) into the pulse septum gap (PS) that bends the particles further into the transport channel to the synchrotron.

A number of monitors for orbit and bunch length measurements is provided. Back leg windings on the bending magnets (BM) and vertical dipole correction magnets are used for orbit corrections.

List of Parameters

Energy	450 MeV
Circumference	28,8 m
Optical cell length	14,4 m
Number of bending magnets	8
Property " " "	gradient sector magnet
Bending radius	1,00 m
Number of quadrupoles	8
Strength of the quadrupole field	
bending magnet	$k = -0,5\ m^{-2}$
focusing quadrupole	$k = 1,02$ "
defocusing quadrupole	$k = -1,62$ "
Chromaticity	$\xi_x = -5,3$
	$\xi_z = -1,5$
Number of sextupoles	8
Strength of the sextupole field for chromaticity compensation	$m_x = 11,2\ m^{-3}$
	$m_z = -5,2\ m^{-3}$
Aperture	A_x = 100 mrad mm
	A_z = 20 mrad mm
Natural beam emittance	$\varepsilon_x = 3 \cdot 10^{-7}$ mrad mm
	$\varepsilon_z \simeq 1,5 \cdot 10^{-8}$ "
Working point	$Q_x = 1,75$
	$Q_z = 1,69$
Damping time constant	α_{syn} = 12 ms
	α_x = 24 "
	α_z = 24 "
Momentum compaction factor	$\alpha = 0,31$
Energy loss per turn	$U_0 = 3,63$ keV
Linac energy spread	$\Delta E/E = \pm 7 \cdot 10^{-3}$

Rf-Parameters:	1st system	2nd system
Frequency	10,4 MHz	125 MHz
Harmonic number	1	12
Peak voltage	22 kV	21 kV
Synchronous phase	9,5°	0°
Duty cycle	cw	∿ 4 %
Phase oscillation frequency	17 kHz	58 kHz
Natural bunch length	2σ=2,4 ns	0,76 ns
Rf power	10 kW	2 kW

Filling time for positron accumulation in PETRA ≤ 4 min

Status

After design studies in 1977 construction of the components startet in 1978. In January 1979 most of the parts of the storage ring had been built. During a four weeks' shut down period in February 1979 the ring has been installed. All components are in place with the exception of the rf system. The installation of the cavities and transmittersis scheduled for May, 1979.

First injection tests and studies on beam behaviour will start now (March 1979). From July to October 1979 DORIS will be stand-by for PIA, an intermediate storage facility for the PETRA injection. After this period it is planned to relieve DORIS totally from this task.

References

1 A. Febel, G. Hemmie, G. Mühlhaupt, K. Wille "PETRA INJECTION SYSTEM" Proceedings of the X Internation. Conference on High Energy Accelerators, Protvino, July 1977, Vol. 1, p. 464

2 A. Febel, G. Hemmie, G. Mühlhaupt "Auslegung des Zwischenspeichers für die Positronen-Injektion nach PETRA" Technical Note DESY-PET 77/29