Internal Report
DESY M-80/17
August 1980

STATUS AND PERFORMANCE OF PIA

A. Febel and G. Hemmie

DESY behält sich alle Rechte für den Fall der Schutzrechtserteilung und für die wirtschaftliche Verwertung der in diesem Bericht enthaltenen Informationen vor.

DESY reserves all rights for commercial use of information included in this report, especially in case of apply for or grant of patents.

"DIE VERANTWORTUNG FÜR DEN INHALT
DIESES INTERNEN BERICHTES LIEGT
AUSSCHLIESSLICH BEIM VERFASSEN."

STATUS AND PERFORMANCE OF PIA

A. Febel and G. Hemmie

Deutsches Elektronen-Synchrotron DESY, Hamburg, W. Germany

ABSTRACT

The storage ring PIA, designed to produce intensive single 500 MHz positron bunches, was installed last year. In June positrons were accumulated and compressed in a single bunch of 1 ns length for the first time.

The accumulation efficiency was raised up to 56 % by matching the linac beam to the PIA optics and by compensating the sextupole components in the bending magnets by additional sextupoles. Since July 1979 PIA has been running routinely for PETRA and DORIS:

The linac (50 Hz, 450 MeV) delivers 9 bursts (100 ns, 2×10^9 positrons each), which are accumulated and damped to a bunch length of 80 cm by a 10.4 MHz cavity. Then the bunch is compressed to 25 cm length by a 125 MHz rf system in 60 ms and then ejected.

Up to 10^{10} positrons were accumulated in a circulating bunch. The ejection efficiency is 90 %, the repetition rate of PIA 4 Hz.

INTRODUCTION

As part of the PETRA injection system the small storage ring PIA has the task to produce single 2 ns positron bunches of high intensity. This is necessary for the following reasons: The design number of positrons in each of four PETRA buckets is 1×10^{12} (these values are meanwhile achieved). Since the damping time for horizontal betatron oscillations in PETRA is about 100 ms at 7 GeV at least 5×10^8 positrons have to be delivered to the PETRA ring within a single bunch, resulting in a filling time of 15 min if there were no losses. The DESY positron linac yields only 2×10^7 particles within 2 ns. One possible method to improve the intensity in the 500 MHz bunches is the use of an intermediate storage ring. So in the first year of PETRA operation the DORIS storage ring was run in this mode as part of the PETRA injection system¹⁾. This system worked fine inspite of its complexity, but DORIS was almost fully occupied by the PETRA injection and could not be used for high energy physics. Therefore in 1978/79 the old idea of having a small storage ring at the end of the linac was realised. Due to PIA the PETRA injection system is now very simple (Fig. 1): Single positron bunches of high intensity created in PIA are injected at 450 MeV into the DESY synchrotron, accelerated up to 7 GeV, transferred to PETRA and accumulated there in the assigned buckets. The repetition rate is 4 Hz, comfortably small as compared to the damping rate in PETRA.

WORKING PRINCIPLE OF PIA

PIA works in the following way: The linac, running at 50 Hz, delivers 9 bursts of positron S-band bunches with a pulse length of ~ 100 ns each and with 2×10^9 particles within an energy spread of $\pm .5$ %. They are transferred to PIA via a small transport system, injected and accumulated there.

Fig. 1: PETRA Positron Injection

The energy of the positrons is 450 MeV. PIA has a circumference of 28.8 m ($\approx 1/80$ of PETRA's), the revolution time is 96 ns. The beam is injected within one turn with the help of two beam bump kickers which have a horizontal betatron phase shift of 180° between them and are respectively located upstream and downstream of an injection septum magnet. These kickers move the already accumulated beam every 20 ms to the edge of the current strip of the septum before the next linac pulse is injected.

Since the bending radius of the PIA magnets is 1 m, the energy loss of the 450 MeV beam is 3.63 keV per turn. This loss is compensated by a 10.4 MHz cavity (harmonic number $h = 1$) that runs at a peak gap voltage of 22 kV leading to a synchronous phase angle of 9.5° . The radial betatron oscillations are damped with a time constant of 24 ms which allows an injection repetition rate of 50 Hz. In longitudinal direction the originally 24 m long burst is damped down to a bunch length of 80 cm with a time constant of 12 ms. 20 ms after the last (i.e. the 9th) injection a second cavity with a resonant frequency of 125 MHz ($h = 12$) is powered. Its peak voltage of 21 keV compresses the bunch adiabatically within 100 μ s and then the bunch length is damped down again by radiation to $2\sigma = 25$ cm within a time of 40 ms. This bunch fits well into the 500 MHz buckets of the DESY synchrotron. It will be ejected using an ejection kicker magnet and the same septum magnet that is used for injection (Fig. 2).

SOME COMPONENTS IN DETAIL

There are 8 bending magnets, 45° sector magnets with a magnetic field of 1.43 T at 450 MeV on the central orbit and with superimposed defocusing gradient field of .75 T/m ($k = .5 \text{ m}^{-2}$). Measurements showed that at this excitation the magnets are already partially saturated and contain sextupole components which cannot be neglected. 4 horizontally focusing (QF) and 4 de-

Fig. 2: The Storage Ring PIA

focusing (QD) quadrupole magnets with focusing lengths in the range of 1.5 to 2 m determine the working points to be around 1.6 to 1.8. Without the quads PIA would be a weak focusing machine. 2×4 sextupole magnets of the PETRA type are installed, two of them each between two adjacent quads. They were thought to be necessary to compensate the chromaticity of the machine to zero or to positive values in order to overcome the head-tail instability. At present four of them are used to raise the acceptance of PIA which would otherwise be heavily reduced by the sextupole fields in the bending magnets.

6 short dipole magnets in the straight sections allow for correcting the closed orbit vertically. Corrections in the horizontal plane are achieved by powering backleg windings in the PIA bending magnets.

A pressure of less than 3.5×10^{-9} torr in the vacuum system is provided by nine 400 l/s pumps beneath the bigger tanks (kickers, septum and cavities) and four 30 l/s pumps in the short straight sections, leading to a lifetime of nearly an hour which is mainly determined by Coulomb scattering at the nuclei of the restgas. This is by far sufficient for normal operation of the storage ring and is even good enough for measurements with the stored beam.

Both cavities are made of aluminium. The 10.4 MHz one has an unloaded Q_0 of 3000 and a shunt impedance of $43 \text{ k}\Omega$. It is driven by a 7 kW tetrode transmitter. In order to avoid self-bunching of the beam, the Q-value of the 125 MHz cavity is reduced to 500 during the injection pulses by a loop coupled to an rf load. Just before being excited the resonator is tuned into resonance by switching on a short circuit a quarter wavelength apart from

the loop. The input power is 200 W.

OPERATION AND PERFORMANCE OF PIA

The PIA ring was designed in the years 1977/78 and assembled in February 1979 with all components except the rf systems. Soon after the first injection 500 beam revolutions could be seen in PIA. More were not expected at that time due to the radiation energy loss of the positron beam. The rf cavities and the transmitters were installed in May 1979 and in June the first accumulated bunch circulated in PIA. It had already the short length to fit into a single 500 MHz bucket of DESY and PETRA (see Fig. 3).

The initially very low accumulation rate raised by matching the linac positron beam to the acceptance of PIA and by compensating the inherent sextupole components in the dipole fields. The last cure was found by using the LIMATRA tracking program. The compensation was done by powering one family of four sextupole magnets and shifting the chromaticity $\xi = \frac{\Delta Q}{\Delta p/p}$ from $\xi_x = -16$ and $\xi_z = +5$ back to the natural values of -4 and -1.3 as calculated from linear optics. There was no necessity for totally compensating the chromaticity since at circulating currents of less than 20 mA no single bunch instability could be observed.

With these two procedures the accumulation rate was brought up to 90 mA/s. The accumulation efficiency is 56 %, and 90 % of the circulating beam (up to 10^{10} particles) are ejected and transferred to DESY and PETRA. A typical scope picture showing the accumulation process in PIA during one cycle is seen in Fig. 4.

Fig. 3: Bunch Length before and after Compression by the 125 MHz rf System
(Time Scale: 2 ns/div)

Fig. 4: Positron Current in PIA
(Time Scale: 50 ms/div)

PIA is now operated with nearly the same optics that had been proposed^{2,3)} with almost zero dispersion at the injection point, large horizontal acceptance and a relatively large dispersion in the long straight sections. The measured Q-values are $Q_x = 1.64$ and $Q_z = 1.61$. The ratio of the beam height to the beam width was measured by the synchrotron light monitor to be about 5 %, but it indeed rises to 100 % when shifting the working point to $Q_x = Q_z$.

REFERENCES

- 1) A. Febel, G. Hemmie, G. Mühlhaupt, K. Wille "PETRA INJECTION SYSTEM",
Proceedings of the Xth International Conference on High Energy Accelerators,
Protvino, July 1977, Vol 1, p. 464
- 2) A. Febel, G. Hemmie, G. Mühlhaupt "Auslegung des Zwischenspeichers für
die Positroneninjektion nach PETRA", Technical Note DESY-PET 77/29
- 3) A. Febel, G. Hemmie, "PIA, the Positron Intensity Accumulator for the
PETRA Injection", IEEE Trans., June 1979, Vol. NS-26, No. 3, p. 3244