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POSITRON BEAMS FOR THE PF STORAGE RING

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Abstract At the Photon Factory of KEK, positron storage operation started in July 1988 using a short-pulsed beam (< 2 ns) which had been utilized for the e^+/e^- colliding experiments in TRISTAN. However, there was a problem in that it took a long time for injection. To overcome this difficulty, the system producing a tens-nanosecond positron beam has been developed for use in the positron generator. The beam is adequate for the PF ring to reduce the injection time, since it contains several times as many positrons as in the short-pulsed beam. With a 40-ns beam, the accumulation rate was increased by a factor of six, and a reduction of the injection time was successfully achieved; it now typically takes less than 20 minutes for accumulating positrons from 0 mA to 350 mA.

INTRODUCTION

Regarding positron storage operation[1,2] at the PF, one problem has been that the time required for accumulation is too long. To make it shorter, it is necessary to increase the total charge, which may be achieved by using a beam with a longer pulse width. Problems accompanying positron storage have been solved due to closer co-operation between personnel at the PF linac and the PF ring.[3] The state of the linac is presented here. We investigated following subjects: (1) To supply a beam which would contain sufficient charge, or a short beam which could be accumulated in a single bucket in the ring. (2) To make it possible to quickly switch over from one operation mode to another.

Two kinds of positron beams are now available: a semi-long pulsed beam (~40 ns) and a short-pulsed beam (~2 ns). The progress and the present status of positron beams for the PF ring are discussed.

CIRCUMSTANCES OF POSITRON INJECTION

In compliance with a request by the staff of the PF ring in 1987, it was decided to accumulate positrons for test operation. The purpose was to remove the beam instabilities due to ion trapping or micro-particle trapping which occurred in electron beams and, as a result, to supply more stable synchrotron-radiated light for users.[1] Although a positron beam with a pulse width of 2 ns was already available for TRISTAN at that time, it was estimated that it would take more than two hours for this beam to accumulate positrons up to 300 mA. Therefore, injection into the PF ring would compete with that for TRISTAN since the free time between injections for TRISTAN was only about one hour. Thus, investigations were pursued with a project team aiming at accumulating positrons up to 300 mA within 30 minutes.

It turned out that a semi-long pulsed beam was indispensable for realizing positron storage as normal operation. However, there were some problems which needed to be solved. With regard to the problems in the linac, the lifetime of the electron gun should be mentioned first. The lifetime of the gun used at that time was only a few months; this fact caused concern regarding what would be the consequence of extracting a 40-ns beam which contained much more charge than a 2-ns beam. The next problem was that for the coexistence of PF and TRISTAN it was essential to make it possible to switch over from one operation mode to another quickly. It was therefore necessary to develop a system which made it possible to remotely change the parameters for the beam transport and trigger mode as well as the pulse width of the beam. Furthermore, with an increase in the injection current, another problem encountered was that the rf power fed to the buncher was insufficient. To overcome the last difficulty, the rf power to the injection unit was reinforced by modifying the configuration and by adding one more klystron.[2]

Since the problems were only partially solved when positron injection into the PF ring started on July 18 last year, the 2-ns beam for TRISTAN had been used until July 30. Due to the poor charge contained in the beam pulse, it took more than two hours to accumulate positrons from 0 mA to 250 mA. Nevertheless, it was fortunate that we could succeeded to accumulate positrons without losing the remaining beam at injection; hence, the actual injection time became half of that, since it was only requested to resupply the positrons lost. From December 5 when operation of the PF ring was resumed, it became possible to utilize the 40-ns beam by virtue of the steady progress in the control and trigger systems as well as the electron gun.[4] And the injection time was successfully reduced to less than 40 minutes. Thereafter, owing to continual efforts to improve the injection time in the PF linac and the ring, the time was recently further reduced to less than 20 minutes. These improvement are described in detail in the following.

PULSE WIDTH OF BEAMS

Two kinds of positron beam are now available, as mentioned before. In the PF, it is usually not necessary that the beam should be shorter than 2 ns, as in the colliding experiments of TRISTAN, since the beam fill the ring only partially. Hence, it is possible to utilize a (semi-)long pulsed beam for PF. At first, a ~500-ns beam was tested: however, it turned out that measurements of the positron beam were difficult since the peak current was very low. Then, the 20- and 40-ns beams were tested; finally, the 40-ns beam was chosen. The beam of the semi-long (40 ns) pulse has an advantage in that it contains much charge in a pulse and its pulse width is adequate for measurement. The 2-ns beam has been used so far only for tests in the PF ring.

BEAM CURRENT IN EACH SECTION OF THE LINAC

The beam current in each section of the linac is shown in Fig. 1. Figure (A) / (B) corresponds to a beam with a pulse width of 40 ns / 2 ns. The data express the currents of the electron beam (left-hand side of the arrow which indicates the target position), and of positron beam (right-hand side of the arrow). The numbers along the axis of the abscissas represent the sectors of the linac. The positron-beam current at sector 5 (the end of the linac) is about one thousandth of the electron beam striking the target.

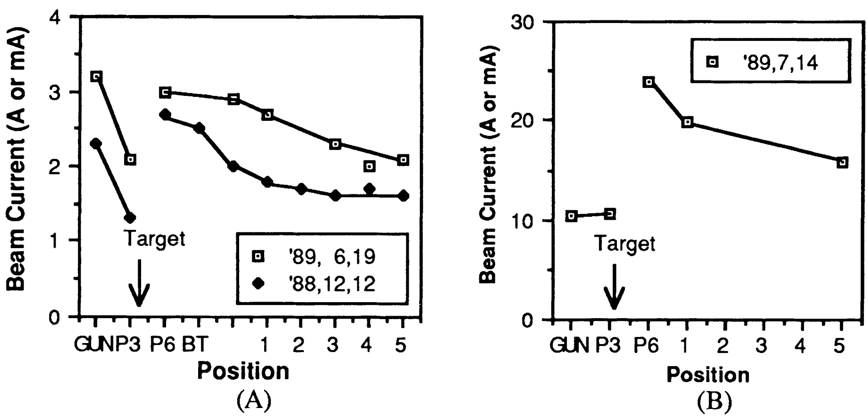


FIGURE 1 The beam current in each section of the linac. (A) 40-ns beam, (B) 2-ns beam The electron/positron current is displayed in A/mA.

ENERGY SPECTRUM AND EMITTANCE

The energy spectra of the 40-ns positron beam were measured at the beam transport line between the linac and the ring. The energy resolution of 0.1 % was set by a slit in the line . Figure 2 shows the beam intensities as functions of time and the beam energy. Spectra were taken by varying the rf phases of the positron generator. The spectra (A) and (B) correspond to 0 and 6 degrees of the rf phases, respectively. The energy spread obtained under the best condition was 0.5 % at full width.

The emittance of the electron / positron beam was measured near the target / at the end of the linac (2.5 GeV). Normalized emittances were obtained in units of π·m·rad horizontally (1.0×10^{-3}) and vertically (1.1×10^{-3}) for electrons, and horizontally (1.7×10^{-3}) and vertically (2.3×10^{-3}) for positrons.

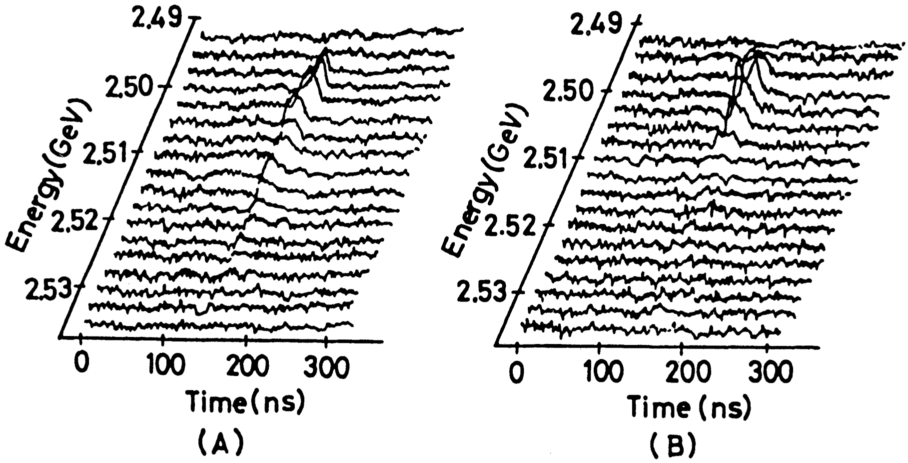


FIGURE 2 Energy spectra of the 40-ns-positron beam. The rf phases of the positron generator were (A) 0 deg. and (B) 6 deg.

SELECTION OF OPERATION MODE

Positron and electron beams with a widths of 2 ns are injected several times within periods two hours or so for TRISTAN; a positron beam of 40 ns is injected two or three times a day for the PF. Therefore, it is very important to switch over from one operation mode to another quickly. By selecting a mode with pushing buttons on the console in the main control room, the following two devices are switched: One is the coaxial switch for selecting the 40-ns or 2-ns beam.[5] This is used to connect one of the two grid pulsers with the gun. The other is the selector for switching the trigger signals synchronized with the revolution frequency of the PF ring or the TRISTAN accumulation ring. It is possible to select trigger signals remotely of the 40 ns / 2 ns positron beam for PF / TRISTAN. However, the trigger signals of the 2-ns positron beam for the PF can not be chosen remotely. Upon selecting an operation mode, the parameter set of the beam transport is also changed using computers.

CURRENT IN THE LINAC AND ACCUMULATION RATE IN THE RING

The current of the 40-ns beam gradually increases in the linac. Figure 3 shows the progress of the beam during the past year. The abscissa indicates the number of days (counted from July 11 when positron test injection started). The parts without data indicate machine maintenance periods. The data were measured with wall current monitors at two places where the beam energies were about 300 MeV (WM-16) and 2.5 GeV (WM-58). At the monitor of WM-16, the current is rather stable and is well in proportion to the injection current from the gun.[4] On the other hand, there is a fluctuation in the current at the monitor of WM-58. This fact implies that the final current is affected by other factors.

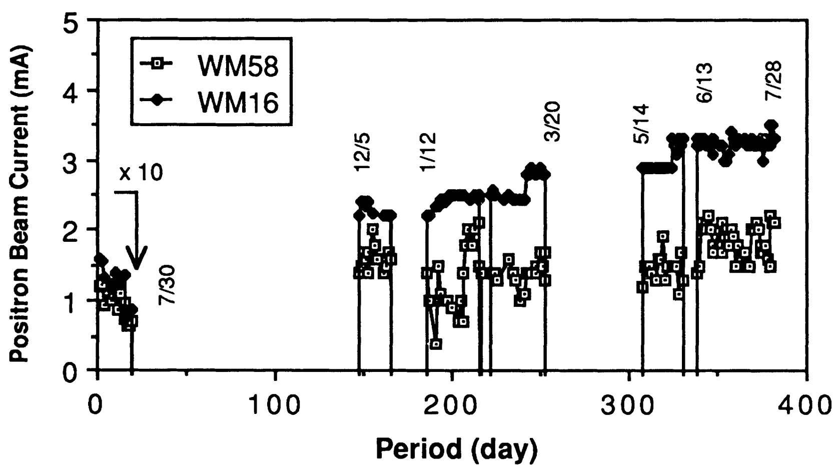


FIGURE 3 The progress of the 40 ns positron beam for the PF ring. Until July 30 last year, the 2 ns beam was used, till then the 40 ns beam.

Recently, the accumulation rate in the PF ring has been remarkably increased. It is shown in Fig. 4. In the latest operation term, the accumulation rate became 0.3~0.6 mA/s, larger by a factor of six than the 0.05~0.1 mA/s obtained last year using a 2-ns beam. It was found that there was a rather frequent lack of trigger signal (~30 %) because of a double synchronization with the revolution frequency and 119 MHz. This problem was easily solved by downgrading the coincidence accuracy of these frequencies. This is the main reason for the increase in the accumulation rate. A typical example of injection (July 18, '89) is shown in Fig. 5. In this case, the accumulation rate was constantly ~0.43 mA/s (as shown in (A)), and the time required for injection was less than 15 minutes (as shown in (B)) including the time for operation mode selection.

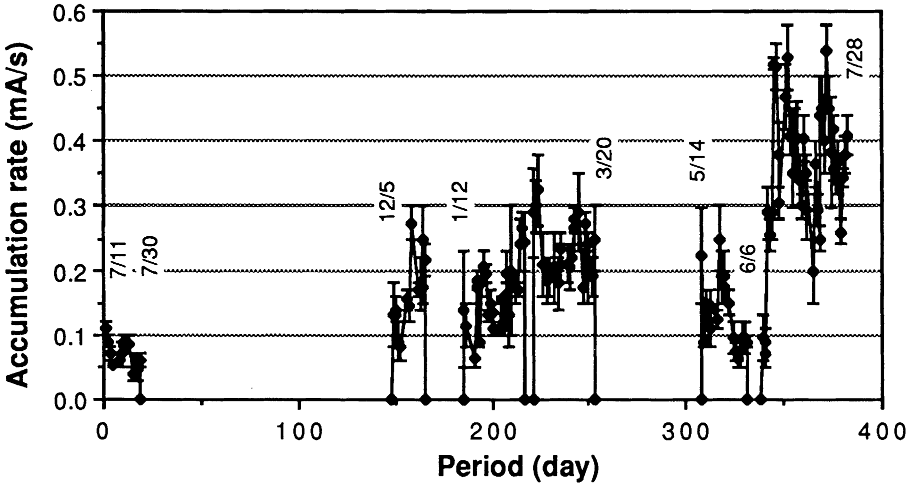
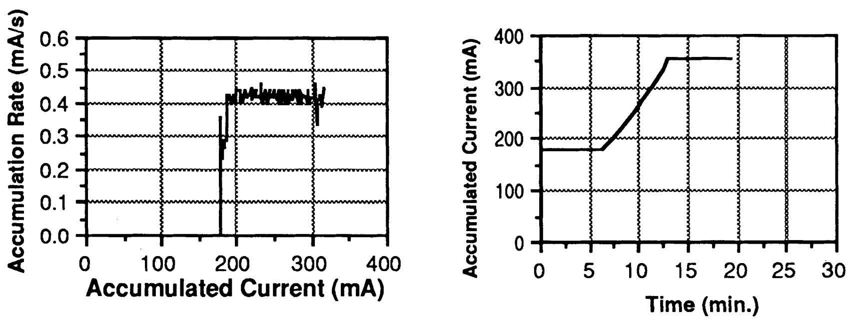


FIGURE 4 The progress of the accumulation rate in the PF ring.



(A) (B)

FUGURE 5 (A) Accumulation rate, and (B) change of stored current at injection.

SUMMARY

At the PF storage ring, the time required for accumulating positrons from 0 to 350 mA is now less than 20 minutes, and there is no interference between the PF and TRISTAN. Thus, the expected purpose has been attained as far as injection is concerned.

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