# PRESENT STATUS AND REINFORCEMENT PLAN OF THE KEK POSITRON GENERATOR

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## Abstract

The KEK positron generator has successfully provided positron beams to both TRISTAN and the Photon Factory (PF). However, to meet increasing requirements regarding positron beam use, the focusing system of the KEK positron generator will be extensively reconstructed. This paper describes the present status, the reinforcement strategy and design of the positron generator focusing system.

## Introduction

As a part of the TRISTAN project the KEK positron generator [1] was constructed on the south-west side of the PF 2.5-GeV electron linac during 1982-1985; it was then combined with the 2.5-GeV linac. In the autumn of 1986 it started routine-operation to inject a 2.5-GeV positron beam into the TRISTAN ring; in the autumn of 1988, the PF ring changed the storage beam from electrons to positrons in order to realize more stable operation. Figure 1 shows the composition of the KEK positron generator: a 250-MeV primary electron linac, a positron radiator with a quarter-wave-transformer (QWT)-type focusing system, a 250-MeV post-linac and a 30°-beam transport to transfer the positrons to the 2.5-GeV linac. A distinctive feature of the KEK positron generator is the conjunction of a compact focusing system with a high-current (>10 A), short pulse(<2 ns) linac as a primary electron linac. This choice enables low-power operation (<100 kW) of the focusing system and the direct injection of a single-bunch beam ( <2 ns = 1/(500-MHz ring accelerating frequency) ) to the TRISTAN ring, with the required positron current (>10 mA).

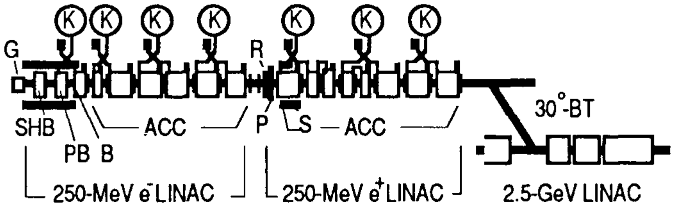

Fig. 1. Block diagram of the KEK positron generator: G is the electron gun; SHB, a subharmonic buncher; PB, a prebuncher; B, a buncher; ACC, a regular accelerator section; R, a positron radiator; P, a pulsed solenoid; S, a uniform solenoid; K, a klystron.

Instead of energy-front studies in the TRISTAN PHASE-I experiment, high-luminosity operation of the colliding ring is aimed at PHASE-II, which started this year. Furthermore, in a few years, a B-physics plan is eagerly expected to be realized as PHASE-III. In these experiments, additional positron beams are required in order to save injection time; especially, the B-Physics plan requires roughly ten times as many positrons as the present beam produces. To meet such requirements, an integrated upgrade is necessary for the injector linac (e.g., to increase the primary electron energy, etc.); improvements of the positron focusing system started first.

## Present Status

The 2.5-GeV linac injects positrons to both TRISTAN and PF. For PF, a 40-ns beam is used instead of the 2-ns beam for TRISTAN, because a single-bunch beam is not required for PF at present and it is advantageous for both increasing the charge number and suppressing the space-charge effect. These two kinds of beams are accelerated by switching a gun-grid pulser and by turning on/off a 119-MHz subharmonic buncher (SHB). The operational parameters of the positron generator are summarized in Table 1.

TABLE 1
Operational Parameters of the Positron Generator

| | | |
|---|---|---|
| General | | |
| Acceleration frequency | 2856 | MHz |
| Pulse repetition | 25 | Hz |
| Primary electron linac | | |
| Energy | 250 | MeV |
| Peak current | 10(2) | A |
| Pulse width | 2(40) | ns |
| Emittance | 0.05 | πMeV/c cm |
| Electron-to-positron converter | | |
| Radiator(thickness) | tantalum | 8.2 mm |
| Pulsed solenoid | QWT | type |
| Conversion rate | 0.3 | % |
| Positron beams | | |
| Peak current at 250 MeV | 30(6) | mA |
| Peak current at 2.5 GeV | 15(2) | mA |
| Energy spread at 2.5GeV | 0.5(0.8) | % at FWHM |
| Emittance | 0.15 | πMeV/c cm |

( ): positrons for PF

Figure 2 shows a typical display of the injection time for TRISTAN and PF, respectively. Under routine TRISTAN operation, every 2-2.5 hours the colliding beams are renewed. A current of 12 mA ($e^+$, $e^-$ x 2 bunch, 3 mA each) is stored and accelerated in the colliding ring (main ring MR, circumstance c = 3018 m) through the accumulator ring (AR, c = 381 m). During the setup time (30-40 minutes) for the colliding beam, the linac spends 4-6 minutes for four injections of the positron beam and <1 minutes for an electron beam.

For the PF 2.5-GeV storage ring (c = 187 m), the linac injects a positron beam of up to 350 mA every 12 hours and, sometimes, every 24 hours. Because of the full-energy injection, only the loss current is quickly filled up. After a short adjustment of the linac beam, the linac completes the injection within 5-6 minutes. In the case of the initial fill from the vacancy, it takes < 20 minutes.

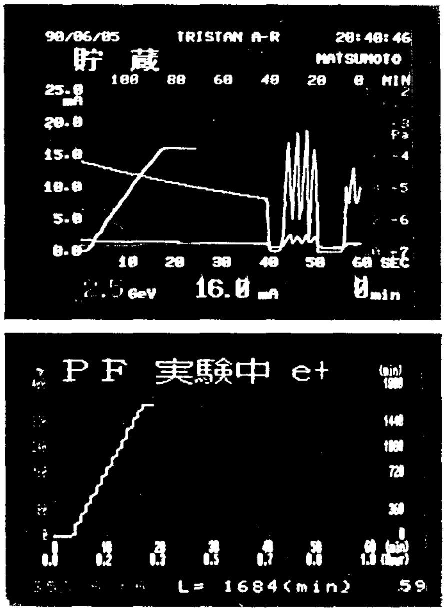

Fig. 2. Display for injections to TRISTAN and PF

## Reinforcement Plan

### General Feature of the QWT-type Focusing

The specific positron yield, n, for primary electrons striking a radiator with an energy E is approximately (for the forward angle) given by

$$n/E = (d^2n/Ed\Omega dP)\ \delta\Omega\ \delta P,$$

where $d^2n/Ed\Omega dP$ is the measured specific yield at 0° (e.g., $0.24\times10^{-3}(1-(25/E(\mathrm{MeV})))^2$; $\delta\Omega$ and $\delta P$ are, respectively, the solid angle and the momentum width of the positrons acceptable by the focusing system. Hence, assuming that both E and $d^2n/Ed\Omega dP$ are constant, the positron yield depends on parameters $\delta\Omega$ and $\delta P$, which are determined by the positron focusing system.

The KEK positron generator adopts the QWT-type focusing system as shown in Fig. 3. A strong axial field, Bi(effective length L), just behind the radiator is produced by a pulsed solenoid; it is followed by a lower field, Bf, applied over the accelerator sections.

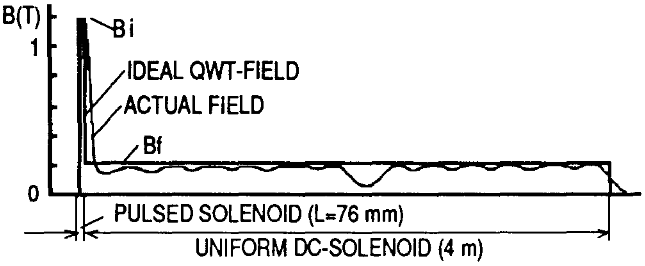

Fig. 3. Field distribution of the positron focusing system.

Using the analytical expression for the QWT system [3], and assuming that the accelerator aperture, a, is constant, the proportionality between the focusing system parameters and the field parameters are represented as follows:

| | |
|---|---|
| (Admittance) | $U \propto Bf$ |
| (Matched beam on the positron radiator) | |
| radius | $x \propto Bf/Bi$ |
| transverse momentum | $p \propto U/x \propto Bi$ |
| longitudinal momentum | $P \propto BiL$ |
| (Positron acceptance and yield) | |
| solid angle | $\delta\Omega \propto (p/P)^2 \propto L^{-2}$ |
| momentum acceptance | $\delta P \propto PBf/Bi \propto BfL$ |
| positron yield | $n \propto \delta\Omega\delta P \propto Bf/L$ |

The above expressions make the problem clear:
(1) For a larger solid angle, it is necessary to fabricate a shorter pulsed solenoid. The strength, Bi (times L), determines the acceptable positron momentum, P. It is preferable that Bi is higher, since it suppresses any debunching effects due to speed and orbit differences of positrons.
(2) For a wider momentum acceptance, it is effective to make Bf stronger.
(3) The positron yield is proportional to Bf/L.
Adding to these features, the following should also be taken into account:
(4) As the solid angle becomes larger, the positron production cross section decreases with a rough dependence of $\exp(-\theta/0.35)$, where $\theta$ is the positron production angle, p/P.
(5) A larger Bf increases the debunching effect of the orbit difference.

## Reinforcement Schedule

A reinforcement of the KEK positron generator focusing system will be performed, dividing it into two stages (Table 2). At first, using the present pulsed solenoid, the solenoid field Bf will be reinforced from 0.2 to 0.4 T. In this condition, though the solid angle is not changed, the momentum acceptance increases. As for the matching condition of the beam on the radiator, the beam radius may be twice as large as the present radius; this means that the beam adjustment on the target becomes rather easy. One problem to be discussed is debunching due to orbit differences; assuming that the accelerator gradient, dP/dz, and Bf are constant, the phase slip is given by [3]

$$\delta\phi = (\pi/\lambda) \int (p/P)^2 \, dz = (\pi/\lambda)(p^2/(PdP/dz)).$$

The maximum transverse momentum in a field Bf is calculated by $U/\pi a$. Substituting 0.43 MeV/c, 8.7 MeV/c, 10 MeV/c/m, and 0.105 m into p, P, dP/dz, $\lambda$, respectively, one finds that $\delta\phi$ is $0.02\pi$, i.e., 3.6°. This phase slip may be within a tolerance.

**TABLE 2**
**Parameter Change of the QWT System**

| | Present | Step 1 | Step 2 |
|---|---|---|---|
| Solenoidal field | | | |
| pulsed solenoid Bi(T) | 1.2 | -----> | 2.0 |
| effective length L(mm) | 76 | -----> | 50 |
| DC solenoid Bf(T) | 0.2 | 0.4 | 0.4 |
| Acceptance | | | |
| U(πMeV/c cm) | 0.15 | 0.30 | 0.30 |
| Matched beam on the radiator | | | |
| radius x(cm) | <0.12 | <0.24 | <0.14 |
| momentum P(MeV/c) | 8.7 | -----> | 9.5 |
| transverse momentum p(MeV/c) | 1.25 | -----> | 2.1 |
| Positron yield (relative values) | | | |
| solid angle dW | 1 | -----> | 2.3 |
| momentum acceptance dP | 1 | 2 | 1.3 |
| specific yield n/E | 1 | 2 | 2.4 |

In the next stage the pulsed solenoid will be improved. The pulsed solenoid of the KEK positron generator was fabricated while considering that of DESY [1]; to avoid any accidents, it was modified so that the water-cooled coil is installed outside of the vacuum. Consequently, it has become more difficult to make a compact coil. Improvement of the pulsed coil will be carried out gradually.

## Design of the Focusing System

By increasing Bf, the acceptance of the focusing system will become 0.3 πMeV/c.cm, twice as large as before; to obtain this acceptance over the entire accelerator length, not only a uniform solenoid for producing Bf, but the downstream quadrupole magnet system will also be reconstructed. Figure 4 shows an illustration of the new focusing system as well as an example of the calculated matched beam. In the new system, the uniform solenoid installed over the accelerator section is extended from 4 to 8 m. In order to monitor the positron current, an $e^+/e^-$ separator comprising of an achromatic bending system is introduced at the exit of the solenoid, since electrons which also emerge from the radiator are transported as well as the positrons. Downstream of the solenoid system, first, a quadrupole-singlet system (FODO-system) is applied over the accelerator sections and then periodic quadrupole triplets are set between the accelerator sections.

## References

1. A. Enomoto et al., "FOCUSING SYSTEM OF THE KEK POSITRON GENERATOR", NIM A281 (1989) 1-9.
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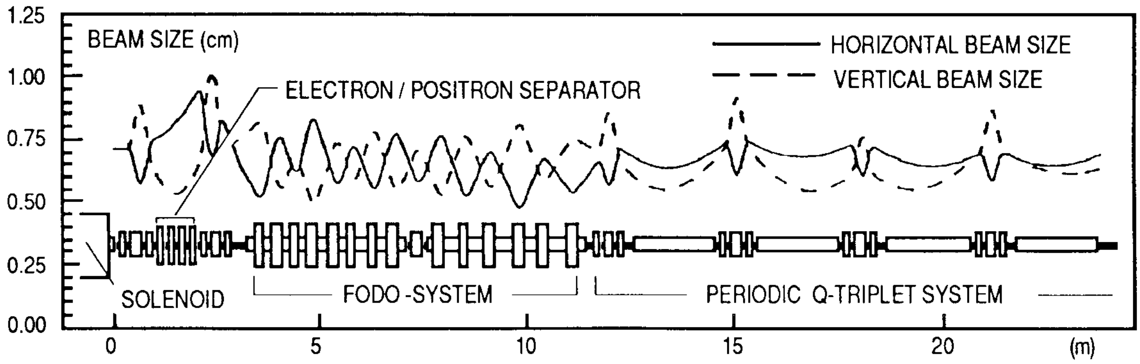

Fig. 4. The new configuration of the reinforced positron generator focusing system and calculation of the matched beam using the computer code TRANSPORT.