EE

KEK Preprint 94-23
May 1994
A/M

The KEK Slow-Positron Source

T. SHIDARA, A. ENOMOTO, T. KAMITANI, H. KOBAYASHI, T. KURIHARA,
A. SHIRAKAWA, H. HIRAYAMA, I. KANAZAWA,
A. ASAMI and K. NAKAHARA

*Contributed to the 10th International Conference on Positron Annihilation,
Beijing, The People's Republic of China, May 23 - 29, 1994.*

National Laboratory for High Energy Physics, 1994

KEK Reports are available from:

Technical Information & Library
National Laboratory for High Energy Physics
1-1 Oho, Tsukuba-shi
Ibaraki-ken, 305
JAPAN

Phone: 0298-64-1171
Telex: 3652-534 (Domestic)
(0)3652-534 (International)
Fax: 0298-64-4604
Cable: KEK OHO
E-mail: LIBRARY@JPNKEKVX (Bitnet Address)
library@kekvax.kek.jp (Internet Address)

THE KEK SLOW-POSITRON SOURCE

TETSUO SHIDARA[1], ATSUSHI ENOMOTO[1], TAKUYA KAMITANI[1], HITOSHI KOBAYASHI[1], TOSHIKAZU KURIHARA[1], AKIHIRO SHIRAKAWA[1], HIDEO HIRAYAMA[2], IKUZO KANAZAWA[3], AKIRA ASAMI[4] AND KAZUO NAKAHARA[1]

[1]Photon Factory, KEK, National Laboratory for High Energy Physics, Oho, Tsukuba, Ibaraki 305, Japan

[2]Radiation Safety Control Center, KEK, National Laboratory for High Energy Physics, Oho, Tsukuba, Ibaraki 305, Japan

[3]Faculty of Education , Tokyo Gakugei University, Koganei, Tokyo 184, Japan

[4]Naruto University of Education, Naruto, Tokushima 772, Japan

Keywords: slow positron source, electron linac, positron beams

ABSTRACT

The KEK slow-positron source is in the final stage of construction. More than 10^9 e^+/s slow-positrons are expected utilizing the PF 2.5-GeV electron linac as its primary beam source.

A slow-positron beam, which is produced by bombarding a target assembly (a water-cooled tantalum rod of 5 radiation lengths and a moderator with multiple tungsten vanes), is directed by a 30-m beam-transport system to an experimental area through a 2.5-m thick radiation shield floor. A high-voltage station capable of applying 60 kV is installed in the beam transport system in order to vary the energy of the positron beam for depth-profile measurements. A Penning-trap system is planned in order to convert the pulse characteristics of the beam to a dc beam. The brightness enhancement of the positron beam for positron reemission microscope experiments is also planned at the experimental area.

At a preliminary test with a 2.0-GeV, 2-kW primary beam, 4×10^6 e^+/s slow positrons were observed by detecting annihilation γ-rays at the end of the beam-transport line. Further improvements are expected by careful chemical and thermal treatments of the moderator.

INTRODUCTION

In recent years, there has been increasing interest in the use of slow-positron beams (ranging from eV to keV) in various fields of solid state physics. The advantage of utilizing positron beams is in its simpler interactions with matter in contrast to low-energy electrons. For example, the interpretation of low-energy electron diffraction (LEED) requires extensive computations, whereas that of low-energy positron diffraction (LEPD) is simple owing to the absence of any exchange forces. However, LEPD might not be a practical method due to its poor intensity obtained from a radioactive-isotope-based positron source.

In conventional laboratories, the slow-positron intensity is restricted to 10^6 e^+/s by the strength of the available radioactive source. Although a reactor-based slow-positron source is possible to increase the intensity by more than two orders of magnitude, it requires difficult technical efforts. An accelerator-based source is another candidate which would enable an increase in the slow-positron intensity [1-6]. Since our PF 2.5-GeV electron linac [7, 8] is one of the strongest linear accelerators in the world, we started construction of the KEK slow-positron source from FY 1991, aiming to produce more than 10^9 e^+/s slow positrons utilizing this linac as its primary beam source [9].

We present here the almost completed KEK slow-positron source and its performance tests as well as its future plan.

LAYOUT OF THE KEK SLOW-POSITRON SOURCE

The KEK slow-positron source comprises a beam line for the primary electron beam, a target-moderator assembly, a slow-positron beam-transport line and relevant assemblies.

Figure 1 shows the reconstructed beam lines in the beam switchyard at the end of the PF 2.5-GeV linac. The primary electron beam is injected into the target through an achromatic beam-transport line comprising two 18° deflecting magnets and a quadrupole magnet. Although the nominal beam power of the PF 2.5-GeV linac is 6.25 kW (an energy of 2.5 GeV, a peak current of 50 mA, a pulse length of 1 μs and a pulse repetition rate of 50 pulse/s), an average beam power of 30 kW can be obtained from this linac [8].

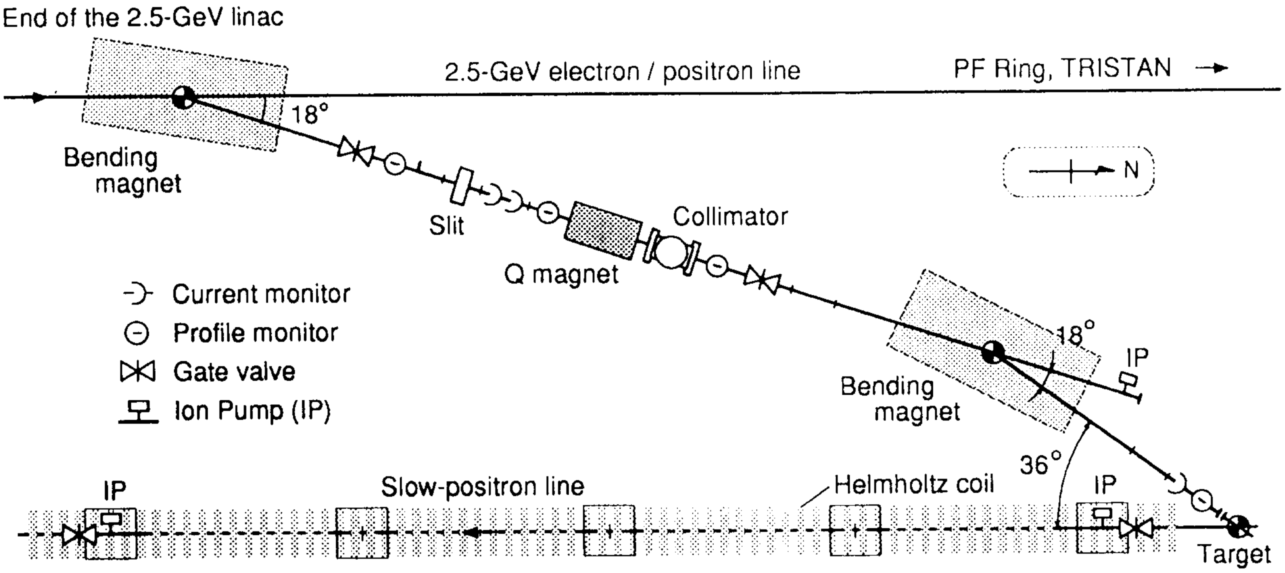

Fig. 1 Reconstructed beam lines at the beam switchyard of the PF 2.5-GeV linac.

The target-moderator assembly comprises a water-cooled tantalum rod of 5 radiation lengths and a moderator with multiple tungsten vanes (thirteen 25-μm thick sheets). Electrostatic focusing grids are located just above the moderator. The most efficient target thickness for an incident electron energy of 2.5 GeV was derived using the EGS4 Code [10, 11]. According to the calculated energy spectra of positrons emitted from tantalum targets [12], we estimated the slow-positron beam intensity to be 2×10^9 e^+/s with a full beam power of 30 kW [9].

The extracted slow-positron beam is directed by a 30-m long beam-transport line with an axial magnetic field of 100 G to an experimental area at the ground level through a 2.5-m thick radiation shield floor. A high-voltage station capable of applying 60 kV was installed in the initial part of the beam-transport line in order to vary the energy of the positron beam dedicated to depth-profile measurements (figure 2). A device controller, combining a personal computer and a programmable sequence controller through optical fiber, is adopted in order to control the monitors and power supplies at a high-voltage potential. Penning-trap electrodes are also installed at this station in order to reduce the velocity of positrons for making a dc beam from a pulsed beam with a limited length.

A brightness-enhancement stage for microbeam use, especially for positron reemission microscope experiments, is installed at the end of the slow-positron beam-transport line. Details are described in a separate paper.

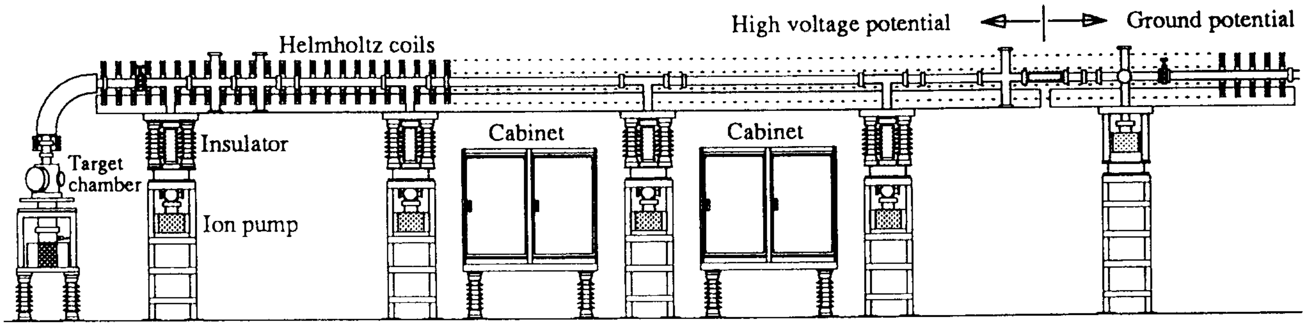

Fig. 2 Slow-positron beam line at high voltage.

As for beam monitors, channel-electron multipliers (CEM) for the beam intensity and micro-channel plates (MCP) for the beam profile are intensively used.

PERFORMANCE TESTS

Since the construction of the KEK slow-positron source had been almost completed, we started its performance tests. At the initial stage, a slightly low-power primary beam of 10 W (an energy of 2.0 GeV, a pulse length of 2 ns and a repetition rate of 25 pulse/s) was used in order to refrain from radioactivating the target circumference. The proper trajectory of the slow-positron beam was achieved by adjusting 20 sets of steering coils along the beam-transport line with the help of CEM and MCP monitors. The positron intensity at the end of the transport line was estimated by detecting annihilation γ-rays utilizing a BGO scintillator with a photomultiplier tube (HAMAMATSU H2611). 4×10^4 e^+/s slow positrons were observed. The observed positron yield was 1/20 of the estimated value [9]. This might be due to the condition of the moderator, since we put the moderator into the target-moderator chamber without any thermal treatment.

The energy spectrum of the transported slow positrons was estimated by differentiating the curve of the annihilation γ-ray counts versus the potential of the retardation grid located in front of the annihilation target (figure 3). Its energy spectrum shows a peak at 370 eV, which reflects an applied target potential of 400 V. The width of the peak mainly results from the sizable distribution of the positron momentum perpendicular to the beam-line axis.

After achieving a proper slow-positron trajectory, a primary beam of 2 kW (with an energy of 2.2 GeV, a pulse length of 0.8 µs, a peak current of 48 mA and a pulse repetition rate of 25 pulse/s) was directed to the target-moderator assembly; 4×10^6 e^+/s slow positrons were observed at the end of the slow-

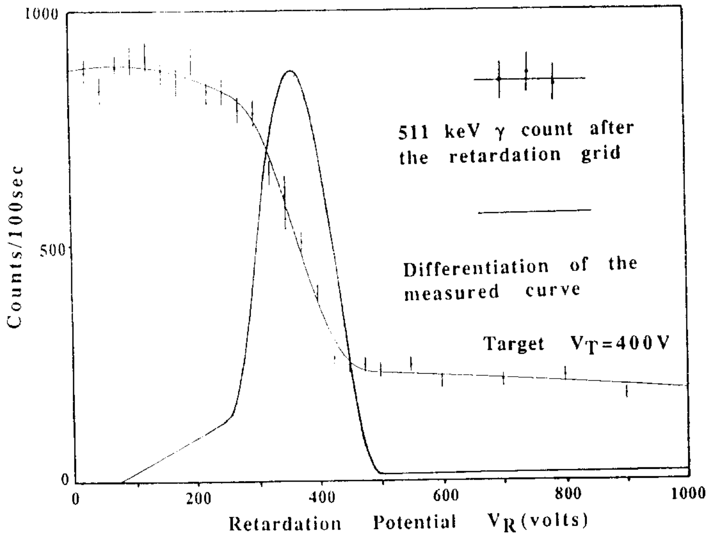

Fig. 3 Energy spectrum of the transported slow-positron beam.

positron beam-transport line. During irradiation of the 2 kW beam, the vacuum pressure of the target-moderator chamber increased up to 1 × 10^4 Pa. Further treatment; such as baking or long-term irradiation of the assembly, is being awaited.

FUTURE PLAN

Improvement in the positron yield has first priority. A careful thermal treatment of the moderator assembly is inevitable. The power of the primary electron beam will then be gradually increased up to 30 kW in order to obtain the designed intensity of 2 × 10^9 e^+/s.

Since we have already achieved a positron intensity of 4 × 10^6 e^+/s in our slow-positron source, we have opened this facility to slow-positron users. Fortunately, since KEK is the first inter-university research institute in Japan, the circumstances for users are excellent. We are, therefore, planning to install a slow-positron beam switch system capable of supplying slow-positron beams to several experimental stations one by one.

CONCLUSION

The KEK slow-positron source is almost completed. During a preliminary test, slow positrons of 4 × 10^6 e^+/s were obtained. Although further improvements are being awaited, we have already opened this facility to slow-positron users.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude for the encouragement and support received from Director General, Prof. H. Sugawara as well as the staff of the KEK administration department in initiating this project. We are also indebted to N. Ohshima of Tokyo Gakugei University for his assistance. The staff of the PF 2.5-GeV linac is also acknowledged for machine operation, especially Prof. H. Iwasaki and Prof. I. Sato for their continuous encouragement.

REFERENCES

1) R. H. Howell, R. A. Alvarez and M. Stanek, Appl. Phys. Lett. 40, 751 (1982).
2) R. Ley, K. D. Niebling, A. Osipowicz, A. Picard and G. Werth, Proc. 7th Int. Conf. on Positron Annihilation, New Delhi, 1985, eds. P. C. Jain, R. M. Singru and K. P. Gopinathan (World Scientific, Singapore), 996 (1985).
3) L. D. Hulett, Jr., T. A. Lewis, D. L. Donohue and A. Pendyala, Proc. 8th Int. Conf. on Positron Annihilation, Gent, 1988, eds. L. Dorikens-Vanpraet, M. Dorikens and D. Segers (World Scientific, Singapore), 586 (1989).
4) T. Akahane, T. Chiba, N. Shiotani, S. Tanigawa, T. Mikado, R. Suzuki, M. Chiwaki, T. Yamazaki and T. Tomimasu, Appl. Phys. A51, 146 (1990).
5) R. Suzuki, Y. Kobayashi, T. Mikado, H. Ohgaki, M. Chiwaki and T. Yamazaki, Proc. 9th Symp. on Accelerator Science and Technology, Tsukuba, 237 (1993).
6) Y. Itoh, M. Hirose, S. Takamura, O. Sueoka, I. Kanazawa, K. Mashiko, A. Ichimiya, Y. Murata, S. Okada, M. Hasegawa and T. Hyodo, Nucl. Instr. Meth., A305, 269 (1991).
7) J. Tanaka, Nucl. Instr. Meth., 177, 101 (1980).
8) I. Sato, Nucl. Instr. Meth., 177, 91 (1980).
9) A, Asami, et al., Materials Science Forum 105-110, 1833 (1992).
10) W. R. Nelson, H. Hirayama and D. W. O. Rogers, SLAC-265 (1985).
11) H. Hirayama, KEK Internal, 89-17 (1990).
12) H. Hirayama, Proc. 2nd Workshop on Researches Using Positrons, Tokyo, 1991 (JAERI Takasaki), 60 (1991).