GENERATION AND CONTROL OF AN INTENSE SLOW POSITRON BEAM

R. Suzuki, T. Ohdaira, T. Mikado, H. Ohgaki,
M. Chiwaki and T. Yamazaki

Electrotechnical Laboratory, 1-1-4 Umezono,
Tsukuba, Ibaraki 305, Japan

Abstract

An intense slow positron beam-line was constructed at the Electrotechnical Laboratory in order to carry out various experiments on materials researches. The beam-line can generate a short pulsed positron beam of variable energy and of variable pulse period, which is used for variable-energy positron lifetime measurements and time-of-flight experiments. In this paper, we discuss the generation and control of the slow positron beam.

Introduction

Slow or monoenergetic positrons are known to be a powerful probe to study surface phenomena and microstructural properties in various materials. In 1987, an intense slow positron beam-line has been constructed at the linac facility of the Electrotechnical Laboratory (ETL) for materials researches [1]. The beam-line generates a slow positron beam with high intensity from a high energy electron beam of the ETL linac.

In order to perform experiments using the intense slow positron beam, such as positron lifetime spectroscopy, time of flight (TOF) measurements of secondary emitted particles, etc., we have developed a pulsing system which generates a pulsed positron beam of variable energy (0 - 30 keV) and of variable pulse period. By using the pulsed slow positron beam, we have successfully studied various sample properties by means of positron lifetime spectroscopy and time-of-flight (TOF) experiments [2].

In this paper, we discuss the generation of the intense pulsed positron beam, control and measurement system, and a new positron beam-line.

Generation of an Intense Slow Positron Beam

An intense slow positron beam of ~1×10^8 positron/s at the maximum is produced from a high energy electron beam (~70 MeV, 1 μs, 100 pps) of the low energy branch of the ETL linac with a Ta-converter and W-moderator. The positron beam is initially a pulsed beam corresponding to the linac pulse. However, the repetition rate of the linac is too low and the pulse width is too wide for high count-rate positron lifetime measurements and TOF experiments. Furthermore, relatively high energy positrons included in the initial beam affects worsening of the resolution and background component.

In order to eliminate these problems, the positrons are stored temporarily in a linear-storage section as shown in Fig. 1. The linear storage section (LSS) uses two grids for the storage [3]. The positron beam is storaged in the LSS by rapidly rising the potential of the grids when the beam entered the LSS. Then, we can obtain time-stretched positron beam by gradually reducing the potential of the exit grid. The time-stretched positron beam is used for the pulsing system.

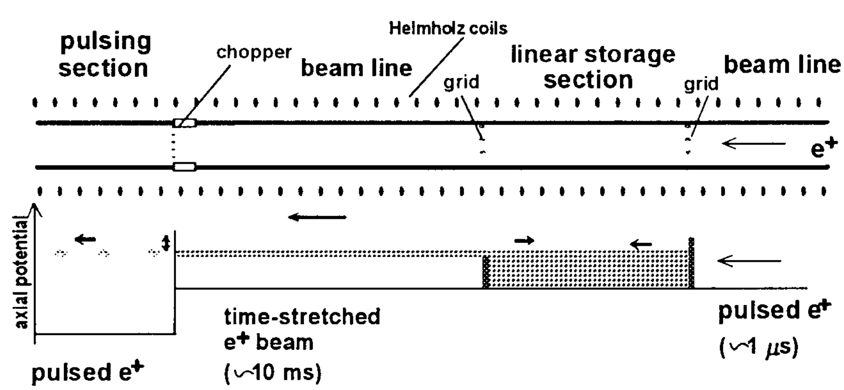

Fig. 1. Presently installed linear storage section

Positron Pulsing System

The pulsing system consists of three main devices; a chopper, a sub-harmonic pre-buncher (SHPB) and a buncher [4] as shown in Fig. 2. The chopper generates a pulsed beam (~5 ns, ~300 eV) from the time-stretched beam. The SHPB compresses the pulse width of the chopped beam to ~1 ns at the buncher, and then the buncher further compresses the pulse width to about 100 ps at the sample position. The fundamental frequency of the buncher, f_B, is ~150 MHz, the operating frequency of the SHPB is a quarter of the fundamental frequency, and the chopper frequency is variable: $f_B/(4n)$, (n=1, 2, ...).

As a result, the positron pulsing system generates a pulsed beam with high intensity, variable energy and variable pulse period. A positron lifetime spectrum can be obtained by measuring the time interval between the timing signal of the pulsing system and timing signal of an annihilation γ-ray detected with a BaF_2 scintillation detector.

Remote Control and Data Acquisition

Since we must simultaneously adjust both the parameters of the electron linac and the parameters of the pulsing system in the experiments, we have developed a remote control system which is connected to the Ethernet LAN. The control system provides remote and automatic control of high voltage power supply and pulsing devices.

In order to realize high count rate measurements, a multi-channel buffer, which consists of programmable application specific IC and 1 Mbit RAM, was installed in the system. By the use of this buffer, the dead time due to analog-to-digital converter has been reduced from ~100 μs to 4 μs [5].

Present Status of the Positron Beam

The pulsing system enables us to perform positron lifetime measurements with high resolution and high count rate. Figure 3 shows the positron lifetime spectra at the maximum resolution and at the maximum count rate.

In the spectrum at the maximum count rate, there exists a relatively large background component due to unbunched positrons at the buncher of the pulsing system. Furthermore, the resolution at the maximum count rate (328 ps) is significantly less than that at the maximum resolution (192 ps).

The worsening of the resolution and background is mainly due to the large energy spread of the positron beam. The energy spread affects more seriously to the TOF experiments since the energy of pulsed positrons for the TOF experiments (10 - 50 eV) is lower than that for the lifetime experiments (0.5 - 30 keV).

To realize high count-rate positron lifetime spectroscopy and TOF measurements with high time resolution, a narrowing of the energy spread of the positron beam is required. The large energy spread mainly arises from the LSS (Fig. 1) since the energy of the positron beam is conserved in the LSS [5].

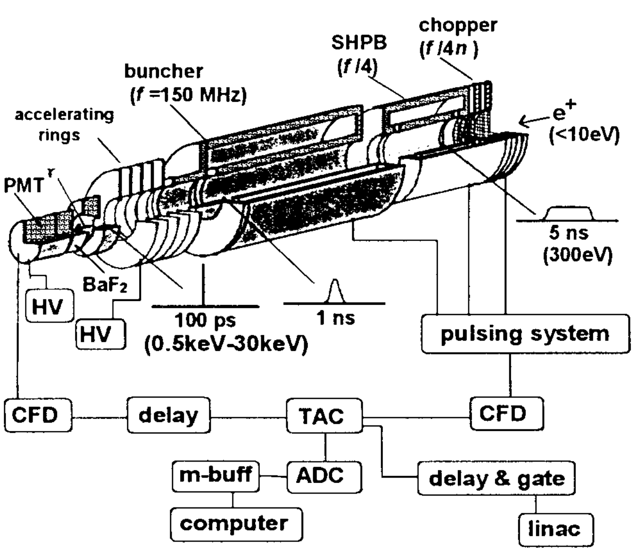

Fig. 2. Positron pulsing system and positron lifetime measurement system.

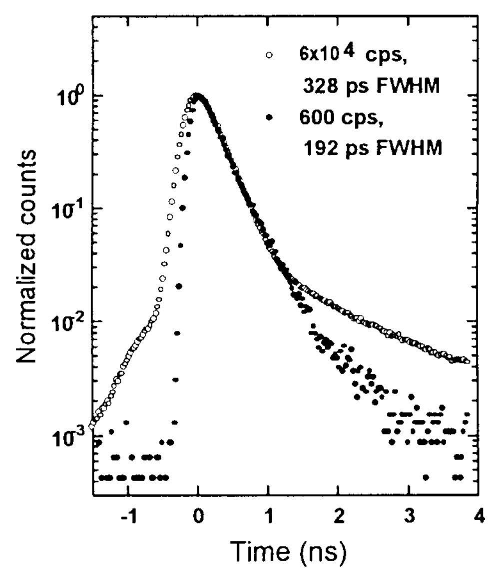

Fig. 3. Positron lifetime spectra measured at the maximum count rate and at the maximum resolution.

New Intense Slow Positron Beam-Line

To generate a low energy spread positron beam, we have a plan to construct a new positron beam-line as shown in Fig. 4. In this beam-line, a re-designed LSS as shown in Fig. 5 will be installed. In the case of this configuration, the positrons are stored in a tube which is isolated from the beam-line. The potential of the tube is suddenly dropped when the ~1 μs pulsed positron beam enters the tube, and the potential is then gradually increased. If the potential of the beam-line of the downstream side is lower than that of the upstream side, positrons are extracted to the pulsing system. If the increasing rate of the tube voltage is sufficiently low, we can produce very low energy-spread positron beam [5].

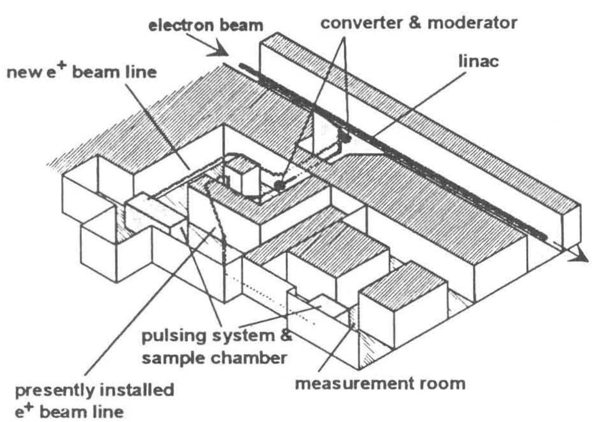

Fig. 4. Intense slow positron beam-line at the ETL.

Conclusion

We have described the generation and control of an intense slow positron beam. The intense pulsed positron beam has enabled us to perform variable-energy positron lifetime spectroscopy and TOF experiments. The new positron beam-line will provide high resolution and high count rate measurements.

References

[1] T. Mikado, R. Suzuki, M. Chiwaki, T. Yamazaki, N. Hayashi, T. Tomimasu, S. Tanigawa, T. Chiba, T. Akahane and N. Shiotani, Proc. 3rd Japan-China Joint Symp. Accelerators for Nuclear Science and Their Applications (Riken, Wako, 1987) p. 163.

[2] R. Suzuki, T. Mikado, H. Ohgaki, M. Chiwaki, T. Yamazaki, and Y. Kobayashi, AIP Conference Proceedings 303 (AIP, USA, 1994) p.526.

[3] T. Akahane, T. Chiba, N. Shiotani, S. Tanigawa, T. Mikado, R. Suzuki, M. Chiwaki, T. Yamazaki and T. Tomimasu, Appl. Phys. A 51 (1990) 146.

[4] R. Suzuki, Y. Kobayashi, T. Mikado, H. Ohgaki, M. Chiwaki, T. Yamazaki and T. Tomimasu, Positrons at Metallic Surfaces, ed. A.Ishii, (Trans. Tech Publ. Ltd., Switzerland, 1993) p.365.

[5] R. Suzuki, T. Mikado, H. Ohgaki, M. Chiwaki and T. Yamazaki, to be published in Proc. 6th SLOPOS Workshop.

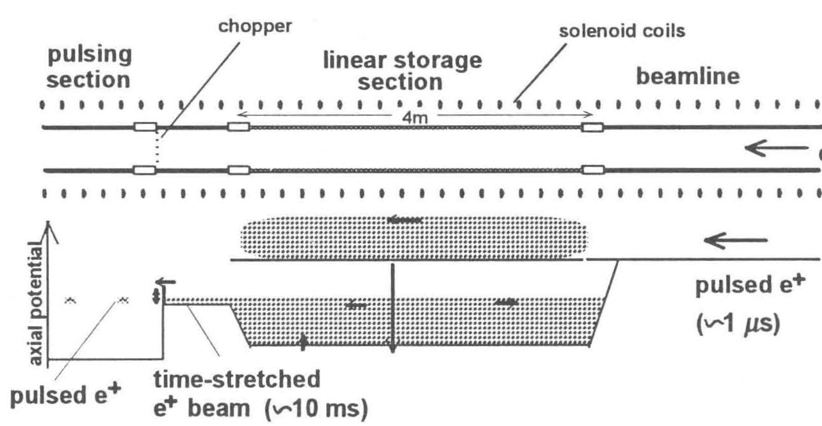

Fig. 5. The linear storage section which will be installed in the new beam-line.