Development of The Slow Positron Beam at ISIR in Osaka University

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Abstract

A new slow positron beamline has been constructed at the end of the beamline to supply two kinds of beams for several experiments; the one is short pulsed beam and the other is high brightness beam. In this paper, the design and preliminary experiment using these beams are mainly presented.

1. Introduction

A slow positron beam has been produced using an electron linear accelerator, where the usual energy is about 100MeV, the current is about 400mA and the repetition is 30Hz, and the produced positrons are transported with about 1cm diameter to the experimental room along the magnetic field line. Several applications are considered such as PALS, RHEPD, positronium spectroscopy and so on. In these applications, the positrons would be stored and bunched and those would be extracted from the magnetic transport system and electrostatically focused on the remoderator to obtain a high brightness beam. The mean transport energy of positrons is usually around 1 keV and its dispersion is a few hundreds eV. The transport energy corresponds to the extraction voltage from the moderator and this is the best condition in our facility. The high transport energy makes the storing efficiency worse and requires long Penning trap. The wide energy spread introduces aberration in the electrostatic transport system which follows the extraction system and high transport energy makes the applied voltage to the electrostatic lens higher. To avoid these defects, the remoderator was equipped in the magnetic transport system[1] and we could obtain qualified positron beam with low transport energy and small energy spread. The new beamline with two beam ports which would supply pulsed beam and high brightness beam, was developed. In following sections, the brightness enhancement experiment and bunching experiment using the new beamline are shown.

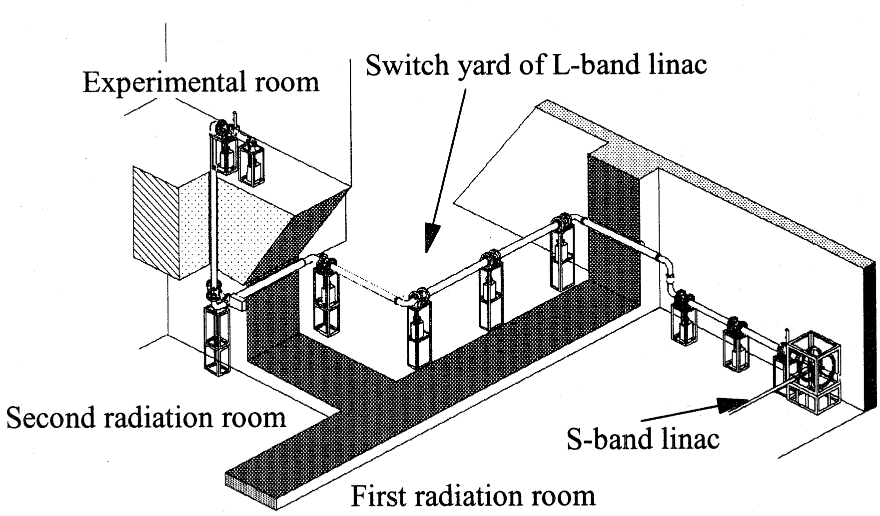

Figure 1. Schematics of the slow positron beamline.

2. Experimental setup

The schematic drawing of the slow positron beamline is shown in Fig. 1. The positrons were produced by the electron linac and travel to the experimental room. The whole distance from the production area to experimental room was about 30 m. The beamline in the experimental room is shown in Fig. 2. In the middle of the higher beamline denoted by the large Helmholtz coils, the beamline switch was equipped.

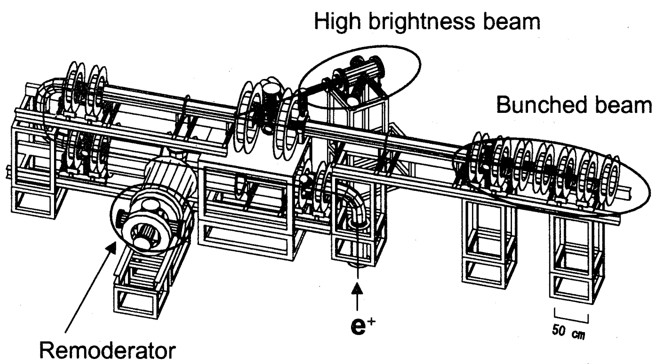

Figure 2. Schematics of the beamline in the experimental room.

3. Brightness enhancement experiment

The brightness enhancement experiment was carried out. The positrons were extracted from the magnetic transport system and electrostatically focused on the remoderator. In the preliminary experiment, several electrodes were used to suppress beam divergence. In this experiment, the final beam diameter could be reduced to about 0.5mm. However, the total transport efficiency from magnetic field region to the sample was 0.2 %. It was thought with the aid of calculation that many positrons died in the electrostatic transport system especially in the vicinity of the remoderator. As the main reason came from the fact that the extracted beam had a great divergence angle according to the consevation of anonical angular momentum, the effect originating fringing field of both magnetic lenses and electric lenses should be taken into account. By considering these points, a new transport system was designed. In the design, we took experimentally measured beam parameters, which were presented in section 1, as the initial beam ones. As the region between the exit of the magnetic transport system and the remoderator, includes both electric and magnetic field regions, we assumed paraxial approximation and that the magnetic and the electric field distributions followed analytical function.

The results showed that the one set of Einzel lens system was enough and the diameter of the beam on the remoderator was about 4 cm and focusing angle was within 20 degrees. According to these results, the new focusing system was constructed. In Fig.3, the experimental setup and the results are shown. In this experiment, the observed beam on the remoderator was shifted and rather diverged, however, the diameter was supposed to be several cm. The transport efficiency was about 35 % which was evaluated by measuring annihilation γ-rays coming from the MCP. As the parts of positrons were lost at bending section, which was a left corner in Fig.3, and also the parts of those arrived at MCP could not annihilate entirely, this efficiency will be improved by adjusting the beam position through the transport system.

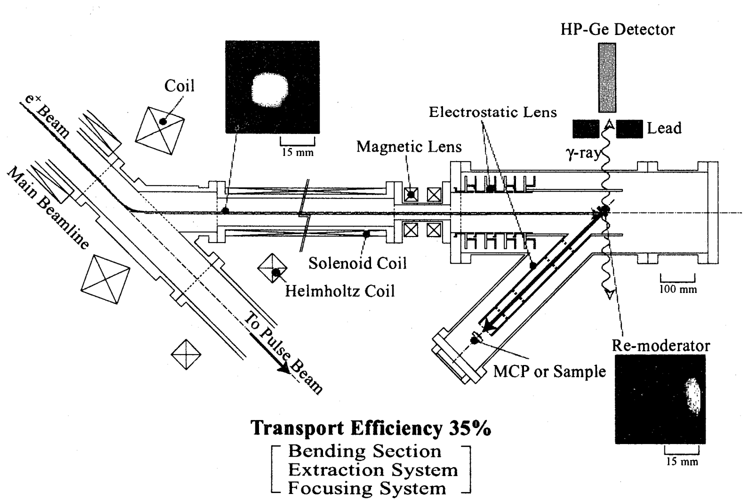

Figure 3. Experimental setup and data of the brightness enhancement experiment.

4. Bunching experiment

There are two ways to bunch the positron beam. The RF oscillator and the arbitrary waveform generator (AWG) are commonly used as a modulator of the transport energy of positrons.[2][3] To get intense bunched beam, AWG was adopted, since wider pulse width

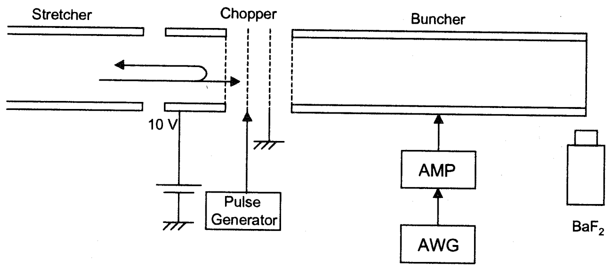

Figure 4. Schematics of the bunching system.

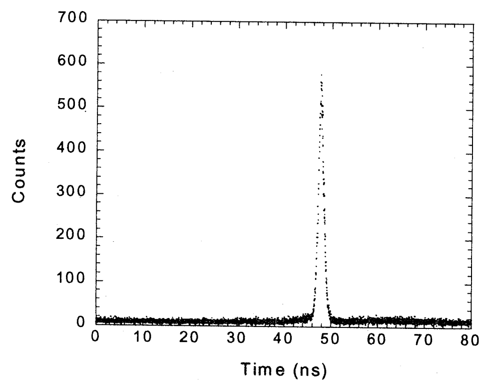

Figure 5. Time spectrum of the bunched positrons measured by annihilation γ-rays coming from aluminum plate.

would be available. To get high acquisition rate and well-bunched beam, the original pulsed positron beam would be stretched as long as possible and the energy spread should be reduced as small as possible. To realize this, Penning trap was inserted in the magnetic transport system, however, the present transport energy is too high to confine whole positrons in it. By equipping the remoderator in the magnetic transport system, the transport energy could be reduced to several eV. Schematic drawing of the bunching system is shown in Fig.4. During the stretching period, by increasing the potential of the electrode in the stretching section, some positrons with the energy above 10 V come out and the parts of these positrons are bunched by following electrodes. Third mesh was equipped for the sake of decoupling of the voltages applied to chopper and buncher. The time spectrum obtained in the experiment is shown in Fig.5. The operating conditions were as follows: pulse width = 20 ns, bunching period = 220 ns. This data was obtained by measuring the annihilation γ-rays coming from the aluminum plate. The FWHM of this spectrum was estimated as 1.3 ns. This value is not enough to use. This would be improved by optimization of the applied voltage to chopper and buncher and by taking impedance matching carefully.

5. Summary

A new slow positron beamline was constructed. This beamline had two branches and in each branch, bunched positron beam and high brightness beam would be produced. The remoderator in the magnetic field was also equipped in this beamline to adjust the transport energy. In the beamline for high brightness beam, the best conditions for the arrangement of electrodes and voltages were required to focus the beam on the remoderator with small radius. These parameters were found by evaluating the beam trajectories throughout the region between magnetic transport system and remoderator, in which both electric and magnetic field existed, and also the emittance at the remoderator. The obtained beam size at the remoderator was supposed to be close to estimated one. The transport efficiency was about 35%. This will be improved by adjusting magnetic field in the transport system. The bunching system was designed and constructed. The obtaied pulse width was about 1.3 ns. This width is not enough for use. The precise adjustment of the voltages applied to chopper and buncher, and the impedance matching will be required in further investigations.

References

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