Generation of Slow Positron Beam and Beam Bunching

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Abstract

Two items are described in this report. One is about the outline of our slow positron beam system, which has been fabricated as a commercial prototype. The other is about the calculation result of positron beam bunching, which will be an additional function to the system.

I. INTRODUCTION

Positron has a unique characteristic. It is very sensitive to material defects. Recently LSI scale is getting smaller and smaller. Silicon wafer and oxide layer for LSI are required to be free from defects and impurities. And material surface modifications, for example ion implantation, are going to become widespread in industries. Slow positron beam is applicable to the material defect analysis of these thin layers. Material fatigue is also a serious problem for nuclear power plants. Slow Positron is also effective to this.

We started the R&D of slow positron beam system from 1991. The construction was finished in 1992 and started Doppler Broadening Measurement. Now we are considering to produce bunched beam for Life Time Measurement. Several bunching systems are being operated in the world[1][2][3]. The design of bunching system must be is to make it compact and cheap for commerce.

II. CONFIGURATION OF SLOW POSITRON BEAM SYSTEM

The schematic diagram of our slow positron beam system is shown in Fig.1. The size is about 3.8mL x1.4mW x1.6mH. Positron source is a radioisotope, 22Na, and its activity is 185MBq. Fast positrons from 22Na is irradiated to Venetian blind type moderator, made of 25 μm tungsten ribbons. Extracted 10eV beam from the moderator is transported to the sample through EXB energy filter and accelerating tube. Beam

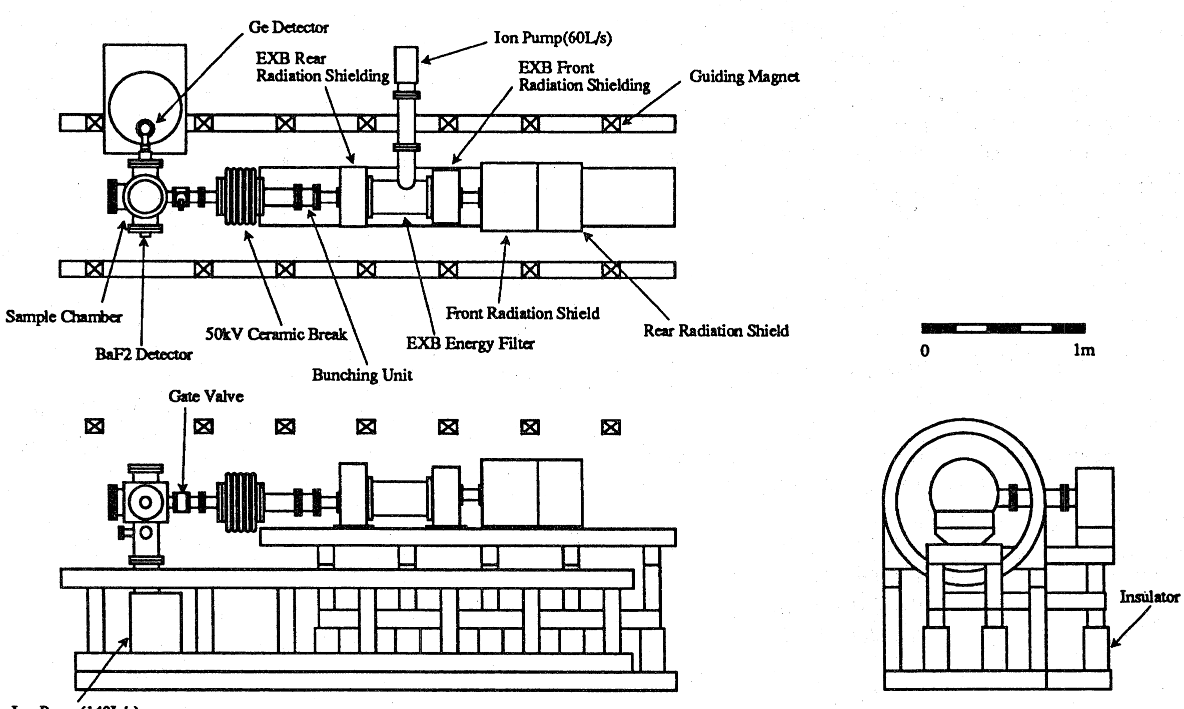

Fig.1 Schematic Diagram of Slow Positron Beam System

transportation from the moderator to the sample is by conventional 0.01 Tesla magnetic field. Maximum accelerating voltage is 50kV. Radioisotope is covered by minimum 13cm thickness lead shields, which are cast into the stainless steel cases. And two 11cm lead shields are located at the upstream and the downstream of EXB part. With these shields, maximum radiation rate at the outside of the focusing coil rings is 0.12 μSv/h. These shields are very heavy, but by pressurized air slider, it's easy to be moved. Two ion pumps are equipped at the EXB part and at the sample chamber.

III. Positron Beam Bunching System

A. Design Considerations

A bunching system will be installed between the EXB and the accelerating tube. The available space is about 470mm. And the distance from the end of the bunching system to the sample is about 700mm. The sample's potential is the ground level. The bunching system consists of a pulsing chopper, a pulsing buncher and an RF buncher. A two channel standard pulse generator will be used as the pulser. A signal generator and an RF amplifier will be used as the RF source. The pulsing chopper has three grids, the pulsing buncher has three grids and the RF buncher has two grids. In this report, the positron loss at grids is not considered. At the chopper, DC positron beam must be decelerated to around 3eV, because of the pulse height limit of the pulse generator. To minimize the growth of energy spread at the chopper, the distance between the second and the third grid is long. Fortunately it has a bunching effect also. The principle of the pulsing buncher is unique. The pulsed electric field is applied between two grids. A chopped beam comes in, and then an accelerating electric field is applied in a moment. The chopped beam is accelerated differently, depending on the position. The positrons of the head part are accelerated a little and the positrons of the tail part are accelerated much. Bunching can be realized by a pulsed electric field.

B. Bunching System

Bunching system layout is shown in Fig.2. The energy of input positron beam is 10eV, and it has some energy spread. The pulsing chopper has three grids(G1, G2, G3), and the pulsing buncher has three grids(G4, G5,G6). There are a drift space(DRFT) after the RF gap(GAP). Pulsing points are G2 and G5. The potentials of G1, G3, G4 and G6 are constant. RF electric field is only in the RF gap.

Input positron beam is decelerated to around 3eV at the chopper. Chopping pulse width of G2 is 10ns. While the G2 pulse is low, beam can pass and is chopped. When chopped beam comes between G4 and G5, G5 pulse gets low. And when chopped beam comes between G5 and G6, G5 pulse gets high. Chopped beam is bunched while moving from G4 to G6. When beam passes through RF gap, the bunch length is around 4ns. RF gap is 5mm and RF frequency is 50MHz. The length of drift space after RF gap is 100mm.

C. Input Positron Beam Quality

Energy spread characteristic of the input 10eV beam is

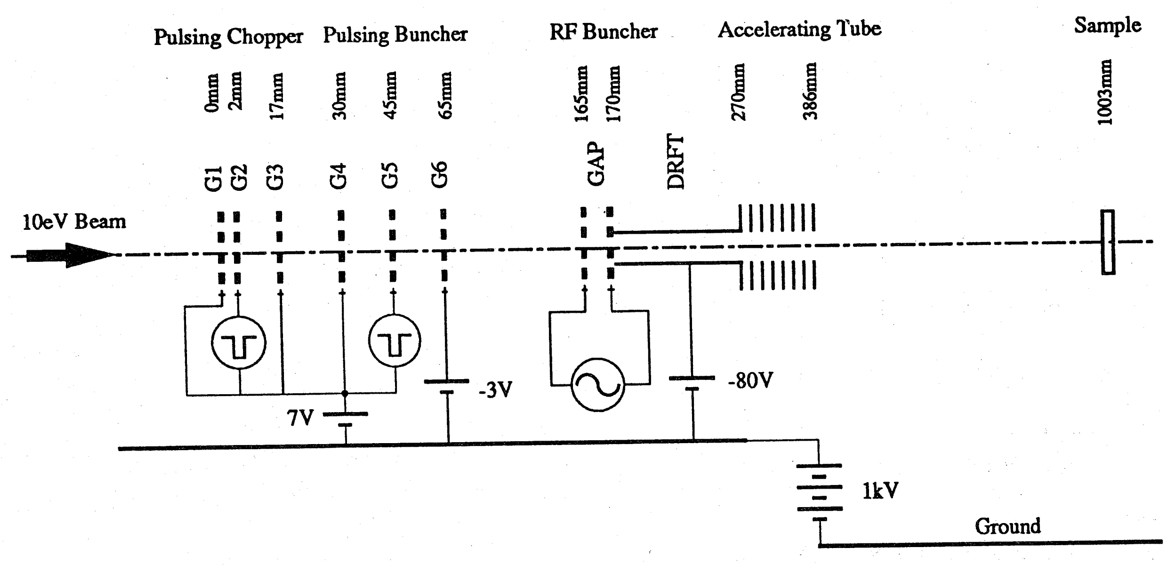

Fig.2 Layout od Bunching System

shown in Fig.3. From this graph, the energy distribution is a triangle. Energy spread is 2.7eV at FWHM. This energy spread probably originates at the moderator. Moderator is made of tungsten, which has a work function, 2eV, to the vacuum. And our moderator is in magnetic field. As the emitted direction from tungsten surface is very wide, positron has some spiral motion. There is data about the energy spread[4]. In that case, there is no magnetic field near moderator and the energy spread is 2.1eV at FWHM. It's supposed that our energy spread originates from the work function distribution and the spiral motion.

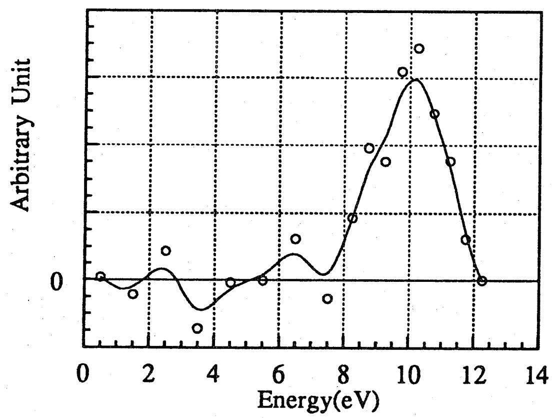

Fig.3 Energy Spread of Input 10eV Beam

D. Pulse Rise Time

Typical wave form is shown in Fig.4. In this test, the pulse generator is HP8131A and the oscilloscope is HP54201A. A coaxial cable from the pulse generator is connected to assembled grids. Two grids sandwich an 2mm insulation disc. Another monitoring coaxial cable is connected between grids and the oscilloscope. The rise time is around 3ns. The rise time of the pulse generator is 0.5ns. This degradation is probably from the connection imperfection. In the following calculation, the pulse rise time is set to 3ns.

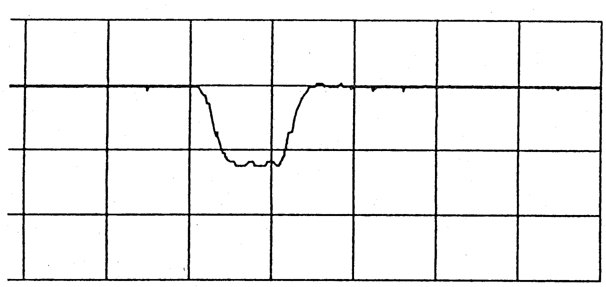

Fig.4 Typical wave form at the grids (10ns/div, 4V/div)

E. Calculation

Calculation result is shown in Fig. 5. Input beam energy is represented by 8.5, 9, 9.5, 10, 10.5, 11 and 11.5eV, because energy spread is from 8eV to 12eV. At each energy, positron beam is represented as a particle train at intervals of 1ns. From Fig.5, the bunch width at the sample is around 0.8ns. The calculation parameters are shown in Fig.2. The G2 pulse is that high is 12V, low is 2V and the pulse width is 10ns. The G5 pulse is that high is 7V, low is -3V, the pulse width is 10ns and the delay from G2 is 28ns. The electric field of RF gap is a sine wave. The amplitude is 27.5V/5mm.

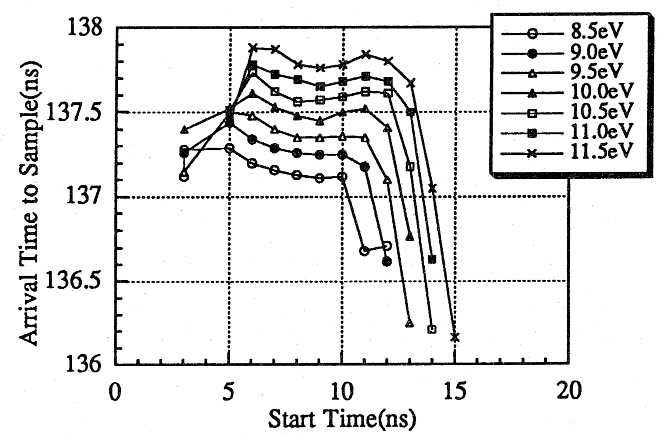

Fig.5 Bunch width at the sample

IV. CONCLUSIONS

The outline of our slow positron beam was described. The energy spread of the positron beam proved 2.7eV at FWHM and a tiangle distribution. The pulse rise time was 3ns. The energy spread and the rise time must be improved to shorten the bunch length.

The result of calculation is 0.8ns bunch width as shown in Fig.5. In the calculation, the pulsing buncher is located at the waist point in each energy. And the RF gap is located at the waist point in seven groups, from 8.5eV to 11.5eV. Those are can be located in the real waist points. And the positron energy at DRFT can be increased.

V. REFERENCES

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