DESIGN STUDIES FOR THE POSITRON FACTORY

S.Okada, H.Sunaga, H.Kaneko, S.Masuno, A.Kawasuso, T.Sakai, H.Takizawa and K.Yotsumoto
Takasaki Establishment, Japan Atomic Energy Research Institute
1233 Watanuki, Takasaki, Gunma 370-12, Japan
Y.Honda and S.Tagawa
The Institute of Scientific and Industrial Research, Osaka University
Ibaraki, Osaka 567, Japan

Abstract

In the design study for the Positron Factory, a feasibility of simultaneous extraction of multi-channel monoenergetic positron beams, which had been proposed at the previous conference (Linac 94), was demonstrated by an experiment using an electron linac. On the basis of the experimental result, an efficient moderator structure, which is composed of honeycomb-like assembled moderator foils and reflectors, is proposed.

Introduction

We have been promoting design studies for the 'Positron Factory' [1], in which linac-based intense monoenergetic positron beams are planned to be applied for advanced materials characterization and new fields of basic research. A tentative goal of the slow (i.e. monoenergetic) positron beam intensity is 10^{10}/sec, which is larger by two orders of magnitude than those of existing strongest beams in the world. We have performed a conceptual design of a high-power electron linac of 100 kW class with a beam energy of 100 MeV and developed a newly designed electron-positron converter. We have proposed a concept of simultaneous extraction of multi-channel mono-energetic positron beams, on the basis of a Monte Carlo simulation, in a design study on a positron moderator. In this report, an experimental result to confirm the feasibility of this concept is demonstrated.

Design Studies

Linac and converter

We have performed design studies on a high-power electron linac and an electron to positron & photon converter as follows[2]:

1) An optimum electron beam energy for slow positron generation was estimated to be around 100 MeV.
2) It was calculated that a tentative goal of the slow positron beam intensity (10^{10}/sec) could be attained with a linac of 100 kW class with the above energy range.
3) A technical survey study confirmed a feasibility of manufacturing such a state-of-the-art linac.
4) Further detailed analyses were carried out concerning thermal deformation of the accelerator structures, beam instability, reliability of the components, down-sizing of the machine and a computer-aided control system.
5) A 'self-driven rotating converter' suitable for the high power beam was proposed and successfully tested. A concept of the linac is shown in Fig. 1. Some details of the design has been changed from that presented at Linac 94.

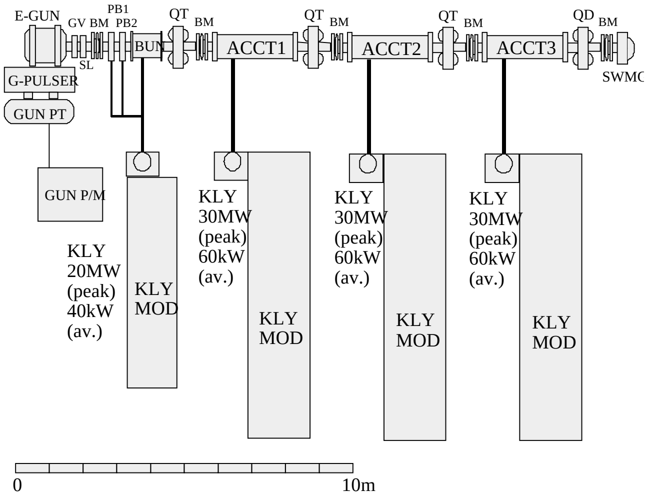

Fig. 1 A concept of the high-power electron linac for the Positron Factory.
Beam Energy: 100 MeV
Beam Current: 1 mA (average)
Beam Power: 100 kW (average)
Pulse Width:

Multi-channel positron moderator assemblies

We have proposed 'multi-channel moderator assemblies' to supply multiple slow positron beams simultaneously as shown in Fig. 2 [2]. The slow positron yield, that is a ratio of the number of slow positrons emitted from each tungsten moderator assembly to that of incident electrons onto the tantalum converter, was estimated using a newly developed Monte Carlo simulation system [3]. The result is shown in Fig.3. The contribution by energetic positrons from the converter to generate slow positrons drastically decreased at the assemblies distant from the converter. It was deduced from tracking of the particles that this is caused by spatial spread of the positron beam. On the contrary, there still were sufficient slow positron yields originating in energetic photons, even at the rear assemblies. This is because the photons go almost straightforward and cause pair production reactions uniformly in every assembly. Thus produced positrons have comparatively lower energies, which results in higher probabilities to be thermalized in each moderator foil.

To demonstrate a feasibility of the simultaneous extraction of multi-channel slow positron beams, we fabricated a set of 2 channel tungsten moderator assemblies as shown in Fig. 4. The set was composed of 18 tungsten foil layers of 25 mm in thickness. Slow positrons from each 9 layers were separately extracted by 2 tungsten mesh grids. Each moderator layer was divided into 3 parts, electrically separated and biased to drift emitted slow positrons by sloping the electric field toward the extraction grids. We observed the slow positron beam profile from the assemblies with a MCP (micro channel plate), using a 100 MeV electron beam from a S-band electron linac at Osaka University.

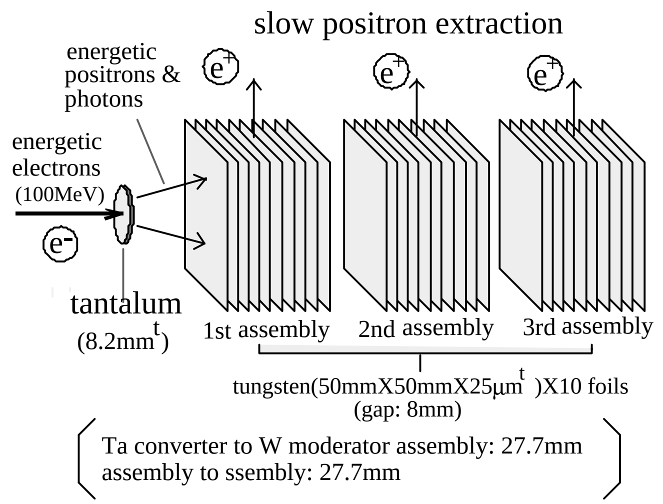

Fig. 2 A concept of the simultaneous multi-channel extraction of slow positron beams by multiple moderator assemblies and the geometry for the Monte Carlo simulation.

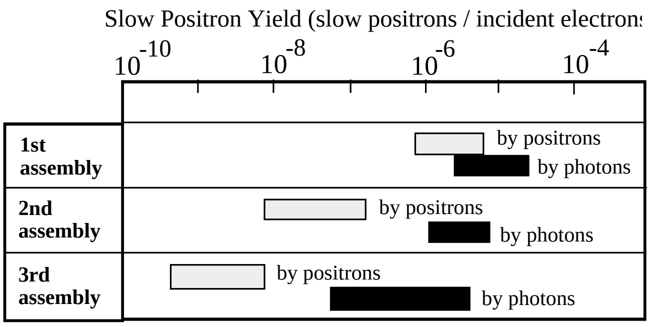

Fig. 3 Slow positron yields (ratios of the number of slow positrons to that of incident electrons) at the multiple moderator assemblies calculated with the Monte Carlo simulation for the case indicated in Fig. 2. Contributions by positrons and photons emitted from the converter are separately evaluated.

The result is shown also in Fig.4. Three peaks were observed in the slow positron beam intensity profile. The largest one was attributed to slow positrons from the first channel which was nearer to the tantalum converter. The second and third peaks were both attributed to slow positrons from the second channel. It is assumed that back-scattered positrons and pair production reactions by photons give rise to the third peak, because thick tungsten plates were placed at the end of the second moderator assembly. This means that positrons and photons passing through the first and second assemblies still have a potential to generate slow positrons, and also that it will be efficient to place a heavy metal at the end in fabrication of moderator assemblies.

The intensity of slow positrons from the second channel was smaller only by an order of magnitude than that from the first channel, which agreed well with the simulation result. It was concluded that such an extra positron beam will be useful for preliminary or potential researches which are promoted simultaneously with main experiments using the strongest beam.

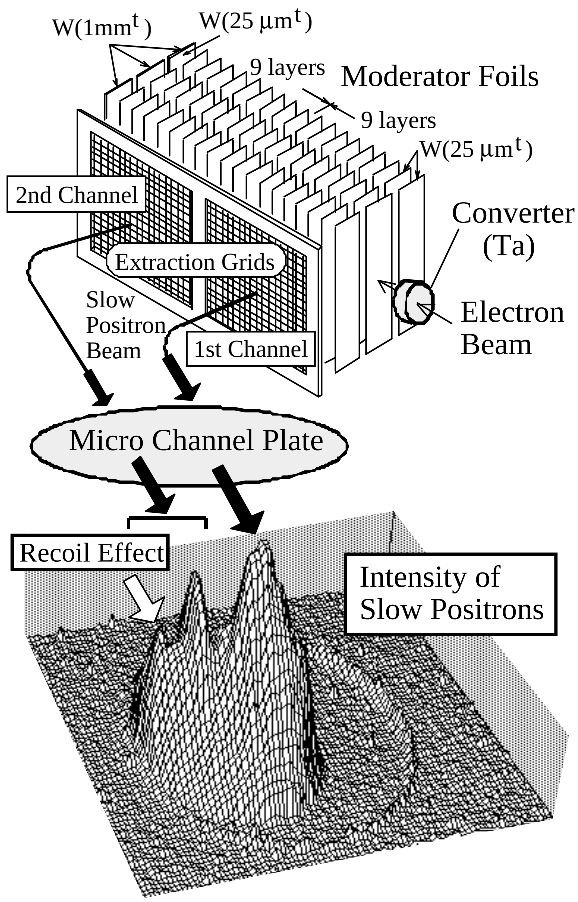

Fig. 4 Experimental setup of 2-channel moderator assemblies for the demonstrative experiment of the simultaneous extraction of multi-channel monoenergetic positron beams and the intensity of extracted slow positrons observed with a MCP.

Proposal of a new efficient moderator structure

The above result suggests usefulness of a heavy metal plate for a reflector and importance of the assembly structure. To evaluate the structure effect, we calculated conversion efficiencies from energetic positrons and photons to slow positrons for the following three cases as indicated in Fig.5. The first structure is a usual one, which consists of ten tungsten foils of 25 μm in thickness parallel placed. The second is a set of these foils whose surrounding planes except for the positron and photon injection side and the slow positron extraction one are enclosed by thick tungsten plates. The third structure has an additional set of eleven tungsten foils crossing the above foils in the second one to make a honeycomb-like assembly of foils enclosed by the reflectors.

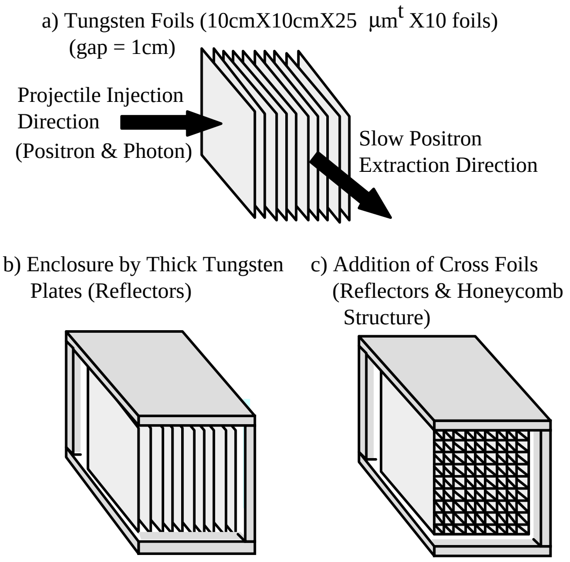

Fig. 5 Proposed new structures of positron moderator assembly.

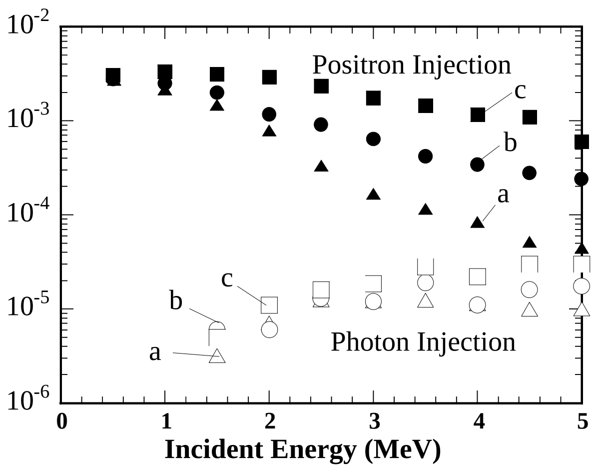

Fig. 6 Calculated conversion efficiencies from energetic positrons and photons to slow positrons in positron moderator assemblies having different structures shown in Fig. 5.

Figure 6 shows the calculation result. It is obvious that the structure effect is remarkable especially for higher energy projectiles. The number of the higher energy positrons and photons emitted from the converter is more than that of the lower energy ones. Therefore, the slow positron yield in the third structure is expected to increase by a few times that in a usual one. The moderator assembly with a honeycomb-like structure enclosed by reflectors proposed here is promising for realizing an intense monoenergetic positron beam of more than 1010/sec in intensity.

Conclusion

In the design study for the Positron Factory, we demonstrated a feasibility of simultaneous extraction of multi-channel monoenergetic positron beams using an electron linac, by an experiment. A more efficient moderator structure, which was suggested by the experimental result, is proposed. The world highest monoenergetic positron beam of more than 1010/sec in intensity will be realized by the use of a high-power electron linac of 100 kW class with a beam energy of 100 MeV.

References

[1] S. Okada and H. Sunaga, Nucl. Instr. and Meth. **B56/57** (1991) 604-609.

[2] S. Okada et. al., Proc. 1994 Int. Linac Conference (Tsukuba, 1994) 570-572.

[3] S. Okada and H. Kaneko, Appl. Surface Science **85** (1995) 149-153.