〔P7-04〕

INVESTIGATION ON THE POSITRON FACTORY PROJECT AT JAERI (XII) - Summary of the Conceptual Design -

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The Positron Factory has been planned at Japan Atomic Energy Research Institute (JAERI). The factory is expected to produce linac-based monoenergetic positron beams having world-highest intensities of more than 10^{10} e^+/sec, which will be applied for R&D of materials science, biotechnology and basic physics & chemistry. In this article, results of the survey study and the conceptual design, which have been supported by governmental budgets since 1990 and were completed in 1998, are summarized. A new concept of a local shield to suppress the radiation and activation levels around the target system is also proposed..

1. Introduction

At the Takasaki Establishment, Japan Atomic Energy Research Institute (JAERI), researches on materials science and biotechnology are in progress using a variety of ion beams. The research fields have stepped into a novel stage of 'quality control on matter itself' at the atomic level, which means both observation and manipulation of the microscopic structures. Positron beam, which is generated as 'slow' (i.e. monoenergetic) positron beam and sometimes accelerated, is a powerful tool for this purpose as well as ion beam. By the combined use of ion beams and positron spectroscopy, we found a unique state of vacancy-hydrogen interaction in silicon. Here proton-implanted silicon was studied by positron lifetime in comparison with He-ion-implanted and electron-irradiated silicons [1]. We also succeeded in the first observation of RHEPD (Reflection High Energy Positron Diffraction) from a silicon surface by the use of an isotope-based electrostatic slow positron beam, and demonstrated usefulness of positron as a topmost surface sensitive probe [2]. Such an isotope-based slow positron beam, however, cannot be applied for advanced analyses like time-dependent observation of transient phenomena and fine structure investigation of sub-micron size local region of materials, because of the insufficient intensity.

We have been promoting design studies for the 'Positron Factory' [3], in which linac-based intense monoenergetic positron beams are planned to be applied for materials science, biotechnology and new fields of basic research i.e. initiative of 'anti-particle science'. A tentative goal of the slow positron beam intensity is 10^{10}/sec, which is larger by two orders of magnitude than those of existing strongest beams in the world. The survey study and the conceptual design have been supported by governmental budgets since 1990. The conceptual design was completed in 1998. In this paper, the results of the design studies on the essential components such as a high-power electron linac and the target system, which have already been reported, are summarized, and a new design of a local shield surrounding the target system is described.

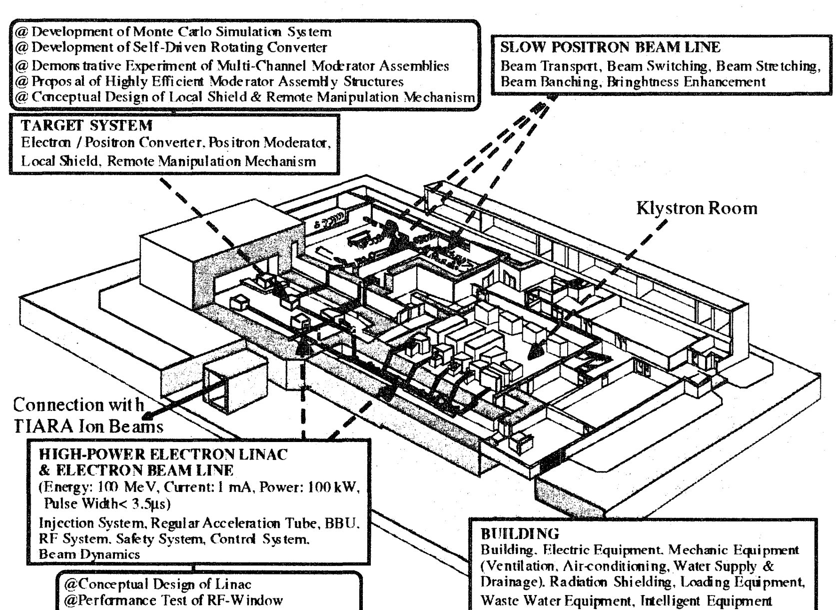


Fig.1. An overview of the planned facilities and the design study items.

2. Summary of previously reported design studies

An overview of the planned facilities is shown in Fig.1. We have done the survey study and the conceptual design of the facilities composed of a high-power electron linac, electron beam lines, a target system, slow positron beam lines and building. The items of the design studies are indicated by @ in the figure. They include performance tests and demonstrative experiments for feasibility studies of the essential components.

2.1. High-power electron linac

We confirmed the feasibility of a dedicated high-power electron linac of 100 kW class with a beam energy of 100 MeV on the basis of detailed analyses concerning thermal deformation of the accelerator structures, beam instability, reliability of the components, down-sizing of the machine and a computer-aided control system [4].

In addition to the linac itself, the durability of the electron beam window and the RF window of the wave guide circuit from the klystron were confirmed by over-load operation tests using pilot devices [5].

2.2. Electron-to-positron converter

We have proposed a 'self-driven rotating converter' [4] which has pivot-type axles and bearings and rotates by a driving force of the coolant itself. The coolant (water) works as a lubricating material as well. We fabricated a pilot model and confirmed the feasibility by an electron beam irradiation test, three months performance test and a finite element calculation.

2.3. Multi-channel moderator assemblies

Based on calculations with a newly developed Monte Carlo simulation system EGS4-SPG [6], we have proposed 'multi-channel moderator assemblies' [4] to supply multiple slow positron beams simultaneously. The availability of this method was demonstrated by an experiment using an electron linac and a set of 2 channel tungsten moderator assemblies [7].

2.4. Efficient moderator structure

The above demonstrative experiment result suggests usefulness of a heavy metal plate for a reflector and importance of the assembly structure. It has been found from calculations with EGS4-SPG that the slow positron yield in the honeycomb-like assembly with reflectors is more than three times larger than that in the usual one [8].

3. A new concept of local shield & remote manipulation mechanism

To suppress the activation of air surrounding the target system and reduce the thickness of concrete walls of the building, we performed a conceptual design of a local shield as shown in Fig. 2, on the basis of the shield calculations. In the design, we intend to reduce the radiation level by two orders with the local shield during the linac operation.

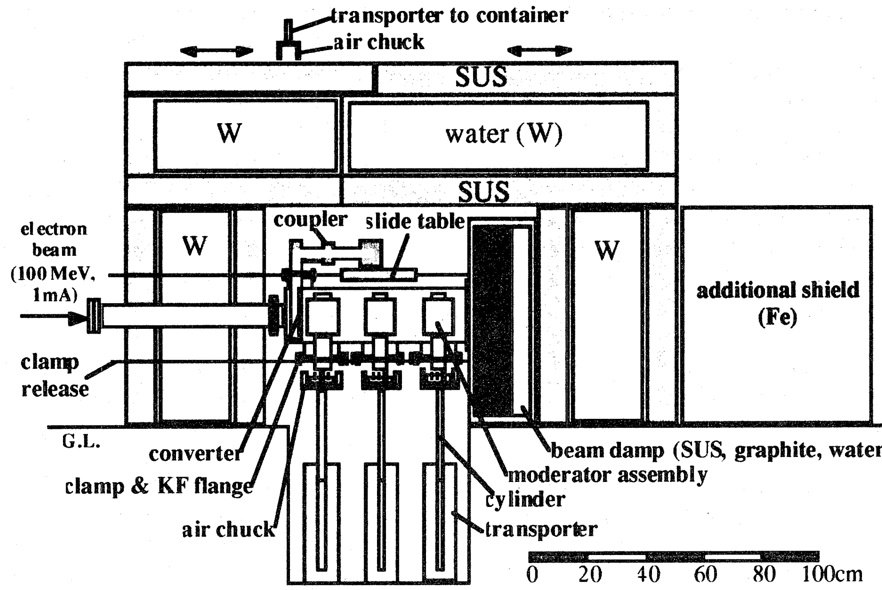
The target system is surrounded by structures consisting of 12 cm-thick steel, 30 cm-thick water and 12 cm-thick steel. The water works as a shield for neutrons and also as a coolant. An additional iron shield of 65 cm in maximum thickness for the forward beam direction will be effective in order to reduce the thickness of the concrete wall. An activated converter and moderator assemblies are manipulated by remote control and transported to containers, using air chucks, a coupler with compressed air, KF-type flanges with clamps and clamp releases with screw drive.

The inside of the local shield is vacuum. Consequently the activation of air in the target room is suppressed to permissible level as shown in Table 1. The calculated result in the table also shows that the saturated activation of the local shield itself is lower than, for example, that of a typical cyclotron.

Table 1. Calculated activation of air, local shield and target.

Activation of Air	
^{3}H (12.3y):	5.6×10^{-2} Bq/cm^3
^{7}Be (53.6d):	1.1×10^{-4} Bq/cm^3
^{11}C (20.3min):	1.1×10^{-3} Bq/cm^3
^{13}N (9.96min):	5×10^{-2} Bq/cm^3
^{15}O (123sec):	6×10^{-3} Bq/cm^3
^{16}N (7.14sec):	2×10^{-7} Bq/cm^3
^{38}Cl (37.3min):	2×10^{-5} Bq/cm^3
^{39}Cl (55.5min):	1.5×10^{-4} Bq/cm^3
^{41}Ar (1.83h):	1.8×10^{0} Bq/cm^3

Activation of Target System (Dose Rate at 1 m from Local Shield Surface)	
local shield (Fe):	^{55}Fe (2.6y) 0 Sv/h
	^{59}Fe (45.6d) 15 mSv/h
	^{46}Sc, ^{54}Mn, ^{51}Cr etc. 26 μSv/h
converter (Ta):	^{180m}Ta (8.1h) 6×10^{-2} mSv/h
	^{180}Ta (115d) 4×10^{-1} mSv/h
moderator (W):	^{182}Ta (115d) 4×10^{-2} μSv/h
	^{183}Ta (5d) 3×10^{-2} μSv/h
	^{181}W (121.2d) 3 μSv/h
	^{185}W (75.1d) 3 μSv/h
	^{187}W (23.9d) 2×10^{-3} μSv/h
water:	^{3}H (12.6y) 0 Sv/h
	^{7}Be (53.3y) 1×10^{-2} mSv/h



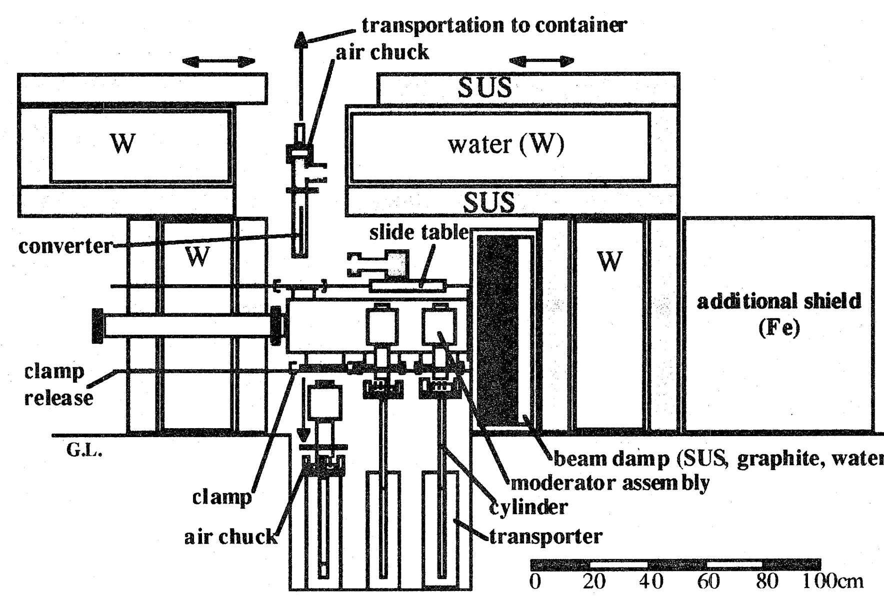


Fig.2. A concept of the local shield of the target system and the remote manipulation mechanism.
Top: during the electron bombardment
Bottom: during the manipulation of the converter and the moderator assembly

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