Accelerator System at The Wakasa Wan Energy Research Center

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Abstract

The Wakasa-wan Energy Research Center (WERC), which is located at Tsuruga, Fukui, Japan, is founded as an institute for the local industries and researchers. One of the research themes of WERC is the application of the radiation. For the purpose, the accelerator system is now under construction at WERC.

The system consists of a 5 MV Schenckel type tandem accelerator and a 200 MeV proton synchrotron. By using the tandem accelerator, we can perform the element analysis, the improvement of the bio-species and ion-implantation into various materials. The tandem accelerator works as an injector for the synchrotron and the synchrotron is for the cancer therapy and also bio and material science.

1 INTRODUCTION

The Wakasa Wan Energy Research Center (WERC) was constructed as the first institution close to local industry under the suggestion of Science Council of Japan. WERC are opened to the local industries and scientists. We perform the research of application of our machine to local industries and the training of technicians in the area. The utilization of radiation is performed among many researches at WERC [1].

Now, we are constructing an ion beam accelerator system. By using ion beams with wide range energy from 200 keV ion implanter, 5 MV tandem accelerator and 200 MeV proton synchrotron, we will study material science, development of ion beam analyses, cancer therapy or improvement of plants. Figure 1 shows our accelerator complex. For the applications of ion beams, four irradiation rooms are prepared [2, 3].

In this paper, we report the ion sources, the accelerator system, beam lines, and future plans of their applications.

2 TANDEM AND SYNCHROTRON ACCELERATOR SYSTEM

Some of the applications of our accelerator system are high intense irradiation experiment and cancer therapy, therefore, the system is expected to have controllability of the time structure and current of the high intense beam. Also the system is used for the micro analysis such as PIXE, RBS and/or ERDA experiments. The beam energy should be variable continually and controlled precisely. To achieve above expected character, an electrostatic tandem accelerator with high intense negative ion sources and a synchrotron were introduced to our laboratory.

The maximum terminal voltage of the tandem accelerator is 5 MV, which is generated by a Schenkel rectifier. The Schenkel type generator allow to accelerate high intense beam (DC: 100 μA, pulse: 18 mA$\times$250 μs$\times$0.5 Hz) owing to 1 mA of the conveyor current. By using large capacitance for the terminal condenser, the ripple of the voltage when injection of pulse beam is reduced to 2 kV at the terminal voltage of 5 MV. It corresponds to energy dispersion of 4×10^{-4} and one tenth less than RFQ-DTL system. For the charge exchange, an argon gas stripper is used. The concentration of the gas into the stripper section is done by the recirculation by four turbomolecular pumps (50l/s$\times$4).

The tandem beam is injected to the synchrotron and then accelerated to 200 MeV in the case of proton and 55 MeV/u for the heavy ion, of which energy is enough to be for the cancer therapy for most Japanese people.

The circumfence of the synchrotron is 33.2 m. The superperiodicity is 4. Each lattice has QF-D-QD-D-QF and it is operated in separate function style. Horizontal and vertical tunes are 1.75 and 0.85, respectively.

The beam from tandem accelerator is injected by multi-turn injection method. The beam remains captured for about ten turns. The acceleration is done by an asynchronous RF cavity. In order to reduce the space charge effect in the early acceleration period, the higher harmonic wave is added to the cavity. After the acceleration, the beam is slow-extracted during 0.5 sec flat top period by a RF-knockout method. Figure 2 shows the time structure of the extracted beam from the synchrotron. For the irradiation experiments under precisely controlled dose, it is important for the current to be as constant as possible. The figure shows that the condition is achieved well. The design and achieved intensities of the tandem and synchrotron system are shown in Table 1.

3 ION SOURCES

We have two ion sources. One is plasma sputtering type source and is used for the ionization of hydrogen and solid elements. Another for the gas elements, especially helium.

The principle of the generation of the negative ion from the plasma sputtering source is the conversion of the atom

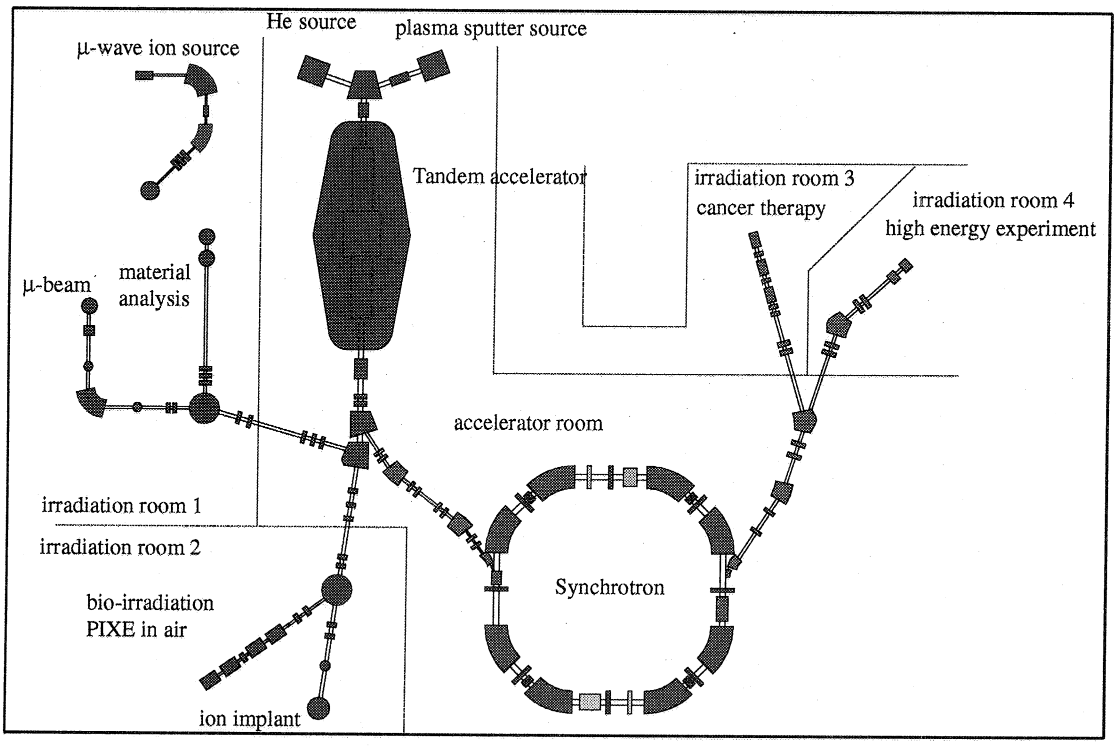

Figure 1: Schematic layout of the accelerator system of WERC

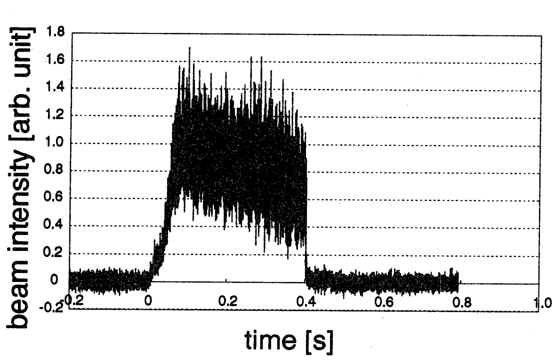

Figure 2: Time structure of the beam by "slow-extraction"

Table 1: Design and achieved beam intensities

	Design	Achieved
Injection to tandem	18 mA	9.8 mA
Extraction from tandem	6 mA	4.7 mA
Injection to synchrotron	6 mA	4.5 mA
Storage particle (200 MeV)	1.3×10^{11}	1.0×10^{11}
Extraction from synchrotron	10 nA	8.0 nA

to the negative ion using the electron penetrating through the binding potential barrier [4]. In order to reduce the work function, the surface is adsorbed with Cs. For negative hydrogen ion, the hydrogen plasma is used. For the other ion, xenon plasma is used. The plasma generated by arc discharge sputters a target surface at 0.7 kV. Using this ion source, for example, the proton beam is injected to the tandem accelerator up to 90 μA. The arc discharge can be to operated by pulse mode. Duty cycle of 15-25 Hz and pulse width of 100 μs are usually used for the injection to the synchrotron. In the case of using pulse mode, maximu 18 mA proton beam is injected to the tandem accelerator.

The helium ion source system consists of a helium positive ion source and a charge exchange cell. The principle of the ionization is the hot cathode discharging and the enclosure by the bucket type magnetic field [5]. Extracted positive ions are transported through the charge exchange cell. The cell is filled with lithium vapor. The beam current of the negative helium ion injected to the tandem accelerator amounts to 50 μA.

4 BEAM LINES

The beam extracted from the tandem accelerator of which terminal voltage is set at maximum 1.7 MV is transported to the irradiation room 1. The room has two beam lines. One is for the microanalysis experiments. The beam is focused to the size of 2 μm by using a set of magneticquadrupole doublet and a fine slit. In the terminal chamber, PIXE, RBS, ERDA experiments are available. Another for the low energy implantation.

In the irradiation room 2, we can perform the experiments setting the terminal voltage at maximum 5 MV. We have two beam lines in the room. One is for the medium energy implantation of ion beam analysis such as transmission type ERDA. From the end of the another beam line, the beam can be extracted to the air. By using three apertures, the beam size is reduced to 10 μm diameter. We can apply the beam to the bio-irradiation or archeological matter.

In the irradiation room 3 and 4, we can use the beam extracted from the synchrotron. In the room 3, we have two beam lines. Both lines are for the cancer therapy. The beam is extracted in the perpendicular direction from the one beam line and horizontally extracted from the other. Both lines have scatteres and wobbler magnets which are used for making the irradiation area with the diameter of 15 cm. In the room 4, high energy irradiation experiments or developments for the therapy are performed.

5 NEW BEAM LINE

In the irradiation room 2, installation of new beam line is scheduled. The beam line consists of a couple of fine x-y slits, large scattering chamber with diameter of 450 mm, Wien filter, TOF counter and gas counter for Z identification.

The scattering chamber is insulated, therefore, it is very easy to measure the primary beam current without any effect of the secondary electron even if using thick target. The chamber has a target goniometer and two turn tables with solid state detectors for scattering phenomena. Also it is equipped with a Si X ray detector, a CZT (Cd-Zn-Te) X ray detector for PIXE experiments, TOF stop counter for RBS trigger TOF and a BGO gamma detector, which is for the gamma ray emission in the nuclear reaction. Inside wall of the chamber is coated with carbon, which reduces X ray background together with carbon collimator.

Wien filter is for recoil mass spectrometry. Pole length is 450 mm and maximum electrostatic and magnetic fields are 45 kV/cm and 0.4 T. Along down stream of the Wien filter, a time-zero counter using thin foil, electrostatic mirror and MCP, multi anode gas counter. These are available for the accelerator mass spectrometry (AMS) after future modification of the injection system of the tandem accelerator.

6 SUMMARY

The Wakasa Wan Energy Research Center was established as an institute opened and close to the local industries and scientists. In order to contribute the local industry, we have been constructing accelerator system in the aim of the utilization of the radiation.

The energy of the beam from the accelerator complex is from sub MeV to sub GeV and its applications are in the very wide range such as material science, archeology, agriculture and fishery, cancer therapy and so on.

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