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Status report of Sasaki Taro memorial PIXE Center

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Abstract. The present status of Sasaki Taro memorial PIXE Center, Hakodate, Japan is described. A compact AVF cyclotron has been installed to provide a 3-MeV proton for PIXE analyses. The experiments have been performed using a horizontal beam line for conventional measurements or a vertical beam line where the beam extracted into air is delivered to targets on a movable stage for 2-dimensional scanning. Research programs have been planed for both multi-purpose use in various fields of research and commercial use.

Keywords: Sasaki Taro memorial PIXE Center, Compact AVF cyclotron for PIXE, Horizontal and vertical irradiations, 2-dimensional scanning using a movable stage, PIXE for medical studies and commercial use.

INTRODUCTION

A PIXE center was established at Hakodate, Japan in 1995. Although the 3 MeV-cyclotron installed at the PIXE center had successfully been used for the PIXE analyses, we unfortunately met the cyclotron trouble due to not only an RF fault but also the deflector trouble to interrupt the research programs. In 2006 the PIXE center could restart the PIXE analyses as Sasaki Taro memorial PIXE Center (STPC). In this paper the present status of STPC will be described.

AVF CYCLOTRON FOR PIXE ANALYSIS

The PIXE analysis system of STPC is shown in FIGURE 1. The AVF cyclotron consists of a magnet of a radial-sector design, an RF-system and an internal ion source of a hot cathode PIG type. A constant-energy proton beam of 3 MeV can be provided for PIXE analyses. The cyclotron parameters are summarized in TABLE 1.

FIGURE 1. Whole view of the AVF cyclotron, the horizontal beam line and the vacuum chamber for PIXE measurements. The vertical beam line is not included in this photo.

TABLE 1. Principal parameters of the AVF cyclotron

Magnet / RF	Parameters
Pole radius	20 cm
Number of sectors	4
Sector angles	32^o (hill) and 58^o (valley)
Average field	1.7 T
Pole gaps	2.4 cm (hill) and 5.2 cm (valley)
Number of Dees	2
Dee angle	52^o
Dee voltage	20 kV (0-peak)
Frequency	51.7 Mhz

FIGURE 2 shows the inside of the AVF cyclotron. The isochronous field of the cyclotron is produced using a magnet with 4 radial sectors. The radius of the magnet pole is 20 cm while the pole gap is 2.4 cm for the hill and 5.2 cm for the valley. The average filed strength is 1.7 T. The ion source is installed at the central region of the cyclotron. The typical lifetime of the filament is about 200 hours. There are two beam probes to measure radial beam-intensity distribution in the cyclotron.

The proton beam is accelerated through the two Dee electrodes excited with an RF signal whose voltage and frequency are 20 kV (0-peak) and 51.7 Mhz, respectively. The beam accelerated up to 3 MeV is extracted from the cyclotron using a deflector and a subsequent magnetic channel which are installed at the valleys of the magnet pole as seen in Figure 2. The electro-static field of the deflector can be increased up to 25 kV/cm. A gap between the electrode and the septum of the deflector can be adjusted to optimize the beam extraction. As shown in Figure 3, the intensity and spot size of the beam extracted from the cyclotron is monitored using a beam stopper coated with ZnS.

Details for design of the cyclotron have been described elsewhere[1].

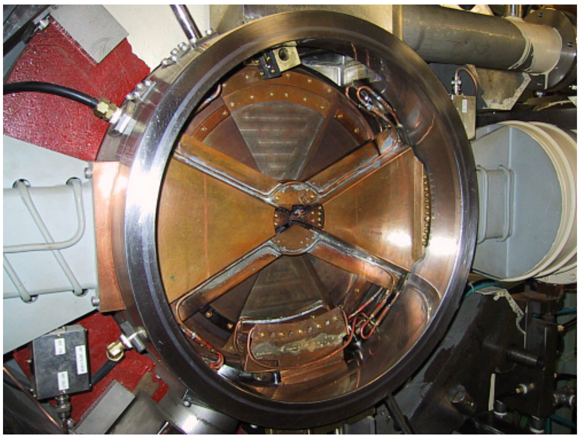

FIGURE 2. Inside view of the 3-MeV AVF cyclotron at the Sasaki Taro memorial PIXE Center, Hakodate, Japan.

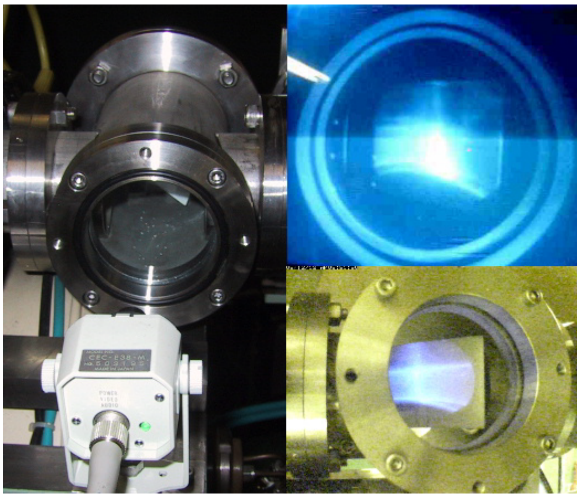

FIGURE 3. Beam viewer system at the beam exit of the cyclotron. The beam spot is monitored with a CCD camera.

BEAM TRANSPORT SYSTEM

The proton beam from the cyclotron is delivered into the beam transport system and transported with quadrupole magnets and steering magnets by monitoring the beam intensity and spot size with Faraday cups and beam viewers. A vacuum chamber for conventional PIXE analyses is installed at the end of the horizontal beam line. A slit system to adjust the beam spot size on target is equipped just upstream of the chamber.

Recently, the PIXE system of STPC was upgraded by installing a new beam line for vertical irradiation. The proton beam is transported into the new beam line with a switching magnet newly installed at the middle of the horizontal beam line (FIGURE 4), and bent vertically with a dipole magnet (FIGURE 5). In addition, the beam can be extracted into air through a piece of Kapton foil at the end of the vertical line and delivered to the sample target. 2-dimensional scanning analysis can be made using a scanning target stage as well.

The control system of hard-wired type is currently employed for control of the cyclotron and beam transport system. Thus, all of the control parameters are adjusted with potentiometers. In the next upgrade, we plan to replace the present control system with a PC(Personal computer)-based system[3] using the LabVIEW software[2] for graphical user interface and the programmable logic controllers[4] (PLC). The parameter setting and monitoring can be made with the PLCs consisting of CPU and several modules such as Input/Output, Analog-to-Digital, Digital-to-Analog and network modules.

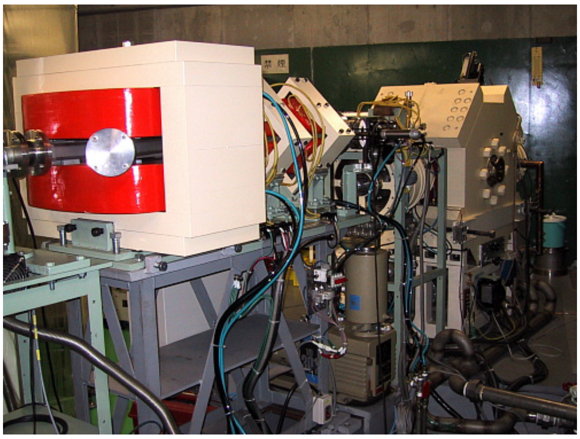

FIGURE 4. Switching magnet installed in the beam line to switch the beam from the cyclotron into the vertical beam line.

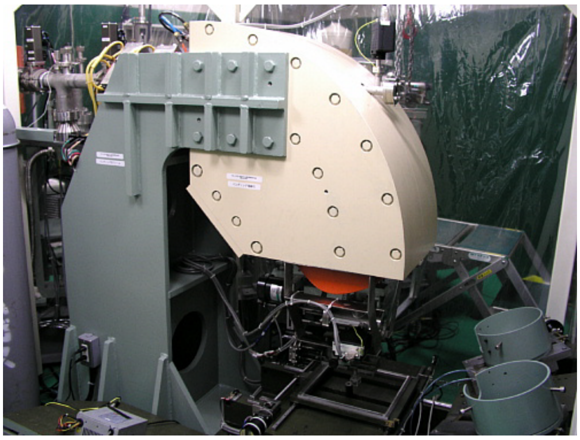

FIGURE 5. Bending magnet for vertical irradiation. The 2-dimensional scanning stage is equipped just downstream of the magnet.

BEAM TESTS

In recent years the research programs could not be performed because of the cyclotron troubles concerning the RF-system and the deflector system. After repairing the cyclotron, the beam intensity of about 100 nA is currently obtained at the exit of the cyclotron although the typical beam intensity of a few μA is designed. Thus, the beam tests to improve the beam intensity have been done by tuning various cyclotron parameters.

During the beam tests we could restart the PIXE experiments successfully. A tentative X-ray energy spectrum obtained in the beam test is shown in Figure 6.

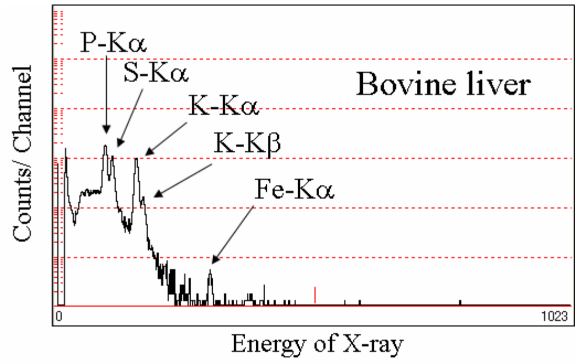

FIGURE 6. Tentative spectrum of X-rays from a sample of bovine liver measured during the beam test.

NEW RESERCH PROGRAMS IN MEDICAL FIELDS

In the next phase of research programs at STPC, we are preparing to provide the proton beam for not only commercial use but also multi-purpose use in various fields of research.

Recently, we have also carried out experiments[5,6] in medical fields such as research for proton therapy with small animals and the development of radiation-controlled drug-delivery system (DDS) for cancer therapy at Cyclotron and Radioisotope Center (CYRIC)[7], Tohoku University. These studies need quantitative analyses for various heavy elements in drugs, cells and the related materials. Therefore, PIXE plays important roles in the above studies.

Thus, we are planning to perform PIXE experiments at STPC concerning the DDS based on micro-capsules containing the liquid drug for local control of the drug density distribution in patient's body. Recent topics and new information about upgrade of the PIXE system will also be described in the web site[8] of STPC.

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