Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 17-18, 2018

Design and Construction of External PIXE Beamline of the 1.7 MV Tandem Accelerator for Restoration and Preservation of Cultural Properties

Jun Mok Ha [a*], Seoung Ho Lee [b], Kye-Ryung Kim [a], Jae Kwon Suk [a], Min Young Kim [a], Hye Ran Jeon [a], Sang Min Ha [a], and Yong Sub Cho [a]
[a]*Korea Multi-purpose Accelerator Complex (KOMAC), Korea Atomic Energy Research Institute (KAERI), 181 Mirae-ro, Geonchon-eup, Gyeongju, Gyeongbuk, 38180, Korea*
[b]*Applied Nuclear-Atomic Science (ANAS) Lab., 89 Seokbong-ro, 58 beonan-gil, Daedeok-gu, Daejeon, 34320, Korea*
[*]*Corresponding author: jmha@kaeri.re.kr*

1. Introduction

Particle induced X-ray emission or proton induced X-ray emission (PIXE) is an analytical method which is the measurement of characteristic X-rays emitted from a target sample due to the irradiation of a high energy ion beam (typically 1-2 MeV of H or He) [1]. PIXE can identify various constituents up to ppm (parts per million) composition in the target sample non-destructively, precisely, and quantitatively [2]. Micro-element analysis based on a PIXE system has a detection limit orders of magnitude lower than can be attainable by X-ray spectrometry techniques using electron excitation such as X-ray fluorescence (detection limit of XRF: ~200 ppm). Under favorable conditions, a detection limit ~1 ppm for thin foils and ~10 ppm for thick samples can be achieved [3]. Therefore, the PIXE analysis system has been successfully applied to solving problems in various fields, including corrosion and oxidation, semi-conductors, metallurgy, thin films, geoscience, air pollution and atmospheric science, biology, medicine, art, archaeology, water analysis, and forensic science [4-6]. However, since the measurement of characteristic X-rays of the target samples through the conventional PIXE system was carried out under vacuum conditions, the replacement time of target samples was long and the analysis of specific samples such as liquid, powder, and bulky one like cultural properties was difficult, and furthermore, it is possible to damage the target samples by the irradiation heat of particle beam because the cooling system was hard to install in a narrow vacuum chamber [7]. On the other hand, an external PIXE system using an extracted particle or proton beam into air can easily solve the problems of conventional PIXE due to its features, and therefore, recently, various types of external PIXE analysis systems have been actively developed [8].

Here, we present design, construction, and vacuum test of external PIXE beamline of the 1.7 MV tandem accelerate at Korea Multi-purpose Accelerator Complex (KOMAC) for applying to restoration and preservation treatment of cultural properties.

2. Methods and Results

In this section, the detailed procedures of design, construction, and vacuum test of external PIXE beamline of the 1.7 MV tandem accelerator at KOMAC are described.

2.1 1.7 MV Tandem Accelerator

The 1.7 MV tandem accelerator (S5DH-1, NEC) at KOMAC is schematically and optically displayed in Figure 1. The accelerator voltage is 0.1 ~ 1.7 MV (voltage stability: < 1 kV) and maximum energy and beam current of proton beam are 3.4 MeV and 10 μA, respectively. The low energy part of 1.7 MV tandem accelerator was composed of ion source (source of negative ions by cesium sputtering; SNICS), buncher, and tandem accelerator tank as shown in Fig. 1a. There are 4 beamlines such as implantation for ion insertion into materials (-30 degree of main beam line of tandem accelerator), Rutherford back-scattering (RBS)/elastic recoil detection (ERD) for composition and depth profile for samples (-15 degree), neutron for standard mono-energy neutron source (0 degree), and PIXE for analysis of microelements (+15 degree).

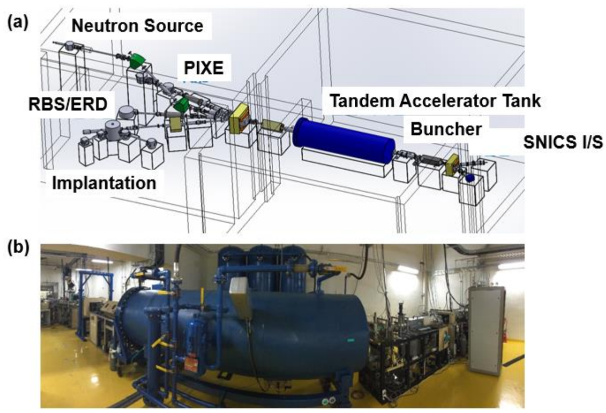

Fig. 1. (a) Schematic and (b) optical image of the 1.7 MV tandem accelerator at KOMAC.

2.2 Design of External PIXE Beamline

Among the 4 beamlines of 1.7 MV tandem accelerator, the PIXE beamline was newly designed and upgraded for development of external PIXE system. The simulation was carried out using a NEC (National

Electrostatics Corp.) Ion Optic Program and the simulated result of beam optics for the external PIXE system was shown in Fig. 2a. When a magnetic quadrupole doublet at the external PIXE beamline is used for focus and extraction, the extracted beam size is minimized at less than 200 mm from exit window. The optimized magnetic field gradient of X and Y axis are 300.3 and 424.8 gauss/mm, respectively.

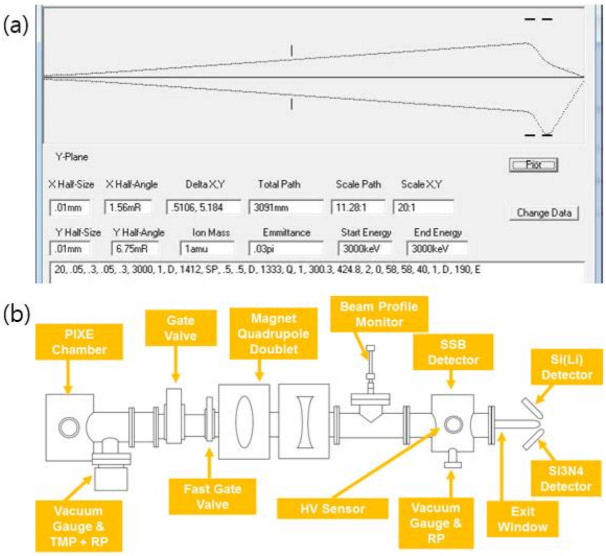

Fig. 2. (a) A simulated result of beam optics and (b) Conceptual design for the external PIXE system.

The conceptual design for the PIXE system at KOMAC was fixed based on the simulated result (Fig. 2b).

2.3 Alignment of External PIXE Beamline

Fig. 3 shows the procedures of construction and alignment of external PIXE beamline. The external PIXE beamline was constructed in consideration of the simulated result and conceptual design, and the detail alignment of external PIXE beamline was theodolite and laser level devices for the optimization of beam optics of external PIXE analysis system.

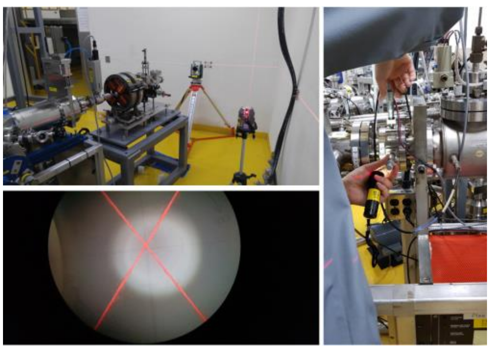

Fig. 3. Alignment of external PIXE beamline of 1.7 MV tandem accelerator at KOMAC.

2.4 Construction of External PIXE Beamline

The constructed external PIXE beamline was as shown in Fig. 4. Each part of the external PIXE beamline was well assembled, and therefore the vacuum degree of the external PIXE beamline was easily reach at lower than 10^{-6} torr. At a next step, we will carried out the proton beam extraction into air through the exit window.

Fig. 4. Fraction of counts lost with voltage and charge sensitive preamplifiers as a function of the true count rate.

3. Conclusions

The external PIXE beamline of 1.7 MV tandem accelerator at KOMAC was designed and developed through simulation of beam optics, conceptual design of the beamline, and alignment and construction of total external PIXE beamline. Beam optics of the beamline was carefully simulated and the beamline was well aligned for optimization of beam optics. At a next step, we will extract a proton beam into air through the constructed beamline and develop the external PIXE analysis system for applying to restoration and preservation treatment of cultural properties.

4. Acknowledgement

This work has been supported through National Research Foundation (NRF) of Korea (No. 2017M2A2A6A01071289) and KOMAC operation fund of KAERI by MSIT (Ministry of Science and ICT).

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