# Operation of the Pelletron tandem accelerator

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The tandem accelerator (Pelletron 5SDH-2, 1.7 MV max.) in the Nishina R&D Building, which is managed by the Detector Team of RNC, is a joint-use equipment at the Wako campus. Figure 1 shows the configuration of the beam elements. Two ion sources are located in the upstream of the accelerator. One is the RF charge-exchange ion source called Alphatross, which is mainly used for the extraction of $He^-$ ions. The negative charge state of He ions is realized by transmission through Rb vapor. The other one is the Source of Negative Ions by Cesium Sputtering (SNICS). Almost all other ions can be extracted from SNICS as negative ions, *e.g.*, $H^-$ and $C^-$. These ions are installed as a solid cathode, *e.g.*, $TiH_2$ for $H^-$, to be sputtered by Cs ions.[1)] Thus far, the ion species of H, He, Li, B, C, N, O, Si, Ti, Ni, Cu, and Au have been accelerated by 0.5–1.7 MV.

The accelerator has four beam lines named BL-E/W*nn* (*nn* stands for the bending angle). BL-E45 is used for surface modification. BL-E15 is reserved for the analysis of Rutherford backscattering (RBS) spectrometry/ elastic recoil detection analysis (ERDA). The microbeam port is BL-W30, which employs tapered glass capillary with an end-window to irradiate biological sample in solution.

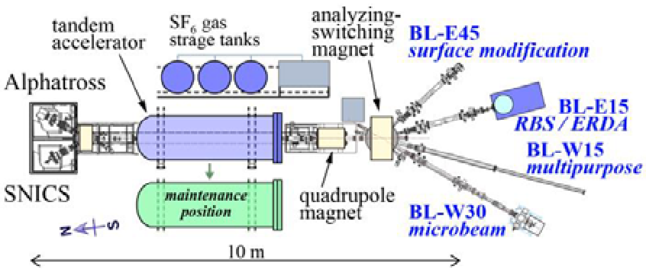


Fig. 1. Pelletron tandem accelerator and beamlines in the Nishina R&D Building.

Fig. 2. BL-W15 started to be used again as a multipurpose beam line after the renewal of the beam diagnostic system. The degree of vacuum level for the user setup is required to be better than $10^{-4}$ Pa. (Left). A setup for calibration of gamma ray detectors using a resonance reaction with a carbon target bombarded by 1 or 2 MeV proton beams (Right).

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Table 1. Beam conditions and experiments conducted in the tandem accelerator.

| Ion | Energy [MeV] | Beam current [pnA] | Experiment | Operation time [days] |
|---|---|---|---|---|
| $^1H^+$ | 1.0–3.0 | 0.008–420 | Irradiation | 25 |
| $^4He^{+,2+}$ | 2.0–4.8 | 0.2–300 | Irradiation | 4 |

The range of the ion beams is several 10 $\mu$m at most for water (density = 1 g/cm$^3$). Only $H^+$ can have ranges greater than 100 $\mu$m for water. All the experiments except for microbeam irradiation with the glass capillaries should be performed in vacuum chambers, where heavy ions of several MeV, such as Au ions, can provide stopping powers greater than 200 keV/$\mu$m at only the surface layer of samples or detector-sensitive areas.

This year, BL-W15 (Fig. 2) started to be used again after the renewal of the beam diagnostic system consisting of two $Al_2O_3$ fluorescent plates with current monitors. This system helps to focus the beams down to a few cm in diameter at the end of the line by tuning a quadrupole magnet as shown in Fig. 1. The beam line was used for the experiments of detector calibration and Nishina School.

During the annual reporting period from Jan. 1 to Dec. 31, 2018, the total machine time including a machine study was 29 days, where the condition test of the ion sources is not counted. The ion species accelerated in 2018 were only light ions $H^+$, $He^+$, $He^{2+}$ with energies ranging from 1.0 to 4.8 MeV, as summarized in Table 1. Experimental studies were performed on the following subjects.

(1) Machine study of a proton microbeam using tapered glass capillaries (1 day)
(2) Test of microbeam irradiation on single cells at BL-W30 (24 days)
(3) ERDA experiments using carbon ions (0 day)
(4) Educational experiment of proton capture by a carbon nucleus for Nishina School (1 day)
(5) Development of charged particle/gamma ray detector to be used for RIBF experiments (2 days)
(6) Other development using protons (1 day)

Since the experimental area is approved as a second-class radiation-controlled area, the users of all measurements can access their setup even during the beam irradiation time. The users are free from any setup for remote control utilities. These points are the advantages of using the RIKEN Pelletron accelerator.

Reference

1) R. Middleton, *A Negative-Ion Cookbook* (Univ. Pennsylvania, Philadelphia, PA 19104, 1990).