

R&D in AVF cyclotron

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We aim to increase the beam intensity and energy in the AVF cyclotron. In 2020, 7.25 MeV/nucleon He beams with intensity greater than $40 \mu\text{A}$ were stably supplied for RI-production experiments, and the maximum beam energy was successfully increased from 14 MeV to 30 MeV for protons. This paper describes the supply of a 30 MeV proton beam and the temperature-monitoring system in the deflector septum for extracting beams with an intensity greater than 1 kW.

Previously, the maximum energy of the AVF cyclotron for protons was 14 MeV; however, in the summer of 2017, the new central region was installed to accelerate beams with higher energies, for example, a 30 MeV proton (Harmonic $H = 1$ acceleration) and 14 MeV/nucleon deuteron.¹⁾ The shape of the old and new central regions, orbits of 30 MeV protons, and the central orbit of normal $H = 2$ operation are shown in Fig. 1. In February 2020, an acceleration test was conducted because the RI-production experiment using the 30 MeV proton beam was scheduled. The results of this test showed that a part of the beam in the second turn hit the phase slit, which was modified in 2019, and the shape of the slit was corrected in a hurry. As a result, a 30 MeV proton beam with a current of $10 \mu\text{A}$ was successfully accelerated and supplied for the user's experiment in June. The passing efficiency in the AVF cyclotron was approximately 7%.

To prevent the deflector septum from melting due to beam loss, a system was installed to monitor the temperature of the septum with thermocouples (TCs) and to stop the beam when an abnormal temperature rise is detected. Figure 2 shows a part of the deflector to which the TCs are attached. The septum is made of

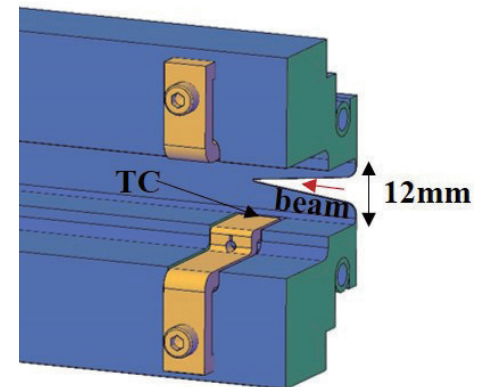


Fig. 2. Tip of the deflector septum to which thermocouples are attached.

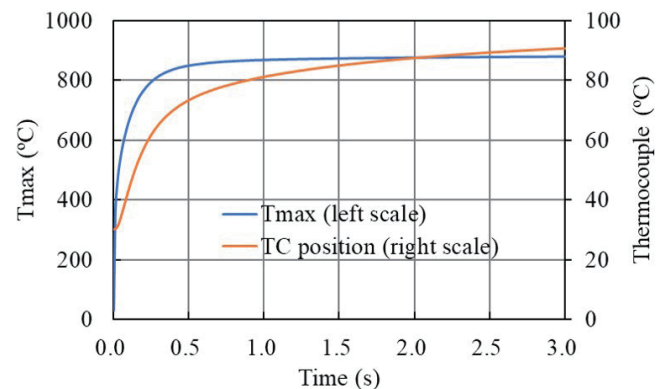


Fig. 3. Time response of temperatures on the septum calculated by ANSYS.

copper, and it has a thickness of 0.3 mm and a height of 12 mm. As shown in the figure, the septum has a notch with a length of 20 mm in the beam direction for dispersing beam loss. The two TCs were attached 6 mm above and below the tip of the septum notch. Figure 3 shows the time response of the temperatures at the tip of the septum notch (beam loss point) and the TC position calculated with ANSYS²⁾ for a beam loss of 300 W (assuming a beam diameter of 2 mm). These calculation results show that the maximum temperature of the septum exceeds the melting point of copper (1085°C) within 1 s with a beam loss of approximately 370 W. Further, it is found that the temperature rise at the TC position was as small as one tenth of the maximum temperature and its response speed was slow. Therefore, we will stop the beam before the septum melts when the temperature rise for each 0.1 s measurement interval exceeds a predetermined value owing to any abnormal beam loss. The system will be used in 2021 when the permission limit on the radiation protection for the 7.25 MeV/nucleon He beams will be increased to $70 \mu\text{A}$.

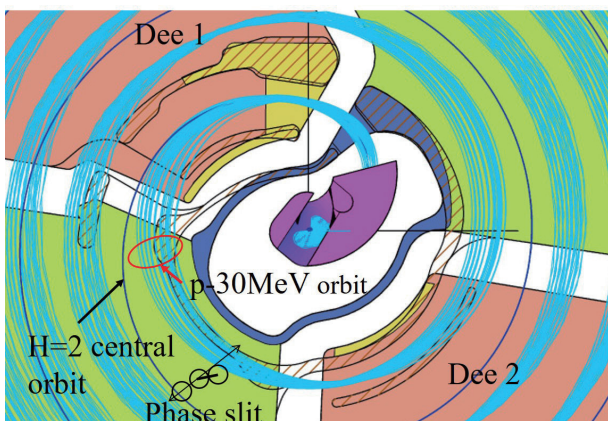


Fig. 1. New and old central region of the AVF Cyclotron. Hatched area indicates the old region. Beam orbits for 30 MeV protons and the central orbit of the normal $H = 2$ acceleration are also shown.

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References

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