ANSYS code calculations for measuring beam spot temperature

Z. Korkulu,*1 K. Yoshida,*1 Y. Yanagisawa*1, and T. Kubo*1

RIBF cyclotrons can accelerate very heavy ions such as uranium up to 345 MeV/nucleon. The goal beam intensity is expected to be 1 particle μA (6.2×10^{12} pps), which corresponds to a beam power of 82 kW in the case of ^{238}U[1]. An important aspect in increasing beam intensity is limiting the maximal temperature due to beam energy loss in the material. Controlling this absorbed power is a key challenge. Therefore, a high-power production target system[2,3] was designed and constructed in 2007 for the BigRIPS separator[4,5]. The water-cooled rotational disk targets and ladder-shaped fixed targets are currently in operation.

As the fixed ladder-shaped target, a Be taper of 3-mm thickness was irratiated by a ^{238}U beam of 345 MeV/nucleon, up to 38 pnA with a beam spot size of 1.5-mm diameter. This target was tightly mounted on a water-cooled target holder using a 5-mm thick aluminum fixing plate. Although the present primary beam intensity is much lower than the goal value, the beam spot temperature at various conditions was measured and compared with thermal simulations to examine the beam power tolerance and to evaluate the cooling capacity of the high-power production target. The finite element thermal analysis code, ANSYS[6], was used to model thermal distributions in the targets.

Figure 1 shows the quarter model of the ladder-shaped target and the result of the temperature distribution calculated by the steady-state thermal analysis. The mesh of the target body is generated using three-dimensional hexahedral elements 0.2 mm in size. The input power was given as the heat generation, which is approximately 87 W/mm^3. In addition, the total absorbed power in the whole Be target, not the quarter model, is approximately 460 W for 35 pnA intensity. Owing to the high energy deposition in the target, the target system is cooled using a forced convection mode. For forced convection, the heat transfer coefficient of the cooling channel was calculated (using JAERI formula[7]) and used in the simulation. For this simulation, the cooling water (25°C) flowed at 3.5 l/min through the cooling channel. To ensure efficient heat transfer, the temperature-dependent thermal conductivity of Be and Al were used at temperatures between 25 and 750°C. As shown in Fig. 1, the maximum temperature of the target center was approximately 650°C under the above mentioned conditions. Figure 2 shows the calculated and measured beam spot temperature on a Be target as a function of the primary beam intensity of ^{48}Ca, ^{78}Kr, and ^{238}U. For all primary beams, the temperature is always below the melting temperature (1278°C) of the Be target for beam intensities used in the simulation. In order to reach the goal intensity, it is recommended to use a water-cooled rotating disk target with a suitable velocity so that different parts of the target are irradiated by bunches.

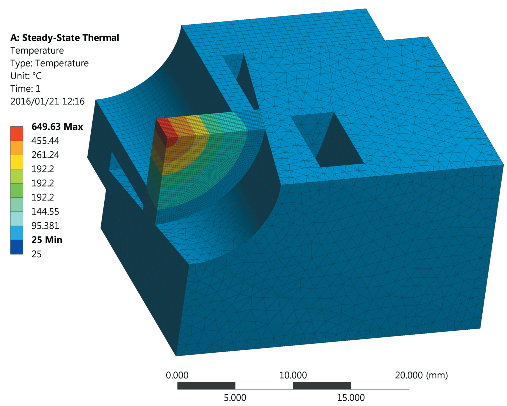

Fig. 1. Quarter finite element analysis model and the calculated temperature distrubiton in the Be target.

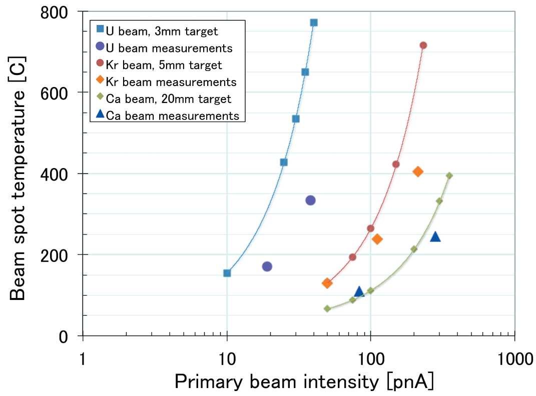

Fig. 2. Calculated and measured beam spot temperature on a Be target as the function of a different primary beam intensity.

Presently, the beam spot temperature calculated using the ANSYS code is higher than the measured beam spot temperature[8]. Discrepancy between the measured temperature and the simulation can be caused by the suboptimal spatial resolution of the thermal camera system. Since the spatial resolution of the thermal camera is approximately 2 mm, some improvements to achieve a more accurate measurement will be necessary.

References

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*1 RIKEN Nishina Center