ROTATING CARBON DISK STRIPPER FOR INTENSE HEAVY-ION BEAMS

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Abstract

A charge stripper system which uses a fast-rotating disk of carbon was developed for intense heavy-ion beams at the RIKEN RI-beam factory. A beam test by ^{86}Kr beam at 46 MeV/nucleon was performed. Charge state fractions of ^{86}Kr were measured.

INTRODUCTION

A charge stripper is an essential device in a heavy-ion accelerator complex. Charge strippers increase the variety of acceleration scheme and decrease the construction cost of accelerators. In the RIKEN RI-beam factory (RIBF), ions from hydrogen to uranium are planned to be accelerated by four cyclotrons (and an AVF cyclotron for lighter ion injection) and linacs combined with four stripper sections [1]. The stripper discussed here is referred to as the third stripper in Ref. [2]. In the typical acceleration scheme under investigation, the third stripper typically strips a 3 pμA ^{238}U^{72+} beam at 50.5 MeV/nucleon to 88+ by a 14 mg/cm^2 thick carbon plate. The power deposited to the stripper is approximately 3 kW, which easily evaporate a carbon plate placed in a vacuum chamber. In order to cope with such a high power deposit, the carbon plate is rotated enlarging the area from which thermal radiation is emitted.

STRUCTURE OF ROTATING DISK STRIPPER

Figure 1 shows the schematic of the rotating carbon disk stripper. A 120 mm diameter disk of glassy carbon

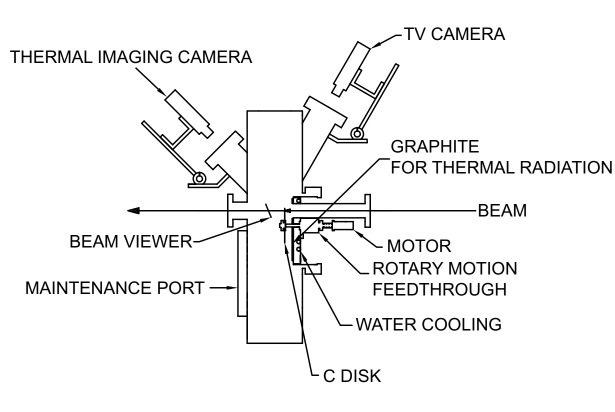

Figure 1: Schematic of rotating carbon disk stripper.

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is placed in a vacuum chamber. The carbon disk is connected to an AC servo motor placed outside the vacuum chamber by a water-cooled ferrofluid sealed rotary motion feedthrough. The geometrical thickness distribution of the carbon disk at the radius of the beam spot was measured with micrometer, and found that the thickness was uniform within 0.9%. When a ^{238}U beam at 50.5 MeV/nucleon is bombarded on a 14 mg/cm^2 thick carbon plate, the beam loses approximately 8% of kinetic energy [3]. Therefore, if the density of the carbon disk is uniform, the energy of the uranium beam is expected to vibrate approximately 0.07%, which is comparable to the energy straggling (one sigma) 0.03% [4]. The angular straggling (one sigma) is expected to be 0.9 mrad [5]. The maximum rotation frequency of the disk is 3000 rpm. A beam viewer, a sheet of ZnS(Ag) connected to a pneumatic linear motion feedthrough, is inserted to the beam position, and the beam spot on it is observed by a TV camera placed outside the vacuum chamber through a viewing port. Another viewing port facing the beam spot on the carbon disk is prepared for a thermal imaging camera. The center of the beam spot is designed to be placed at approximately 8 mm inside from the outer edge of the carbon disk. The heat deposited in the carbon disk is mainly lost by the thermal radiation because of the small thickness of the disk. An array of graphite plates is soldered to a water-cooled copper plate close to the carbon disk for the purpose of absorbing the thermal radiation emitted from the carbon disk.

THERMAL CALCULATION

A calculation on temperature increase was made by a finite element method code, ANSYS, by the method similar to that in Ref. [6]. In the calculation, a 3 pμA uranium beam was bombarded on a 120 mm diameter 14 mg/cm^2 thick carbon disk rotating at 1000 rpm. The beam heats up the disk losing energy following Bragg curve, and the temperature of the doughnut shape area increases. The energy deposited to the disk is lost by thermal radiation from the surface of the disk, and small amount of energy is absorbed by the rotating shaft. The maximum temperature reached the equilibrium after approximately 1 sec irradiation. Figure 2 shows the result of the calculation after approximately 3 sec irradiation. The disk was rotated clockwise. The red band from head at left middle to tail at downward drawn clockwise decreasing the width shows the hottest part. The beam was bombarded on the head part of the red band. The maximum temperature was calculated to be 1549°C, that was sufficiently lower than the evaporating temperature of

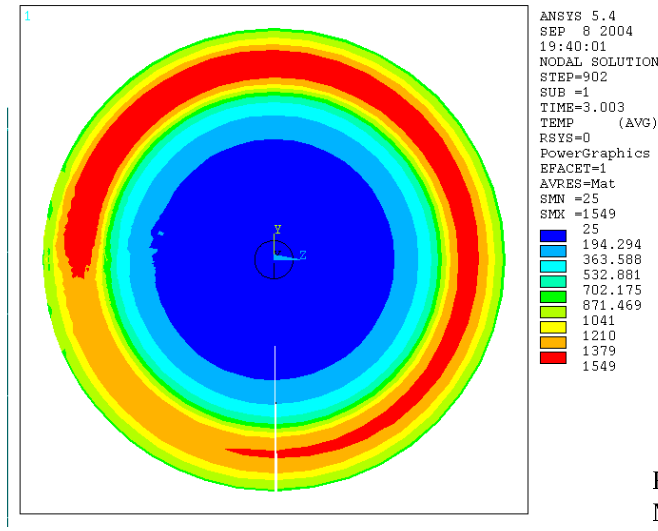

Figure 2: Calculation of temperature increase of the carbon disk bombarded by 3 pμA uranium beam. Calculation was made by ANSYS.

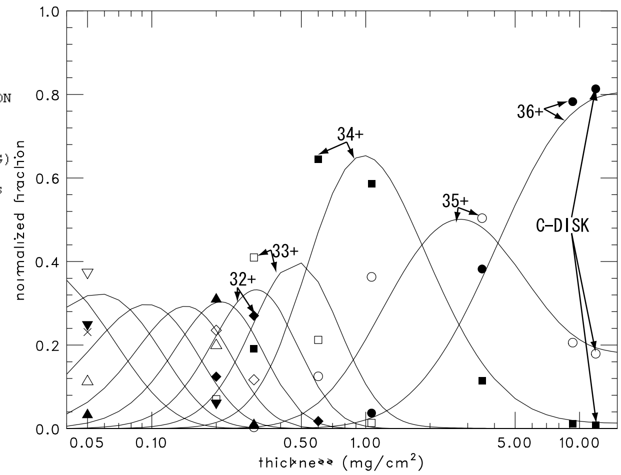

Figure 3: Charge state fractions of ^{86}Kr at 46 MeV/nucleon. Horizontal axis indicate the thickness of the stripper and vertical axis indicate the charge state fractions. The charge state fractions are normalized by the sum of the measured charge state distribution. The rightmost points are the data of 12 mg/cm^2 thick carbon disk rotating at 1000 rpm. The other points are the data of carbon foils, aramid films and a polyimide film. Solid lines indicate the calculations by GLOBAL [7].

carbon.

BEAM TEST

A beam test was performed by a ^{86}Kr^{26+} beam at 46 MeV/nucleon. The krypton beam from the RRC was bombarded on a 12 mg/cm^2 thick carbon disk rotating at 1000 rpm. The charge stripped ions were separated by a 90° bending dipole magnet according to the charge states, and the beam currents were measured by a Faraday-cup. The beam spot on the beam viewer was almost spherical and the diameter was approximately 5 mm. The typical beam intensity was 0.1 pμA. The power deposited to the disk was approximately 18 W, which was much smaller than the expected power deposited by a 3 pμA uranium beam at the RIBF. A dim image of the beam spot on the carbon disk was observed by a TV camera. No visible deformation of the carbon disk was observed after the beam test.

Figure 3 shows the charge state fractions of ^{86}Kr at 46 MeV/nucleon. The data of a 12 mg/cm^2 thick carbon disk rotating at 1000 rpm are plotted with the data of carbon foils, aramid films and a polyimide film, together with calculations by GLOBAL [7]. The GLOBAL calculation well reproduced the data points of higher charge states, and naturally the data points of the rotating carbon disk also showed consistent tendency with the other data.

SUMMARY

A stripper system for intense heavy-ion beams at the RIBF was developed employing a fast rotating carbon disk. A thermal calculation by ANSYS in the case when a 3 pμA uranium beam was bombarded on a 120 mm diameter carbon disk rotating at 1000 rpm showed that the maximum temperature was much lower than the evaporating temperature of carbon. A beam test by a 0.1 pμA krypton beam was performed, and no visible damage on the carbon disk was observed. The authors are planning to perform a high load beam test measuring the temperature distribution with a thermal imaging camera, and also planning a beam test to measure the thickness distribution of the disk.

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